



Tier 1 Compensation Education

January 5, 2015

Tier 1 synch reserves are credited at the synch reserve market clearing price when the non-synch reserve market clearing price is above \$0.

1. The quantity of Tier 1 that should be credited is unclear. It could be interpreted as:
 - The amount of Tier 1 estimated by the market clearing engine on an hour-ahead basis
 - The amount of Tier 1 estimated to be available in the operating hour
 - The amount of Tier 1 calculated to be available in the operating hour based on meter data

What is the appropriate interpretation?

2. Is it appropriate to compensate Tier 1 aside from when it responds to a synch reserve event?

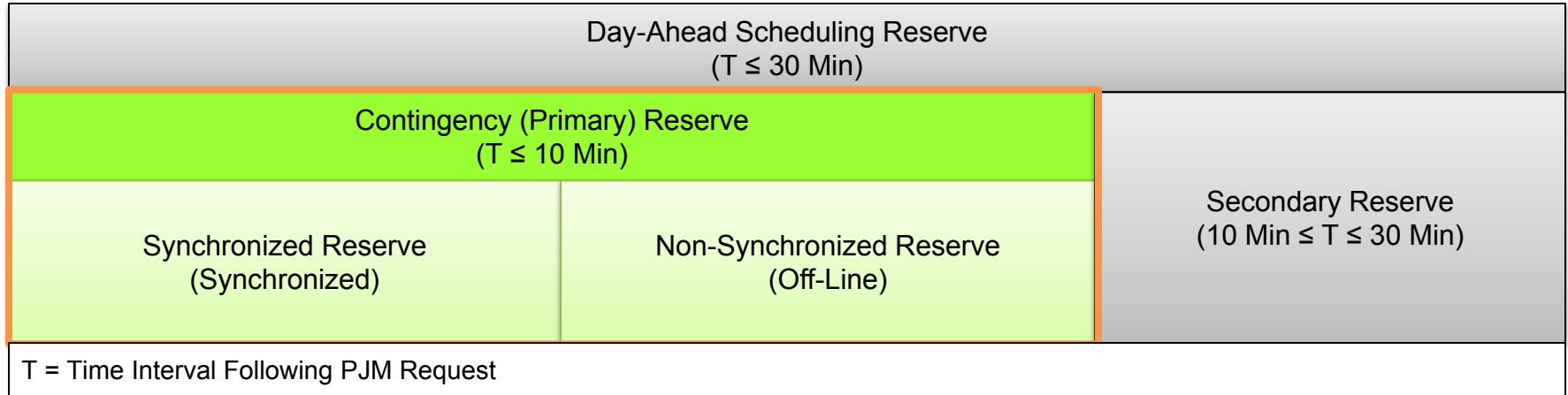
1. Education on issues including definitions of components of primary reserves including synchronized and non-synchronized primary reserves.
 - a. Review the tariff rule directing PJM to pay Tier 1 synchronized reserve when the price of non-synchronized reserve is greater than zero.
 - i. Develop implementing tariff changes and manual changes.
 - b. Review the extent to which PJM has paid for too much Tier 1 synchronized reserves when the price of non-synchronized reserve is greater than zero under existing rules.
 - i. Recommend any appropriate resolution as required.

1. Revised tariff language.
2. Revised Manual language.
3. Recommendation related to level of Tier 1 MW paid the Tier 2 price when the price of non-synchronized reserve is greater than zero.

