



*Working to Perfect the Flow of Energy*

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PJM Manual 11:

**Energy & Ancillary Services  
Market Operations**

Revision: 765

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Prepared by

Forward Market Operations

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## Current Revision

### Revision [765 \(04/09/2015\)](#):

- ~~Added second step on the reserve demand curves in section 2.5.5~~
- ~~Added language in sections 4.2.2 to address the extension of the synchronized reserve requirement under certain emergency conditions~~
- ~~Added language in sections 11.2.1 and 11.2.8 detailing the increase in the day-ahead scheduling reserve requirement under certain emergency conditions to account for the difference between fixed demand and forecasted load in the day-ahead market~~
- [Revised reference to Non-Synchronized Reserve Penalty Factor in table in section 2.5](#)
- [Cleaned up references to other manuals in sections 3.2.1 and 3.2.4](#)
- [Added language in section 4.1 to address compensation for Tier 1 Synchronized Reserve Resources that do not opt out of a Tier 1 Performance Obligation](#)
- [Added language in sections 4.2.1, 4.2.4, and 4.2.6 to address the determination and communication of Tier 1 availability and Tier 1 estimates](#)
- [Added language in section 4.2.10 detailing compensation for Tier 1 resources that accept a Tier 1 Performance Obligation](#)
- [Added language in section 4.2.12 detailing penalties for non-performance of Tier 1 resources with a Tier 1 Performance Obligation](#)

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## Introduction

Welcome to the ***PJM Manual for Energy & Ancillary Services Market Operations***. In this Introduction, you will find the following information:

- What you can expect from the PJM Manuals in general (see “*About PJM Manuals*”).
- What you can expect from this PJM Manual (see “*About This Manual*”).
- How to use this manual (see “*Using This Manual*”).

### About PJM Manuals

The PJM Manuals are the instructions, rules, procedures and guidelines established by PJM for the operation, planning and accounting requirements of the PJM RTO and the PJM Energy Market. The manuals are grouped under the following categories:

- Transmission
- PJM Energy Market
- Generation and transmission interconnection
- Reserve
- Accounting and Billing
- PJM administrative services

For a complete list of all PJM Manuals, go to [www.pjm.com](http://www.pjm.com) and select “Manuals” under the “Documents” tab.

### About This Manual

The ***PJM Manual for Energy & Ancillary Services Market Operations*** is one of a series of manuals within the PJM Energy Market manuals. This manual focuses on the day-ahead and hourly scheduling activities that are performed by the PJM staff and the PJM Members. The manual describes the rules and procedures that are followed to schedule resources.

The ***PJM Manual for Energy & Ancillary Services Market Operations*** consists of ten sections. The sections are listed in the table of contents beginning on page ii.

### Intended Audience

The intended audience of the PJM Manual for Energy & Ancillary Services Market Operations is:





- *PJM Members* - Any participants requesting to purchase or sell energy to or from the PJM Interchange Energy Market and any participant that schedules bilateral sales or purchases.
- *PJM operations staff* - The PJM operations staff processes the market information and develops the resource schedule.
- *PJM dispatchers* - The PJM dispatchers process PJM Member requests, make hourly schedule adjustments, and post information in the OASIS.
- *Local Control Center dispatchers* - The Local Control Center dispatchers submit hourly schedule changes.
- *Local Control Center operations support staff* - The Local Control Center operations support staff support the day-ahead information requirements.

## References

The References to other documents that provide background or additional detail directly related to the ***PJM Manual for Energy & Ancillary Services Market Operations*** are:

- PJM ExSchedule User Guide
- PJM Manual for [Transmission Operations\(M-03\)](#)
- PJM Manual for [Pre-Scheduling Operations \(M-10\)](#)
- PJM Manual for [Balancing Operations \(M-12\)](#)
- PJM Manual for [Emergency Operations \(M-13\)](#)
- PJM Manual for [Operating Agreement Accounting \(M-28\)](#)
- PJM Manual for [Definitions & Abbreviations \(M-35\)](#)

## Using This Manual

We believe that explaining concepts is just as important as presenting procedures. This philosophy is reflected in the way we organize the material in this manual. We start each section with an overview. Then, we present details, procedures or references to procedures found in other PJM manuals. The following provides an orientation to the manual's structure.

## What You Will Find In This Manual

- A table of contents that lists two levels of subheadings within each of the sections
- An approval page that lists the required approvals and a brief outline of the current revision
- Sections containing the specific guidelines, requirements, or procedures including PJM actions and market participant actions



- Attachments that include additional supporting documents, forms, or tables in this PJM Manual
- A section at the end detailing all previous revisions of the PJM Manual
- A new introduction with the “List of PJM Manuals” table removed.



## Section 1: Overview of Energy & Ancillary Services Market Operations

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

- A description of the scope and purpose of scheduling (see “*Scope & Purpose of Energy & Ancillary Services Market Operations*”).
- A list of the PJM responsibilities (see “*PJM Responsibilities*”).
- A list of the market participants’ scheduling responsibilities (see “*PJM Market Participant Responsibilities*”).

### Scope & Purpose of Energy & Ancillary Services Market Operations

Operation of the PJM RTO markets involves many activities that are performed by different operating and technical personnel. These activities occur in parallel on a continuous basis, 24 hours a day and can be grouped into three overlapping time frames:

- pre-scheduling operations
- scheduling operations and the Day-ahead Energy Market
- dispatching and the Real-time Energy Market

In the PJM Manual for Energy & Ancillary Services Market we focus mainly on the activities that take place one day prior to the Operating Day including the activities associated with the Day-ahead Energy Market. Exhibit 1 presents the scheduling activities in the form of a time line. The reference point for the timeline is the “Operating Day”, recognizing that every new day becomes an Operating Day. This timeline-type of description is used throughout this PJM Manual.

Generation resources, regardless of fuel type, fall into one of two categories, Capacity Resources or Energy Resources. If available, All Generation Capacity Resources, that have an RPM Resource Commitment must submit offer data into the Day-ahead Market and may elect either to Self-Schedule or offer the resource to PJM for scheduling as a PJM RTO-Scheduled Resource. In this section we focus primarily on the PJM Day-ahead Energy Market and the Control Area reliability-based scheduling process that takes place after the Day-ahead Energy Market is closed. Scheduling by PJM includes the Day-ahead Energy Market, the Control Area reliability-based scheduling process and the hourly scheduling process. The Day-ahead Energy Market bid/offer period closes at noon on the day before the Operating Day and the Day-ahead Market results are posted at 1600 on the day before the Operating Day. The Control Area reliability-



based scheduling process occurs throughout the day before the operating day. Hourly scheduling occurs up to sixty minutes prior to an hour during the Operating Day. During the scheduling process, PJM will:

Clear the Day-ahead Market and Day-ahead Scheduling Reserve Market based using Least-cost security constrained resource commitment and dispatch that simultaneously optimizes energy and reserves.

Determine a plan to reliably serve the hourly energy and reserve requirements of the PJM RTO by minimizing the cost to provide additional operating reserves above what was scheduled in the Day-ahead Market if required,

Perform hourly scheduling throughout the Operating Day as required.

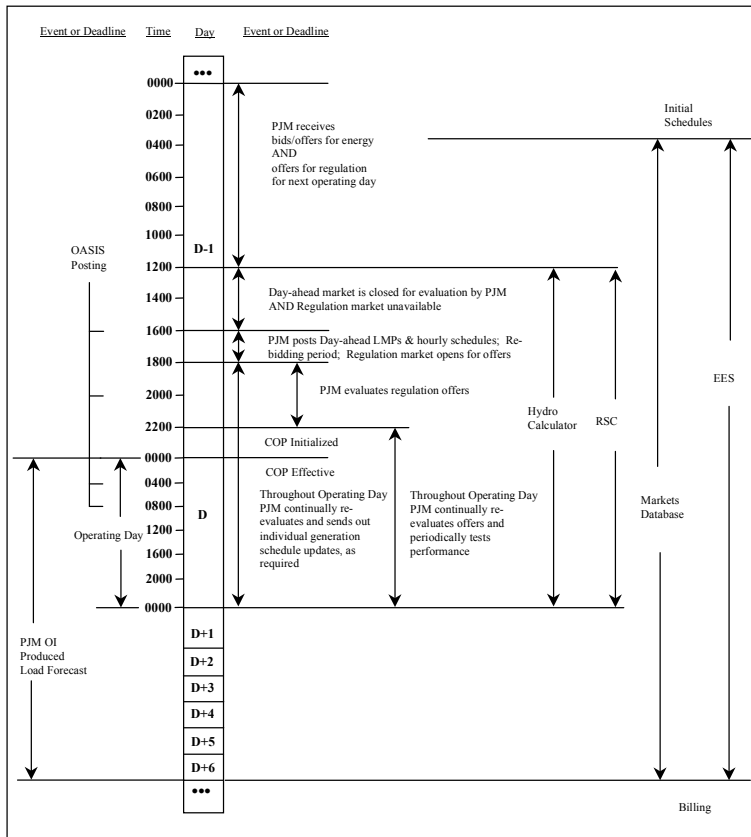


Exhibit 1: Scheduling Timeline



PJM Members submit their bids according to either actual cost or offer price as designated by the Operating Agreement of PJM Interconnection, L.L.C. for each generation resource.

In this manual, Locational Marginal Price (LMP) is defined as the marginal price for energy at the location where the energy is delivered or received. For accounting purposes, LMP is expressed in dollars per megawatt-hour (\$/MWh). In performing this LMP calculation, the cost of serving an increment of load at each bus from each resource associated with an eligible energy offer is calculated as the sum of the following three components of Locational Marginal Price: System Energy Price, Congestion Price, and Loss Price. In this manual, unless otherwise specified, the terms “LMP” or “Locational Marginal Price” refer to the total LMP value including all three components. For information on the concept of Locational Marginal Prices, please refer to Section 2 of this manual.

## 1.1 PJM Responsibilities

In the Day-ahead Market, PJM determines the least-price means (minimizing production cost in terms of bid prices submitted) of satisfying the Demand bids, Decrement bids, operating reserves and other ancillary services requirements of the market buyers, including the reliability requirements of the PJM RTO. In addition to the Day-ahead Market scheduling process, PJM will also schedule resources to:

- Satisfy the reserve requirements of the PJM RTO by minimizing the cost to provide additional operating reserves above what was scheduled in the Day-ahead Market if required,
- Provide other ancillary services requirements of the market buyers,
- Satisfy all other reliability requirements of the PJM RTO. Specifically, PJM's responsibilities to support scheduling activities for all PJM Members include:

Develop the Day-ahead Market financial schedules based upon participant-supplied bids, offers and bilateral transaction schedules using least-cost security constrained resource commitment and dispatch analysis.

