



Reserve Event Performance Measurement & Penalty Rules

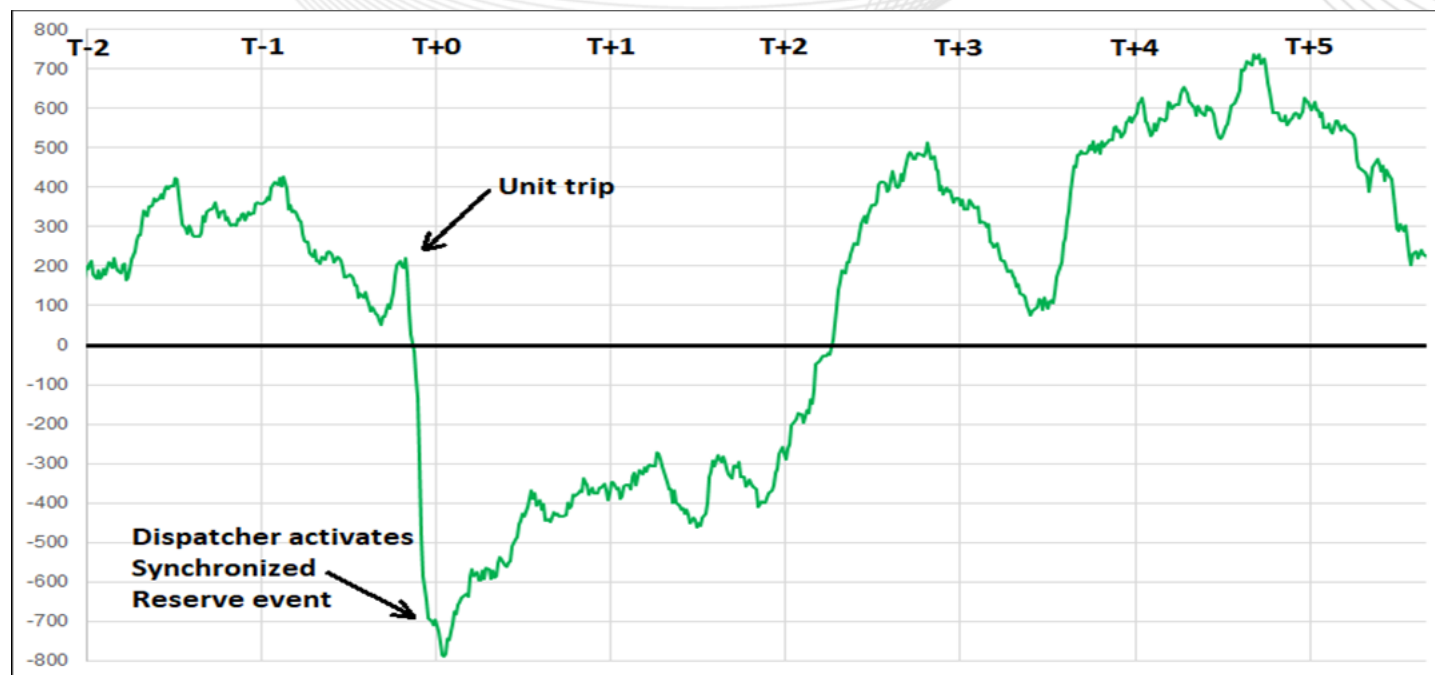
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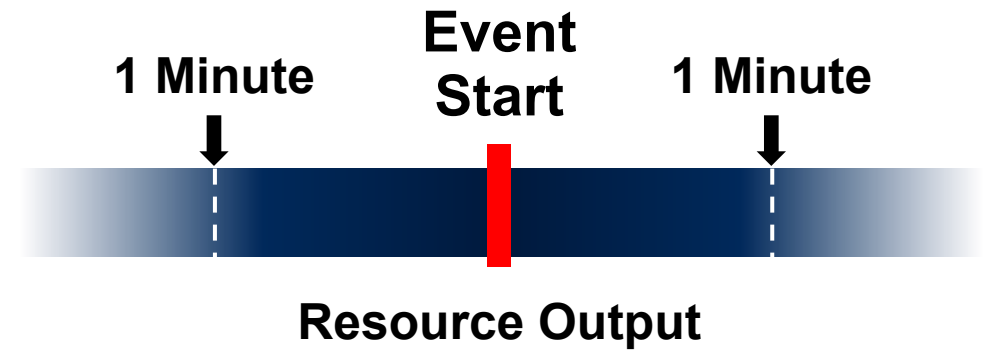
October 10, 2023