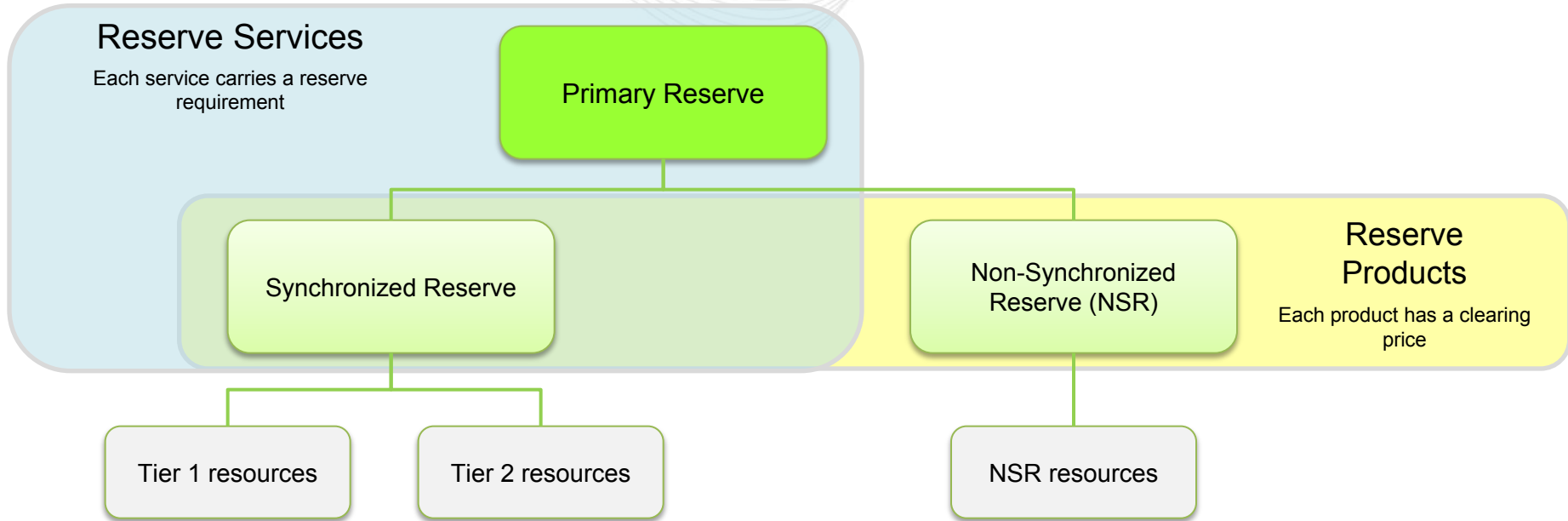


Reserve Overview

Reserves are additional generation capacity above the expected load. Scheduling excess capacity protects the power system against the uncertain occurrence of future operating events, including the loss of energy or load forecasting errors.