Post the following information after the Day-ahead Market clears at 4:00 p.m.:

- Schedules for Next Day by participant (generation & demand),
- Transaction Schedules,
- Day-ahead LMPs, Day-ahead Congestion Prices, & Day-ahead Loss Prices
- Day-ahead Binding Transmission Constraints,
- Day-ahead Net Tie Schedules,
- Day-ahead Reactive 500 kV Interface Indicator Limits,



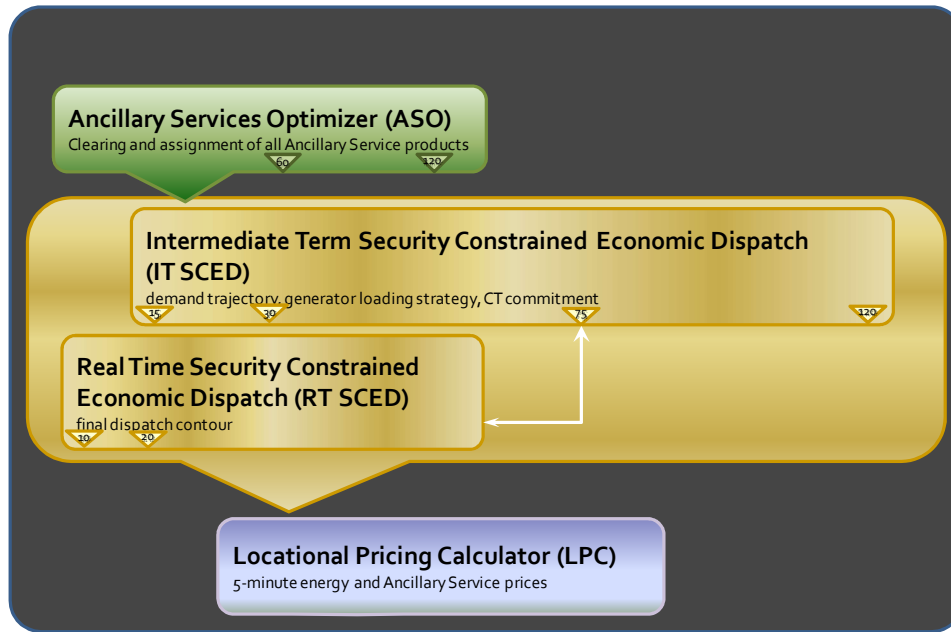
- PJM State Estimator
- Locational Pricing Calculator (LPC)

Each of the PJM LMP modules is described in detail below.

## 2.5 Real-Time Market Applications

To conduct the real-time markets, a multi-module, software platform is used by PJM to dispatch energy, and ensure adequate reserves in real-time and regulation in near time. The applications jointly optimize the products on a 5-minute basis to ensure that all system requirements are met using the least cost resource set. The real-time market applications consist of the following:

- **Ancillary Service Optimizer (ASO):** The Ancillary Services Optimizer (ASO) performs the joint optimization function of energy, reserves and regulation. The ASO creates an interval-based solution over a one hour look-ahead period, as well as performs the regulation three pivotal supplier test. The ASO will make commitments for ancillary services (Synchronized Reserve, Non-Synchronized Reserve, & Regulation) to meet requirements. ASO does not calculate market clearing prices. The main functions of ASO are the commitment of all regulation resources and inflexible reserve resources for the next operating hour.
- **Intermediate Term Security Constrained Economic Dispatch (IT SCED):** The Intermediate Term Security Constrained Economic Dispatch (IT SCED) application is used by PJM to perform various functions over a 1-2 hour look-ahead period. Historical and current system information is used to anticipate generator performance to various requests, and to provide accurate information regarding generator operating parameters under multiple scenarios. The IT SCED solves a multi-interval, time-coupled solution to perform the following functions:
  - Calculate energy dispatch trajectory for use in real-time dispatch
  - Resource commitment for energy and reserves
  - Execution of the Three Pivotal Supplier Test for energy
  - Forward determination of reserve shortages
- **Real-Time Security Constrained Economic Dispatch (RT SCED):** The Real-Time Security Constrained Economic Dispatch (RT SCED) application is responsible for dispatching resources to maintain the system balance of energy and reserves. Historical and current system information is used to anticipate generator performance to various requests, and to provide accurate information regarding generator operating parameters under multiple scenarios. RT SCED will jointly optimize energy and reserves on online, dispatchable resources to ensure system needs are maintained. The results from the RT SCED are energy basepoints, Tier 2 and Non-Synchronized reserve commitments that are sent to resource owners in real-time. All quantities may change with each solution based on system economics and reserve needs.



The real time market applications and various other applications communicate jointly and the most recent information from each application is stored and upon request provides the relevant data to each application. To run the real-time market, data is processed from the markets database and other PJM systems. A dispatch solution is executed automatically every five minutes or when executed by the operator. To calculate the solution, data from multiple sources is used, including but not limited to, data regarding online and available resources, resource offers, forecasted load, scheduled and current interchange, as well as various other input parameters.

Real-time data sources include:

- Load forecast data from EMS
- Constraint data - resource sensitivities from EMS
- State Estimator output from EMS
- Outage data from eDART
- Transaction data from EES

Multiple cases are then produced, with each solution solving the security constrained economic dispatch problem. Each of these solution cases contains:

- A recommended set of zonal dispatch rates



- A list of exceptions to the dispatch rates for constraint control
- Individual resource dispatch rates
- Individual Resource Desired MW level
- Individual Resource Reserve Commitments

Embedded within the IT SCED and RT SCED are reserve demand curves for each product in each modeled location that are used to articulate the value of maintaining each reserve requirement and ensure product substitution between energy and reserves up to the specified penalty factor. For example, if the penalty factor for synchronized reserves is \$100/MWh, resources with merit order prices that exceed the penalty factor will still be committed but the clearing price will be capped at the penalty factor. Such resource will be compensated additionally after the fact to the true cost to provide the service. Additionally, the penalty factor provides a clear indicator of the reserve position of the RTO and modeled sub-zones. As the price of either reserve product increases to value near the penalty factor, it indicates to market participants that the system is nearing a reserve shortage. This provides market participants an advanced signal indicating a potential reserve shortage.

#### Reserve Demand Curves and Penalty Factors

- Separate demand curves exist for the Synchronized Reserve and Non-Synchronized Reserve requirements. These demand curves apply to both the RTO and MAD reserve requirements.
- Under normal operating conditions, each reserve demand curve is a single step function at the price of the penalty factor at the value of the requirement for the specific product.
- Under Hot Weather Alert, Cold Weather Alert or escalating emergency procedures as defined in Manual M-13, each reserve demand curve becomes a two-step function if additional resources are brought online by PJM dispatch to account for operational uncertainty after the second resource commitment which occurs after 18:00 the day prior to the Operating Day. The first step is defined as described above. The second step is defined at a lower penalty factor than the first step and at an extended reserve requirement quantity. The calculation of the extended reserve requirement is defined in Section 4.2.2 Synchronized Reserve Requirement Determination.
- The penalty factors shown below will be used for the dates specified. The penalty factors are the same for each product and location where a reserve requirement exists.

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Start Date	End Date	Synchronized Reserve Penalty Factor (\$/MWh)		Non-Synchronized Primary Reserve Penalty Factor (\$/MWh)	
		1 <sup>st</sup> Step on Demand Curve	2 <sup>nd</sup> Step on Demand Curve	1 <sup>st</sup> Step on Demand Curve	2 <sup>nd</sup> Step on Demand Curve
June 1, 2012	May 31, 2013	250	N/A	250	N/A
June 1, 2013	May 31, 2014	400	N/A	400	N/A
June 1, 2014	May 31, 2015	550	300	550	300
June 1, 2015		850	300	850	300

- PJM will review the penalty factors used on an annual basis to ensure that they permit PJM Operators to fully utilize all assets on the system and accurately value each product.

## 2.6 PJM State Estimator

The Real-time LMP calculation depends upon having a complete and consistent power flow solution as input. This input requirement can be achieved by using a state estimator. The state estimator is a standard power system operations tool whose purpose is to provide a base case power flow solution for input into other computer programs.

The state estimator uses actual operating conditions that exist on the power grid (as described by metered inputs) along with the fundamental power system equations to calculate the remaining flows and conditions that are not metered. Since the state estimator solution provides a complete and consistent model of actual operating conditions based upon observable (metered) input and an underlying mathematical model, it can be used to provide the basis for the Locational Marginal Price calculations.

The inputs to the state estimator are the available (metered) real-time measurements, the current status of equipment (lines, generators, transformers, etc.), and the bus load distribution factors.



Regulation on any qualified resource, and the merit order price for any self-scheduled Regulation resource is set to zero.

In the after-the-fact settlement, any resources self-scheduled to provide Regulation are compensated based on the processes described in Manual 28.

## 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:

- Generation resources must be able to provide 0.1 MW of Regulation Capability in order to participate in the Regulation Market. Demand Resources must be able to provide 0.1 MW of Regulation Capability in order to participate in the Regulation Market.
- Generation resources must have a governor capable of AGC control.
- Resources must be able to receive an AGC signal. Resources MW output must be telemetered to the PJM control center in a manner determined to be acceptable by PJM.
- New resources must pass an initial performance tests (minimum 75% compliance required). Current resources that are qualified on the date of implementation of regulation market changes do not need to re-qualify for the signal that they currently follow. However, initial qualification does not preclude a resource from being disqualified from the regulation market for non-performance.
- Resources must demonstrate minimum performance standards, as set forth in the PJM Manual 12: Balancing Operations, Section 4: Providing Ancillary Services.
- 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.
- Demand Resources must complete initial and continuing training on Regulation and Synchronized Reserve Market as documented in Manual 40: Certification and Training Requirements, [Section 2.6: Training Requirements for Demand Response Resources Supplying Regulation and Synchronized Reserve](#).
- Effective 6/1/2015: When a Demand Resource that is eligible for the Regulation Market is called for a mandatory Emergency or Pre-Emergency Load Management Event, it will be 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.

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The following information must be supplied through the eMKT System:

- Resource Regulating Status (available, unavailable, self-scheduled)
- Regulation Capability (above and below regulation midpoint, MW)
- Regulation Maximum and Minimum values, considering any necessary offsets (MW)
- Regulation Signal Type – RegA or RegD
- Cost-Based Regulation Offer (\$/MWh): This value will be validated using the unit-specific operating parameters submitted with the regulation offer and the applicable \$12/MWh regulation margin adder. The portions of the cost based offer are split into:
  - Regulation Capability portion capturing the Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at Lower Loads. The margin adder may only be added to the Regulation Capability portion; and,
  - Regulation Performance portion representing Cost Increase due to Heat Rate Increase during non-steady state operation and Cost Increase in VOM.
    - The \$/MW value determined in this step will be converted to \$/ΔMW by dividing the value by mileage ΔMW/MW for the applicable signal for that offer.
- Price-Based Regulation Offer (\$/MWh, optional): This value is capped at \$100/MWh, and its submission is optional on the part of the market participant. The portions of the cost based offer are split into:
  - Regulation Capability portion capturing the resource owner's price to reserve MWs for regulation in \$/MW; and,
  - Regulation Performance portion capturing the resource owner's price to provide regulation movement in \$/ΔMW.

