equations to calculate bus voltage and angle and flows based on metered data. Since the state estimator solution provides a complete and consistent model of actual operating conditions based upon metered input and an underlying mathematical model, it can be used to provide the basis for RT SCED case solutions.

A new state estimator solution is typically available every minute to RT SCED and can provide the following inputs:

- AC power flow solution.
- Actual generator MW output.
- Bus loads.
- Tie-line flows.
- MW losses by transmission zone.
- Actual MW flow on any constrained transmission facility.

2.7 Locational Pricing Calculator (LPC)

The function of the Locational Pricing Calculator (LPC) is to determine the Real-time LMP values and Regulation and Reserve Clearing Prices on a five (5) minute basis. The LPC engine performs a pricing run solution where Integer Relaxation is applied to eligible Fast-Start resources only for the purposes of calculating LMPs and Ancillary Service MCPs. Real-time LMPs and Regulation and Reserve Clearing Prices are derived from the inputs of the latest approved Real-time Security Constrained Economic Dispatch (RT SCED) program solution, referred to as the reference case, for the target time at the end of the current five (5) minute interval. If there is not an approved RT SCED solution for the target time at the end of the current five (5) minute interval, LPC will use the most recent approved RT SCED solution prior to the target time as the reference case. LPC will use the offered in parameters for Energy and Reserves from the reference case as inputs as well as offered in parameters for Regulation that are effective at the target time for each LPC case solution. The Real-time LMPs and Regulation and Reserve Clearing Prices calculated by LPC are applied to each five (5) minute Real-time Settlement Interval ending at the LPC target time. In the event of an outage to RT SCED, the LPC will use the RT SCED case that best represents the conditions over the outage period as determined by the Market Operator. In the event multiple RT SCED cases are approved for the same target time and one of the reference cases is a shortage case, the shortage case shall be used as the reference case for LPC. In the event multiple RT SCED cases are approved for the same target time and one of the reference cases is an Intelligent Reserve Deployment (IRD) case, the approved IRD case shall be used as the reference case for LPC. In the event there is a RT SCED Shortage and a RT SCED IRD case approved for the same target time, the IRD case shall be used as the reference case for LPC.

The LPC calculates LMPs for each of the PJM nodes in the state estimator model and for interface busses used as a proxy for transfers to and from PJM and external control areas. The Real-time LMPs are defined as the cost to serve the next increment of load at each node, in the LPC pricing run, taking into account eligible resource Real-time offer prices and the nodes' location with respect to transmission limitations and incremental system losses.

The LPC is an incremental linear optimization program that is formulated to jointly optimize and price both Energy and Reserves. The objective is to minimize the cost function including the cost of Energy and Reserves subject to the power balance constraint, the Synchronized and Primary Reserve Requirements, specific generator and Demand Resource operating limitations, except in cases in which Integer Relaxation is applied, transaction MW limits, and any transmission constraints that currently exist on the system and a normalized distribution of system losses to a network location.

Every five (5) minutes the LPC calculates:

- Locational Marginal Prices (LMPs).
- Synchronized Reserve Market Clearing Prices (SRMCPs).
- Non-Synchronized Reserve Market Clearing Prices (NSRMCPs).
- Regulation Market Clearing Prices (RMCPs) and Regulation Market Performance Clearing Prices (RMPCP), which are then used to derive the Regulation Market Capability Clearing Price (RMCCP).

Each Energy and Reserve clearing price is calculated as the cost to serve the next MW of demand for each individual product considering its impact on the others. For example, LMPs are calculated such that they reflect the cost to serve the next MW of Energy demand in each location while considering the impact of that additional MW of Energy on the ability to meet the Primary Reserve and Synchronized Reserve Requirements. Regulation Clearing Prices are calculated as the cost of the last resource committed to meet the Regulation Requirement, as further described in Section 3 of this Manual.

2.7.1 Energy Offers used in Real-time Price Calculation

As described in Section 2.1 of this Manual, Real-time economic dispatch is performed in the Real-time security constrained economic dispatch software program, known as the dispatch run. Real-time prices are calculated in a subsequent execution of the Locational Pricing Calculator (LPC) software program, known as the pricing run. The pricing run executes the same optimization as the dispatch run but additionally applies Integer Relaxation to Eligible Fast-Start Resources. Integer Relaxation is the process by which the commitment status for an Eligible Fast-Start Resource is allowed to vary between zero and one, inclusive of zero and one.

Real-time prices shall be determined for every five (5) minutes, using the applicable marginal energy offer of the resources being dispatched using the offer schedule on which the resource is committed in the dispatch run. PJM will determine a resource's applicable marginal energy offer by comparing the megawatt output of the resource from the pricing run with the Market Seller's Incremental Energy Offer curve or, for Eligible Fast-Start Resources, the Market Seller's Composite Energy Offer. For Eligible Fast-Start Resources, the amortized Start-Up Costs and amortized No-Load Costs, expressed in dollars per megawatt-hour, are added to the resource's Incremental Energy Offer to determine a Composite Energy Offer, as described below:

- The amortized Start-Up Cost for a generation resource equals the resource's applicable Start-Up Cost amortized over (A) the resource's Economic Maximum or Emergency Maximum output, whichever is applicable and (B) the resource's Minimum Run Time. The Emergency Maximum output will only be used for amortization when PJM Operations declares calling on offline emergency resources or declares deploying emergency segments on online resources. The amortized Start-Up Cost is included

in the resource's Composite Energy Offer during the resource's Minimum Run Time rounded up to the nearest twelfth of an hour. After the Minimum Run Time has been met, the amortized Start-Up Cost is not included in the Composite Energy Offer.

