# Pricing Impacts Due to Reserve Shortages

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May 13, 2021

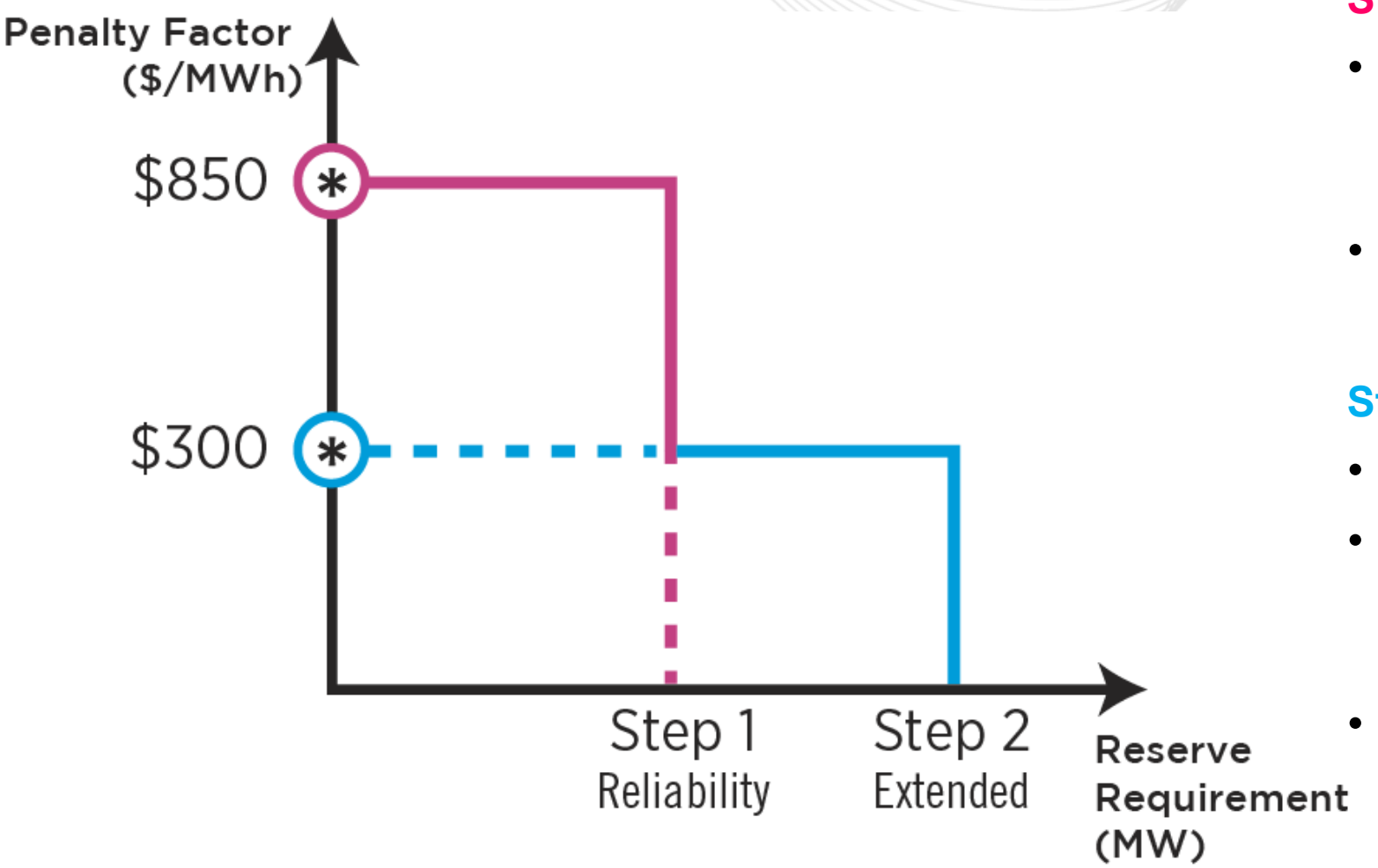
# Order 825

- FERC Order 825 directed RTOs/ISOs to implement Shortage Pricing
  - Issued June 16, 2016
- Order 825 requires that shortage pricing be invoked whenever a shortage of energy or operating reserves is indicated in an RTO's/ISO's pricing run software ***for a particular pricing interval***
  - The amount of available reserves dips below the reserve requirement in the Real-Time Security Constrained Economic Dispatch (RT SCED) application
    - Available Synchronized Reserve MW < Synchronized Reserve Requirement
    - Available Primary Reserve MW < Primary Reserve Requirement
  - Voltage reduction action or manual load dump action is initiated
- PJM implemented these changes on May 11, 2017