The \$/MW value determined in this step will be converted to \$/ΔMW by dividing the value by mileage ΔMW/MW for the applicable signal 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 Manual M-15: Cost Development Guidelines, PJM will validate 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. Any cost-based offer prices that exceed this value will be rejected by the eMKT System. An example of this calculation is available on the PJM website at <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>.

If a market participant does not submit a cost-based regulation offer price they will not be permitted to participate in the PJM Regulation Market until such offer



has been validated. 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 eMKT System to support the cost-based regulation offer price. If any of these parameters are not submitted they will default to zero.

- **Heat Rate @ EcoMax [BTU/kWh]:** The heat rate at the default economic maximum for a resource. The economic maximum that will correspond to this rate value will be the default economic maximum that is shown on both the Daily Regulation Offers and Unit Details pages.
- **Heat Rate @ RegMin [BTU/kWh]:** The heat rate at the default regulation minimum for a resource. The regulation minimum that will correspond to this rate value will be the default regulation minimum that is 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.
- **Fuel Cost [\$/MBTU]:** The fixed fuel costs of the resource. This value will be used to determine the heat rate adjustments during steady-state and non steady-state operation for the purpose of providing regulation.

### 3.2.2 Regulation Market Data Timeline

Cost-based and Price-Based Regulation Offer(s) and any applicable cost information must be supplied prior to 6:00 p.m. day-ahead and is applicable for the entire 24-hour period for which it is submitted. Resource Regulating Status, Regulation Capability, and Regulation Maximum and Regulation Minimum information may be submitted or changed up until sixty (60) minutes prior to the beginning of the operating hour, at which time the Regulation market closes. 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 the lowest of all the high limits and the Regulation Minimum the highest of all the low limits), the regulation software will utilize the most restrictive minimum and maximum of all applicable limits for real time.

- Should a unit wish not to participate in the regulation market in any given hour on the operating day, the following update should be made at least 60 minutes prior to the operating hour in the Regulation Updates screens of the eMKT System:
  - Set Offer MW to zero
  - Set Available status to Not Available.



- Should a unit's regulation operating parameters change after the regulation market closes for an hour, the following changes may be made through direct communication with the PJM Scheduling Coordinator:
  - Resource Regulating Status
  - Available to unavailable
  - Self-scheduled to unavailable
- High Regulation Limit may be decreased but not increased and Low Regulation Limit may be increased but not decreased.
- Regulating capability may be decreased but not increased.
- Regulation Maximum capability may be decreased but not increased and Regulation Minimum capability may be increased but not decreased.
- Any resource that is unavailable for energy when the Regulation market closes and becomes available during the operating hour may also be made available or self-scheduled for regulation. Any associated regulation offer information may be changed for such resources, since none was considered in the calculation of RMCP.
- Resources that are self-scheduled for energy but do not have an available bandwidth above the self-scheduled value and below the applicable maximum greater than or equal to twice the regulation offer cannot be evaluated for the full amount of the offer. Such resources will be evaluated for regulating capability equal to half the bandwidth available.

### 3.2.3 Regulation Bilateral Transactions

- Bilateral regulation transactions may be reported to PJM. Such reported bilateral regulation transactions must be for the physical transfer of regulation and must be reported by the buyer and subsequently confirmed by the seller through the eMKT System no later than 1600 the day after the transaction starts. 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 MW amount, the seller, and the start and end time of the transaction via the eMKT System. The seller confirms the transaction via the eMKT System by 1600 the day after the start date of the bilateral transaction.
- Payments and related charges associated with the bilateral regulation 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 eMKT schedules associated with its bilateral regulation transactions previously reported to PJM for all days where delivery had not yet occurred.

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### 3.2.4 Regulation Requirement Determination

- The total PJM Regulation Requirement for the PJM RTO is determined in whole MW for the on-peak (0500 – 2359) and off-peak (0000 – 0459) periods of day. Further detail can be found in Manual [12](#), Section 4.4.3 Determining Regulation Assignment.
- Demand Resources will be limited to providing 25% of the regulation requirement.

### 3.2.5 Regulation Obligation Fulfillment

- LSEs may fulfill their regulation obligations by:
- Self-scheduling the entity's own resources;
- Entering contractual arrangements with other market participants; or
- Purchasing regulation from the regulation market.

### 3.2.6 Regulation Offer Period

- Resource owners wishing to sell regulation service must at least supply a cost-based regulation offer reflecting both Regulation capability offer cost and the Regulation performance cost of the resource 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.
- Regulation offers are locked as of 6:00 p.m. the day prior to operation. The Markets Database is generally unavailable for entry between 12 noon and 4:00 p.m. the day prior to operation while the Day-ahead market is being cleared. All resources listed as available for regulation with no offer price have their offer prices set to zero.

### 3.2.7 Regulation Market Clearing

- PJM clears the regulation market simultaneously with the synchronized reserve market, and posts the results no later than 30 minutes prior to the start of the operating hour.

### Dispatch

- Economic ramp rate must be adjusted when resources provide regulation to minimize the conflict between energy and regulation products. The segment specific ramp rates should be calculated from the economic ramp rate as follows:

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

- 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 resource's net MW output is near or above the current set point. The IGD set point will only move down when the RT-SCED LMP justifies lowering the resource and the resource's net MW output is near or below the current set point. The minimum ramp rate is a member-entered, unit-specific percentage of the bid-in ramp rate for each resource. If no value is entered for the resource, a default of zero will be used.
- A small dead band will be used to determine if the resource's MW output is near the current set point. The settings for this dead band will be the greater of 5 percent of the current net MW for the resource or 5 MW.

### Regulating Capability

- For each resource, PJM will calculate an adjusted Capability Cost, as

$$\text{Adjusted Regulating Capability Cost (\$)} = \frac{\left(\frac{\text{Capability Offer (\$/MW)}}{\text{Benefits Factor of Offered Resource}}\right) * \left(\frac{\text{Capability (MW)}}{\text{Historic Performance Score}}\right)}$$

- By dividing the regulating capability offer by benefits factor of the specific offered resource and the historic performance score. The historic performance score is discussed in Manual 12 – Balancing Operations, Section 4.5.5 Disqualification and Requalification of a Resource.

### Mileage and the Performance Offer

- Mileage is the summation of movement requested by the regulation control signal a resource is following. It is 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 calculates the performance-adjusted Performance Cost, as



*Adjusted Performance Cost (\$)*

$$= \frac{\left( \text{Performance Offer } (\$/\Delta MW) \right) * \left( \frac{\text{Mileage of Offered Resource}}{\text{Signal Type } (\Delta MW / MW)} \right) * \left( \text{Capability } (MW) \right)}{\left( \frac{\text{Benefits Factor of Offered Resource}}{\text{Historic Performance Score}} \right)}$$

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- Similar to the Adjusted Regulating Capability Offer, the Adjusted Performance Offer is adjusted by the benefits factor of the specific offered resource and the historic performance score of the resource. Benefits factor is discussed later in this section. The historic performance score is discussed in Manual 12 – Balancing Operations, Section 4.5.5 Disqualification and Requalification of a Resource. The performance offer is priced on a \$ per change in MW, to normalize the performance between signal types, the historical mileage is a rolling 30-day average by the signal type that the resource has qualified to follow.
- Lost Opportunity Cost
- Estimated resource opportunity cost is calculated as follows:
  - The Market Clearing Engine (MCE) optimizes resource energy schedules and forecasts LMPs for the operating hour while respecting appropriate transmission constraints and Ancillary Service requirements.
  - MCE utilizes the lesser of the available price-based energy schedule or most expensive available cost-based energy schedule (the “lost opportunity cost energy schedule”), and forecasted LMPs to determine the estimated opportunity cost each resource would incur if it adjusted its output as necessary to provide its full amount of regulation.
- Regulation opportunity cost is divided into three components.
  - The lost opportunity cost incurred in the shoulder hour preceding the initial regulating hour while the unit moves uneconomically into its regulating band to comply with the next hour’s regulation assignment.
  - The lost opportunity cost incurred in the actual regulating hour from reducing or raising the unit’s output uneconomically for the purpose of providing regulation.
  - The lost opportunity cost incurred in the shoulder hour following the final hour of the regulation assignment while the unit moves from its uneconomic regulation set point back to its economic set point.
- The approximate formula for the lost opportunity incurred during the shoulder hours can be defined as:

$$|LMP_{SH} - ED| * GENOFF * TIME, \text{ where:}$$





- a.  $LMP_{SH}$  is the forecasted shoulder hour LMP at the generator bus,
  - b. ED is the price from the lost opportunity cost energy schedule associated with the setpoint the resource must maintain to provide its full amount of regulation, and
  - c. GENOFF is the MW deviation between economic dispatch and the regulation setpoint.
  - d. TIME is the percentage of the hour it would take the unit to reduce GENOFF MWs using the applicable offer-in ramp rate.
- The approximate formula for the lost opportunity cost incurred during the regulating hour is:

$$|LMP - ED| * GENOFF, \text{ where:}$$

- e. LMP is the forecasted hourly LMP at the generator bus,
  - f. ED is the price from the lost opportunity cost energy schedule associated with the setpoint the resource must maintain to provide its full amount of regulation, and
  - g. GENOFF is the MW deviation between economic dispatch and the regulation setpoint.
- All unit-specific lost opportunity costs will be divided by the benefits factor of the specific offered resource and the resource's historic performance score for the purposes of commitment and setting the regulation market clearing prices. Benefits factor is discussed later in this section. The historic performance score is discussed in Manual 12 – Balancing Operations, Section 4.5.5 Disqualification and Requalification of a Resource.

$$Adjusted\ Lost\ Opportunity\ Cost\ (\$) = \frac{\left( \frac{\text{Estimated Lost Opportunity}}{\left( \frac{\$}{MW} \right)} \right)}{\left( \frac{\text{Benefits Factor of Offered Resource}}{\left( \frac{\$}{MW} \right)} \right)} * \frac{\left( \frac{\text{Capability}}{\left( \frac{MW}{\text{Historic Performance Score}} \right)} \right)}{\left( \frac{MW}{\text{Historic Performance Score}} \right)}$$

- Both lost opportunity cost calculations are defined simplistically for the purpose of the manual. The actual calculations are integrations that may be visualized as the area on a graph enclosed by the lost opportunity cost energy schedule, the points on that curve corresponding to the resource's desired economic dispatch and the setpoint necessary to provide the full amount of regulation, and the LMP.
- PJM may call on resources not otherwise assigned in order to provide regulation, in accordance with PJM's obligation to minimize the total cost of energy, operating