- If the Minimum Run Time is less than five (5) minutes, the Minimum Run Time used to calculate the amortized Start-Up Cost is five (5) minutes and the amortized Start-Up Cost is added to the Incremental Energy Offer for the first five (5) minute interval in which the resource runs.
- To determine the amortized Start-Up Costs for Economic Load Response Participant resources, the Minimum Down Time is used in place of the Minimum Run Time and shutdown cost is used in place of Start-Up Cost in the above equation.
- The Amortized Start-Up Cost will be adjusted from in the Composite Energy Offer, as described in Section 2.7.3 of this Manual, if the resource exceeds the reasonably expected cost during the Offer Verification screening process as described in Section 2.6.3.3 of this Manual.

- The amortized No-Load Cost equals the resource's applicable No-Load Cost, amortized over the resource's Economic Maximum or Emergency Maximum output, whichever is applicable, and included in the Composite Energy Offer for all intervals in which the generation resource is pool-scheduled.
  - The amortized No-Load Cost will be adjusted in the Composite Energy Offer, as described in Section 2.7.3 of this Manual, if the resource exceeds the reasonably expected cost during the Offer Verification screening process as described in Section 2.6.3.3 of this Manual.
- For purposes of calculating Real-time Prices, the applicable marginal Incremental Energy Offer used in the calculation of Real-time Prices shall not exceed $2,000/megawatt-hour.
- If a generation resource that is an Eligible Fast-Start Resource submits an offer that results in a Composite Energy Offer with a maximum segment that exceeds $2,000/megawatt- hour then the amortized Start-Up Cost may be adjusted from the determination of the Composite Energy Offer. If the resulting Composite Energy Offer is still in excess of $2,000/megawatt-hour, then the amortized No-Load Cost shall may be adjusted from the determination of the Composite Energy Offer.
- If an Economic Load Response Participant resource that is an Eligible Fast-Start Resource submits an offer that results in a Composite Energy Offer with a maximum segment that exceeds $2,000/megawatt-hour then the amortize shutdown cost may be adjusted from the determination of the Composite Energy Offer.

All Fast -Start resources, with the exception of self-scheduled resources that specify intent to not follow dispatch, are eligible to set LMP.

2.7.2 Determination of LMPS for De-Energized Busses

Due to equipment outages, the main transmission system may contain some de-energized busses for which LMPs cannot be directly calculated. It is necessary for settlement purposes that LMPs for these de-energized busses be established. The methodology for determining LMPs at de-energized busses is to assign to them the LMPs at their neighboring energized

busses. The following criteria for a search is designed and implemented in the Market Clearing Engine.

Search rules:

1. Search at the same voltage level.
    a. Check whether any of the other busses belonging in the same voltage level as the de-energized bus is energized. If an energized bus is found, set the LMP of the de-energized bus equal to the LMP of the energized bus. If a suitable replacement cannot be found, proceed to step 2.
2. Search at the same station.
    a. Check whether there are any energized busses located at a voltage level different from the de-energized-bus voltage level but at the same station. If an energized bus is found, set the LMP of the de-energized bus equal to the LMP of the energized bus. If a suitable replacement cannot be found, proceed to step 3.
3. Search in the nearest neighboring stations.
    a. Rank all the transmission lines out of the de-energized bus station in the descending order of their admittances.
    b. Check whether there is any energized bus in the next station available in the rank. If one is found, set the LMP of the de-energized bus equal to the LMP at the energized bus.

If by searching all the neighboring stations no energized bus is found, the PJM Market Operator is notified that a de-energized bus exists for which no suitable replacement could be found using the above steps and is required to manually search for a suitable replacement. PJM Market Operators also reviews the suitability of the replacements selected by the Market Clearing Engine, and in cases where modeling discrepancies cause the selection of a sub-optimal replacement, may elect to use a more suitable replacement.

2.7.3 Determination of Energy Offers for Generation Resources with Composite Energy Offers greater than $1,000/ MWh and equal to or below $2,000/MWh

When a Fast-Start capable resource submits a Composite Energy Offer that exceeds $1,000/MWh but is below $2,000/MWh at the resource's Economic Maximum value, the components that make up the offer are verified for reasonableness as described in Section 2.3.6.3 of this Manual.

If the submitted components of the Composite Energy Offer are deemed not reasonable, adjustments are made to the ensure the resulting Composite Energy Offer is no less than $1,000/MWh or the sum of the verified offer components as described in the PJM Operating Agreement, Schedule 1, Section 2.4.The chart below describes how the Composite Energy Offer components may be adjusted in the event the Start-Up and/or No-load cost exceed (fail) or do not exceed (pass) the reasonably expected cost for the determination of LMPs.

