RCSTF PJM Solution Package

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Updates

- This presentation has been updated from the PJM package presentation from 3/12/2024.
- Updates include:
  - A specific proposal on changes to PJM reserve requirements to address near-term changes needed for reliability (Slides 39-40)
  - Minor clarification updates to address confusion about the proposed changes to deployment. Previous presentations used the term “AGC,” intending to refer to PJM’s centralized controller logic and may have inadvertently created the impression that changes to resource-level automatic generation control was intended, which is not the case (Slides 7-10).

- The package proposed here is focused on incremental changes that PJM proposes to implement in the immediate term to address acute challenges.
- PJM anticipates that any solutions advanced in the immediate term will be followed up with additional and more comprehensive solutions for the immediate term scope moving forward.

Challenges to be Addressed in the Immediate Term

- All-Call does not align with other dispatch instructions, which creates confusion and introduces communication delays
- PJM lacks the tools required to deploy less than 100% of held reserves
- Resource financial incentives are sometimes at odds with PJM reserve deployment instructions
- Current performance evaluation will sometimes assess a MW shortfall on resources that were unable to provide those MWs
- A lack of confidence in reserve performance has led to a 30% increase in PJM's synchronized reserve reliability requirement

Deployment

Deployment: Challenges to Address

- Dispatchers lack tools to deploy less than 100% of the reserves held
- Communication delays caused by the All-Call
- Inconsistency between how instructions are given during a spin event and during normal dispatch
- Confusion on what PJM is requesting from resources during a spin event

Deployment Proposed Solution

- Dispatcher initiates the reserve event, entering the amount of reserves to be deployed (either in MW or %)

- **Reserve deployment instructions to generators will be transmitted as an update to basepoints.** Deployed reserve MWs are added to the current output of each resource and sent out immediately through telemetry, along with a notification that we are in a spin event.

  – This addition of the deployment MWs will happen outside of the dispatch and pricing optimization, and therefore will not be reflected in LMP

- For demand response resources, deployment instructions continue to go through DR Hub

- While the event persists, dispatch instructions to dispatch-following resources with a reserve deployment assignment would be the greater of a) the original deployment instruction sent or b) the new economic dispatch point calculated by SCED

Deployment Example 1

For target time T_2, Resource 1 has a 100 MW target basepoint and a 20 MW reserve assignment. At time T_{start}, the resource is operating at 100 MW and is immediately requested to load all 20 MW of reserve.

*BP_{spin}= *Output at* T_{start} + *Reserve Deployment*

**BP_n': *MAX*(BP_{spin}, T_n)

SCED DISPATCH CALCULATED FOR NEXT TARGET TIME

BP_2: 100 MW BP_3: 100 MW BP_4: 100 MW

RESERVE DEPLOYMENT CALCULATED

BP_{spin}: 120 MW* BP_3': MAX(100 MW, 120 MW)** BP_4': MAX(100 MW, 120 MW)**

INSTRUCTION SENT TO RESOURCE

100 MW   120 MW   120 MW   120 MW

Deployment Example 2

For target time T_2, Resource 2 has a 100 MW target basepoint and a 20 MW reserve assignment. At time T_{start}, that resource is operating at 100 MW and immediately requested to load all 20 MW of reserve.

*BP_{spin} = *Output at* T_{start} + *Reserve Deployment*

**BP_n': *MAX*(BP_{spin}, T_n)

SCED DISPATCH CALCULATED FOR NEXT TARGET TIME

BP_2: 100 MW

BP_3: 90 MW

BP_4: 80 MW

RESERVE DEPLOYMENT CALCULATED

BP_{spin}: 120 MW*

BP_3': MAX(120 MW, 90 MW)**

BP_4': MAX(120 MW, 80 MW)**

INSTRUCTION SENT TO RESOURCE

100 MW

120 MW

120 MW

120 MW

Deployment Example 3

For target time T_2, Resource 3 has a 100 MW target basepoint and a 20 MW reserve assignment. At time T_{start}, that resource is operating at 100 MW and is immediately requested to load all 20 MW of reserve.