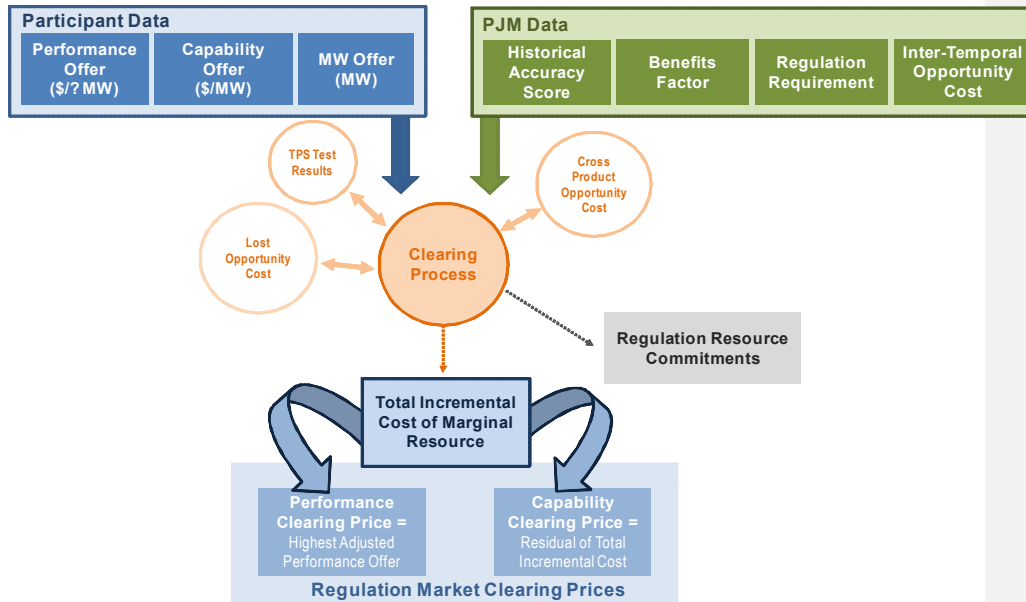
reserves, regulation, and other ancillary services. If a resource is called on by PJM for the purpose of providing regulation, the resource is eligible for recovery of Regulation lost opportunity costs as well as start-up, no-load, and energy costs. Please refer to Manual 28: Operating Agreement Accounting for additional settlements details.

- Resources not eligible or with no lost opportunity associated with providing regulation:
  - Energy resources that are self-scheduled to provide energy and do not supply an energy offer.
  - Demand Resources
- Notwithstanding the above, resources that do not submit an energy offer curve will have a Lost Opportunity Cost of zero.

#### Total Offer

- 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 follows:

$$\text{Adjusted Total Offer Cost (\$)} = \begin{pmatrix} \text{Adjusted} \\ \text{Regulation} \\ \text{Capability} \\ \text{Cost} \\ (\$) \end{pmatrix} + \begin{pmatrix} \text{Adjusted} \\ \text{Lost} \\ \text{Opportunity} \\ \text{Cost} \\ (\$) \end{pmatrix} + \begin{pmatrix} \text{Adjusted} \\ \text{Performance} \\ \text{Cost} \\ (\$) \end{pmatrix}$$



- MCE ranks all available regulating resources in ascending merit order price, and simultaneously determines the least expensive set of resources necessary to provide energy, regulation and synchronized reserve for the operating hour 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 the MCE application be unable to fulfill both the Regulation and Synchronized Reserve requirements, regulation receives the higher priority.
- PJM will clear the market to meet the Regulation Capability Requirement. The Regulation Capability Requirement sets the amount of regulating capability that PJM believes it would need to absorb sustained RTO ACE deviations adjusted by the benefits factor of a specific offered resource and the resource's historic performance score. Benefits factor is discussed later in this section. The historic performance score is discussed in Manual 12 – Balancing Operations, Section 4.5.5 Disqualification and Requalification of a Resource. The market will assign units until the constraint is met, by



*Regulation Capability Requirement*

$$MW \leq \sum_{i=0}^n \text{Capability } (MW)_{i*} * \text{Benefits Factor of Offered Resource}_i$$

\* Historic Performance Score<sub>i</sub>

- With the Regulation Capability constraint satisfied, the Rank Price (\$/MW) of the last assigned resource sets the Regulation Market Clearing Price (RMCP). This RMCP is used to derive the clearing price for the Regulation Capability and Regulation Performance components. First the Regulation Market Performance Clearing Price (RMPCP) is calculated by finding the maximum performance offer from the set of all cleared resources' performance offers as follows:

*Regulation Market Performance  
Clearing Price  
\$/MW*

$$= \max_{\text{Assigned Resources}} \left( \frac{\left( \begin{array}{c} \text{Performance} \\ \text{Offer} \\ (\$/\Delta MW) \end{array} \right) * \left( \begin{array}{c} \text{Actual Mileage} \\ \text{of} \\ \text{Offered Resource Signal Type } \Delta MW / MW \end{array} \right)}{\left( \begin{array}{c} \text{Benefits Factor} \\ \text{of} \\ \text{Offered Resource} \end{array} \right) * \left( \begin{array}{c} \text{Historic} \\ \text{Performance} \\ \text{Score} \end{array} \right)} \right)$$

- Then the RMPCP is subtracted from the RMCP for the Regulation Market Capability Clearing Price (RMCCP), which is the residual between the RMCP and RMPCP.

$$\text{Regulation Market Capability Clearing Price } \$/MW = \left( \begin{array}{c} \text{Regulation Market} \\ \text{Clearing Price} \\ \$/MW \end{array} \right) - \left( \begin{array}{c} \text{RM Performance} \\ \text{Clearing Price} \\ \$/MW \end{array} \right)$$

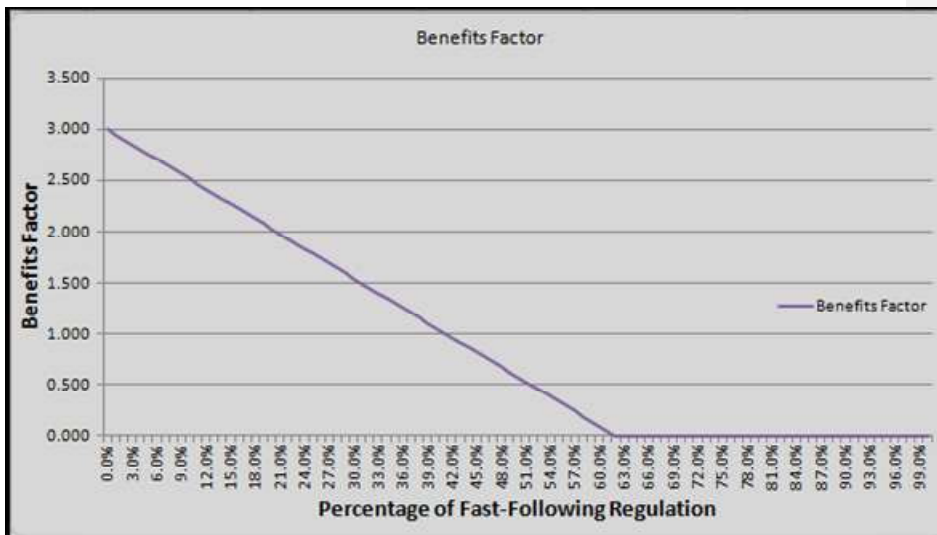
- The five minute regulation clearing prices are posted in the eDATA user interface public view. RMCP(s) and other billing determinant information is also available on the PJM website at <http://www.pjm.com/markets-and-operations/market-settlements/preliminary-billing-reports.aspx>
- If no Regulation Market Results are posted to the eMKT MUI for an hour, PJM will continue the current assignments, as needed, into the un-posted hour. There will be no impact to the price calculation, the real time hourly integrated Regulation Clearing Prices will be used for settlement.

**Benefits Factor Function**

Regulating resources can follow either a RegA (traditional) or RegD (dynamic) signal based on their resources' limitation and business practices. The regulating resources cleared in any hour can be any set of or mix of both traditional and dynamic resources. There is an operational relationship between the regulating resource mix and how the regulation requirement is satisfied. This relationship is

included in the market clearing and settlement process as the Benefits Factor Function because the relationship is depicted as a curve.

The benefits factor translates fast moving resource's MWs into traditional MWs or Effective MWs. These Effective MWs reflect the rate of substitution between resources following the different regulation signals. For market clearing, each dynamic resource will be assigned a decreasing and unique benefits factor. The benefits factor of the offered resource or resource specific benefits factor is the marginal point on the benefits factor function that aligns with the last MW that specific resource will add to the dynamic resource stack.



The benefits factor ranges from 2.9 to 0 where a benefits factor of 1 is equivalent to a traditional resource. The Benefits Factor Function will be fixed during the initial deployment. PJM will review the benefits factor as operational conditions warrant the re-evaluate the relationship when needed. These operational conditions could include, among other factors, changes to the regulation signal tuning parameters, changes in the set of resources providing regulation service, and changes to the regulation requirement.

PJM determines the benefits factor based on the expected impact that fast-following resources have on the NERC reliability criteria. Determination of expected response will be based a combination of off-line models, analysis of the



regulation signals, and the historical operational data as it accumulates. Historical operational data will be given increasing weight to the benefits factor determination over time. Changes to the benefits factor function will be made periodically after review at the Operating Committee.

The net impact of the use benefits factor is to increase in the likelihood of dynamic resources being selected in the clearing process, up to the point of diminishing returns. Beyond the point of diminishing returns (1 to 0), the benefits factor will decrease the likelihood of fast-following resources getting clearing.

### Three Pivotal Supplier

PJM utilizes the Three Pivotal Supplier (TPS) Test in the regulation market to mitigate market power as detailed in section 3.2.2A.1 of the PJM Tariff. Each supplier, from 1 to n, is ranked from the largest to the smallest offered MW of eligible regulation supply adjusted by the resource-specific benefits factor and the resource specific performance score in each 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 benefits factor of offered resource and the resource specific performance score are combined with a third supplier adjusted by the benefits factor of offered resource and the resource specific performance score, and the resulting combined supply is subtracted from total effective supply adjusted by the benefits factor of offered resource and the resource specific performance score. The resulting net amount of eligible supply is divided by the regulation requirement for the hour adjusted by the resource-specific benefits factor and the resource specific performance score (D). Where j defines the supplier being tested in combination with the two largest suppliers (initially the third largest supplier with j=3). Equation 0-1 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 three pivotal supplier test. Iterations of the test continue until the combination of the two largest suppliers and a supplier j result in 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 will be offer-capped.



- Regulating resources are offer-capped at the lesser of their cost-based or market-based regulation offer price.
- An offer-capped resource will only be offer-capped for a single hour at a time as the TPS Test is rerun for each hour of the day.
- Resource merit order price (\$/MWh) = Resource regulation offer + estimated resource opportunity cost per MWh of capability adjusted by the resource-specific benefits factor and the resource specific performance score.