Scenario	Submitted Composite Energy Offer at EcoMax ($/MWh)	Submitted Incremental Energy Offer ("IEO")	Reasonability Test Results		Composition of Composite Energy Offer*	Adjustment and/or Offer Capping
			Submitted Start-Up Cost	Submitted No-load Cost		
1	≤ $1,000	≤ $1,000	N/A	N/A	IEO + ASU + ANL	No Offer Verification Trigger
2	$1,000 < Offer ≤ $2,000	≤ $1,000	Pass	Pass	IEO + ASU + ANL	None
3	$1,000 < Offer ≤ $2,000	≤ $1,000	Pass	Fail	IEO + ASU + adjustment (If needed)	Cap at the higher of $1000 or IEO + ASU; No-load Cost may be included to cap offer at $1,000
4	$1,000 < Offer ≤ $2,000	≤ $1,000	Fail	Pass	IEO + ANL + adjustment (If needed)	Cap at the higher of $1000 or IEO + ANL; Start-Up Cost may be included to cap offer at $1,000
5	$1,000 < Offer ≤ $2,000	≤ $1,000	Fail	Fail	IEO + Adjustment (If needed)	IEO Offer plus No-load Cost, up to submitted value to cap Composite Energy Offer to $1,000; Use Start-Up Cost, if additional cost are needed.
6	$1,000 < Offer ≤ $2,000	$1,000 < Offer ≤ $2,000	Pass	Pass	IEO +ASU +ANL	None
7	$1,000 < Offer ≤ $2,000	$1,000 < Offer ≤ $2,000	Pass	Fail	IEO +ASU	None
8	$1,000 < Offer ≤ $2,000	$1,000 < Offer ≤ $2,000	Fail	Pass	IEO +ANL	None
9	$1,000 < Offer ≤ $2,000	$1,000 < Offer ≤ $2,000	Fail	Fail	IEO	Incremental is verified above $1000, no additional cost are added

*The Start-Up Cost and No-load Cost included in a Composite Energy Offer will be at their amortized value. In this chart, "ASU" represents amortized Start-Up Cost, "ANL" represents amortized No-load Cost. Please refer to Section 2.7.1 for how the amortization process applies to the Start-Up and No-Load costs.

2.7.4 Determination of Energy Offers for Generation Resources with offers greater than $2,000/MWh

Generation resources with cost based Incremental Energy Offers in excess of $2,000/MWh are dispatched in economic merit order but are capped at $2,000/MWh for the purposes of calculating LMP.

2.7.5 Determination of Energy Offers for Composite Energy Offers Greater than $2,000/MWh

When a Fast-Start capable generation resource submits a Composite Energy Offer with a maximum segment that exceeds $2,000/MWh, the components that make up the offer are verified for reasonableness as described in Section 2.3.6.3 of this Manual. Based on the results of the reasonableness verification, adjustments are made to ensure the resulting Composite Energy Offer is no greater than $2,000/MWh as described in the PJM Operating Agreement, Schedule 1, Section 2.4.

The chart below describes how the Composite Energy Offer components may be adjusted in the event the Start-Up and/or No-load cost exceed (fail) or do not exceed (pass) the reasonably expected cost for the determination of LMPs.

Scenario	Submitted Composite Energy Offer at EcoMax ($/MWh)	Submitted Incremental Energy Offer ("IEO")	Reasonability Test Results		Composition of Composite Energy Offer*	Adjustment and/or Offer Capping
			Submitted Start-Up Cost	Submitted No-load Cost		
1	> $2,000	≤ $1,000	Pass	Fail	IEO + ASU + adjustment (If needed)	1) IEO + ASU or 2) If Incremental + ASU ≤ $1,000, cap at $1,000; Add ANL to cap at $1000, if needed 3) If Incremental + ASU > $2,000, cap at $2,000; Adjust down ASU to cap offer at $2000
2	> $2,000	≤ $1,000	Fail	Pass	IEO + ANL + adjustment (If needed)	1) IEO + ANL or 2) If Incremental + ANL ≤ $1,000, cap at $1,000; Add ANL to cap at $1000, if needed 3) If Incremental + ANL > $2,000, cap at $2,000; Adjust down ANL to cap offer at $2000
3	> $2,000	≤ $1,000	Fail	Fail	IEO + adjustment (If needed)	Cap Composite Energy Offer at $1,000; first include ANL up to submitted No-load Cost and if needed, include ASU until Composite Energy Offer = $1,000
4	> $,2000	≤ $1,000	Pass	Pass	IEO + ASU + ANL	Cap Composite Energy Offer at $2,000; adjust down ASU first to zero, ANL, until Composite Energy Offer equals $2,000.
5	> $2,000	>$1,000	Pass	Pass	IEO + ASU + ANL	If IEO+SU+NL is greater than $2000, Cap Composite Energy Offer at $2,000; adjust down ASU first to zero, then ANL down to zero, until Composite Energy Offer equals $2,000.
6	> $2,000	>$1,000	Pass	Fail	IEO + ASU	Exclude ANL from Composite Energy Offer, if resultant Composite Energy Offer > $2,000 then cap Composite Energy Offer at $2,000 by adjusting Start-Up Cost
7	> $2,000	>$1,000	Fail	Pass	IEO + ANL	Exclude ASU from Composite Energy Offer, if resultant Composite Energy Offer > $2,000 then cap Composite Energy Offer at $2,000 by adjusting No-load Cost
8	> $2,000	>$1,000	Fail	Fail	IEO	Exclude ASU and ANL from Offer, Composite Energy Offer = IEO, since IEO above $1,000

*The Start-Up Cost and No-load Cost included in a Composite Energy Offer will be at their amortized value. In this chart, "ASU" represents amortized Start-Up Cost, "ANL" represents amortized No-load Cost. Please refer to Section 2.7.1 for how the amortization process applies to the Start-Up and No-Load costs.