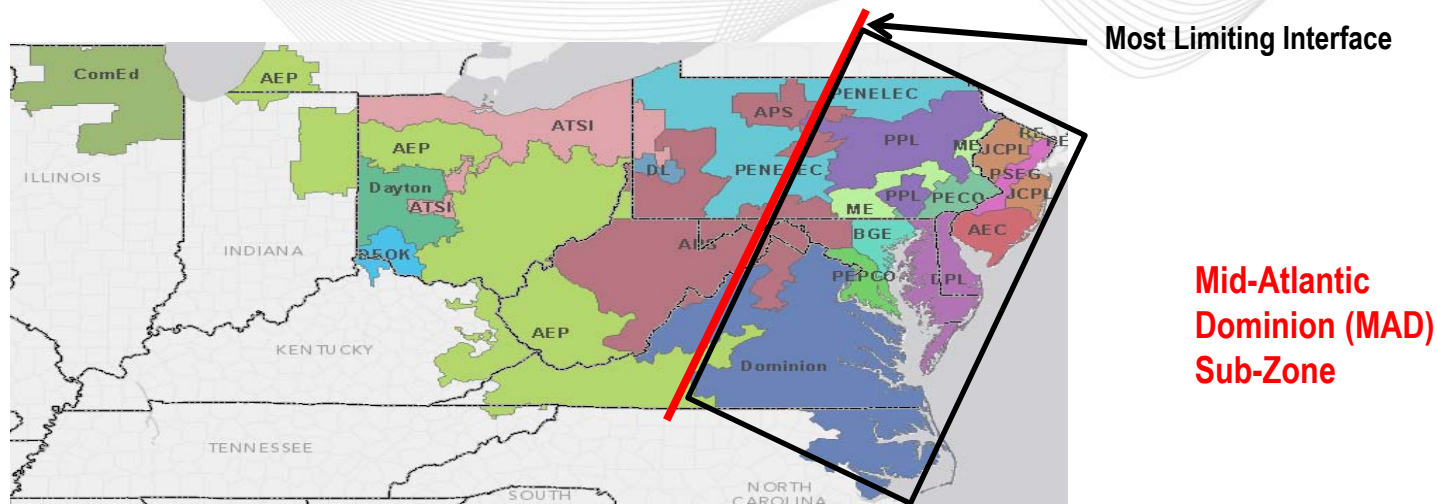


- The main goal of these resources is to recover the ACE back to its pre-contingency level within the allotted timeframe
- These resources provide a quick boost of generation (or load reduction) to the system to recover ACE after a resource loss, large tie errors, and under frequency conditions
 - Synchronized reserves can not control over-frequency



Tier 1 (Economic)	Online units that are following economic dispatch and only partially loaded and therefore are able to increase output within 10 minutes following PJM dispatcher request to an event
Tier 2 (Non-Economic)	Resources that offered into the Synchronized Reserve Market and cleared. Resources must deviate from economics to provide synchronized reserve <ul style="list-style-type: none">- Condensers (CTs and hydro) transition to online Tier2 condense mode- Dispatchable units deviating from economics to provide Tier2 MW- Demand Response that can drop load
10 minute Non-Synchronized Reserve	Resources currently not synchronized to the grid <ul style="list-style-type: none">- shutdown run-of-river hydro- Shutdown pumped hydro- Offline industrial combustion turbines, jet engine/expander turbines, etc

RTO Reserve Zone and Mid-Atlantic Dominion Subzone



Mid-Atlantic Dominion (MAD) sub-zone due to potential reserve deliverability issues

- Defined based on most limiting transfer interface
- Resources with 0% or greater raise help distribution factor on the interface are included in MAD sub-zone
- The interface modeled may be revised to match operation and meet the system reliability need.
- <http://www.pjm.com/markets-and-operations/ancillary-services/synchronized-service.aspx>

- The Primary Reserve Requirement is defined as the amount of 10-minute reserve (synchronized or non-synchronized) that must be available
 - Inclusive of the Synchronized Reserve requirement
 - May be met with Tier 1 or Tier 2 or Non-synchronized 10 minute resources
- RTO reserve zone requirement is the greater of:
 - Calculated RFC minimum requirement OR
 - 150% of the largest contingency in the PJM footprint
 - » Usually 2063 MW
- Mid-Atlantic Dominion sub-zone requirement is equal to a static predefined value
 - » Usually 1700 MW

Of the 2063 MW RTO reserve zone requirement,
1700 MW must be deliverable to the Mid-Atlantic Dominion sub-zone

Why Does PJM Maintain Primary Reserves?

- Reliability Reason
 - Primary Reserves provide a backfill in case synchronized reserve did not adequately respond to a spin event
- Market Reason
 - A non-zero Non-Synchronized Reserve Market Clearing Price is a good indication that the system is getting tight on reserves

Synchronized Reserve Requirement

- The Synchronized Reserve Requirement is defined as the amount of 10-minute reserve that must be synchronized to the grid
 - May be met with Tier 1 or Tier 2 resources
- RTO reserve zone requirement will be the greater of:
 - Calculated RFC minimum requirement OR
 - Largest contingency in RTO Synchronized Reserve Zone
 - » Usually 1375 MW
- Mid-Atlantic Dominion sub-zone requirement will be equal to largest contingency in the Mid-Atlantic Dominion region
 - » Usually 1300 MW

Of the 1375 MW RTO reserve zone requirement,
1300 MW must be deliverable to the Mid-Atlantic Dominion sub-zone

Meeting Synchronized Reserve Requirement

Synchronized Reserve Requirement is met with:

Tier 1 Estimate

plus

Available Transfer Capability (Reserve subzones only)

plus

Tier 2 cleared

If adequate Tier 1 Synchronized Reserve is available (based on Tier 1 Estimate), then

- Tier 2 cleared is zero
- SRMCP would be zero for this interval(s)



Tier 1 Overview

Tier 1 is comprised of resources online following economic dispatch that can reliably ramp up from their current output within 10 minutes, in response to a Synchronized Reserve Event.

