Reserves & Operating Reserve Demand Curve Education

Types of Reserves

<table>
<tr><td colspan="3">Day-Ahead Scheduling Reserve
(T ≤ 30 Min)</td></tr>
<tr><td colspan="2">Contingency (Primary) Reserve
(T ≤ 10 Min)</td><td rowspan="2">Secondary Reserve
(10 Min ≤ T ≤ 30 Min)</td></tr>
<tr><td>Synchronized Reserve
(Synchronized)</td><td>Non-Synchronized Reserve
(Off-Line)</td></tr>
<tr><td colspan="3">T = Time Interval Following PJM Request</td></tr>
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Primary Reserve Resource Types

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 - Condensers (CTs and hydro) transition to online Tier2 condense mode - Steam reduced to provide Tier2 MW, - CTs online at min – operating at a point that deviates from economic dispatch, - Demand Response that can drop load
10 minute Non-Synchronized Reserve	Resources currently not synchronized to the grid - shutdown run-of-river hydro, - Shutdown pumped hydro, - Offline industrial combustion turbines, jet engine/expander turbines, etc

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
    - » Any reserves committed in the Dominion zone will be used to meet the 433 MW VACAR Reserve Sharing Group (RSG) commitment

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

Primary Reserve Requirement

- The Primary Reserve Requirement is defined as the amount of 10-minute reserve (synchronized or off-line) that must be available
  - Inclusive of the Synchronized Reserve requirement
- May be met with Tier 1, Tier 2 resources and NSR Resources
- RTO reserve zone requirement will be 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 will be equal to 150% of the largest contingency in Mid-Atlantic Dominion region
    - » Usually 1700 MW
    - » Any reserves committed in the Dominion zone will be used to meet the 433 MW VACAR Reserve Sharing Group (RSG) commitment

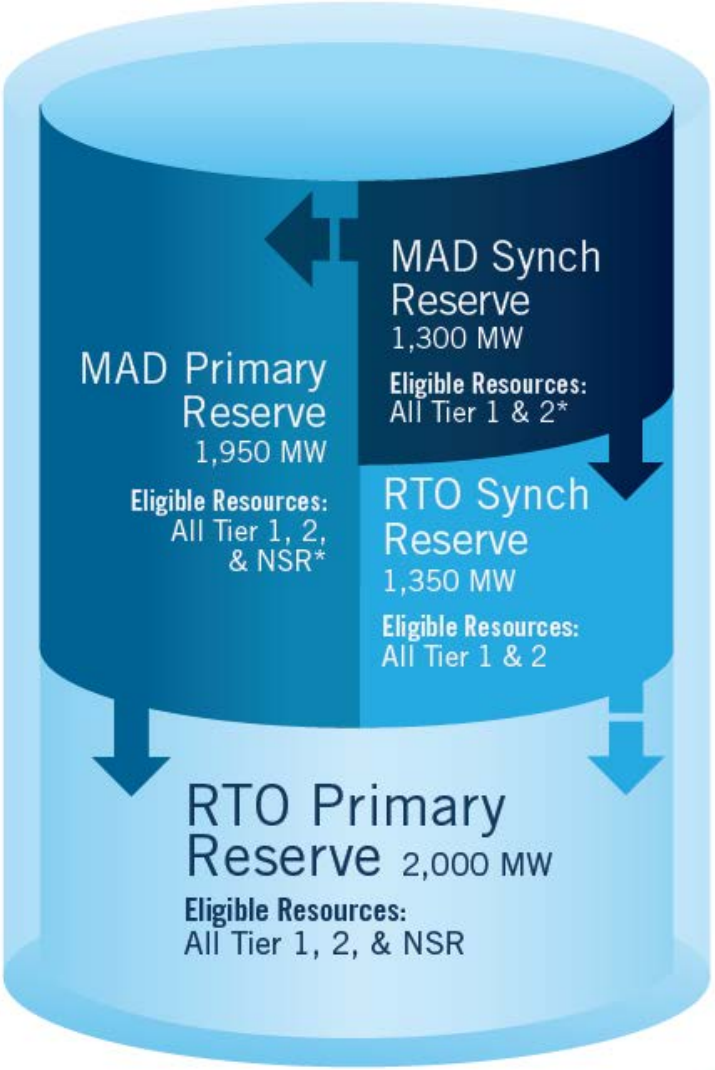
Of the 2063 MW RTO reserve zone requirement,
1700 MW must be deliverable to the Mid-Atlantic Dominion sub-zone