# Pricing Reserve Shortages

- The Real-Time reserve markets are cleared using Operating Reserve Demand Curves (ORDCs)
- When the reserve requirement cannot be met, the reserve shortage is priced using the ***penalty factor*** from the ORDC
  - The penalty factor sets a price for being unable to meet the reserve requirement
- It sends a signal to market participants that as the reserve market clearing price reaches the penalty factor, reserve shortage may occur

# Current ORDC




## Step 1 of Demand Curve

- Represents the Reliability Requirement, which is generally the output of the largest online unit
- Penalty factor for being short Step 1 is $850/MWh

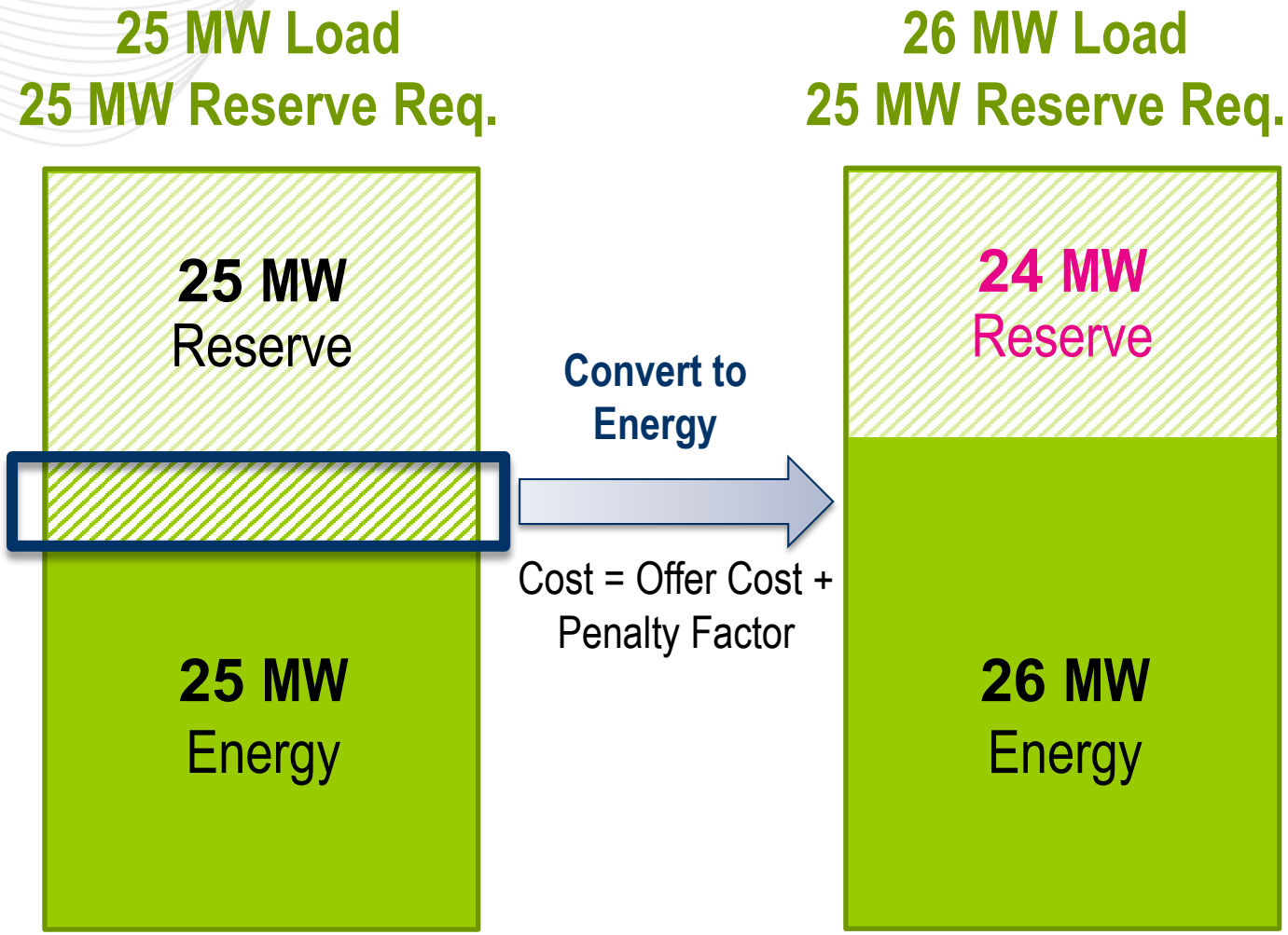
## Step 2 of Demand Curve

- Adds 190 MW to the Reliability Requirement
- Also includes an Optional Adder MW that can be used to capture additional reserves that are scheduled for reliability reasons
- Penalty factor for being short Step 2 is $300/MWh