The Tier 1 Estimate for the resource types listed below is typically set to zero MW during synchronized reserve market clearing for reliability reasons:

1. Battery and Flywheel
2. Hydro
3. Nuclear
4. Solar
5. Wind

Tier 1 MW

- Is not explicitly offered by any market participant for any resource
- Is an incidental reserve MW that is estimated on a given resource, and assumed will be provided with 10 minutes following a spin event
- Has no cost associated with its procurement
- Does not carry a penalty for non-delivery during a spin event
- Receives a credit only if NSRMCP > 0 or when it responds during a spin event
- Can be used to fully or partially meet the 10 minute reserve requirements (synchronized or primary)

1.7.19A Synchronized Reserve.

(a) Synchronized Reserve can be supplied from non-emergency generation resources and/or Demand Resources located within the metered boundaries of the PJM Region. 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 to the Office of the Interconnection, as applicable to the capacity resource's capability to provide these services. During periods for which the Office of the Interconnection has issued a Primary Reserve Warning, Voltage Reduction Warning or Manual Load Dump Warning as described in Section 2.5(d) below, all other non-emergency generation capacity resources available to provide energy shall have submitted offers for Tier 2 Synchronized Reserves. Generating Market Buyers, and Market Sellers offering Synchronized Reserve shall comply with applicable standards and requirements

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(c) The Synchronized Reserve capability of a generation resource and Demand Resource shall be the increase in energy output or load reduction achievable by the generation resource and Demand Resource within a continuous 10-minute period.

Exceptions to Tier 1 Resource Eligibility

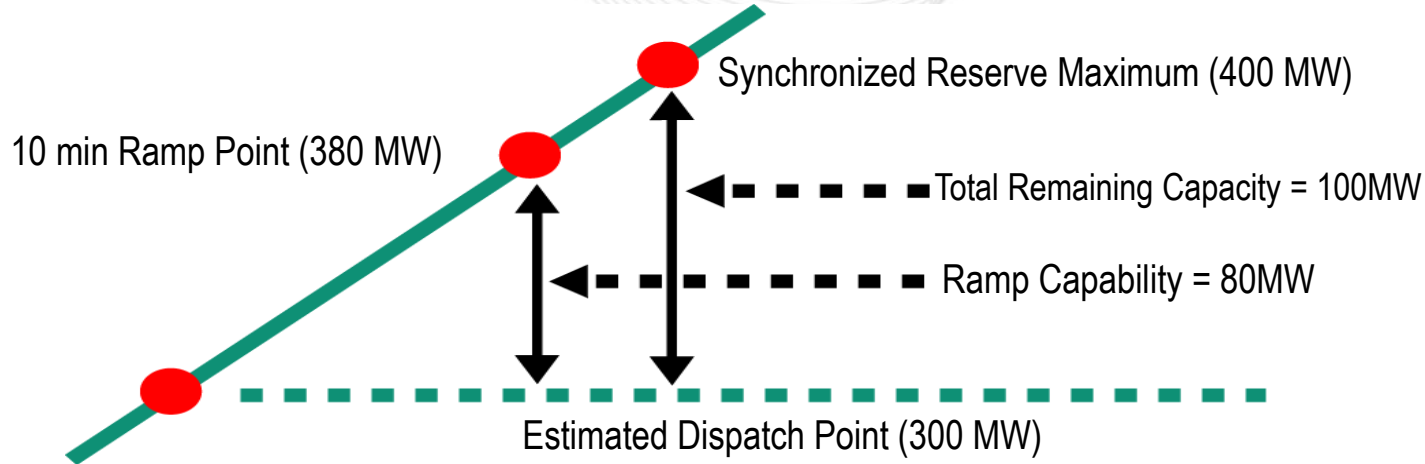
- Certain resource types are automatically deselected from Tier 1 (see section 4.2.1 of M11)
 - Battery, Hydro, Nuclear, Solar, Wind
- Certain dispatch log reasons will automatically deselect a resource from Tier 1, including but not limited to:

Dispatch Log Reasons Candidate for Auto-Tier1 Deselect		
Testing	Reg Testing	Black Start (Testing)
Released	Tripped	Failed to Start
Manual Dispatch	Reactv Gen-Non Disp	DA Comp Non-Dispatch
On Regulation	Taken over by Co	DA React Interface