2.8 The Calculation of Locational Marginal Prices (LMPs) During Emergency Procedures

In order to properly calculate LMPs during Emergency Procedures, PJM performs the following functions to ensure that deployed or purchased emergency capacity is eligible to set LMPs within PJM.

Pre-Emergency and Emergency Demand Response

- Pre-Emergency or Emergency Demand Response are deployed by lead time, by product, and/or by transmission zone or transmission subzone.
- PJM dispatches the resources of all Pre-Emergency or Emergency Load Response Program participants (not already dispatched under the Economic Load Response

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 Markets Gateway System, as input data to the Ancillary Service Optimizer (ASO). ASO then optimizes the RTO dispatch profile and forecasts LMPs to determine hourly 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. The Real-time Security Constrained Economic Dispatch (RT SCED) program jointly optimizes the remaining RTO reserve needs simultaneously with Energy while honoring effective regulation assignments. For more information on how RT SCED uses Synchronized Reserve commitments and Tier 2 Synchronized Reserve offers in the joint optimization, please refer to Section 2.5 of this Manual. The Locational Pricing Calculator (LPC) calculates a clearing price for Synchronized Reserve every five (5) minutes as described in Section 2.7 of this Manual. Five (5) minute, Real-time, Synchronized Reserve Market Clearing Prices (SRMCP) are 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 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 duration 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 as Tier 2. ASO commits 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 jointly optimizes the balance of the Tier 2 required in Real-time with Energy.

During each execution of RT SCED, additional Synchronized Reserves are committed to meet the Synchronized Reserve Requirement based on forecasted system conditions. IT SCED has the ability to project conditions further out into the future and make a recommendation to commit additional inflexible resources for reserves where they are economic. RT SCED has 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 are calculated simultaneously with Energy, Regulation and Non-Synchronized Reserves every five (5) minutes by LPC, in the pricing run, as described in Section 2.7 of this Manual. Integer relaxation for energy in the pricing run may lead to different flexible reserve assignments in the pricing run; however, resources will not be assigned reserves below their economic minimum and commitments from the dispatch run will be used in settlements. In the after-the-fact settlement, any resources cleared as self-scheduled to provide Synchronized Reserves are compensated at the applicable five (5) minute SRMCP. Any pool-scheduled resources selected to provide Synchronized Reserves are compensated at the higher of the applicable five minute SRMCP or their Real-time opportunity cost plus their Synchronized Reserve offer price. LSEs required to purchase Synchronized Reserves are charged their obligation ratio share of the hourly SRMCP Credits 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.

In the event PJM forecasts a credible natural gas pipeline contingency(s), as described in PJM Manual 13: Emergency Operations, Section 3.9, PJM Dispatch will determine the eligibility of resources to provide Synchronized Reserves depending on the severity of the contingency and other system conditions in order to ensure system reliability is maintained.

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:
  - 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 Reserves not available from Tier 1 resources within ten (10) minutes; and
  - dispatchable Demand Resources that have controls in place to automatically drop load in response to a signal from PJM within ten (10) minutes.

- Tier 1 estimates for Demand Resources equals 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, Energy Storage Resources (ESRs), and Hydropower units. Owners of any specific resource(s) of 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 only grants such requested exceptions on a prospective basis. A resource is only credited for Tier 1 Synchronized Reserve if the resource was considered during the market clearing process, unless such resource actually provides Tier1 Synchronized Reserve during a Synchronized Reserve Event. For further information on the exception process, please visit "Communication Process for Consideration of Some Resources for Tier 1" at this link: https://www.pjm.com/-/media/markets-ops/ancillary/communication-process-consideration-of-some-resources-tier-1-synchronized-reserve.ashx?la=en.
- All resources operating on the PJM system 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, compensation refunds exist as described in section 4.2.12 below for response by Tier 2 resources that is 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 monitors compliance with the Tier 2 must offer requirement.
    - To monitor the Tier 2 must offer requirement, PJM checks 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 ten (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 Reserves in Markets Gateway prior to the offer submission deadline (1415 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 Markets Gateway are automatically carried over from one day to the next unless updated. Changes made on the Synchronized Reserve Updates page of Markets Gateway are not carried over into the next day. Any changes made to the Synchronized Updates page supersedes the values on the Offer page.
- The following information must be supplied through the Markets Gateway 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 PJM at the following email address: SRLimitations@pjm.com
  - Resource's energy ramp rate is used for the Tier 2 MW calculation.
- Synchronized Reserve maximum 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 is equal to the lesser of the economic maximum or synchronized reserve maximum for the resource. A resource owner may request a lesser synchronized reserve maximum than the economic maximum if a physical limitation exists. Resource owners may submit a request for this modification via the communication process for consideration of resource physical limitation which can be found on the PJM website under "Modification to Synchronized Reserve Market to Better Reflect the Operating Characteristics of Participating Generating Units" at this location: https://www.pjm.com/-/media/markets-ops/ancillary/communication-process-for-consideration-of-resource-physical-limitation.ashx?la=en.
- Generation resources, including ESRs enrolled in the ESR participation model, 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.
- Synchronized Reserve availability for Tier 2 resources: Resources may be made unavailable to provide Tier 2 Synchronized Reserves only if they are physically unavailable. Otherwise, they must be made available or self-scheduled to provide Tier 2 Synchronized Reserves per the must offer requirement.
- 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.
  - 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 ESRs, are expected to have zero MW Tier 2 Synchronized Reserve offer quantities.
- Synchronized Offer Price for Tier 2 resources ($/MWh): Synchronized Reserve offer prices are capped at a maximum value of the resource's O&M cost (as determined by the Cost Development Subcommittee) plus $7.50/MWh margin.
  - The Offer Price cannot be a negative value.
- All resources listed as available for Tier 2 Synchronized Reserves with no Offer Price have their Offer Prices set to zero.