Reserve Markets and Product Substitution

- Synchronized Reserve Market
  - Cleared for RTO and MAD reserve zones
  - Synchronized Reserves in MAD can be used to satisfy the RTO requirement (locational substitution)
  - Price is always greater than or equal to the Non-Synchronized Reserve Price

- Non-Synchronized Reserve Market
  - Used to procure the balance of the Primary Reserve requirement that is not being met with Synch Reserve
  - Synch Reserve can be used in place of Non-Synch Reserve to meet the Primary Reserve requirement (product substitution)
  - Non-Synch Reserves in MAD can be used to satisfy the RTO Primary Reserve requirement (locational substitution)
  - Price is expected to be zero except when the system is getting shorter on reserves
  - Price is always less than or equal to the Synch Reserve price

Reserve Product Substitution



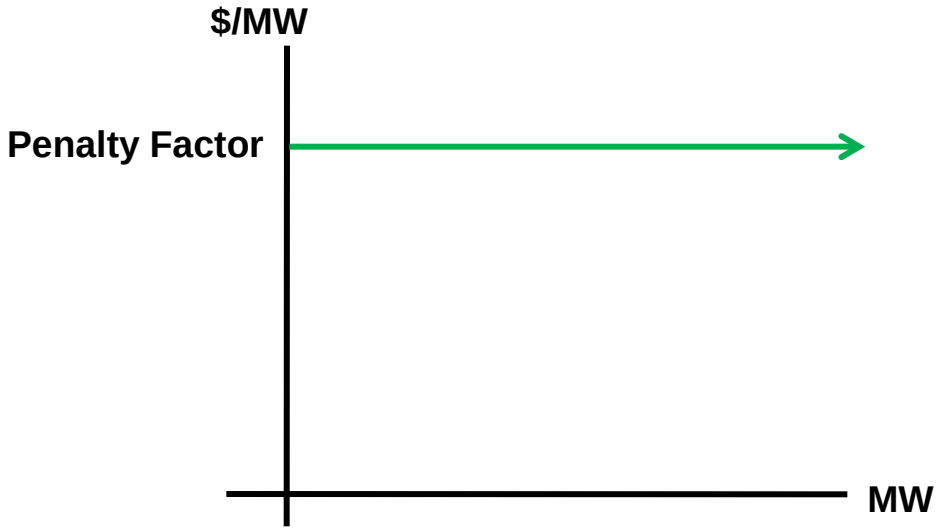
Product Substitution Locational Substitution *Deliverable to MAD

Pricing Reserve Shortages

- When the reserve requirement cannot be met, the reserve shortage will be priced using an Operating Reserve Demand Curve (ORDC)
- The ORDC sets a price that serves as a “penalty factor” for being unable to meet the reserve requirement
- It sends a clear indicator to market participants that as the reserve market clearing price reaches the penalty factor, the system’s ability to maintain reserves is becoming increasingly tenuous and reserve shortage may or has occured
  - Enhanced transparency into shortage conditions