- System Operator may manually deselect a resource from Tier 1 for a period of time

Section 4.2.1 of M11

- 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, unless such resource actually provides Tier1 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/synchronized-service.aspx>



Synchronized Ramp Rate = 8 MW/min, therefore max T1 capability = 8 MW/min * 10min = 80 MW

Ramp Rate is more limiting, so T1 capability = 80 MW

- Questionable data quality
 - Synchronized Reserve Ramp Rate
 - Synchronized Reserve Maximum
- Unit not following economic dispatch
- Special Tier 1 MW calculation for applicable Combined Cycle units
 - See section 4.2.1 of M11

- Tier 1 Estimated MW = Lesser of
$$\{[NVL(\textit{SpinMax}, \textit{EcoMax}) - \textit{Dispatch MW}]\}$$

or

$$[NVL(\textit{Spin RampRate}, \textit{Energy RampRate}) * \textit{DGP} * 10 \textit{ minutes}]\}$$
- Unit's Ramp Rate is adjusted by Degree of Generation Performance (DGP)
 - DGP measures the responsiveness of a generator to dispatch instructions in terms of its actual generation MW output
 - It uses historical and latest generator output and dispatched MW as input
 - It is calculated every 5 minutes for online generating units
 - DGP value ranges from 0 to 1 (closer to zero is worse, closer to 1 is better)
 - ❖ Use of DGP for Tier 1 MW evaluation was presented at the November 2013 Operating Committee Meeting
 - ❖ <http://www.pjm.com/~media/committees-groups/committees/oc/20131105/20131105-agenda.ashx>

Numerical Example of Tier 1 MW Estimation

Synchronized Reserve Requirement = 200 MW

Resource	SpinMax (EcoMax), MW	Dispatch MW	Spin RampRate (Energy RampRate), MW/Min	DGP	Tier 1 Deselected	Traditional Tier 1 Estimate, MW	Revised Tier 1 Estimate, MW
A	500	400	8	0.5	0	80	40
B	300	240	10	0.9	0	60	60
C	100	60	5	0.3	1	40	0
D	200	200	5	0.8	0	0	0
E	300	270	4	0.1	0	30	4
Total Tier 1 MW						210	104
Total Tier 2 Assigned						0	96

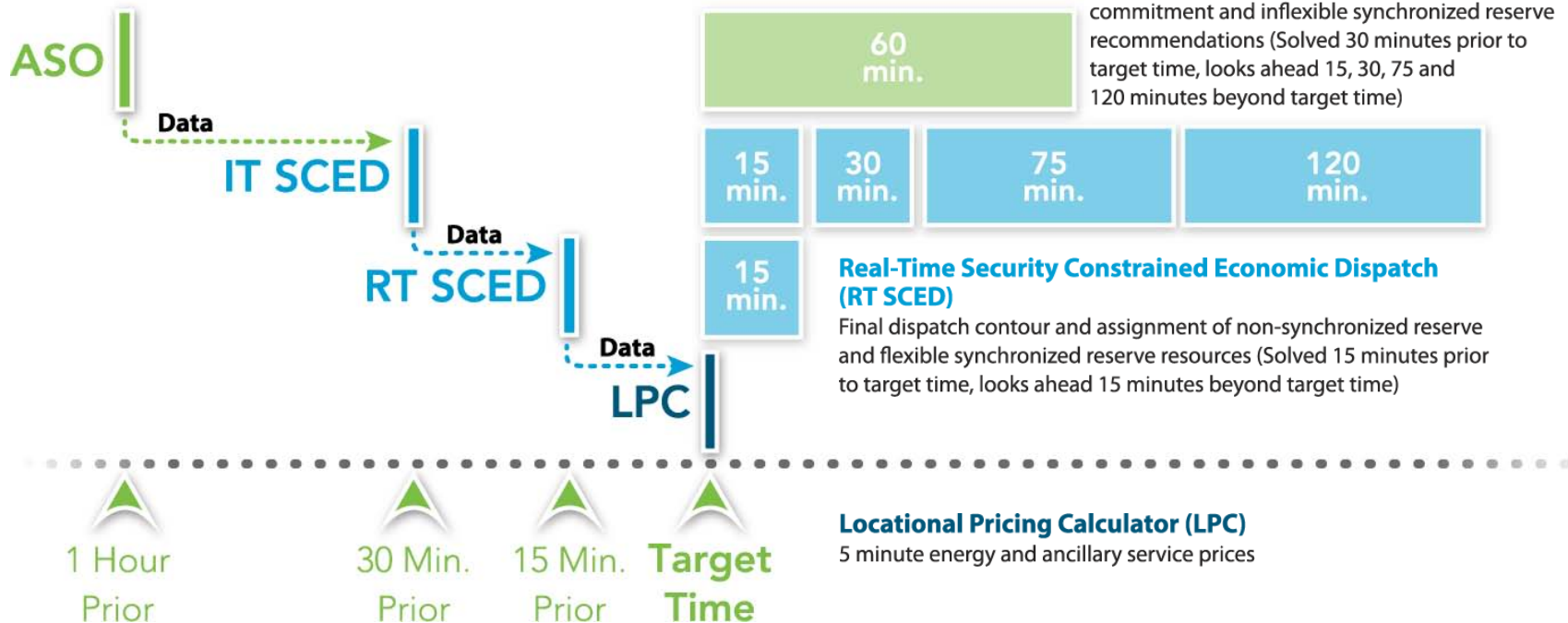
Market Clearing Engines – Final Reserve MW and Price Calculations