- Resources obligated to perform are Generation, Hybrid Resources, Energy Storage Resources, and Economic Load Response resources that have a Real Time Synchronous Reserve Assignment.
 - Resources with a DA Reserve Assignment but no Real Time Reserve Assignment have no performance obligation.
- Resource responses are verified by the PJM Performance Compliance department following each event.
- Actual responses compared to assignments during Synchronized Reserve events are used to determine penalties.



- Synchronized Reserve event start time is when the dispatcher activates a Synchronized Reserve event in EMS.
- Actual response is what a resource's true response is.
- Calculated response is what PJM records the resource's response as.

- Resource response to a synchronized reserve event is the difference between the resource's output at the start of the event and its output ten minutes after the start of the event allowing for small fluctuations and possible telemetry delays
- Resource output at the start of the event
 - The **lowest** telemetered output between 1 minute prior to and 1 minute following the start of the event
- Resource output ten minutes after the start of the event
 - The **greatest** output achieved between 9 and 11 minutes after the start of the event
 - Unit reduction after 10 minute mark before end of event will decrease total response



Response Measurement < 10 Minutes Example

| | | Event Start | | | | | Event End | | |
|------------------------|----|-------------|---|---|---|---|-----------|---|---|
| Minute | -1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Unit Output (MW) | 3 | 4 | 5 | 6 | 5 | 4 | 5 | 6 | 6 |
| Credited Response (MW) | - | 4 | 4 | 4 | 4 | 4 | 4 | - | - |

- Event lasting 6 minutes
 - Unit’s actual response calculation:
 - Maximum of minutes (5 to 7) - minimum of minutes (-1 to 2)
 - $\text{Max}(4, 5, 6) - \text{min}(3, 4, 5) = 6 - 3 = 3 \text{ MW}$
 - Unit’s calculated response:
 - Calculated response is equal to assignment for event less than or equal to 10 minutes
 - Assignment = 4 MW
 - Calculated response = 4 MW

Response Measurement \geq 10 Minutes Example 1 (Shortfall)

| | | Event Start | | | | | | | | | Ten Minutes | | Event End | | |
|------------------------|-----|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-------------|-----|-----------|-----|-----|
| Minute | -1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Unit Output (MW) | 103 | 104 | 105 | 106 | 105 | 104 | 105 | 106 | 106 | 106 | 104 | 103 | 106 | 102 | 109 |
| Credited Response (MW) | - | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 3 | -1 | - |

- For events lasting longer than ten minutes:
 - If the unit outputs more energy at minutes beyond ten, the unit's response is capped at its ten minute response.
 - If the unit outputs less energy at minutes beyond ten, the unit's response is reduced by that MW amount.



Response Measurement > 10 Minutes Example 1 (Shortfall)

- Unit's Response Calculation
 - a. Assignment is 4 MW
 - b. Calculate Initial MW
 - i. Minimum of minutes (-1, 1, 2) = $\text{Minimum}(103, 104, 105) = 103$ MW
 - c. Calculate Response at Minute 10
 - i. Maximum of minutes (9, 10, 11) = $\text{Maximum}(106, 104, 103) = 106$ MW
 - d. Calculate Response for minutes 1 to 10
 - i. c.i. - b.i. = $106 - 103 = 3$ MW
 - e. Calculate Response at Minutes ≥ 11
 - i. Response of minute 11 = minimum of ((d.i.) or (103 - 103)) = minimum of ((3) or (0)) = 0 MW
 - ii. Response of minute 12 = minimum of ((d.i.) or (106 - 103)) = minimum of ((3) or (3)) = 3 MW
 - iii. Response of minute 13 = minimum of ((d.i.) or (102 - 103)) = minimum of ((3) or (-1)) = -1 MW
 - f. Calculate total response
 - i. Sum of minutes (1 to 13) divided by length of event minutes (1 to 13)
 - ii. $(3+3+3+3+3+3+3+3+3+3+0+3+(-1)) / 13$ minutes = $32/13 = 2.4615$ MW
 - g. Calculate total shortfall
 - i. Assignment - Calculated total response
 - ii. $4 - 2.4615 = 1.5385$ MW shortfall