### 3.2.8 Hydro Units

- Since hydro units operate on a schedule and do not have an energy bid, opportunity cost for these units is calculated as follows:
- During those hours when a hydro unit is in spill, the ED value 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 Scheduling Coordinator, and indicating this condition on the Regulation Updates page of the eMKT System.
- If a hydro unit is committed day-ahead with MW greater than zero, the formula is the same as Section 3.2.7.Regulation Market Clearing and Dispatch above, except the ED value is an average of the LMP at the hydro unit bus for the appropriate on-peak (0700 - 2259) or off-peak (0000 – 0659, 2300 - 2359) period, excluding those hours during which all available units at the hydro plant were operating. If this average 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 hydro units, and actual LMPs are used in the lost opportunity costs for settlement.
- If a hydro unit is brought on out of schedule to provide regulation or not committed in day-ahead market with MWs greater than 0, 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.
- When determined to be economically beneficial, PJM maintains the authority to adjust hydro unit schedules for those units scheduled by the owner if the owner has also submitted a regulation offer for those units and made the units available for regulation.
- An example of Regulation Hydro Lost Opportunity Cost Calculations can be found on the PJM website at <http://www.pjm.com/markets-and-operations/ancillary-services/mkt-based-regulation.aspx>

### 3.2.9 Regulation Market Operations

- The PJM Operator maintains total Regulation Zonal capabilities within a +/- 2%, but no less than +/- 15MW bandwidth around the RTO Regulation Requirement.
- The PJM Operator periodically evaluates the set of resources providing regulation, and makes any adjustments to regulation assignments deemed necessary and appropriate to minimize the overall cost of regulation.



- In the event of a regulation excess, the PJM dispatcher deselects resources beginning with the highest cost resource currently providing regulation and moving downward.
- In the event of a regulation deficiency, the PJM dispatcher selects resources to provide regulation beginning with the lowest cost resource currently not providing regulation and moving upward.
- The RMCP and therefore RMPCP and RMCCP does not change based upon regulating resource adjustments made in real time. Any opportunity costs that exceed the RMCP are credited after the fact on a resource-specific basis.
- The PJM Energy Management System (EMS) will send a RTO based signal(s) to each Local Control Center (LCC), as well as signals to individual resources or plants as requested by the owner.
- The PJM Operator communicates any change in resource regulating assignments to individual Local Control Centers. Company total in-service regulating capabilities are then telemetered back to the PJM EMS via the PJM data link.
- Resource regulation assignment changes during transitions between on-peak and off-peak periods begin 30 minutes prior to the new period, and are completed no later than 30 minutes after the period begins.
- For a dual qualified regulation resource, should the assignment change within the operating hour, the resource will continue to be committed or re-committed on the regulation signal type that the resource was initially committed on.

### 3.2.10 Settlements

- Please refer to Manual 28: Operating Agreement Accounting, Section 4: Regulation Accounting for settlement details.
- Regulation settlement is a zero-sum calculation based on the regulation provided to the market by generation owners and purchased from the market by LSEs.
- 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.
- Opportunity cost is calculated as shown above in Section 3.2.7 Market Clearing and Dispatch using actual integrated LMPs as opposed to that which was forecasted. PJM then adjusts the opportunity cost calculated for each resource based on the actual hourly integrated value of the real-time PJM regulation signal to account for the fact that the resource may have been held above or below its regulation set point for greater than half the hour and also adjusted by the resource-specific benefits factor and the resource specific performance score.
- Energy resources that are self-scheduled to provide energy and do not supply an energy offer are not eligible to collect opportunity cost credits. These resources will receive credit equal to the RMPCP and RMCCP times the amount of regulation self-





scheduled on or assigned to them adjusted by the mileage ratio between the requested mileage for the regulation dispatch signal assigned to the resource and the mileage for the traditional regulation signal and the resource's actual performance score for an hour.

- For market settlement, regulating resources are compensated with consideration toward the resource's Regulation performance, and where applicable, the mileage ratio between the requested mileage for the regulation dispatch signal assigned to the resource and the mileage for the traditional regulation signal.



## Section 4: Overview of the PJM Synchronized Reserve Market

Welcome to the Overview of the PJM Synchronized Reserve 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 Synchronized Reserve Market (see “*Overview of PJM Synchronized Reserve Market*”).
- A list of the PJM Synchronized Reserve Market Business Rules (see “*PJM Synchronized Reserve Market Business Rules*”).

### 4.1 Overview of the PJM Synchronized Reserve Market

The PJM Synchronized Reserve Market provides PJM participants with a market-based system for the purchase and sale of the Synchronized Reserve ancillary service. Resource owners submit resource-specific offers to provide Synchronized Reserve, and PJM utilizes these offers together with energy offers and resource schedules from the eMKT System, as input data to the Ancillary Service Optimizer (ASO). ASO then optimizes the RTO dispatch profile and forecasts LMPs to determine hourly commitments of the inflexible Synchronized Reserves. Although the ASO considers all available resources during its commitment process, the hourly commitments for Synchronized Reserve from the ASO are limited to inflexible resources only and may only represent a portion of PJM’s Synchronized Reserve needs for the hour. In real-time PJM will jointly optimize the remaining RTO reserve needs simultaneously with energy and calculate a clearing price for Synchronized Reserve every 5 minutes based on the current system conditions. All 5 minute, real-time, Synchronized Reserve prices will be averaged to calculate the hourly Synchronized Reserve Market Clearing Price (SRMCP) that will be used for market settlement.

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 but are not limited to synchronous condensers that are operating in condensing mode solely for the purpose of providing Synchronized Reserves and demand resources that are prepared to curtail in response to a PJM reserve event.

PJM initially uses forecasted LMPs and resource schedules to estimate the amount of incidental Synchronized Reserve present on the PJM system due to economic dispatch and this capability is designated as Tier 1. Tier 1 is provided by any resource that is on-line, following economic dispatch, and capable of [reliably](#) increasing its output within ten (10) minutes following a call for a Synchronized Reserve Event. If the forecasted amount of Tier 1 estimated for a given hour is insufficient to meet the PJM Synchronized Reserve Requirement,



PJM must commit resources to operate at a point that deviates from economic dispatch in order to provide the remainder of the requirement. The extra capacity that must be committed is designated Tier 2. ASO will commit any inflexible resources that are forecasted to be economic to provide Synchronized Reserves during the operating hour. If the solution does not foresee the need to commit Tier 2 reserves or does not commit enough inflexible resources to meet the Synchronized Reserve requirement due to economics, PJM will jointly optimize the balance of the Tier 2 required in real-time with energy.

During each execution of RT SCED, any additional Synchronized Reserves will be committed that is required to meet the Synchronized Reserve requirement based on current system conditions while the IT SCED has the ability to project conditions further out into the future and [commit-recommend](#) additional inflexible resources for reserves where they are economic. The software applications have the ability to re-dispatch online generating resources to meet the Synchronized Reserve requirement in addition to committing additional flexible resources to provide Synchronized Reserves should they be economic. Prices for Synchronized Reserves will be calculated simultaneously with energy, regulation and non-synchronized reserve every 5 minutes by LPC. For each product, the 5 minute prices will be averaged over the operating hour to determine the hourly Synchronized Reserve Market Clearing Price (SRMCP) that will be used for market settlement.

In the after-the-fact settlement, any [Tier 2](#) resources self-scheduled to provide Synchronized Reserve are compensated at the hourly SRMCP. Any [Tier 2](#) pool-scheduled resources selected to provide Synchronized Reserve are compensated at the higher of the hourly SRMCP or their real-time opportunity cost plus their Synchronized Reserve offer price. [Any resource that does not opt-out of a Tier 1 Performance Obligation is compensated at the hourly SRMCP for any Tier 1 MW used to meet the reserve requirement for those hours where the Non-Synchronized Reserve Market Clearing Price \(NSRMCP\) is above zero dollars.](#) LSEs required to purchase Synchronized Reserve are charged the hourly SRMCP plus their percentage share of opportunity cost credits and Tier 1 credits.

## 4.2 PJM Synchronized Reserve Market Business Rules

### 4.2.1 Synchronized Reserve Market Eligibility

- Synchronized Reserve offers must be submitted for those resources located electrically within the Synchronized Reserve Zone.
- Resources not located electrically within the Synchronized Reserve Zone may not submit Synchronized Reserve offers.
- Resources participating in the Synchronized Reserve market are divided into two Tiers:



- **Tier 1** is comprised of all those resources on-line following economic dispatch and able to ramp up from their current output in response to a Synchronized Reserve Event, or Demand Resources capable of reducing load within 10 minutes.
- **Tier 2** consists of:
  - that additional capacity that is synchronized to the grid and operating at a point that deviates from economic dispatch (including condensing mode) to provide additional Synchronized Reserve not available from Tier 1 resources; and
  - dispatchable load resources that have controls in place to automatically drop load in response to a signal from PJM.
- Tier 1 estimates for Demand Resources will equal zero.
- Tier 1 estimates for other resource types that cannot reliably provide Synchronized Reserve service shall be set to zero MW during the market clearing process. Such resource types include, but are not limited to: Nuclear, Wind, Solar, Batteries, and Hydro units. Owners of any specific resource(s) or these resource types may request an exception from the default zero MW estimated value of their resource(s) if they notify PJM that the resource(s) are able to reliably provide Tier 1 Synchronized Reserve. PJM will only grant such requested exceptions on a prospective basis. A resource will only be credited for Tier 1 Synchronized Reserve if the resource was considered during the market clearing process [and did not opt-out of receiving a Tier 1 Performance Obligation](#), unless such resource actually provides Tier 1 Synchronized Reserve during a Synchronized Reserve Event. For further information on the exception process, please visit: <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>.
- [Tier 1 estimates for resources that are self-scheduled and economically dispatched at their economic minimum will equal zero.](#)
- All resources operating on the PJM system [that can reliably provide Synchronized Reserve service](#) with the exception of those assigned as Tier 2 resources are by definition Tier 1 resources. Any resource capable of operating in condensing mode or physically able to operate with an output less than that dictated by economic dispatch must offer Tier 2. There is no qualification process for Tier 2 resources. However, penalties exist as described in section 4.2.12 below for response by Tier 2 resources that are less than that which is committed.
- All on-line non-emergency generation resources providing energy are deemed to be available to provide Tier 1 Synchronized Reserve and Tier 2 Synchronized Reserve, as applicable to the capacity resource's capability to provide these services. During periods for which PJM has issued a Primary Reserve Warning, Voltage Reduction Warning or Manual Load Dump Warning, all other non-emergency generation capacity resources available to provide energy shall have submitted offers for Tier 2 Synchronized Reserves. PJM will monitor compliance with the Tier 2 must offer requirement.