Ancillary Services Optimizer (ASO)

Clearing and assignment of regulation and inflexible reserve resources
(Solved 60 minutes prior to target time, looks ahead 60 minutes beyond target time)

Intermediate-Term Security Constrained Economic Dispatch (IT SCED)

Demand Trajectory, generator loading strategy, Demand Response commitment for energy, CT commitment and inflexible synchronized reserve recommendations (Solved 30 minutes prior to target time, looks ahead 15, 30, 75 and 120 minutes beyond target time)



- Tier 1 estimated in ASO are posted in eMKT as advisory only
- ASO Tier 1 MW are not used in settlements

Messages | Reports | Node List | Market Results Energy | Market Results A/S

Regulation Results | Synchronized Reserve Results | Primary Reserve Results | DA Scheduling Reserve Results

Synchronized Reserve Results Search

Area: MAD Date: 12/11/2014

Data provided on this page is based on an hour ahead projection. Actual values may vary in real time depending on changes in system conditions.

Synchronized Reserve Results for 12/11/2014								
Hour	Requirement	Tier-1 Est. Projected	Avail. Transfer Projected	Tier-2 Req. Projected	Tier-2 Self-Sched.	Tier-2 Assigned Preliminary	Total Preliminary	Deficiency Preliminary
01	1300	1006	266.2	28	0	28	1034	0
02	1300	998	253.3	48	0	48	1047	0
03	1300	970	301.6	28	0	28	998	0

RTSCED continually re-evaluates reserve every 5 minutes for a 15 minute look-ahead period

- Tier 1 estimated on each applicable unit is final and communicated privately via ICCP link
- When necessary, additional Tier 2 MW is procured intra-hour using flexible Tier 2 resources
- Hourly average of the 5 minute intervals is sent to Settlements for use as a reference
 - Settlements uses Power Meter MW values when calculating Tier 1 credits for response to a synchronized reserve event or when the NSRMCP is greater than \$0

HOUR	REQUIREMENT	TIER1	AVAIL_TRANSFER	TIER2_ASSIGNED	TOTALMW	DEFICITMW
12/11/2014	1300	1171.7	95.1	33.2	1300	0
12/11/2014 0:05	1300	1090.4	176.4	33.2	1300	0
12/11/2014 0:10	1300	1144.4	122.4	33.2	1300	0
12/11/2014 0:15	1300	1144.4	122.4	33.2	1300	0
12/11/2014 0:20	1300	990.9	280.8	28.3	1300	0
12/11/2014 0:25	1300	1005.4	266.3	28.3	1300	0
12/11/2014 0:30	1300	979.9	291.8	28.3	1300	0
12/11/2014 0:35	1300	919.2	352.5	28.3	1300	0
12/11/2014 0:40	1300	1097.6	174.1	28.3	1300	0
12/11/2014 0:45	1300	1081.8	189.9	28.3	1300	0
12/11/2014 0:50	1300	998.3	273.4	28.3	1300	0
12/11/2014 0:55	1300	980.3	291.4	28.3	1300	0
Hourly Average	1300	1050.4	219.7	29.9	1300	0