- 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.
- Should a resource be unable to participate in the Synchronized Reserve Market in any given hour on the Operating Day, the following required updates should be made sixty-five (65) minutes prior to the operating hour in the Synchronized Reserve Update screen of Markets Gateway:
  - Set Offer MW to zero.
  - Set Available status to 'Not Available'.
- Condense to gen cost: This is the cost of transitioning a condenser to generating mode. The value submitted for this cost must be less than or equal to the condensing Startup 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 and 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 zero hours.
- Spin as Condenser: This is used to identify if a combustion turbine or a hydropower resource can be committed for Synchronized Reserve as a condenser.
- Condense Available Status: This indicates a resource's availability to provide voltage and/or reactive support. This value is not directly related to the Synchronized Reserve Market.

4.2.2 Synchronized Reserve Requirement Determination

PJM selects resources in the Primary Reserve and Synchronized Reserve Zones and Reserve Sub-Zones hourly and intra-hourly to provide Primary Reserves and Synchronized Reserves based on a joint optimization between Energy, Regulation, Non-Synchronized Reserves and Synchronized Reserves. Assignments are communicated to the resource owners/operators by Markets Gateway and/or ICCP, DNP or other communication protocol.

- In the PJM RTO there is a single Primary Reserve and Synchronized Reserve Zone and potential Reserve Sub-Zone. Total PJM Primary Reserve and Synchronized Reserve Requirement for each Primary Reserve and Synchronized Reserve Zone and Reserve Sub-Zone is determined in whole MW for each hour of the operating day.
- For the purposes of market clearing, the PJM Primary Reserve and Synchronized Reserve Zone and Reserve Sub-Zone Reliability Requirements are based on the greatest MW loss of all potential Largest Single Contingencies on the system as

documented in PJM Manual 13: Emergency Operations, Section 2.2. Only those potential Largest Single Contingencies communicated by PJM Operations and modeled in the market clearing software will be eligible to set the reserve requirements used in the market clearing process.

- Due to transmission security considerations on the PJM system, it is sometimes necessary to carry a minimum amount of Primary Reserve and Synchronized Reserve in specific sub-zones in PJM such that loading 100% reserve will not result in an overload of any of the PJM transfer interfaces. The Mid-Atlantic Dominion Sub-Zone is defined in the Primary Reserve and 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 Operations and meet the system reliability needs.
- As system conditions dictate, PJM may need to redefine or include additional Sub-Zones into the RTO Primary Reserve and Synchronized Reserve Markets. 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 Requirement 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 PJM's ability to deliver reserves to a specific geographic area of the PJM Region where reserves are required.
- PJM must ensure that adequate Synchronized and Primary Reserve MW are procured and maintained to recover from the loss of the Largest Single Contingency, which is normally the largest online generator's output. However, there are, at times, outage conditions at stations whereby a single fault would trip multiple generators resulting in a loss of generation greater than the Largest Single Contingency. In such instances, PJM will carry an increased Reserve Requirement in equivalent summation of output of those multiple generators in accordance with Reserve Requirements described in PJM Manual 13: Emergency Operations, Section 2.2.
- 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 Primary Reserve and Synchronized Reserve Requirements in the Market Clearing Engine 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 PJM 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 Reliability Assessment and Commitment (RAC) run which occurs after 1415 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.

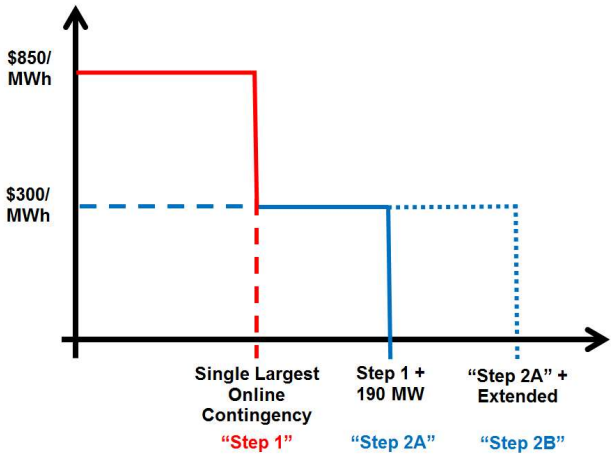
- The requirements will return to their original values upon exit from emergency procedures or when the additional resources have been released by PJM dispatch.
- PJM will notify market participants of changes to the Reserve Requirements in relation to emergency procedures via the Emergency Procedure Posting Application once the decision to change the Reserve Requirements is made.
- Regardless of the Reserve Requirements modeled in the Market Clearing Engine, PJM operators will continue to initiate emergency procedures based on the Reserve Requirements defined in PJM Manual 13: Emergency Operations.