Response Calculation > 10 Minutes Example 2 (Surplus)

| | | Event Start | | | | | | | | | Ten Minutes | | | Event End | |
|------------------------|-----|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-------------|-----|-----|-----------|-----|
| Minute | -1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Unit Output (MW) | 103 | 104 | 105 | 106 | 105 | 104 | 105 | 106 | 106 | 106 | 104 | 108 | 110 | 115 | 109 |
| Credited Response (MW) | - | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | - |

- For events lasting longer than ten minutes:
 - If the unit outputs more energy at minutes beyond ten, the unit’s response is capped at its ten minute response.
 - If the unit outputs less energy at minutes beyond ten, the unit’s response is reduced by that MW amount.



Response Calculation > 10 Minutes Example 2 (Surplus)

- Unit's Response Credit and Calculation
 - a. Assignment is 4 MW
 - b. Calculate Initial MW
 - i. Minimum of minutes (-1, 1, 2) = $\text{Minimum}(103, 104, 105) = 103$ MW
 - c. Calculate Response at Minute 10
 - i. Maximum of minutes (9, 10, 11) = $\text{Maximum}(106, 104, 108) = 108$ MW
 - d. Calculate Response for minutes 1 to 10
 - i. c.i. - b.i. = $108 - 103 = 5$ MW
 - e. Calculate Response at Minutes ≥ 11
 - i. Response of minute 11 = minimum of ((d.i.) or (108 - 103)) = minimum of ((5) or (5)) = 5 MW
 - ii. Response of minute 12 = minimum of ((d.i.) or (110 - 103)) = minimum of ((5) or (7)) = 5 MW
 - iii. Response of minute 13 = minimum of ((d.i.) or (115 - 103)) = minimum of ((5) or (12)) = 5 MW
 - f. Calculate total response
 - i. Sum of minutes (1 to 13) divided by length of event minutes (1 to 13)
 - ii. $(5+5+5+5+5+5+5+5+5+5+5+5+5) / 13$ minutes) = $65 / 13 = 5$ MW
 - g. Calculate total surplus
 - i. Assignment - Calculated total response
 - ii. $4 - 5 = 1$ MW surplus

Resources are credited every 5-minute interval for their RT capped assignment and are expected to be ready to respond to a Synchronized Reserve Event.

**Day-Ahead
SRMCP Credit**
(per hour)

$$= \text{Day-ahead SR Assignment (MW)} \times \text{Day-ahead SR Market Clearing Price (\$/MWh)}$$

**Balancing
SRMCP Credit**
(per 5-min Interval)

$$= \left[\left(\text{Capped Real-time SR Assignment (MW)} - \text{Day-ahead SR Assignment (MW)} \right) \times \text{Real-time SR Market Clearing Price (\$/MWh)} \right] \div 12$$

Capped at Lesser of:

RT SR MW

or

MIN

Eco Max MW

,

RT SR Max MW

-

RT Generation (MW)

*During a Synchronized Reserve Event, the assignment is not capped
Capped Real-time SR Assignment = Real-time SR assignment MW

- Failure to provide directed response results in an obligation to repay all or a portion of the synchronized reserve credits received on both:
 - The day of the event (including five-minute intervals outside of the event)
 - Over the immediate past interval, which is equal to the lesser of:
 - The average number of days between events (21-days for 2023) OR
 - The number of days since resource's last non-performance
- If the event duration is less than 10 minutes, there is no obligation to refund credits due any shortfall.
- See section 6.3.3 of M28: <https://www.pjm.com/-/media/documents/manuals/m28.ashx>

- Obligations to refund synchronized reserve credits due to event performance shortfalls are assessed as RT Synchronized Reserve Shortfall Charges
 - The MW subject to refund in each interval are the Shortfall MW capped at the real-time MW the resource received SRMCP credits for.
 - This refund is charged at the RT SRMCP for each 5-minute interval in which the charge is assessed.
- RT Synch Reserve Shortfall Charge = $\text{Min} (\text{Shortfall MW}, \text{Capped RT SR Assignment}) * \text{RT SRMCP} / 12$