← Reference only

Non-Synchronized Reserve Overview

- ❑ Non-Synchronized Reserve is reserve capability that can be fully converted into energy within 10 minutes of the request from the PJM dispatcher and is provided by equipment not electrically synchronized to the system
 - Shutdown run-of-river hydro
 - Shutdown pumped hydro
 - Offline industrial combustion turbines

- NSR is not explicitly offered by any market participant for any resource
- There is no explicit requirement
 - Used to meet difference between primary and synchronized reserve requirements if it is economic
- Generation resources not available for energy are not eligible
- Generation resources designated as Emergency Only are not eligible
- Assigned NSR resources in a specific locale are paid the NSRMCP for that locale
- Assigned NSR resources may be requested to load during a spin event
 - Historically this has been a very rare occurrence
- Penalty exists for failure to provide adequate response if called for a spin event

- NSR MW quantity available from each generation resource is calculated as

$$\min \left\{ \begin{array}{l} EcoMax, \\ EcoMin + (10 - Startup - NotificationTime) * Energy RampRate \end{array} \right\}$$

- NSR resource implicit offer price is its opportunity cost for not providing energy because its held offline to provide non-sync reserve
 - ❖ $NSR\ LOC_{resource} = \max(0, LMP_{estimated} - Resource\ Marginal\ Cost)$
 - ❖ If the real-time LMP at the generator bus is less than the generator's cost at its EcoMin then the generator has no opportunity cost

Tier 1 Compensation – Settlement Perspective

i) Credits for Synchronized Reserve provided by generation resources that are then subject to the energy dispatch signals and instructions of the Office of the Interconnection and that increase their current output or Demand Resources that reduce their load in response to a Synchronized Reserve Event (“Tier 1 Synchronized Reserve”) shall be at the Synchronized Energy Premium Price less the hourly integrated real-time LMP, with the exception of those hours in which the Non-Synchronized Reserve Market Clearing Price for the applicable Reserve Zone or Reserve Sub-zone is not equal to zero. During such hours, Tier 1 Synchronized Reserve resources shall be compensated at the Synchronized Reserve Market Clearing Price for the applicable Reserve Zone or Reserve Sub-zone for the lesser of the hourly integrated amount of Tier 1 Synchronized Reserve attributed to the resource as calculated by the Office of the Interconnection, or the actual amount of Tier 1 Synchronized Reserve provided should a Synchronized Reserve Event occur.

- Section 6.2
 - Spinning Event and NSRMCP = \$0
 - Effective 10/1/2012, during hours where the Non-Synchronized Reserve Market Clearing Price is zero for the same reserve zone or sub-zone that a Tier 1 resource is located, Tier 1 synchronized reserve credits are equal to the integrated increase in MW generator output (or decrease in MW consumption for demand side response resources) from each resource over the length of a synchronized reserve event multiplied by the difference between the synchronized energy premium and the hourly integrated LMP. The synchronized energy premium is defined as the average of the 5-minute LMPs calculated during the synchronized reserve event plus \$50/MWh. If the hourly integrated LMP is greater than the synchronized energy premium, the Tier 1 credit is zero.

- Section 6.2
 - Spinning Event and NSRMCP > \$0
 - No Spinning Event and NSRMCP > \$0
 - Effective 10/1/2012, when the Non-Synchronized Reserve Clearing Price is non-zero for the applicable reserve zone or subzone, Tier 1 synchronized reserve credits are equal to the applicable reserve zone or sub-zone Synchronized Reserve Market Clearing Price multiplied by the lesser of the integrated increase in MWh output or decrease in MWh of consumption from each resource over the length of a synchronized reserve event and the estimated Tier 1 the resource could have provided. During hours when no synchronized reserve event occurs in the applicable reserve zone or sub-zone, the Tier 1 resource will be compensated using the estimated Tier 1 amount for only those resources that can reliably provide Synchronized Reserve service per the rules in Manual 11, Section 4.2.1 Synchronized Reserve Eligibility.