4.2.2.1 Reserve Demand Curves and Penalty Factors

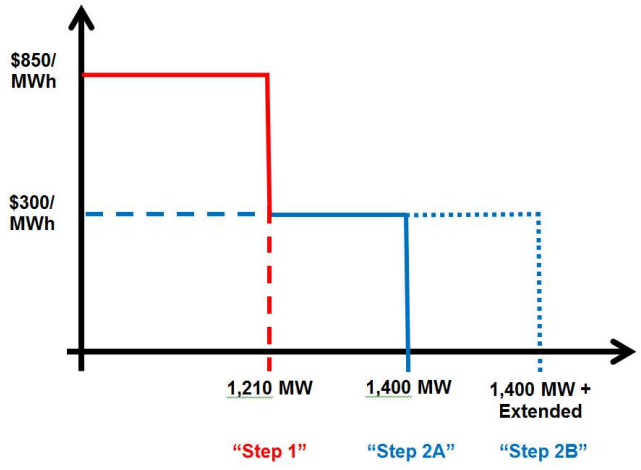
- Embedded within the Real-time Market Clearing Engine are Reserve Demand Curves for each Real-time Reserve product in each Reserve Zone and Sub-Zone. These demand curves are used to articulate the value of maintaining reserves at specified levels and ensure product substitution between energy and reserves up to the specified penalty factors. They are defined with $/MWh penalty factors on the Y axis and desired reserve MW on the X axis. The penalty factor represents the price at which reserves will be valued if the desired reserve MW cannot be met with the available reserves on the system, and also acts as a price cap beyond which reserves will not be procured through market clearing.
- For example, assume the penalty factor to maintain 1,000 MW of Synchronized Reserves is $850/MWh. If there are less than 1,000 MW of reserves available, the deficient MW will be valued at $850/MWh. Similarly, if there sufficient reserves to meet the 1,000 MW requirement, yet they are not available at a prices less than or equal to $850/MWh, resources with merit order prices that exceed $850/MWh will not be cleared and the deficient MW will be valued at $850/MWh. However, such resources can still be committed manually by PJM operations personnel in order to maintain reliability. In this case, such resources will be compensated additionally after the fact to ensure their true cost to provide the service is covered.
- The penalty factor also provides a clear indicator of the reserve position of the RTO and modeled Reserve Sub-Zones. As the price of a reserve product increases to a value near the penalty factor, it indicates to market participants that the system is nearing a reserve shortage. Separate demand curves exist for each of the following reserve product / Reserve Zone or Sub-zone combinations.
  - RTO Synchronized Reserve
  - Mid-Atlantic Dominion Synchronized Reserve
  - RTO Primary Reserve
  - Mid-Atlantic Dominion Primary Reserve

- The demand curves for each of these products and locations are similar in that they share the same penalty factors on the Y axis; however, the desired reserve levels on the X axis differ to reflect the Reserve Requirement differences amongst the reserve products and locations. These demand curves are defined as follows:
- Step 1
  - Penalty Factor = $850/MWh
  - Desired Reserve MW = locational Reliability Requirement for the specified reserve product as defined in Section 4.2.2 above.
    - For Synchronized Reserve, this is typically equivalent to 100% of the output of the Largest Single Contingency in the Reserve Zone or Sub-Zone.
    - For Primary Reserve, this is typically equivalent to 150% of the output of the Largest Single Contingency in the Reserve Zone or Sub-Zone.

- Step 2
  - Penalty Factor = $300/MWh
  - Desired Reserve MW = locational Reliability Requirement for the specified reserve product as defined in Section 4.2.2 above plus 190 MW plus any additional reserves that are being carried in anticipation of heavy load conditions, as referenced in Section 4.2.2 above.



- Due to the Reserve Requirements being based on the Real-time output of the Largest Single Contingency, the MW values on the X axis of the demand curves used in market clearing can change dynamically with each Real-time market clearing case execution. Below is an example of what the demand curve for Synchronized Reserves would look like if the output of the Largest Single Contingency was 1,210 MW for that specific case execution.



4.2.3 Synchronized Reserve Obligation

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. Participants can estimate their share of the PJM Synchronized Reserve Requirement in advance by comparing their hourly load forecast to the PJM hourly load forecasts provided by PJM. 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 obligation load ratio share times the amount of Synchronized Reserve assigned for the Synchronized Reserve Zone. During hours when congestion causes SRMCP to separate, each LSE's obligation is equal to its obligation 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:
LSEs whose Synchronized Reserve Obligations are satisfied through an agreement to share reserves with external entities subject to the requirements in the NERC Reliability Standard BAL-002 do not have a Synchronized Reserve Obligation.

4.2.4 Synchronized Reserve Offer Period

Daily Synchronized Reserve Offer Prices for Tier 2 resources and Synchronized Reserve ramp rates must be supplied prior to 1415 day-ahead.

To accurately reflect each resource's reserve capability and availability during the Operating Day, the following information may be submitted on an hourly basis and/or changed on the Updates screen in Markets Gateway up until sixty-five (65) minutes prior to the start of the operating hour, at which time the Synchronized Reserve Market closes.

- Synchronized Reserve Availability for Tier 2 resources.
- Synchronized Reserve Offer Quantity (MW).
- Synchronized Reserve Maximum (This parameter is called Spin Max on the Markets Gateway Synchronized Reserve Updates screen).

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

- Synchronized Reserve Offer Price ($/MWh).