- To monitor the Tier 2 must offer requirement, PJM will check to ensure that every generator subject to the must offer requirement has submitted a Tier 2 offer greater than or equal to 90% of its energy ramp rate for the ramp rate segment including its economic max, multiplied by 10 minutes. If the Tier 2 offer is less than that quantity, PJM will contact the generation owner regarding the Tier 2 offer.
- Regardless of online/offline state, all non-emergency generation capacity resources must submit a daily offer for Tier 2 Synchronized Reserve in eMKT prior to the offer submission deadline (1800 the day prior to the operating day). Offer MW and other non-cost offer details can be changed during the operating day via the hourly update page (Synchronized Reserve Updates).
- Tier 2 offer quantities submitted for a capacity resource on the Synchronized Reserve Offer page in eMKT are automatically carried over from one day to the next unless updated. Changes made on the Synchronized Reserve Updates page of eMKT are not carried over into the next day.
- The following information must be supplied through the eMKT System:
  - Synchronized Reserve ramp rate for Tier 1 resources (MW/minute). A separate ramp rate may be submitted for multiple segments of a resource's MW range, and these ramp rates must be greater than or equal to the real-time economic ramp rate(s) submitted for the resource. Synchronized Reserve ramp rates that exceed economic ramp rates must be justified via submission of actual data from past Synchronized Reserve Events to the PJM Performance Compliance Department.
  - Resource's energy ramp rate is used for Tier 2 MW calculation.
  - Daily Tier 1 availability status. The default is available, which indicates that the Tier 1 resource is willing to accept a Tier 1 Performance Obligation for the operating day.
  - Hourly Tier 1 availability status. This is an override to the daily status. The default value is null. The value may be available or unavailable, which indicates that the Tier 1 resource is willing to accept (or not accept) a Tier 1 Performance Obligation for the operating hour.
  - Synchronized Reserve maximum (Spin Max) for Tier 1 resources: This value represents the maximum MW output a resource can achieve in response to a Synchronized Reserve Event. Synchronized Reserve maximum for Tier 1 resources must be greater than or equal to the economic maximum for the resource except for qualified resources that have been granted exception due to their physical limitation. Additional information on the communication process for consideration of resource physical limitation can be found on the PJM website at this location: <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>.

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o [The Spin Max can be updated intra-hourly during the operating day to allow a more accurate reflection of a resource's reserve capability and a more reliable Tier 1 MW estimate.](#)

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- o Generation resources must be able to provide 0.1 MW of Tier 2 Synchronized Reserve Capability in order to participate in the Tier 2 Synchronized Reserve Market. Demand Resources must be able to provide 0.1 MW of Tier 2 Synchronized Reserve Capability in order to participate in the Tier 2 Synchronized Reserve Market.
- o Synchronized Reserve availability for Tier 2 resources: Resources may be made unavailable to provide Tier 2 Synchronized Reserve only if they are physically unavailable. Otherwise, they must be made available or self-scheduled to provide Tier 2 Synchronized Reserve per the must offer requirement.
- o Synchronized Reserve offer quantity for Tier 2 resources (MW): This quantity is defined as the increase in output achievable by the resource in ten (10) minutes, or the load reduction achievable in ten (10) minutes.
- o A non-emergency generation capacity resource that cannot reliably provide Synchronized Reserve service may submit an offer quantity of zero MW. The participant responsible for a given resource must be able to justify a zero MW offer quantity. Certain unit types including, but not limited to, Nuclear, Wind, Solar, and Batteries, are expected to have zero MW Tier 2 Synchronized Reserve offer quantities.
- o Synchronized Offer Price for Tier 2 resources (\$/MWh): Synchronized Reserve offer prices will be capped at a maximum value of the resource's O&M cost (as determined by the Cost Development Task Force) plus \$7.50/MWh margin.
- o Energy use for condensing Tier 2 resources (MW): This is the amount of instantaneous energy a condensing resource consumes while operating in the condensing mode. The value submitted as part of the Synchronized Reserve offer must be less than or equal to the actual energy consumed as observed in real time.
- o Should a resource be unable to participate in the Synchronized Reserve market in any given hour on the operating day, the following update should be made 60 minutes prior to the operating hour in the Synchronized Reserve Update screens of eMKT:
  - Set Offer MW to zero
  - Set Available status to Not Available.
- o Condense to gen cost: This is the cost of transitioning a condenser to the generating mode. The value submitted for this cost must be less than or equal to the condensing start cost.



- Shutdown Costs: These are the costs a Demand Resource incurs when reducing load in response to a Synchronized Reserve Event.
- Condense Startup Cost: This is the actual cost associated with getting a resource from a completely off-line state into the condensing mode including fuel, O&M, etc.
- Condense Hourly Cost: This is the hourly cost to condense is equal to the actual, variable O&M costs associated with operating a resource in the condensing mode, including any fuel costs. It does not include any estimate for energy consumed
- Condense Notification Time: The amount of advance notice, in hours, required to notify the operating company to prepare the resource to operate in synchronous condensing mode. The default value is 0 hours.
- Spin as Condenser: This is used to identify if a combustion turbine can be committed for Synchronized Reserve as a condenser.

#### 4.2.2 Synchronized Reserve Requirement Determination

PJM will select resources in the Synchronized Reserve Zone and Reserve Sub-zone hourly to provide synchronized reserve based on a joint optimization between energy, regulation, non-synchronized reserve and synchronized reserve. Assignments will be communicated to the resource owners/operators by eMKT or the appropriate application.

- In the PJM RTO there will be a single Synchronized Reserve Zone and potential Reserve Sub Zones. Total PJM Synchronized Reserve Requirement for each Synchronized Reserve Zone is determined in whole MW for each hour of the operating day.

The PJM RTO Reserve Zone is defined as that amount of 10-minute reserve that must be synchronized to the grid. The Synchronized Reserve requirement will be defined as the greater of the ReliabilityFirst Corporation (RFC) imposed minimum requirement or the largest contingency on the system.

- North American Electric Reliability Council (NERC) standards may impose greater requirements for synchronized reserve following Disturbance Control Standard (DCS) violations. Any such impositions will be incorporated as an increase to the overall control zone synchronized reserve requirement.

Due to transmission security considerations on the PJM system, it is sometimes necessary to carry a minimum amount of synchronized reserve in specific sub-zones in PJM such that loading 100% synchronized reserve will not result in an overload of any of the PJM transfer interfaces. The Mid-Atlantic Dominion Sub-Zone is defined in the Synchronized Reserve Market to ensure that reserves are available in or deliverable to the eastern part of the system under constrained conditions. The Mid-Atlantic Dominion Sub-Zone is defined by the most limiting monitored transfer



interfaces. The interface modeled may be revised by PJM to match operation and meet the system reliability needs.

As system conditions dictate, PJM may need to redefine or include additional sub-zones into the RTO Synchronized Reserve Market. PJM will notify the stakeholders in the event any additional sub-zones need to be created due to unforeseen system conditions that impact reliability.

- PJM shall obtain and maintain for each Reserve Zone and Reserve Sub-zone an amount of Non-Synchronized Reserve such that the sum of the Synchronized Reserve and Non-Synchronized Reserve meets the Primary Reserve objective for such Reserve Zone and Reserve Sub-zone.
- PJM shall create additional Reserve Zones or Reserve Sub-zones to maintain the required amount of reserves in a specific geographic area of the PJM Region as needed for system reliability. Such needs may arise due to planned and unplanned system events that limit the PJM's ability to deliver reserves to specific geographic area of the PJM Region where reserves are required

Certain topology configurations on the system may result in single contingencies that exceed what was previously defined as the Synchronized Reserve Requirement. During these periods, PJM may increase the Synchronized Reserve Requirement to accommodate the larger single contingency. Under most conditions, the increased Synchronized Reserve Requirement will be 75% of the larger single contingency during the off-peak period (0000 – 0459) and 100% of the larger single contingency during the on-peak period (0500 – 2359). This value may be further adjusted by PJM to meet the system reliability needs.

- At times, anticipated heavy load conditions may result in PJM operators carrying additional reserves to cover increased levels of operational uncertainty. PJM may extend the Synchronized Reserve and Primary reserve requirements in the Market Clearing Engines during the on-peak period in order to incorporate these actions in energy and reserve pricing when a Hot Weather Alert, Cold Weather Alert or an escalating emergency procedure (as defined in Manual 13: Emergency Operations) has been issued for the operating day. The extended Synchronized Reserve Requirement and Primary Reserve Requirement will be equal to the existing reserve requirement plus the sum of any additional MW brought online for that hour by PJM dispatch to account for operational uncertainty after the second resource commitment which occurs after 18:00 the day prior to the Operating Day. If reserve deliverability issues are anticipated, then the requirements for the Sub-Zone(s) in which the additional resources are located will be extended. For example, if additional resources are specifically scheduled in the Mid-Atlantic Dominion Sub-Zone in anticipation of transmission constraints inhibiting the delivery of reserves into that region, both the Mid-Atlantic Dominion Sub-Zone and RTO Reserve Zone requirements would be extended. If additional resources are scheduled in the non-Mid-Atlantic Dominion portion of the RTO Reserve Zone, then only the RTO Reserve Zone requirement would be extended.





- The requirements will return to their original values upon exit from emergency procedures or when the additional resources have been released by PJM dispatch.

PJM will notify market participants of changes to the reserve requirements in relation to emergency procedures via the Emergency Procedure Posting Application once the decision to change the reserve requirements is made.

Regardless of the reserve requirements modeled in the Market Clearing Engines, PJM operators will continue to initiate emergency procedures based on the reserve requirements defined in Manual 13: Emergency Operations.

#### 4.2.3 Synchronized Reserve Obligation Fulfillment

- Each Load Serving Entity (LSE) on the PJM system incurs a synchronized reserve obligation in kWh based on their real-time load ratio share and the Synchronized Reserve Zone total assigned MW. During hours when the Synchronized Reserve Market Clearing Price (SRMCP) is the same throughout the Synchronized Reserve Zone, an LSE's synchronized reserve obligation is equal to its load ratio share times the amount of synchronized reserve assigned for the Synchronized Reserve Zone. During hours when congestion causes Synchronized Reserve Market Clearing Prices (SRMCP) to separate each LSE's obligation is equal to its load ratio share within its sub-zone times the amount of synchronized reserve assigned in that sub-zone. Any PJM market participant may incur or fulfill a synchronized reserve obligation through the execution of a bilateral synchronized reserve transaction as described below.
- Participants may fulfill their synchronized reserve obligations by:
  - Owning Tier 1 resources from which the Synchronized Reserve Zone obtains synchronized reserve;
  - Self-scheduling owned Tier 2 resources;
  - Entering bilateral arrangements with other market participants; or
  - Purchasing synchronized reserves from the market.
- Note that LSEs whose reserve obligations are satisfied through an agreement to share reserves with external entities subject to the requirements in NERC Reliability Standard BAL-002 will not have a synchronized reserve obligation

#### 4.2.4 Synchronized Reserve Offer Period

- Synchronized Reserve offer prices for Tier 2 resources and Synchronized Reserve ramp rates are locked as of 1800 hours on the day preceding the operating day. All resources listed as available for Tier 2 Synchronized Reserve with no offer price will have their offer prices set to zero.
- To accurately reflect each resource's reserve capability and availability during the Operating Day, the following information may be submitted and/or changed up until ~~60 minutes prior to the start~~[the end](#) of the operating hour ~~, at which time the Synchronized Reserve Market closes.~~