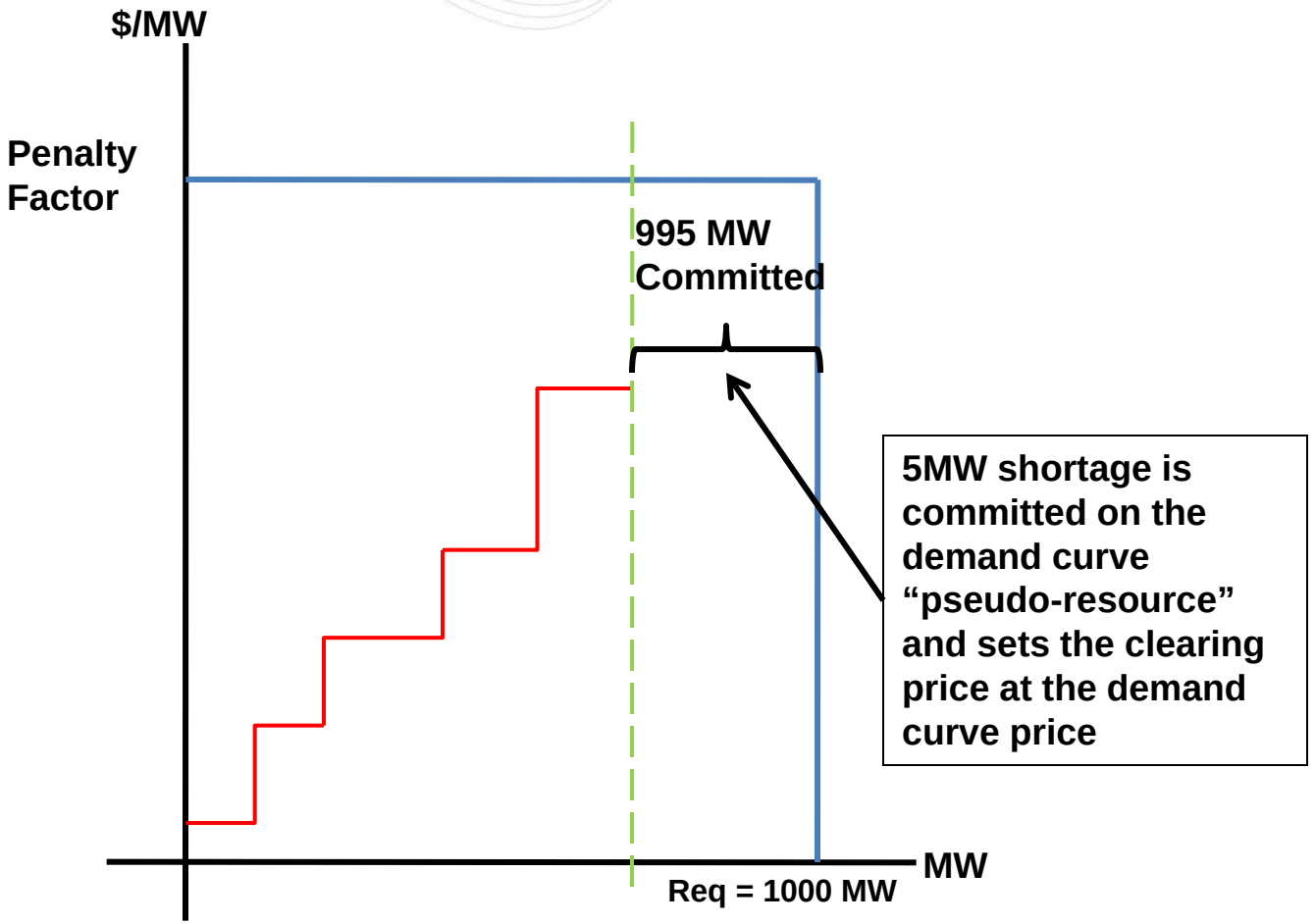
What Does the Penalty Factor Represent?

The penalty factor price of an ORDC can be thought of as a resource with infinite reserve capability at the penalty factor price to ensure the dispatch problem is “solvable” under reserve shortage conditions



A Simple Step Function ORDC

Reserve shortage = 5MW



- The ORDC:
  - Puts a defined, realistic limit on the cost willing to be incurred to substitute reserves for energy
  - Acts as a cap on the market clearing price
- If the cost for a resource to provide reserves exceeds the willingness to pay for that reserve product, it will not be committed for reserves by the dispatch engine
  - The shortage created by not committing such resources will be consumed by the ORDC
  - PJM Operations would still assign reserves out-of-market if available and the cost of those reserves would be recovered through a make whole payment in the reserve market

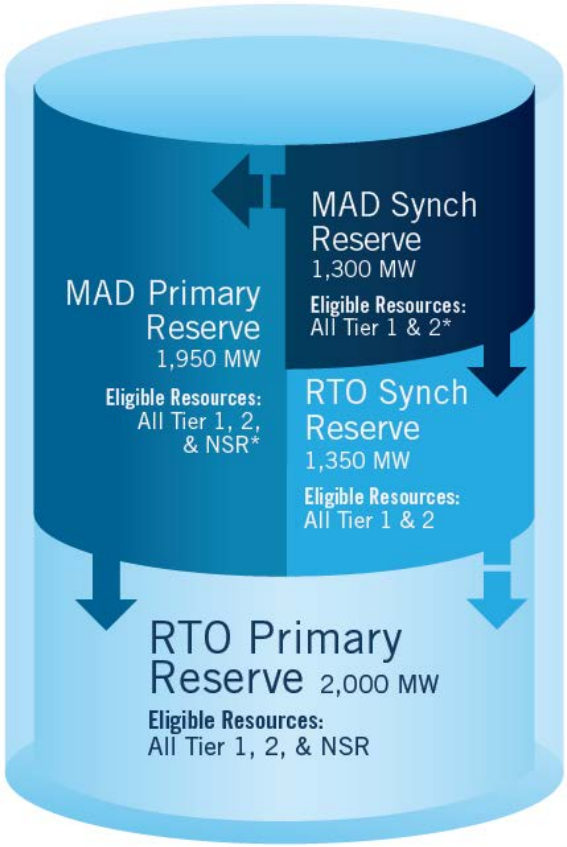
Impact of Multiple Simultaneous Reserve Shortages