Example of a RT Synchronized Reserve Shortfall Charge Calculation

January 10th – Event Results

| Resource | SR Assigned | Response | Under Response | Over Response |
|----------|-------------|----------|----------------|---------------|
| A | 50 MW | 50 MW | 0 | 0 |
| B | 25 MW | 25 MW | 0 | 0 |
| C | 30 MW | 0 | 30 | 0 |

1. Resource A: No charge
2. Resource B: No charge
3. Resource C: Charge for the shortfall

Market Participants that own multiple resources assigned or self-scheduled to provide Synchronized Reserve are permitted to demonstrate aggregate response, such that any resource that responds greater than their assignment (pool or self-scheduled) can be used to offset any resource that responds less than their assignment of Synchronized Reserve during a Synchronized Reserve Event.

- a. Day of Event shortfall charge of $\min(30 \text{ MW}, \text{RT capped assignment})$ applied to all intervals the resource was assigned on January 10th.
- b. Retroactive charge: $\min(30 \text{ MW}, \text{RT capped assignment}) * \text{applicable RT SRMCP}/12$ in the assigned intervals for lesser of 21 days or last non-performance.

See the link for additional examples: <https://www.pjm.com/-/media/training/core-curriculum/ol-reserve-market/06-performance-measurement-and-compensation.ashx>



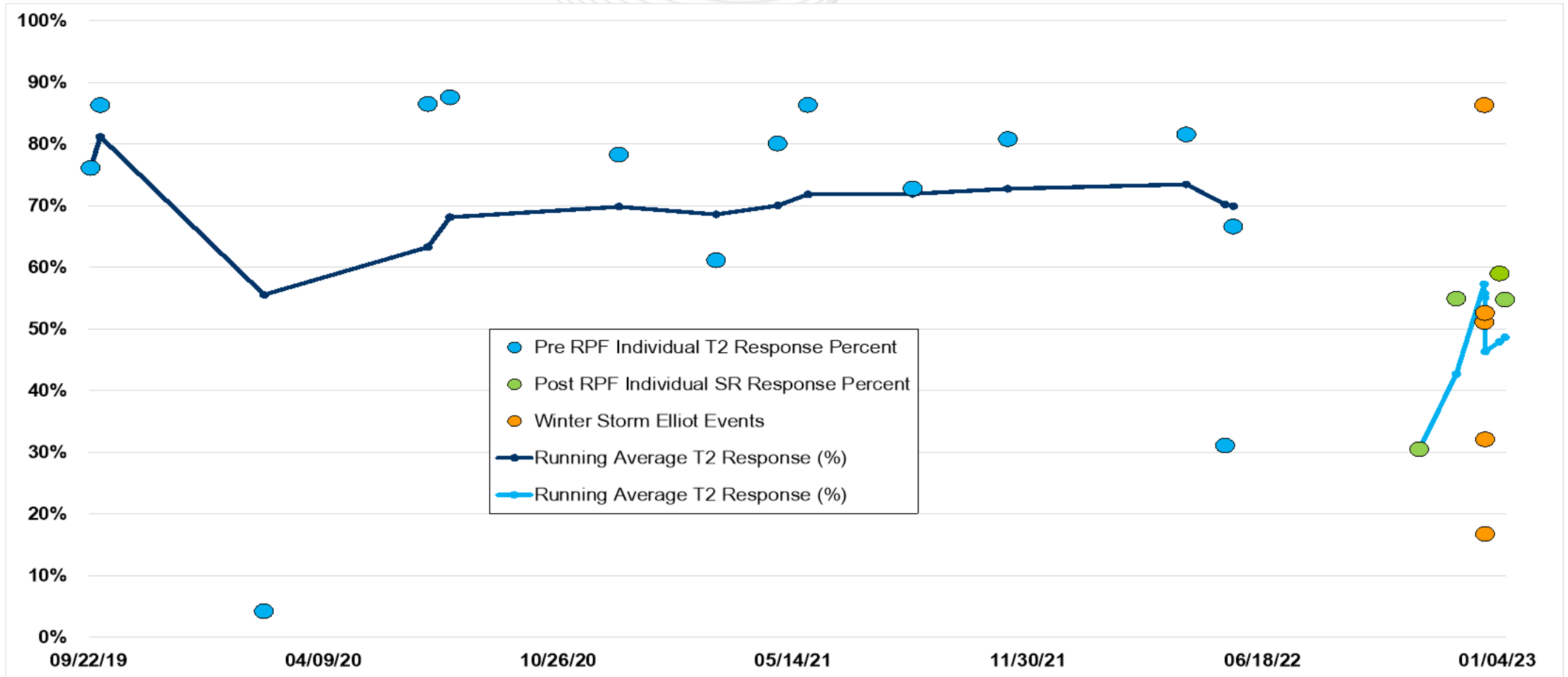
Synchronized Reserve Penalties (\$)