- [Synchronized Reserve Availability for Tier 1 resources](#)
- Synchronized Reserve Availability for Tier 2 resources
- Synchronized Reserve Offer Quantity (MW)
- Synchronized Reserve Maximum (This parameter is called Spin Max on the eMKT Synchronized Reserve Hourly Updates screen)

#### 4.2.5 Bilateral Synchronized Reserve Transactions

- Bilateral synchronized reserve transactions may be reported to PJM. Such reported bilateral synchronized reserve transactions must be for the physical transfer of synchronized reserve and must be reported by the buyer and subsequently confirmed by the seller through the eMKT System no later than 16:00 the day after the transaction starts. 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 after its start time has passed will result in a change in the end time of the transaction to the current hour.
- Bilateral synchronized reserve transactions reported to PJM may be entered either in MW or as a percentage of the purchaser's obligation. Participants will also be required to indicate the reserve zone for which the transaction is applicable.
- Payments and related charges associated with the bilateral synchronized reserve transactions reported to PJM shall be arranged between the parties to the bilateral contract.
- A buyer under a bilateral synchronized reserve transaction 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 Synchronized Reserve 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 [eMarkets-eMKT](#) schedules associated with its bilateral synchronized reserve transactions previously reported to PJM for all days where delivery had not yet occurred.
- PJM calculates and posts Synchronized Reserve Zone preliminary billing data on which market participants can use as a resource for pricing bilateral synchronized reserve transactions. The information can be found on the PJM website at <http://www.pjm.com/markets-and-operations/market-settlements/preliminary-billing-reports.aspx>.

#### 4.2.6 Synchronized Reserve Commitment

- 60-minutes prior to the operating hour PJM will execute the Ancillary Services Optimizer (ASO). The ASO will jointly optimize energy, synchronized reserves, non-synchronized reserves and regulation based on forecast system conditions to determine an economic set of inflexible reserve resources to commit for the operating hour.



- Any self-scheduled offers for synchronized reserves that are available at the time of the ASO execution will be assumed valid and committed for the hour as needed.
- Any reserve commitments on inflexible resources that are made will be locked for the operating hour and communicated via eMKT.
- The following reserve information will be posted to eMKT 30-minutes prior to the operating hour:
  - Reserve requirements for the RTO and each sub-zone
  - Estimated Tier 1 for the RTO and each sub-zone
  - Total synchronized and non-synchronized reserves available for the RTO and each sub-zone
  - Total pool-committed inflexible reserves for the RTO and each sub-zone
  - Total self-scheduled synchronized reserves for the RTO and each sub-zone
  - Forecasted reserve shortage quantities for the RTO and any sub-zone
- Estimated Tier 1 reserves for the RTO and each sub-zone are calculated in real-time by IT SCED and RT SCED. Estimated Tier 1 reserves are subtracted from the synchronized reserve requirement to determine the amount of additional Tier 2 synchronized reserves that are needed to meet the requirement.
  - The Tier 1 estimate MW calculated by IT SCED is not binding.
  - The Tier 1 estimate MW calculated by RT SCED for each Tier 1 resource is binding and becomes a Tier 1 Performance Obligation for the resource any time the Non-Synchronized Reserve Market Clearing Price is greater than \$0. In intervals when the Non-Synchronized Reserve Market Clearing Price is equal to \$0, the Tier 1 estimate MW from RT SCED is not binding and does not become a Tier 1 Performance Obligation.
  - Any resource that has a Tier 1 Performance Obligation when a synchronized reserve event occurs is obligated to respond with their Tier 1 MW calculated at the start of the event within 10 minutes.
  - A market participant may prospectively opt out of accepting a Tier 1 Performance Obligation for a given resource on an hourly basis by setting the Tier 1 Availability Status for that unit to 'Unavailable' in eMKT.
    - Opting out of the Tier 1 Performance Obligation means that the resource will not be obligated to respond to a synchronized reserve event for that hour. Consequently, it also means that the participant elects to forgo compensation for their Tier 1 estimate when the NSRMCP is greater than \$0.
  - Tier 1 estimate from RT SCED will be telemetered via ICCP or other communication protocol to resource owners.



- Any additional Tier 2 synchronized reserves required in real-time in excess of the current Tier 1 on the system and the Tier 2 commitments will be committed via the joint optimization of energy and reserves.
  - Additional Tier 2 synchronized reserve commitments made in real-time may be made on either flexible or inflexible reserves resources by the RTSCED and ITSCED applications, respectively. 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.
  - Flexible [Tier 2](#) reserve resource [Tier 2](#) commitments will not be posted to eMKT but will be telemetered via ICCP or other communication protocol to resource owners.
  - Additional inflexible [Tier 2](#) resource commitments will be communicated to the resource owners via phone call or ~~internet notification~~ [other communication protocol to resource owners.](#)
- Any resource that is committed for Tier 2 when a synchronized reserve event occurs is obligated to respond for their commitment at the start of the event within 10 minutes.
- For the purpose of determining the most economic set of resources with which to meet the Synchronized Reserve requirement, PJM will calculate a resource-specific merit order price for each resource using the following methodology:
  - Resource merit order price (\$/MWh) = Resource synchronized reserve offer + estimated resource opportunity cost per MWh of capability + energy use per MWh of capability + condense startup cost
  - Note: Condense startup cost is not included in the determination of the clearing price.

The resource synchronized reserve offer is that which is submitted by the owner via the eMKT System by 1800 hours on the day preceding the operating day.

Estimated resource opportunity cost for condensing CTs is calculated as follows:

$$O.C. = [positive (forecast LMP - energy offer price)] \times MW \text{ capability} / \text{synchronized reserve capability}$$

Estimated resource opportunity cost for non-condensing resources is calculated as follows:

$$O.C. = |LMP - ED| \times GENOFF, \text{ where:}$$

LMP is the forecasted hourly LMP at the generator bus,

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ED is the price associated with the set point the resource must maintain to provide its assigned amount of synchronized reserve, and

GENOFF is the MW amount of synchronized provided.

This formula is somewhat simplistic. The actual calculation is an integration that may be visualized as the area on a graph enclosed by the resource's price curve, the points on that curve corresponding to the resource's desired economic dispatch and the set point necessary to provide the assigned amount of synchronized reserve, and the LMP.

Energy use for each condensing resource is entered in MW by the owner via the eMKT system as part of the synchronized reserve offer. Estimated energy use is calculated as part of the merit order price as follows:

$$E.U. = \text{forecast LMP} \times \text{energy use MW} / \text{synchronized reserve capability}$$

For each of these calculations, forecast LMP is the result of the 1-hour look-ahead provided Energy resources for which an energy offer is not submitted will be ineligible for opportunity cost credit.

The opportunity cost for a Demand Resource is zero.

- PJM may call on resources not otherwise scheduled to run in order to provide synchronized reserve, 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 synchronized reserve, the resource is guaranteed recovery of synchronized reserve lost opportunity costs as well as start-up, no-load and energy costs. Please refer to Manual 28: Operating Agreement Accounting for additional settlements details.
- Due to transmission considerations on the PJM system, it is sometimes necessary to carry a minimum amount of synchronized reserve in specific areas in PJM such that loading 100% synchronized reserve will not result in an overload of any of the PJM transfer interfaces. The goal is to minimize the cost of synchronized reserve such that given current system conditions, the flow on binding transmission constraints is not increased after a synchronized reserve event is initiated and the associated response is achieved. Therefore, PJM clears the Tier 2 market based on this locational synchronized reserve requirement and calculates sub-zonal Tier 2 clearing prices. Whenever the locational synchronized reserve constraint is not binding, the clearing prices are equal. However, when more synchronized reserve is required in a given area than would have been assigned without this requirement, the clearing prices will separate. Resources will be identified and receive the applicable clearing price based on their location with respect to the binding constraint(s). That is, resources for which synchronized reserve response would help the constraint will receive the higher clearing price, whereas resources for which synchronized reserve response would aggravate the constraint will receive the lower clearing price.



Analysis to determine the location of generation and load buses with respect to the binding constraint is performed with each quarterly network model update. The Mid-Atlantic Dominion sub-zone list resulting from this analysis can be found on the PJM Web site at: <http://www.pjm.com/markets-and-operations/ancillary-services.aspx>.

- 5-minute market clearing prices will be made available in real-time through eData.
- If no Synchronized Reserve Market Results are communicated for an hour, PJM will continue the current [inflexible Tier 2](#) assignments, as needed, into the un-posted hour. [Flexible Tier 2 are continually re-evaluated and committed as needed intra-hourly.](#)

#### 4.2.7 Hydro Units

Hydro units condensing to provide synchronized reserve during times when they were not scheduled to generate incur no opportunity cost. There may or may not be an energy use component, as indicated by the owner as part of the synchronized reserve offer.

- If a hydro unit is held to synchronized reserve condense or reduced to provide synchronized reserve during a time when it is scheduled to generate, it will incur opportunity cost. Since hydro units operate on a schedule and do not have an energy bid, opportunity cost for these units is calculated as follows:
- The formula is the same as that shown under 'Synchronized Reserve Market Clearing',  $O.C. = |LMP - ED| \times GENOFF$ , except the ED value is the average value of the LMP at the hydro unit bus for the appropriate on-peak (0700 – 2259) or off-peak (0000 – 0659, 2300 - 2359) period, excluding those hours during which all available units at the hydro plant were operating. Day-ahead values are used for the purposes of committing Tier 2 resources, and actual LMPs are used in the after-the-fact settlement. If the average LMP value is higher than the actual LMP at the generator bus, the opportunity cost is zero.
- During those hours when a hydro unit is in spill, the ED value 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 on the Regulation Hourly Updates page in the eMKT System.
- When determined to be economically beneficial, PJM maintains the authority to adjust hydro unit schedules for those units scheduled by the owner if the owner has also submitted a synchronized reserve offer for those units and made the units available for spin.

#### 4.2.8 Demand Resources

- Demand resources providing Synchronized Reserve are required to provide metering information at no less than a one minute scan surrounding a synchronized reserve event.
- Metering information for demand resources is not required to be sent to PJM in real time. Load data for all Synchronized Reserve events must be submitted two business days following the event day.



- Members that offer into the Synchronized Reserve market and do not provide complete, accurate and timely load data for all Synchronized Reserve events may be suspended from participating in the Synchronized Reserve Market until corrective measures are implemented and may be referred to the PJM Market Monitor and/or the FERC Office of Enforcement for further investigation as necessary.
- Demand resources are limited to providing 33% of the Synchronized Reserve requirement.
- Demand resources that are considered to be “batch load” resources are limited to providing 20% of the Synchronized Reserve requirement. If PJM determines that satisfying 20 percent of the Synchronized Reserve requirement from Batch Load demand resources is causing or may cause a reliability degradation, PJM may reduce the percentage of the requirement that may be satisfied by Batch Load demand resources in any hour to as low as 10 percent.
- Demand resources must complete initial and continuing training on Regulation and Synchronized Reserve Markets as documented in Manual 40: Certification and Training Requirements, Section 2.6: Training Requirements for demand response Resources Supplying Regulation and Synchronized Reserve.
- Effective June 1, 2015: When a Demand Resource that is eligible for the Synchronized Reserve Market is called for a mandatory Emergency or Pre-Emergency Load Management Event, it will be de-assigned from Synchronized Reserves 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 Synchronized Reserves for the remainder of the mandatory portion of the Load Management Event.