# Pricing Energy During a Reserve Shortage

**During a reserve shortage, the price of energy will continue to represent the cost of serving the next MW of load**

- When the system is short reserves, this cost includes the cost of converting a MW of reserve into energy
- In other words, the energy price is the offer cost of energy, plus the penalty of going short one more MW of reserve
  - The Locational Marginal Price (LMP), as well as the reserve market clearing price, will include the reserve penalty factor



# Locational Shortage Impacts on LMP

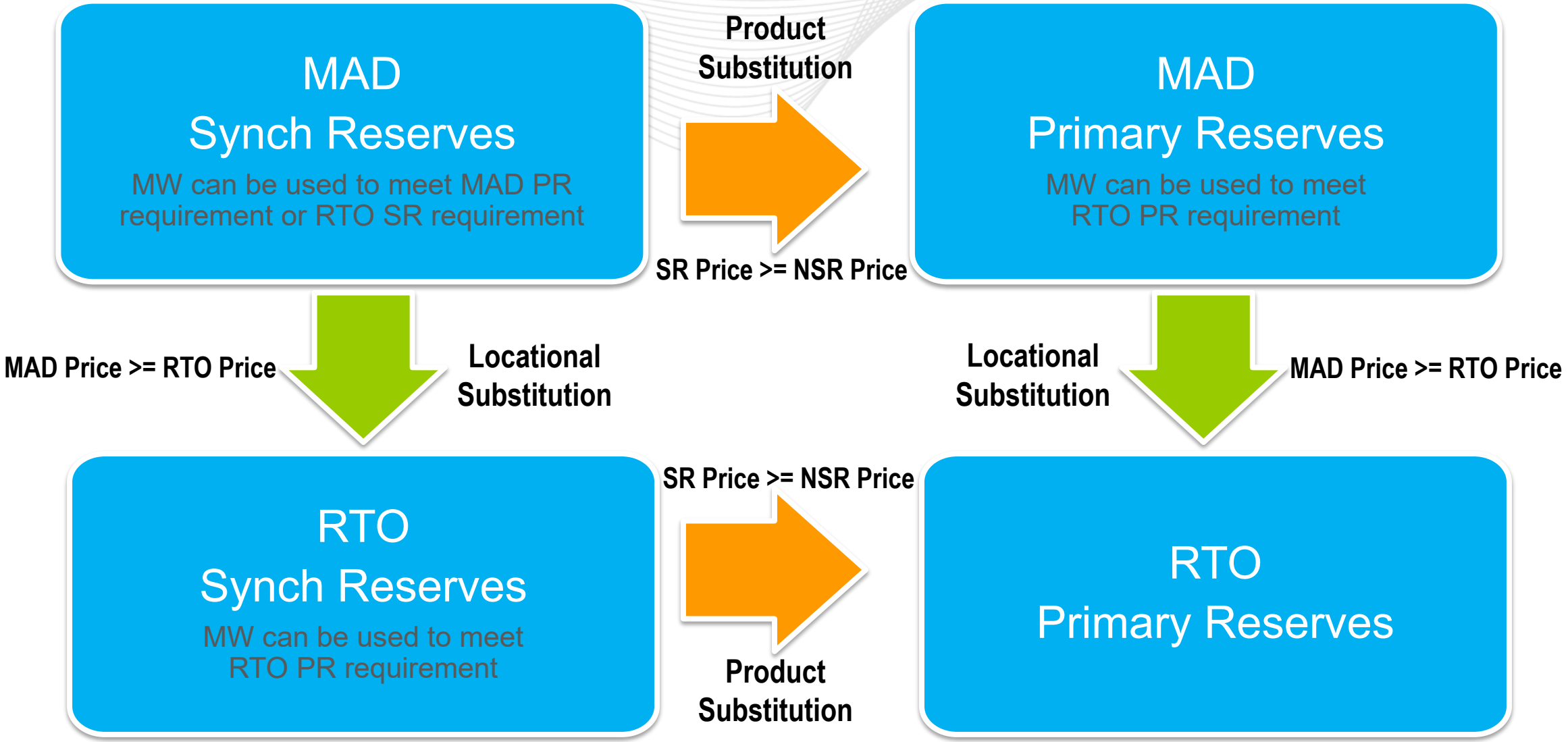
- The Reserve Penalty Factor is not an adder to the energy component of LMP
- The location of the shortage condition and the location of the load reference determine which component(s) of LMP the penalty factor is reflected in.