*BP_{spin} = *Output at T_{start} + Reserve Deployment*

**BP_n': *MAX(BP_{spin}, T_n)*

T_1 T_{start} T_2 T_3 T_{end} T_4

SCED DISPATCH CALCULATED FOR NEXT TARGET TIME

BP_2: 100 MW

BP_3: 130 MW

BP_4: 160 MW

RESERVE DEPLOYMENT CALCULATED

BP_{spin}: 120 MW*

BP_3': MAX(120 MW, 130 MW)**

BP_4': MAX(120 MW, 160 MW)**

INSTRUCTION SENT TO RESOURCE

100 MW

120 MW

130 MW

160 MW

Less than 100% Reserve Deployment Proposed Solution

- To the extent possible, all resources will be deployed pro rata
  - Example: A resource has a 10 MW SR assignment and PJM deploys 80% of held reserves. The resource would be instructed to deploy 8 MW.
- Inflexible generation resources will be deployed to the greater of a) EcoMin and b) the pro rata reserve deployment instruction*
  - Example: A condenser has an EcoMin of 10 MW, a 30 MW SR assignment, and PJM deploys 50% of held reserves. The resource would be instructed to deploy 15 MW.
  - Example: A condenser has an EcoMin of 20 MW, a 30 MW SR assignment, and PJM deploys 50% of held reserves. The resource would be instructed to deploy 20 MW.
- Resources without a dispatchable range will be deployed to their SR assignment*

**Due to these constraints, actual reserves deployed may be greater than the pro rata calculation*

Performance Evaluation

SR Performance Evaluation: Challenges to Address

- While these are edge cases, the calculated assignment and deployment instruction may not align with a resource’s operating posture when the event occurs 100% of the time because the actual time of the event is unknown beforehand.
  - Example 1: Status quo performance evaluation does not account for when a resource is sent a deployment instruction that would dispatch that resource above its EcoMax.
  - Example 2: Depending on where a resource is operationally when an event begins, its ramp limitations may not allow it to achieve the desired deployment.

SR Performance Evaluations: Challenges Example 1

At T_1, Resource 1 is operating at 100 MW, its EcoMax. For target time T_2, it is given a 80 MW target basepoint, positioning to be able to provide 20 MW of reserves, which it is assigned. At time T_{start}, a spin event is called. That resource is operating at 95 MW and is immediately requested to load all 20 MW of reserve, sending it to 115 MW.

INSTRUCTIONS SENT TO RESOURCE FOR THE TARGET TIME				
80 MW for T_2	115 MW for $T_{start+10}$	115 MW for $T_{start+10}$	115 MW for $T_{start+10}$	
ACTUAL RESOURCE OUTPUT				
100 MW at T_1	95 MW at T_{start}	100 MW at T_2	100 MW at T_3	100 MW at $T_{start+10}$

If it achieves EcoMax, Resource 1's performance would be its output at $T_{start+10} – T_{start}$ = 5 MW, which would be a shortfall of 15 MW under status quo.

SR Performance Evaluations: Challenges Example 2

At its position at T_1 Resource 2 is in a segment of its ramp rate curve that corresponds to a capability of 5 MW/min. Beginning at T_2 its target dispatch point places it in a new segment of its ramp rate curve, at which point its ramp rate is 1 MW/min. The resource's capability calculation, based on its output when the optimization engine is run, indicates that the resource has 30 MW of ramp capability and the resource's EcoMax supports that assignment. The optimization clears the resource for 30 MW of reserves.

ACTUAL LINEARIZED RAMP CAPABILITY FOR NEXT 10 MINUTES

30 MW 22 MW 10 MW

Because of when the event occurs, Resource 2 is only capable of providing 22 MW of reserves in 10 minutes (it has 3 minutes of ramp capability at 5 MW/min and then 7 minutes starting at T_2 at ramp capability of 1 MW/min). Under status quo, this resource would be assessed as having a 8 MW shortfall even if it fully utilized its ramp capability.

SR Performance Evaluation Proposed Solution

- For events that are at least 10 minutes, PJM will run two performance evaluation checks. If a resource passes either of the checks, it is evaluated as having met its performance requirements
  - **Check 1:** Updated status quo methodology that caps the expected resource output based on the resource's EcoMax (or SynchMax where applicable). Under this evaluation, a resource would not be assessed a shortfall if it achieves the lesser of its reserve deployment assignment or its EcoMax (or SynchMax where applicable) within 10 minutes and sustains that performance for the event up to the product duration.
  - **Check 2:** Using the resource's segmented ramp rates, PJM will calculate the resource's expected, ramp-limited capability over the 10 minutes following the start of the event based on the resource's starting MW output. PJM will evaluate whether the resource meets or exceeds this expected performance within 10 minutes and sustains that performance for the event up to the product duration requirement.
- If a resource does not pass any of the performance checks, the shortfall MW will be based on the check in which the resource's measured performance was the best.