| Year | Month | Synchronized Reserve Penalties (\$) |
|-------|-----------|-------------------------------------|
| 2022 | October | 215,917.64 |
| | November | 77,556.08 |
| | December | 3,523,716.00 |
| 2023 | January | 2,058,397.31 |
| | February | 0.00 |
| | March | 0.00 |
| | April | 0.00 |
| | May | 0.00 |
| | June | 0.00 |
| | July | 0.00 |
| | August | 0.00 |
| | September | 0.00 |
| Total | | 5,875,587.03 |

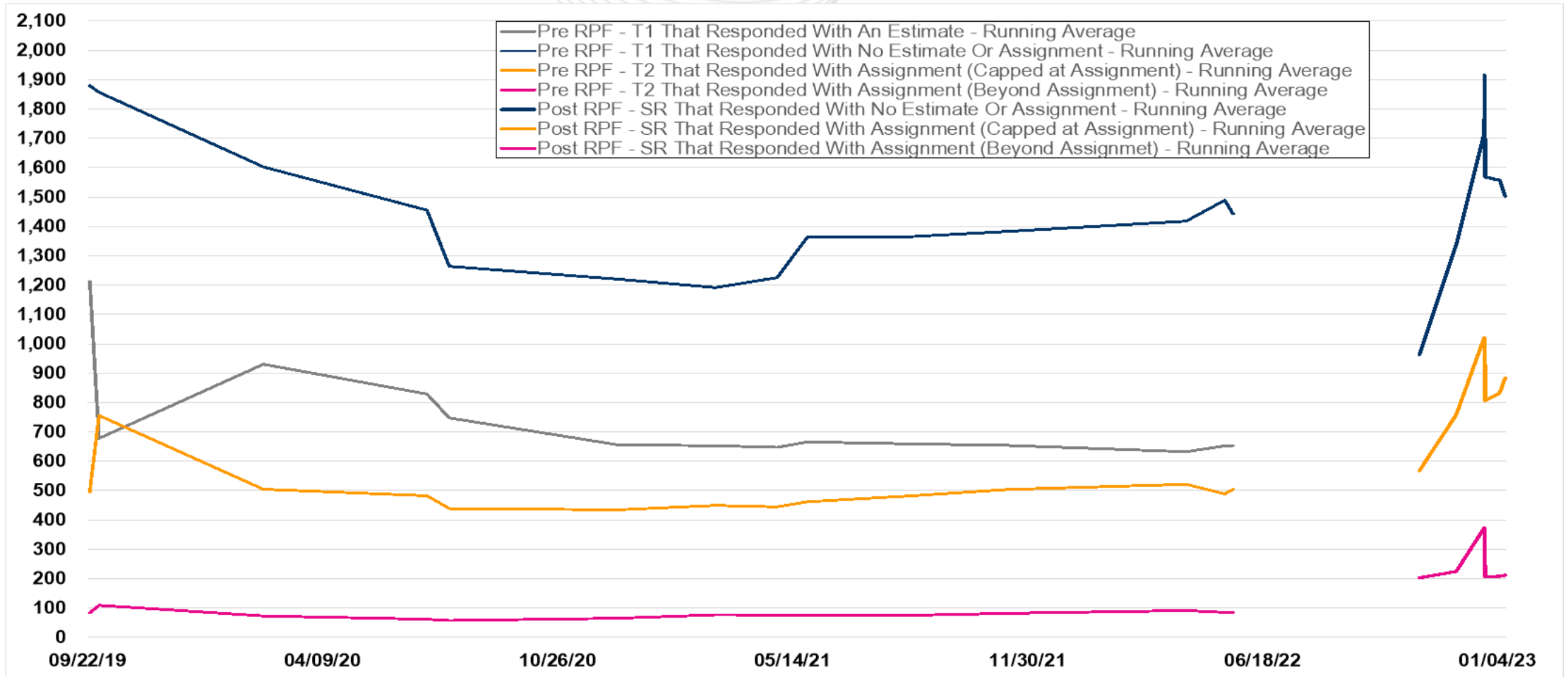
- Measured similar to Synchronized Reserve performance
- In the event a resource that has been assigned to provide Non-Synchronized Reserves fails to provide the assigned amount of Non-Synchronized Reserves in response to a Non-Synchronized Reserve Event, the resource will only be credited for Non-Synchronized Reserve capacity in the amount that actually responded for the continuous five (5) minute intervals the resource was assigned Non-Synchronized Reserves during which the event occurred.
 - No retroactive portion of penalty
- PJM has never had a Non-Synchronized Reserve event since Reserve Price Formation implementation (10/01/22)