Any hourly updates supersede the values on the daily Offers page.

The Real-Time Market Clearing Engines will use the offered in parameters as detailed in Sections 2.5 and 2.7 of this Manual.

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 Reserves and must be reported by the buyer and subsequently confirmed by the seller through the Markets Gateway System no later than 1330 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 are also required to indicate the Reserve Zone or Sub-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 Settlements, 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 Settlements by a Market Participant, PJM shall not accept any new bilateral reporting by the Market Participant and shall terminate all of the Market Participant's reporting of Markets Gateway schedules associated with its 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 which Market Participants can use as a resource for pricing Bilateral Synchronized Reserve Transactions. The data can be found via PJM's Data Miner 2 Tool: http://dataminer2.pjm.com/feed/sync_reserve_prelim_bill/definition.

4.2.6 Synchronized Reserve Commitment

Sixty (60) minutes prior to the operating hour PJM executes the Ancillary Services Optimizer (ASO). The ASO jointly optimizes 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 inflexible self-scheduled offers for Synchronized Reserves that are available at the time of the ASO execution are assumed valid and committed for the hour.

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

The following reserve information will be posted to Markets Gateway thirty (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 each Sub-Zone.
- Any additional Tier 2 Synchronized Reserves required in Real-time in excess of the current Tier 1 on the system and the inflexible Tier 2 commitments which will be committed via the joint optimization of Energy, Reserves and Regulation.
- Additional Tier 2 Synchronized Reserve commitments made in Real-time may be made on flexible reserve resources by the RT SCED application and inflexible reserves resources recommendations by the IT SCED application. Commitments on flexible reserves resources may change with each execution of the RT SCED application while commitments on inflexible reserve resources will respect the minimum run time of those resources.
- Flexible reserve resource Tier 2 commitments will not be posted to Markets Gateway but will be telemetered via ICCP or other communication protocol to resource owners.
- Additional inflexible resource commitments will be communicated to the resource owners via phone call and ICCP or other communication protocol.
- Any resource that is committed for Tier 2 when a Synchronized Reserve Event occurs is obligated to respond ~~for their commitment~~ to the instructions of the Office of the Interconnection at the start of the event within ten (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 Markets Gateway System by 1415 on the day preceding the operating day.

Estimated resource opportunity cost for condensing CTs is calculated, based on the dispatch run, as follows:

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

Estimated resource opportunity cost for non-condensing resources is calculated, based on the dispatch run, as follows:

$$O.C. = |\ LMP\ -\ ED\ |\ x\ GENOFF$$

Where:

LMP	is the forecasted hourly LMP at the generator bus,
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 Reserve 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 correspond 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 Markets Gateway system as part of the Synchronized Reserve Offer. Estimated energy use is calculated as part of the merit order price as follows:

$$E.U. = forecast\ LMP\ x\ energy\ use\ MW\ /\ synchronized\ reserve\ capability$$

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

When calculating the SRMCP in Real-time, the actual LMP is used instead of the forecast LMP in the previous equations and calculated in the LPC engine. The actual five minute SRMCP, calculated using the LPC pricing run, is used for settlements.

The opportunity cost for a Demand Resource is zero.

- PJM may call on resources not otherwise scheduled to run in order to provide Synchronized Reserves, 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 Reserves, the resource is guaranteed recovery of Synchronized Reserve lost opportunity costs as well as start-

up, no-load and energy costs. Please refer to PJM Manual 28: Operating Agreement Accounting for additional settlements details.

- Due to transmission considerations on the PJM system, it is sometimes necessary to carry a minimum amount of Synchronized Reserves in specific areas in PJM such that loading 100% Synchronized Reserves will not result in an overload of any of the PJM transfer interfaces. The goal is to minimize the cost of Synchronized Reserves 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 Event response would help the constraint will receive the higher clearing price, whereas resources for which Synchronized Reserve Event 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 at least once 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 under “Mid-Atlantic-Dominion Sub-Zone Bus and Resource List” at this location: https://www.pjm.com/markets-and-operations/ancillary-services.aspx. Resource owners should be aware if their resources are listed in the file and are therefore located in the Mid-Atlantic Dominion Reserve Sub-Zone. Resources that do not appear in the list may respond only to PJM’s request for Synchronized Reserve Event in the RTO Reserve Zone. Resources that appear in the list may respond to PJM’s request for a Synchronized Reserve Event in the Mid-Atlantic Dominion Reserve Sub-Zone and the RTO Reserve Zone.
- Preliminary five (5) minute market clearing prices will be made available in Real-time through Data Viewer.

4.2.7 Hydropower Units

Hydropower units condensing to provide Synchronized Reserves 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. Only hydropower units not enrolled in the ESR participation model are considered in the rules below.

- If a hydropower unit is held to synchronized reserve condense or reduced to provide Synchronized Reserves during a time when it is scheduled to generate, it will incur opportunity cost. Since hydropower 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 Commitment’, O.C. = |LMP – ED| x GENOFF, except the ED value is the average value of the LMP at the hydropower 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 hydropower 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 hydropower unit is in spilling mode, 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 Markets Gateway System.
- When determined to be economically beneficial, PJM maintains the authority to adjust hydropower 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.
- An example of the Tier 2 synchronized reserve lost opportunity cost calculation is very similar to that of the regulation hydropower lost opportunity cost calculation detailed on the PJM website at https://pjm.com/-/media/markets-ops/ancillary/regulation-uplift-and-lost-opportunity-cost.ashx?la=en.