SR Performance Evaluations: Solution Example Check 2

Four resources (R1, R2, R3 and R4) are assigned reserves based on their calculated 10-minute capability at target dispatch T_2. All four resources have the same segmented ramping capability and are not constrained by their EcoMin or EcoMax limits.

Resource Dispatch Before Spin Event:

75 MW 100 MW

Output	Ramp
125 MW	5 MW/min
150 MW	1 MW/min

When the optimization is run, the resources are sitting at 75 MW. Based on their 10 minute ramp capability at this point, 50 MW are cleared on each resource:

- **5 MW/min * 10 min = 50 MW** *[75 MW + 50 MW = 125 MW]*

SR Performance Evaluations: Solution Example Check 2

A spinning event is called at time $T_{start,}$ four minutes into the interval that ends at T_2. The resources are asked to load their 50 MW reserve assignments. The event ends after 13 minutes.

Actual resource output:

95 MW

Output	Ramp
125 MW	5 MW/min
150 MW	1 MW/min

Starting at time $T_{start,}$ when the event is called, the resources' ramp-limited capability is actually 34 MW:

- 5 MW/min * 6 min = 30 MW *[95 MW + 30 MW = 125 MW]*
- 1 MW/min * 4 min = 4 MW *[125 MW + 4 MW = 129 MW]*
- **30 MW + 4 MW = 34 MW**

The resources are instructed to ramp to 150 MW, but can only achieve 129 MW. They would fail Check 1 because their ramp limitations do not allow them to move up the requested number of MWs in 10 minutes.

SR Performance Evaluations: Solution Example Check 2

The four, ramp-limited resources (R1, R2, R3, and R4) perform as follows.

	$T_{start+10}$		$T_{start+11}$		$T_{start+12}$		$T_{start+13}$		Shortfall
	MW Output	Shortfall	MW Output	Shortfall	MW Output	Shortfall	MW Output	Shortfall	
R1	129 MW	0 MW	129 MW	0 MW	129 MW	0 MW	129 MW	0 MW	0 MW
R2	129 MW	0 MW	130 MW	0 MW	131 MW	0 MW	132 MW	0 MW	0 MW
R3	125 MW	4 MW	--	--	--	--	--	--	4 MW
R4	129 MW	0 MW	126 MW	3 MW	126 MW	3 MW	127 MW	2 MW	2 MW

- R1 meets its ramp-limited performance expectations by ramping up according to its segmented ramp rates. No shortfall is assessed.
- R2 meets its ramp-limited performance expectations within 10 minutes and continues to ramp up, getting closer to its requested output level. No shortfall is assessed.
- R3 does not meet its ramp-limited performance expectations within 10 minutes, and the shortfall at minute 10 becomes its assessed shortfall.
- R4 meets its ramp-limited performance expectations within 10 minutes, but does not sustain it. Its total assessed shortfall is the average of its measured shortfall values at each minute.

NSR Performance Evaluation: Challenges to Address

- Resources holding an non-synchronized reserve assignment are primarily utilized when they are called online for energy outside of a non-synchronized reserve event.
- Currently, the only performance evaluation methodology that exists for evaluating NSR performance is during a non-synchronized reserve event.

NSR Performance Evaluation Proposed Solution

- Status quo for NSR events
- When called online for energy, irrespective of the existence of a spin event, evaluate whether the resource reaches EcoMin within 10 minutes (mirror of status quo for offline SecR)

Compensation, Penalties and Offer Structure

Compensation, Penalties and Offers: Challenges to Address

- The cost of reserve deployment is not in all cases recoverable through the energy market and resources may not be financially indifferent to following PJM deployment instructions in all cases
- Current SR penalties are variable, complex and lack transparency
  - For the same MW shortfall during the same SR event, two resources might have very different penalties, depending on several factors, including a) how often they have cleared the market and b) the SRMCP in intervals in which they previously cleared
  - In 2023, per MW penalties ranged significantly

Deployment Cost Recovery: Example

A resource is operating economically at a flat dispatch level of 45 MW, given an LMP of $20, and holds a reserve assignment of 30 MW. Above 50 MW, the resource's offer price jumps to $100. A spinning event is called and that resource is asked to deploy those 30 MW of reserves. At $20, the resource recovers its cost for the first 5 MW, but not for the remaining 25 MW.

Output	Energy Offer
50 MW	$20
100 MW	$100

The unrecovered deployment costs in each interval would be calculated as the difference between the resources energy offer and real time LMP multiplied by the average MWs deployed in that interval.