| | Penalty Factor May Be Reflected In | | |
|---|---|---|---|
| **Location of Shortage** | **Energy Price** | **Congestion Price** | **Marginal Loss Price** |
| **Mid-Atlantic and Dominion (MAD) Only** | | ✓ | |
| **RTO Only** | ✓ | | ✓ |
| **RTO and MAD** | ✓ | ✓ | ✓ |

# Impact of Multiple Simultaneous Reserve Shortages

- The ORDC represents the max willingness to pay to meet the reserve requirement for a single product in a single location
  - Four separate ORDCs exist to model reserves for each product/location combination
- When there are multiple reserve products with substitution, the ability of one product to meet the requirement for another increases the willingness to pay for the “multipurpose” reserve products
  - Prices become additive

# Reserve Substitution



# Effect of Reserve Product Substitution on Reserve and Energy Prices

**If short Primary Reserve**, the Primary Reserve penalty factor is generally incorporated into both reserve prices and the energy price

| Price | | Calculation |
|---|---|---|
| **Non-Synchronized Reserve** | = | Primary Reserve penalty factor |
| **Synchronized Reserve** | = | Marginal cost of Synchronized Reserve + Primary Reserve penalty factor |
| **Energy Price** | = | Marginal cost of energy + the Primary Reserve penalty factor* |

* Assumes next MW of energy comes from converting reserves to energy

# Effect of Reserve Product Substitution on Reserve and Energy Prices

**If short both Primary Reserve and Synchronized Reserve,**

| Price | | Calculation |
|---|---|---|
| **Non-Synchronized Reserve** | = | Primary Reserve penalty factor |
| **Synchronized Reserve** | = | Synchronized Reserve penalty factor + Primary Reserve penalty factor |
| **Energy Price** | = | Marginal cost of energy + Synchronized Reserve penalty factor + Primary Reserve penalty factor* |

* Assumes next MW of energy comes from converting reserves to energy

# Impact of Multiple Simultaneous Reserve Shortages

When there is a nested region within another, like MAD within RTO, the prices may be additive by location depending on system conditions

## Additive in MAD when:

- Imports limit the ability to deliver reserves from the remainder of RTO to MAD
- The MAD and RTO requirements are simultaneously short

# Limitations on Additivity of Shortages

- From a pricing perspective, the most extreme shortage condition that could occur would be a shortage of Synchronized Reserve and Primary Reserve in both RTO and MAD
  - Violation of all four reserve requirements → 4 * Penalty Factor
- As part of the initial implementation of shortage pricing, an administrative rule was implemented to allow, at maximum, two simultaneous shortages to affect energy and reserve prices (2 * Penalty Factor)
  - Assuage concerns about implementation of demand curves and co-optimization of energy and reserves
  - Prior to the implementation of shortage pricing in 2012, historical experience was that there had never been more than two simultaneous reserve requirement violations at any one time
  - During the Polar Vortex in 2014, PJM experienced a shortage of all four reserve requirements

# Reserve Price Caps

- The Synch Reserve Market Clearing Price is capped at 2 * Penalty Factor ($1,700)
- The Non-Synch Reserve Market Clearing Price is capped at the Penalty Factor ($850)
- The above price caps are applicable regardless of
  - The existence of a shortage condition
  - The existence of additive locational shortage
- Administrative constraint that may understate the reliability contribution of some reserve types
  - Example, the MAD Synch Reserve Clearing Price is still capped at 2 * Penalty Factor even if reserve shortages exist for all four reserve requirements, despite MAD Synch Reserve being able to satisfy all four requirements

# Energy Price Caps

Prior to factoring in congestion and losses, the energy component of LMP will be capped at the energy offer cap + 2 * Penalty Factor from the first step on the ORDC + buffer to account for congestion and loss contriution.

- $2,000 + 2 * $850 +$50 = $3,750 maximum energy component
- **Total LMPs can still rise above this level when factoring in locational congestion and loss prices**

Formation of Locational Marginal Pricing and the System Energy Component of LMP During Reserve Shortage Events

- With example from March 17th, 2021 Shortage Pricing Interval
- https://www.pjm.com/-/media/markets-ops/energy/real-time/shortage-lmp-whitepaper-example.ashx

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