#### 4.2.9 Synchronized Reserve Market Clearing Price (SRMCP) Calculation

- PJM will calculate real-time prices for Synchronized Reserve simultaneously with LMPs every 5-minutes in real-time.
- The real-time prices for Synchronized Reserve will be calculated as the marginal cost to serve an additional MW of synchronized reserve demand in the RTO or applicable sub-zone while simultaneously satisfying energy requirements, regulation requirements, primary reserve requirements and transmission limitations.
- Real-time 5-minute SRMCPs will be published to eData for public view.
- During periods when there is no synchronized reserve shortage, real-time prices for Synchronized Reserve will be determined by the cost of the marginal synchronized reserve resource.
  - The cost of the marginal synchronized reserve resource is defined as its synchronized reserve offer plus any opportunity cost for this resource relative to forgone energy or other ancillary service payments.
  - Non-shortage prices for synchronized reserves will not exceed the sum of the primary reserve and synchronized reserve penalty factors.



- When there is a simultaneous shortage of primary and synchronized reserves the real-time prices for Synchronized Reserve will be the sum of the primary reserve and synchronized reserve penalty factors.
- The real-time prices for Synchronized Reserve will always be greater than or equal to the NSRMCP in the same location because synchronized reserve is a higher quality product than non-synchronized reserves and may be substituted for it.
- The real-time prices for Synchronized Reserve in each hour will be used to calculate the hourly SRMCP that will be used for settlement purposes. The hourly SRMCP for a reserve zone will be the average of the 5 minutes SRMCPs in the applicable zone or sub-zone.

#### 4.2.10 Settlements

- Please refer to Manual 28: Operating Agreement Accounting, Section 6: Synchronized Reserve Accounting for settlement details.
- Synchronized Reserve settlement is a zero-sum calculation based on the synchronized reserve provided to the market by generation owners and purchased from the market by participants.
- Tier 1 credits [for eligible resources that opt out of receiving a Tier 1 Performance Obligation](#) will be awarded ~~to each eligible resource~~ for response [to a synchronized reserve event](#) up to 110% of the resource's capability based on the synchronized reserve ramp rate(s) submitted by the resource's owner day-ahead. Credits to individual resources may be awarded for response greater than 110% of stated capability if other Tier 1 resources under-respond. Credits for response in excess of 110% of capability will be awarded on a pro-rata basis such that the aggregate Tier 1 credits awarded do not exceed 110% of the total possible credits based on the aggregate capability of all eligible Tier 1 resources.
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- Resources providing regulation at the initiation of a synchronized reserve event will be compensated for Tier 1 response. Tier 1 response is calculated according to the following formula:

$$\left\{ \left[ \max \left( 0, \int \left( \text{Output} - \min \left( \text{EcoMax}, \text{RegHighLimit} \right) \right) \right) \right] + \left[ \max \left( 0, \int \left\{ \min \left( \text{EcoMax}, \text{RegHighLimit}, \text{Output} \right) - \left( \text{Initial Output} - (2 \times \text{RegMW}) \right) \right\} \right) \right] \right\}, \text{ where :}$$

- Final Output is the resource's greatest telemetered output between 9 and 11 minutes after synchronized reserve event is initiated
- Initial Output is the resource's lowest telemetered output between 1 minute before and 1 minute after synchronized reserve event is initiated
- RegMW is the resource's assigned amount of regulation

As a result of this formula, resources that are assigned regulation when a synchronized reserve event is initiated will be compensated based on the amount





of response provided beyond their regulation commitment, as well as for any response in excess of their regulation high limit or economic maximum (whichever is lower.) A resource's regulation maximum commitment will be defined as the resource's full regulating range (i.e. – twice the amount of assigned regulation.)

- [Tier 1 resources that accept a Tier 1 Performance Obligation receive credit at the Synchronized Reserve Market Clearing Price whenever the Non-Synchronized Reserve Market Clearing Price is greater than \\$0.](#)
- [Tier 1 resources that accept a performance obligation are credited for the amount of their Tier 1 MW estimate.](#)
- Tier 2 synchronized reserve credits are awarded to generation owners that have either self-scheduled synchronized reserve or sold synchronized reserve into the market. Synchronized reserve credits for resources self-scheduled to provide synchronized reserve are equal to [Tier 2 Synchronized Reserve Market eC](#) clearing [pP](#) Price times the resource's self-scheduled synchronized reserve capability. Synchronized reserve credits for resources that are pool-scheduled to provide synchronized reserve are the higher of:
  - [Tier 2 Synchronized Reserve Market eC](#) clearing [pP](#) Price times the resource's assigned synchronized reserve capability, or
  - The resource's synchronized reserve offer times its assigned synchronized reserve capability plus opportunity cost and/or energy use incurred.
- Opportunity cost and energy use are calculated as shown above in Market Clearing using actual integrated LMP as opposed to that which was forecasted.
- [Tier 1 and Tier 2 Synchronized Reserve resources that respond to a synchronized reserve event will be made whole to their cost to respond to the event unless self-scheduled for energy and dispatched at economic minimum.](#)
- Resources that are pool-assigned Tier 2 synchronized reserve (and actual MWh are less than day-ahead scheduled MWh) and Tier 1 resources that respond to a synchronized reserve event are therefore exempt from deviations for the purpose of accumulating operating reserves charges for the hours during which the Tier 2 assignment or Tier 1 response is effective.

#### 4.2.11 Verification

- The magnitude of each resource's response to a synchronized reserve event (both Tier 1 and Tier 2) is the difference between the resource's output at the start of the event and its output ten minutes after the start of the event. In order to allow for small fluctuations and possible telemetry delays, resource output at the start of the event is defined as the lowest telemetered output between one (1) minute prior to and one (1) minute following the start of the event. Similarly, a resource's output ten minutes after the event is defined as the greatest output achieved between nine (9) and eleven (11) minutes after the start of the event. All resources (both Tier 1 and Tier 2) must maintain an output level greater than or equal to that which was achieved as of ten minutes after the event for the duration of the event or thirty (30) minutes from



the start of the event, whichever is shorter. The response actually credited to a given resources will be reduced by the amount the MW output of that resource falls below the level achieved after ten (10) minutes by either the end of the event or after 30 minutes from the start of the event, whichever is shorter.

- For demand resources that are considered “batch load” resources, a second method of verification will be used for instances where a synchronized reserve event is initiated and the resource is operating at the minimum consumption level of its duty cycle. In this case, the magnitude of the response will be measured as the difference between (a) the resource’s consumption at the end of the event and (b) the maximum consumption within a ten (10) minute period following the event provided that all subsequent minutes following that minute are no less than 50% of the consumption in that minute.

#### 4.2.12 Non-Performance

- There is no consequence for a Tier 1 resource [without a Tier 1 Performance Obligation](#) that does not respond ~~with the amount of Synchronized Reserve that was expected of it in response~~ to a Synchronized Reserve Event. Tier 1 resources ~~without a Tier 1 Performance Obligation~~ are simply credited for the amount of MW response they provide [if they do respond](#).
- [Because Tier 1 resources with a Tier 1 Performance Obligation](#) and Tier 2 resources [are credited with a synchronized reserve payment in expectation of their to](#) responded to a Synchronized Reserve Event [should one occur](#), failure to provide that response results in an obligation to “repay” that credit following instances of non-performance. The following consequences exist for a [resource with a Tier 1 Performance Obligation that does not respond with its Tier 1 estimate MW or a](#) Tier 2 resource that does not respond with its assigned amount of Synchronized Reserve:
  - The resource is credited for [Tier 1 or](#) Tier 2 Synchronized Reserve capacity in the amount that actually responded for all hours the resource [had a Tier 1 Performance Obligation or](#) was assigned or self-scheduled Tier 2 Synchronized Reserve on the day the event occurred, and;
  - The owner of the resource incurs a retroactive obligation to refund at SRMCP the amount of the shortfall measured in MW for all of the hours the resource was assigned or self-scheduled over the immediate past interval, the duration of which is equal to the lesser of the average number of days between events as determined by the annual review of the last 2 years, or the number of days since the resource failed to respond with its [Tier 1 Performance Obligation or](#) assigned or self-scheduled [Tier 2](#) Synchronized Reserve amount in response to a Synchronized Reserve Event.
  - The annual review will be completed during the month of November and cover a 2 year window from November 1st (year – 2) through October 31st (current year). The penalty days calculation will be the average interval between Synchronized Reserve Events over the last two years of Synchronized Reserve Event data, rounded down to a whole day value. The

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results will be communicated to the Operating Committee in December and implemented annually on January 1st.

- Market Participants that own multiple resources [with Tier 1 Performance Obligations or resources](#) assigned or self-scheduled to provide Tier 2 Synchronized Reserve are permitted to demonstrate aggregate response, such that any resource that has responded greater than their [Tier 1 Performance Obligation or](#) assignment or self-scheduled [Tier 2](#) can be used to offset any resource that has responded less than their [Tier 1 Performance Obligation or](#) assignment or self-schedule of Tier 2 Synchronized Reserve during a Synchronized Reserve Event. The Market Participant's aggregate response shall not affect how an individual resource is credited for [Tier 1 or](#) Tier 2 Synchronized Reserve it provides as described above, but shall be used to determine what the Market Participant owes in refund charges for each resource that was [obligated to provide Tier 1 or](#) assigned or self-scheduled to provide Tier 2 Synchronized Reserve and responded less than their [Tier 1 estimate or](#) assignment or self-schedule of Tier 2 Synchronized Reserve. Additional details can be found in Manual 28, Section 6.3: Charges for Synchronized Reserve.
- In cases where a Synchronized Reserve Event lasts less than 10 minutes, Tier 2 resources are credited with the amount of Synchronized Reserve capacity they are assigned [and Tier 1 resources with a Performance Obligation are credited with the amount of their Tier 1 estimate](#). Tier 1 resources [that do not accept a Performance Obligation](#) are credited with the amount of response provided over the length of the event, as determined via measurement parallel to that which is described above in the Verification section. That is, the output of each resource at the start of the event is defined as the lowest telemetered output between one (1) minute prior to the start of the event and one (1) minute after the start of the event, and the output at the end of the event is defined as the greatest telemetered output between one (1) minute prior to the end of the event and one (1) minute following the end of the event
- Resources that choose to respond to a Synchronized Reserve Event for their reserve zone in an hour when they are cleared or assigned 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.