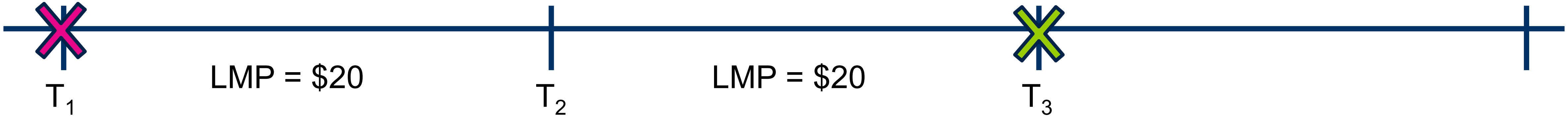
Unrecovered costs = Energy offer of deployed MW – energy revenues from deployed MWs

- Energy offer of deployed MW = area under the incremental offer curve for the deployed MW
- Energy revenues from deployed MWs = Deployed MW * LMP / 12

Deployment Cost Recovery: Example

Output	Energy Offer
50 MW	$20
100 MW	$100

The event occurs at the start of the interval, and ends after 10 minutes. LMP in both intervals is $20. The resource deploys half its reserves (or 15 MW additional) in each interval.**



Interval 1:

- Unrecovered Deployment Costs = 5 MW ($20 - $20)/12 + 10 MW($100 - $20)/12 = $67

Interval 2:

- Unrecovered Deployment Costs = 5 MW($20 - $20)/12 + 25 MW($100 - $20)/12 = $167

Total Unrecovered Deployment Costs = $234

***For simplicity, this example assumes instant, full deployment of reserves at the start of each interval (i.e., a step function). In reality, the actual sampled output would be used.*

Proposed Changes to Make-Whole Payments for Reserve Deployment

- PJM will calculate make whole payments for resources that deploy reserves to make them financially indifferent to following PJM reserve deployment instructions

- Make whole payments for the unrecovered costs of deploying synchronized reserves will be credited through the synchronized reserve market and costs will be allocated to the synchronized reserve market

- Make whole payments will be offset by revenue above costs earned from synchronous reserve market clearing price credits for that operating day

Penalties – Synchronized Reserves

- The day of penalty will remain the same as status quo
- The status quo retroactive penalty will be removed
- A **flat, per MW penalty** will be charged to each resource with a MW shortfall when a resource fails to perform during a SR event
- The per MW penalty charge will be the **greater** of:
  - The penalty factor ($850)
  - System energy price in the interval in which the resource was expected to have fully deployed (i.e., 10 minutes after the start of the event)

Penalties – Non-Synchronized and Secondary Reserves

- Two elements of penalties for non-performance moving forward:
  - Penalties based on reserve market clearing price credits
  - LMP-based penalty for failure to convert reserves to energy

Penalties based on Reserve Market Credits

- For offline resources holding a SECR assignment that fail to perform, the adjustments to reserve credits will remain the same (i.e., adjustments to reserve credits within the operating day or to the last time the resource was online)
- For resources holding a NSR assignment that fail to perform, regardless of the existence of an event, the adjustments to reserve credits will mirror penalties for offline SECR (described in the previous bullet)

- If an offline SECR or NSR resource fails to convert procured reserves into energy when called upon, that resource will need to pay for that shortfall based on real-time LMP
- The payment for undelivered energy will be calculated based on the shortfall MWs, starting in the interval in which the resource was expected to have fully deployed the requested reserves (i.e., 10 minutes for NSR and 30 minutes for SECR after the resource is deployed or called-on for energy).
- The payment for undelivered energy will be applied for the product’s duration requirement (i.e., for NSR, 30 minutes or a total of 6 intervals, for SECR 60 minutes or a total of 12 intervals).

A NSR resource is assessed as having a 5 MW shortfall when called on to deploy non-synchronized reserves. For each of the following 6 intervals, the resource is required to pay for this 5 MW shortfall at LMP.