- The ORDC represents the willingness to “go short” a single product in a single location
- When there are multiple reserve products with substitution, the willingness to pay (penalty factors) are additive
- When there is a nested region within another, like MAD within RTO, the penalty factors are additive by location

Linkage of Reserve Substitution to Reserve Value

1 MW MAD Primary Reserve satisfies both the MAD and RTO Primary Reserve requirements

1 MW RTO Primary Reserve only satisfies RTO Primary Reserve requirement



1 MW MAD Synch Reserve satisfies all 4 requirements

1 MW RTO Synch Reserve satisfies both the RTO Synch Reserve and Primary Reserve requirements

Product Substitution Locational Substitution *Deliverable to MAD

Pricing During a MAD Primary Reserve Shortage

- If short Primary Reserve in the MAD reserve zone, the Primary Reserve penalty factor is incorporated into both MAD reserve prices and the LMP

Price	Range
RTO Non-Synchronized Reserve	$0 - $550
RTO Synchronized Reserve	$0 - $1100
MAD Non-Synchronized Reserve	$550
MAD Synchronized Reserve	$550 - $1100
LMP	Cost to serve the next MW of energy inclusive of 1 reserve shortage

Pricing During a MAD Synchronized Reserve Shortage

- If short Synchronized Reserve in the MAD reserve zone, the Synchronized Reserve penalty factor is incorporated into the MAD synchronized reserve price and the LMP

Price	Range
RTO Non-Synchronized Reserve	$0 - $550
RTO Synchronized Reserve	$0 - $1100
MAD Non-Synchronized Reserve	$0 - $550
MAD Synchronized Reserve	$550 - $1100
LMP	Cost to serve the next MW of energy inclusive of 1 reserve shortage

Pricing During a Shortage of MAD Primary and Synchronized Reserves

- If short both Primary Reserve and Synchronized Reserve in the MAD reserve zone, the Primary Reserve and Synchronized Reserve penalty factors are incorporated into the MAD reserve prices and the LMP

Price	Range
RTO Non-Synchronized Reserve	$0 - $550
RTO Synchronized Reserve	$0 - $1100
MAD Non-Synchronized Reserve	$550
MAD Synchronized Reserve	$1100
LMP	Cost to serve the next MW of energy inclusive of 2 reserve shortages

Pricing During a MAD and RTO Primary Reserve Shortage

- If short Primary Reserve in both reserve zones, the Primary Reserve penalty factor is incorporated into both MAD and RTO reserve prices and the LMP

Price	Range
RTO Non-Synchronized Reserve	$550
RTO Synchronized Reserve	$550 - $1100
MAD Non-Synchronized Reserve	$550
MAD Synchronized Reserve	$550 - $1100
LMP	Cost to serve the next MW of energy inclusive of 1 reserve shortage

Pricing During a MAD and RTO Synchronized Reserve Shortage

- If short Synchronized Reserve in both reserve zones, the Synchronized Reserve penalty factor is incorporated into both MAD and RTO synchronized reserve prices and the LMP

Price	Range
RTO Non-Synchronized Reserve	$0 - $550
RTO Synchronized Reserve	$550 - $1100
MAD Non-Synchronized Reserve	$0 - $550
MAD Synchronized Reserve	$1100
LMP	Cost to serve the next MW of energy inclusive of 2 reserve shortages

Pricing During Shortages of MAD and RTO Primary and Synchronized Reserve

- If short Primary Reserve and Synchronized Reserve in both reserve zones,

Price	Range
RTO Non-Synchronized Reserve	$550
RTO Synchronized Reserve	$1100
MAD Non-Synchronized Reserve	$550
MAD Synchronized Reserve	$1100
LMP	Cost to serve the next MW of energy inclusive of 2 reserve shortages

Penalty Factor Phase-In and Effect on Max Prices

Yr	Dates	Penalty Factor	Max Energy Price (absent congestion and losses)	Max SRMCP	Max NSRMCP	Generator Offer Cap
1	Oct 2012 – May 2013	$250	$1,500	$500	$250	$1,000
2	Jun 2013 – May 2014	$400	$1,800	$800	$400	$1,000
3	Jun 2014 – May 2015	$550	$2,100	$1100	$550	$1,000
4	Jun 2015 onward	$850	$2,700	$1700	$850	$1,000

Gen offer cap + 2 * penalty factor

2 * penalty factor

1 * penalty factor

Unchanged