- Offline generation resources assigned to provide Secondary Reserve in real time and dispatched by PJM for energy during the Operating Day are required to reach Economic Minimum output within 30 minutes
- Secondary Reserve credit is reduced by any shortfall
- Secondary Reserve Shortfall MW = For a real-time offline generation resource that does not reach Economic Minimum output within 30 minutes as instructed by PJM. Shortfall = assignment in this scenario. This shortfall MW will be applied to all prior intervals in which the resource was assigned to provide real-time Secondary Reserve starting at the later of:
 - (A) the last interval the resource was online or
 - (B) the beginning of that Operating Day and continuing up to the interval the resource failed to come online.
- For a real-time Economic Load Response that does not reduce by at least the Economic Minimum within 30 minutes as instructed by PJM. This shortfall MW will be applied to all prior intervals in which the resource was assigned to provide real-time Secondary Reserve starting at the later of:
 - (A) the last interval the resource reduced load at PJM's instruction or
 - (B) the beginning of that Operating Day, through the earlier of
 - (C) the next interval in which the resource is dispatched to reduce load or
 - (D) the end of the Operating Day.

Response (%)



Response (MW)



- Concerns about significant decrease in actual response from resources assigned to provide Synchronized Reserves post RPF
 - Down by an average of 20%
- Resources assigned to provide Synchronized Reserves have an obligation to respond or have penalties applied
- Small sample size of events
- PJM has been monitoring and reaching out to resources
 - Determined common causes as well as some recommendations

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Reserve Event Performance Measurement & Penalty Rules



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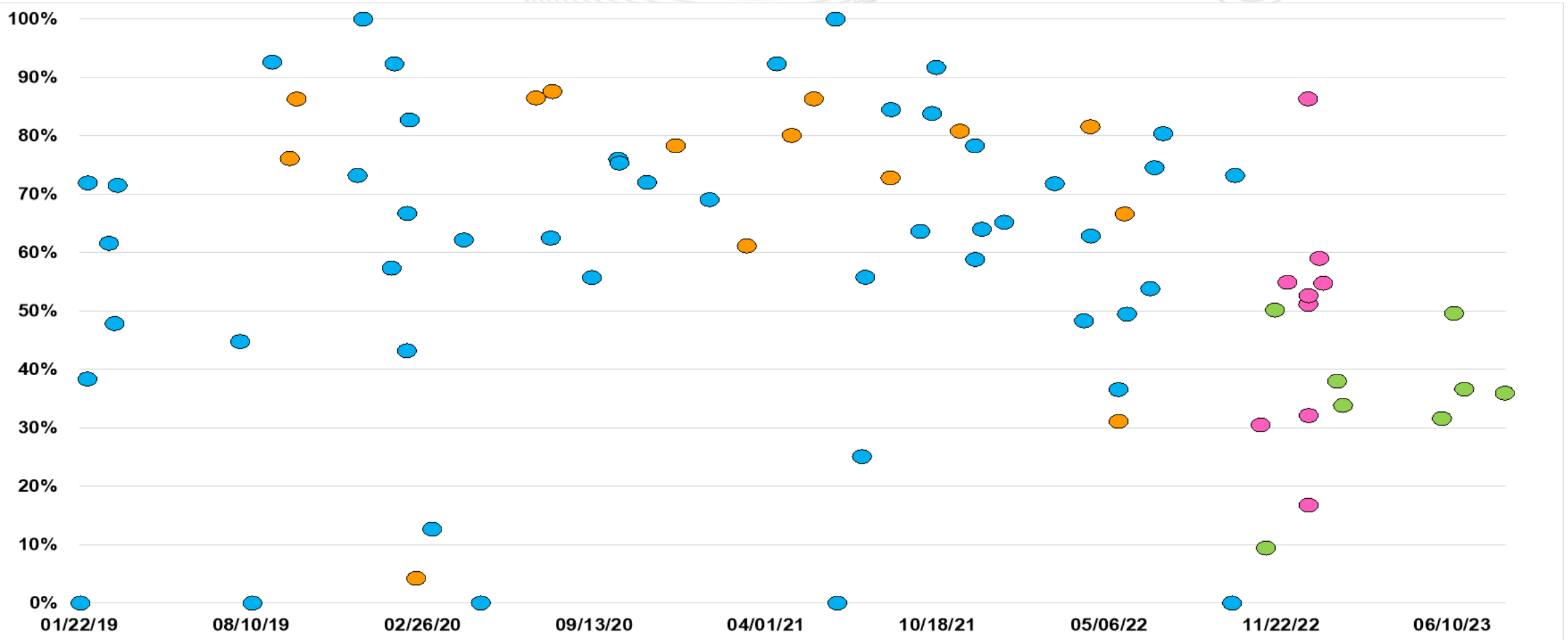
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Appendix