- Effective July 1, 2014
 - Settlements began using exceptions to Tier 1 resource eligibility as defined by Market Operations
 - If unit is flagged as ineligible for Tier 1 during market clearing for one interval within an hour, the unit is ineligible in Settlements for the entire hour
- Key Points:
 - Market Operations and Settlements are consistent in determining unit eligibility
 - Settlement Tier 1 MW calculation did not change

- Tier 1 Actual Estimate MW:
 - Lesser of Sync Reserve Ramp Rate adjusted by $DGP * 10 \text{ min}$ or (Sync Reserve Max MW – Power Meter MW)
 - Sync Reserve Ramp Rate and Sync Reserve Max MW are obtained from eMKT
- Tier 1 Response MW: Tariff 3.2.3 A (k)
 - Difference between:
 - Lowest telemetered gen output between 1 minute before and 1 minute after the start of the event
 - Greatest telemetered gen output between 9 and 11 minutes after the start of the event

- Event Details
 - Synchronized Reserve Event – 18 minutes
 - Unit reduction during event – 18 MW
 - Interval LMPs during the 18 min event - \$55, \$55, \$80, \$70
 - Hourly LMP (12 intervals) = \$47

Tier 1 Response receives credit at Tier 1 premium price

- Unit MW increase scaled over duration of event to obtain Tier 1 Response
 - $18 \text{ MW} * 18 \text{ min} * 1 \text{ hr} / 60 \text{ min} = 5.4 \text{ MWh response}$
- Average 5 minute LMPs over the duration of the event
 - $(\$55 + \$55 + \$80 + \$70) / 4 = \$65 \text{ MWh}$
- If the RT LMP for the hour at the generator pnode is \$47 then the Tier 1 credit is
 - $5.4 \text{ MWh} * [(\$65/\text{MWh} + \$50/\text{MWh}) - \$47/\text{MWh}] = \367.20
- If the hourly RT LMP is greater than the synchronized energy premium price, then the Tier 1 credit is \$0

Tier 1 paid the SRMCP times the lesser of the Tier 1 Response and the Tier 1 Actual Estimate

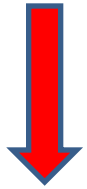
- Using 5.4 MWh response, SRMCP = \$25, and Tier 1 Actual Estimate = 4.5 MWh
- Tier 1 credit is
 - $\$25 * \min(5.4 \text{ MWh}, 4.5 \text{ MWh}) = \112.50

Tier 1 paid the SRMCP times the Tier 1 Actual Estimate

- Using SRMCP = \$25 and Tier 1 Actual Estimate = 4.5 MWh
- Tier 1 credit is
 - $\$25 * 4.5 \text{ MWh} = \112.50

Sync Reserve Event?	NSRMCP	MWh Used	Price	Comment
No	\$0	N/A	N/A	No credit provided
No	> \$0	Tier 1 Actual Estimate	SRMCP	
Yes	\$0	Tier 1 Response	Premium Price - RTLMP	
Yes	> \$0	Min(Tier 1 Actual Estimate, Tier 1 Response)	SRMCP	Treated like Tier 2 and compensated at SRMCP

Tier 2 MW, Tier 1 MW, and NSR MW are prioritized based on the level of reliability each provides



1. Tier 2 (online, obligated to respond to spin event)
2. Tier 1 (online, not obligated to respond to spin event but helps to meet SR requirement)
3. NSR (offline, obligated to respond to spin event)

Synchronized Reserve, being more reliable than NSR, also satisfies the same requirement that NSR satisfies (Primary Reserve)

Compensating Tier 1 resources at the SRMCP when the NSRMCP is greater than \$0 reflects the value of the service provided by Tier 1 resources and the ability for these resources to be counted towards both the Synchronized Reserve and Primary Reserve requirements.