Interval	LMP ($)	Penalty ($)
11/30/2024 18:45	25.99	--
11/30/2024 18:50	26.97	--
11/30/2024 18:55	30.21	12.59
11/30/2024 19:00	32.26	13.44
11/30/2024 19:05	30.23	12.60
11/30/2024 19:10	29.32	12.22
11/30/2024 19:15	26.11	10.88
11/30/2024 19:20	23.65	9.85
	Total	**71.57**

Interval the reserves were deployed

Interval the reserves should have been fully converted to energy

Where the buyback at each interval is calculated as:

Payment = MW Shortfall x LMP/12

- Status quo
- The expected penalty calculation methodology would be updated to reflect the new penalty structure
- Adjustments to the make-whole payments would make resources at least indifferent to following PJM deployment instructions
- Changes to the deployment and performance evaluation should better address issues with the current capability calculation

Secondary Reserve Duration Requirement

- Update the secondary reserve product definition to specify a duration (or sustainability) requirement, which is currently missing
- Set the secondary reserve product duration to 60 minutes

- For reserves assignments that are determined to be undeliverable during a deployment event, settlements will cap the reserve assignment by any undeliverable MWs for that interval.
  - Example: From the Check 2 performance evaluation example, a resource is cleared for 50 MW, but when deployed, its ramp-limited capability only allows it to provide 34 MW. That resource would incur no penalties for only providing 34 MW, and its reserves assignment credits for that interval would be capped at 34 MW.

Challenges to Address: Clearing of Condensers for SR

- Reserve assignments for resources in condensing mode are cleared in the hour ahead engine (inflexible reserves in ASO)
- This reserve assignment is binding and cannot be adjusted by SCED even if there is an available dispatchable range on the resource
- Because these resources are not included in the economic optimization, they cannot set price

Clearing of Condensers for SR Proposed Solution

- The hour ahead engine will continue to commit resources in condensing mode to provide synchronized reserves
- If these resources have an available dispatchable range, that flexibility will be available to the SCED engine when clearing the SR resources to meet the requirement
- The reserve assignments for resources with a dispatchable range will therefore be set by the economic clearing engine, and these resources will be able to set price

Clearing of Condensers for SR Solution Example

- A resource in condensing mode is picked up for synchronized reserves by the hour ahead engine. It has an EcoMin of 20 MW and can achieve 30 MW within 10 minutes of flipping from condense to generate mode. It is therefore given an SR assignment of 30 MW in the hour ahead engine.
  – In status quo, this 30 MW assignment would be binding in the optimization engine, and the resource would not be able to set price
  – Under this proposed solution, the SCED engine could clear this resource economically for SR anywhere from 20 MW – 30 MW, and this resource could be marginal.

Reserve Requirements

Reserve Requirements: Challenges to Address

- The 30-minute reserve requirement does not currently reflect the operational risks that dispatch must account for on a day-to-day basis

- Extending one of the extended reserve requirements to address operational uncertainty would cascade into all three, and could force the over-procurement of unneeded reserves.
  - For example, if PJM needed to procure additional 30-minute reserves to address operational uncertainty, that would require also procuring the same amount of additional SR and PR.

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Proposed Changes to Reserve Requirements

- Revise the 30-minute Reliability Requirement to better capture day-to-day operational risks, similar to the previously used methodology in the Day Ahead Scheduling Reserve (DASR)
  - 30-Min Requirement = MAX(Load Forecast Peak*(Avg. Load Forecast Error + Avg. Forced Outage Rate), Primary Reserve Requirement, Active Gas Contingency)
- Update Manual 11 to clarify that each extended reserve requirement can be extended independently.

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Acronyms

Acronym	Term & Definition
LMP	**Locational Marginal Price** is defined as the marginal price for energy at the location where the energy is delivered or received. For accounting purposes, LMP is expressed in dollars per megawatt-hour ($/MWh). LMP is a pricing approach that addresses Transmission System congestion and loss costs, as well as energy costs.
AGC	**Automatic Generation Control** is equipment that automatically adjusts generation.
SCED	**Security Constrained Economic Dispatch** is the optimization engine used to calculate dispatch and reserve assignments and to set prices.
MW	A **Megawatt** is a unit of power equaling one million watts (1 MW = 1,000,000 watts) or one thousand kilowatts (1 MW = 1,000 KW). To put it in perspective, under non-severe weather conditions, one MW could power roughly 800 to 1,000 average-sized American homes.

PJM Glossary

Acronyms

Acronym	Term & Definition
SR	**Synchronized Reserves** is a reserve capability that can be converted fully into energy within 10 minutes following the request of PJM. Equipment providing Synchronized Reserve must be electrically synchronized to the power system.
NSR	**Non-Synchronized Reserves** is a reserve capability that can be converted fully into energy within 10 minutes following the request of PJM. Equipment providing Non-Synchronized Reserve need not be electrically synchronized to the power system.
SECR	**Secondary Reserves** is a reserve capability that can be converted fully into energy within 30 minutes following the request of PJM. Equipment providing Secondary Reserve need not be electrically synchronized to the power system.

PJM Glossary


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