All Synchronized Reserve Events Since 2019

Response (%)



Pre RPF Individual Event T2 Response Percent with duration

- < 10 minutes (Blue)
- ≥ 10 minutes (Orange)

Post RPF Individual Event SR Response Percent with duration

- < 10 minutes (Green)
- ≥ 10 minutes (Pink)



Generation And DR Response Comparison By 10+ Minute Event

| Event Start (ET) | Generation Resources Assignment (MW) | Generation Resources Response (MW) | Generation Response (%) | DR Resources Assignment (MW) | DR Resources Response (MW) | DR Response (%) |
|------------------|--------------------------------------|------------------------------------|-------------------------|------------------------------|----------------------------|-----------------|
| 10/29/22 | 1,669 | 386 | 23.1% | 189 | 181 | 96.0% |
| 11/29/22 | 1,703 | 927 | 54.4% | 24 | 22 | 93.2% |
| 12/23/22 | 1,721 | 1,479 | 85.9% | 70 | 69 | 98.0% |
| 12/23/22 | 1,622 | 726 | 44.8% | 224 | 218 | 97.7% |
| 12/24/22 | 1,717 | 898 | 52.3% | 50 | 32 | 64.3% |
| 12/24/22 | 1,459 | 377 | 25.9% | 206 | 158 | 76.5% |
| 12/24/22 | 979 | 152 | 15.5% | 118 | 107 | 90.8% |
| 01/05/23 | 1,559 | 897 | 57.5% | 155 | 115 | 74.3% |
| 01/10/23 | 1,998 | 1,071 | 53.6% | 370 | 227 | 61.2% |
| | Average | | 47.9% | Average | | 80.3% |

| Acronym | Term & Definition |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DR | Demand Resource means a resource with the capability to provide a reduction in demand. |
| SRMCP | Synchronized Reserve Market Clearing Price is defined as the marginal price for synchronized reserves in a reserve zone or sub-zone. For accounting purposes, SRMCP is expressed in dollars per megawatt-hour (\$/MWh). Resources that are assigned synchronized reserve in a five-minute interval are paid the SRMCP in that interval. |
| SR | Synchronized Reserve means the reserve capability of generation resources that can be converted fully into energy or Economic Load Response Participant resources whose demand can be reduced within ten minutes from the request of the Office of the Interconnection dispatcher, and is provided by equipment that is electrically synchronized to the Transmission System. |
| RPF | Reserve Price Formation refers to the set of reserve market enhancements that were implemented on October 1, 2022. |
| T2 | Tier 2 refers to a subset of synchronized reserve resources that were backed down from where it would otherwise be economic for them to provide energy in order to accommodate a synchronized reserve assignment. Prior to the Reserve Price Formation implementation, only Tier 2 resources were required to perform during a synchronized reserve event. |