4.2.8 Demand Resources

Demand Resources providing Synchronized Reserves are required to provide metering information at no less than a one (1) minute scan surrounding a Synchronized Reserve Event. Residential customers without one (1) minute metering may participate using the statistical sampling method detailed in PJM Manual 19: Load Forecasting and Analysis, Attachment D and subject to PJM approval.

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 (2) 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% 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%.

Demand Resources must complete initial and continuing training on Regulation and Synchronized Reserve Markets as documented in PJM Manual 40: Certification and Training Requirements, Section 2.6: Training Requirements for Demand Response Resources Supplying Regulation and Synchronized Reserve.

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 Reserves simultaneously with LMPs every five (5) minutes in Real-time.

The Real-time prices for Synchronized Reserves will be calculated as the marginal cost to serve an additional MW of synchronized reserve demand in the RTO Reserve Zone or applicable Reserve Sub-Zone while simultaneously satisfying energy requirements, regulation requirements, primary reserve requirements and transmission limitations.

Preliminary Real-time five (5) minute SRMCPs will be published to Data Viewer for public view.

During periods when there is no synchronized reserve shortage, Real-time prices for Synchronized Reserves 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. For further details regarding the opportunity cost calculation, please refer to Section 4.2.6 of this Manual. In the pricing run, the cost of the marginal synchronized reserve resource may also include amortized Start-Up and amortized No-Load Costs due to integer relaxation for eligible Fast-Start resources.

$$Cost\ of\ the\ Marginal\ Synchronized\ Reserve\ Resource = Synchronized\ Reserve\ Offer + Lost\ Opportunity\ Cost + (Amortized\ Start\ Up\ Cost + Amortized\ No\ Load\ Cost)^{*}$$

*Amortized Start-Up and No-Load Cost may only be included in the pricing run due to integer relaxation for eligible Fast-Start resources.

- Non-shortage prices for Synchronized Reserves will not exceed the sum of the Primary Reserve and Synchronized Reserve Penalty Factors from the first step of the demand curve.

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 Non-Synchronized Reserve Market Clearing Price (NSRMCP) in the same location because Synchronized Reserve is a higher quality product than Non-Synchronized Reserves and may be substituted for it.

4.2.10 Settlements

Please refer to PJM 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 Reserves provided to the market by generation owners and purchased from the market by participants.

~~Tier 1 credits will be awarded to each eligible resource for response 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.~~

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:

$$\left\{\begin{matrix}[] \\ [0 0]\end{matrix}\right\}$$

$$\left\{\begin{matrix}[max(0,\ (Final\ Output - min(EcoMax,\ RegHighLimit)))] \\ + \\ [max(0,\ (min(EcoMax,\ RegHighLimit,\ Final\ Output) - Initial\ Output - (2*RegMW)))]\end{matrix}\right\}$$

Where:

Final Output	is the resource's greatest telemetered output between nine (9) and eleven (11) minutes after a Synchronized Reserve Event is initiated.
Initial Output	is the resource's lowest telemetered output between one (1) minute before and one (1) minute after a 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.)

Please refer to PJM Manual 28: Operating Agreement Accounting, Section 6: Synchronized Reserve Accounting for further details on Tier 1 Synchronized Reserve Credits and Tier 2 Synchronized Reserve Credits.

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 (10) 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 (10) 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 (10) 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 resource will be reduced or increased by the amount the MW output of that resource ~~falls below~~differs from the level achieved after ten (10) minutes by either the end of the event or after thirty (30) minutes from the start of the event, whichever is shorter but will be capped at

the resource's Synchronized Reserve assignment or if the resource has no assignment (Tier 1) at the PJM-calculated expected amount of response based on the energy dispatch signals and instructions of the Office of the Interconnection.

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 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 are simply credited for the amount of response they provide capped at the resource's expected response.

Since Tier 2 resources are credited with a capacity payment any time they are expected to be ready to respond to a Synchronized Reserve Event, failure to provide that response results in an obligation to "repay" that credit following instances of non-performance. The following consequences exist for a Tier 2 resource that does not respond with the lesser of its assigned amount of Synchronized Reserve or the PJM calculated expected response based on the energy dispatch signals and instructions from PJM:

- The resource is credited for Tier 2 Synchronized Reserve capacity in the amount that actually responded for all Real-time settlement intervals (five (5) minutes) the resource 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 the SRMCP the amount of the shortfall measured in MW for all of the Real-time settlement intervals 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 two (2) years, or the number of days since the resource failed to respond with its assigned or self-scheduled Synchronized Reserve amount in response to a Synchronized Reserve Event.
    - The annual review described above will be completed during the month of November and cover a two (2) year window from November 1st (year – 2) through October 31st (current year). The 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 results will be communicated to the Operating Committee in December and implemented annually on January 1st.

In cases where a Synchronized Reserve Event lasts less than ten (10) minutes, Tier 2 resources are credited with the amount of Synchronized Reserve capacity they are assigned. The owner of the resource will not incur a retroactive obligation to refund any shortfall between the amount of Tier 2 assigned or self-scheduled and the amount of response provided during the event. Tier 1 resources 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 Section

4.2.11 of this Manual. 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 ten (10) minutes of the end of the Synchronized Reserve Event. From the start of the event, through the event, and for the ten (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.