Reserve Market
Objectives

• Define Reserve products
• Explain the Reserve requirements
• Calculate Reserve offers
### Reserves

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.

<table>
<thead>
<tr>
<th>Day-Ahead Scheduling Reserve (T ≤ 30 Min)</th>
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<tbody>
<tr>
<td>Contingency (Primary) Reserve (T ≤ 10 Min)</td>
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<tr>
<td>Synchronized Reserve (Synchronized)</td>
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<tr>
<td>Secondary Reserve (10 Min ≤ T ≤ 30 Min)</td>
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</tbody>
</table>

*T = Time Interval Following PJM Request*
Day-Ahead Scheduling Reserves
The Day-Ahead Scheduling Reserve (DASR) requirement is the sum of the requirements for all zones within the RTO and any additional reserves scheduled:

- In response to an RTO-wide Hot or Cold Weather Alert or other conservative operations

Total 2016 DASR Requirement is 5.70%
Day-Ahead Scheduling Reserve Market Overview

• The Day-Ahead Scheduling Reserve product is:
  – Offer-based market for 30-Minute Reserve that can be provided by both Generation and Demand Resources
  – Market that is designed to clear existing Day-Ahead Scheduling Reserve requirements as defined by reliability standards: (RFC & SERC)
  – Day-Ahead, forward market that clears simultaneously with Day-Ahead Energy Market
  – Costs of Day-Ahead Scheduling Reserve product will be allocated by real-time load ratio share

Purpose: To encourage and incent generation and demand resources to provide the flexible capability to provide 30-minute reserves
Who Can Provide Reserves?

• Resources with the ability to provide reserve capability in 30 minutes including primarily:
  – Online Steam generation with capability to increase output from DA dispatch point
  – Offline CTs that can start to provide Reserve
  – Hydro and Pumped Storage Units
  – Demand Resources

• DASR offers may be submitted only for those resources located electrically within the PJM RTO
Who Can Be Committed for DASR? - Example

- 500MW unit that would otherwise be dispatched to full load in Day-Ahead is reduced to 400MW to provide Day-Ahead Scheduling Reserve
  - Unit’s offer is $30, Day-Ahead LMP is $50
  - If unit clears for Day-Ahead Scheduling Reserve, the unit is paid a clearing price that includes the opportunity cost (about $20), plus any offer to provide Day-Ahead Scheduling Reserve

- Units with a dispatchable range based on the DA dispatch point could be “cleared” as Day-Ahead Scheduling Reserve

- Off-line CTs with a Day-Ahead Scheduling Reserve offer could be cleared
DASR Clearing Process

- DASR Clearing Process
  - Is a simultaneous, least-cost optimization with the energy market as part of the Day-Ahead Market mechanism
  - The Day-Ahead Scheduling Reserve Requirement will be calculated based on the PJM RTO load forecast for the upcoming operating day
  - Will result in an hourly RTO clearing price for Day-Ahead Scheduling Reserve for the next day
How Will Resources Provide Day-Ahead Scheduling Reserve?

• The Day-Ahead Scheduling Reserve Requirement is not maintained in Real Time
  – There are no Day-Ahead Scheduling Reserve events for resources to respond
  – Resources will be responding to normal PJM dispatch instructions

• Those resources receiving a day-ahead award for Day-Ahead Scheduling Reserve would receive the hourly clearing price for the awarded MW amount as long as they were capable of providing the reserve in real time as scheduled

• Performance will be measured after the fact
  – No Penalty for non-performance (penalty = forgone revenue)
Operating Scenarios - Measuring Response

Unit is Online and Following PJM Dispatch with Day-Ahead Scheduling Reserve Award

Eco Min ⇔ (Economic Max – DASR Market Award)

***Resource can be self-scheduled with Dispatchable Range

Resource is paid DASR Clearing Price * DASR Market Award

IMPORTANT!

Those resources receiving a Day-Ahead award for Day-Ahead Scheduling Reserve, that have a Real-time Dispatchable Range that is less than the resource’s Day-Ahead Dispatchable Range become ineligible to receive a Day-Ahead Scheduling Reserve Market payment
Operating Scenarios - Measuring Response

Unit is **Offline** and requested to start by PJM with Day-Ahead Scheduling Reserve Award

1. Start time + notification time of less than or equal to 30 minutes
2. Requested to start at any hour of the day
3. The unit completes startup within specified startup and notification time from the time the PJM operator issued the instruction

Resource is paid DASR Clearing Price X DASR Market Award

**IMPORTANT!**

Those resources receiving a day-ahead award for Day-Ahead Scheduling Reserve, that have a Real-time Dispatchable Range that is less than the resource’s Day-Ahead Dispatchable Range **become ineligible** to receive a Day-Ahead Scheduling Reserve Market payment
Synchronized and Non-Synchronized Reserves
Reserve Zone Structure

One Reserve Zone:

• RTO Reserve Zone
  - Mid-Atlantic Dominion (MAD) sub-zone due to potential deliverability issues
    • Defined based on most limiting transfer interface
    • Resources with 3% or greater raise help distribution factor on the interface are included in MAD sub-zone
  - Merging the Mid-Atlantic plus Dominion zones recognizes their electrical similarity as being downstream of major interfaces
  - Reduces reserves that must be held overall and will reduce overall system costs of maintaining reserve during non-shortage conditions
RTO Reserve Zone

Most Limiting Interface

Mid-Atlantic Dominion (MAD) Sub-Zone

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Reserve Products

Reserve Services
Each service carries a reserve requirement

Primary Reserve

Synchronized Reserve

Non-Synchronized Reserve (NSR)

Tier 1 resources

Tier 2 resources

NSR resources

Reserve Products
Each product has a clearing price
# Primary Reserve Resource Types

<table>
<thead>
<tr>
<th>Tier 1 (Economic)</th>
<th>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</th>
</tr>
</thead>
</table>
| 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 |
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

• Mid-Atlantic Dominion sub-zone requirement will be equal to 150% of the largest contingency in Mid-Atlantic Dominion region
  • Any reserves committed in the Dominion zone will be used to meet the VACAR Reserve Sharing Group (RSG) commitment
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

• Mid-Atlantic Dominion Sub-Zone requirement will be equal to largest contingency in the Mid-Atlantic Dominion region
  • Any reserves committed in the Dominion zone will be used to meet the Reserve Sharing Group (RSG) commitment
Synchronized Reserve Obligation

• Who must acquire Reserves?
  – All Distribution Providers (DP)
  – Obligation determined from real time load ratio share
  – Obligation is by reserve zone
A must offer requirement is applied to the Synch Reserve and Non-Synchronized Reserve Markets

• Implicit must offer requirements are already built into the design of Tier 1 Synch Reserve and NSR
  – All online generation resources following PJM’s dispatch and operating below eco max are automatically considered in the commitment of Tier 1 resources
  – All available offline generation capable of providing energy within 10 minutes are automatically considered in the commitment of NSR

• No Three Pivotal Supplier test - already a cost based market
**Must Offer Requirement**

There is a must offer requirement for Tier 2 Synch Reserve resources

- All non-emergency capacity resources available to provide energy and capable of providing synchronized reserves must submit offers for Tier 2 Synchronized Reserves
  - Applies only during periods for which PJM has issued a Primary Reserve Warning, Voltage Reduction Warning or Manual Load Dump Warning

- Penalty for violating the must offer requirement is referral to the Market Monitor, similar to the day-ahead must offer requirement for capacity generation resources
Fulfilling Obligation: Purchasing from Market

• Participants may enter into bilateral transactions with other participants to fulfill their obligation

• Any obligation remaining will be fulfilled by purchasing from the market
  – Non-Synchronized Reserves
    • Loads located in the MAD sub-zone will pay the MAD NSRMCP
    • Loads located outside the MAD sub-zone will pay the RTO NSRMCP
  – Synchronized Reserves
    • Loads located in the MAD sub-zone will pay the MAD SRMCP
    • Loads located outside the MAD sub-zone will pay the RTO SRMCP
Market Price Timing

• PJM will clear markets for:
  – Synchronized Reserves
  – Non-Synchronized Reserves
  – Clearing prices for all markets will be calculated on a 5-minute basis
Non-Synchronized Reserve Offers

• The Non-Synchronized Reserve Market is a cost-based market

• Being off-line and available within 10-minutes as a part of economic dispatch does not entail a cost, therefore:
  
  − No explicit offer is entered in eMKT
    
    • All eligible resources will be considered to have an offer of $0/MWh
    
    • The NSR MW available from each resource will be calculated based on:
      
      ▪ Startup and Notification Time from lesser of cost schedule and price schedule
      ▪ Economic Minimum
      ▪ Synch Reserve Ramp Rate, or energy ramp rate in absence of a synch reserve ramp rate
Synchronized Reserve Offer

• Synchronized Reserve Cost Data
  – Heat Rate at ‘Economic Max MW’ in [Btu/kWh]
  – Heat Rate at ‘Economic Max – Synchronized MW’ in [Btu/kWh]
  – VOM – Variable Operating and Maintenance in [$/MBtu]
    • For condensing units, only VOM required
    • Used in Synchronized market only to validate true cost
      ▪ See PJM Manual M-15 Cost Development Guidelines for details
  – Cost offer limited to cost plus $7.50
Tier 2 Compensation

• Synchronized reserve credits for resources assigned self-scheduled synchronized reserve equal:
  – The Tier 2 clearing price times the resource’s self-scheduled synchronized reserve capability less any shortfall due to failure to provide assigned capability during a synchronized reserve event

• Synchronized reserve credits for resources that are assigned pool scheduled synchronized reserve are the higher of:
  – The Tier 2 clearing price times the resource’s assigned synchronized reserve capability less any shortfall due to failure to provide assigned capability during a synchronized reserve event or:
  – The resource’s synchronized reserve offer times its assigned synchronized reserve capability less any shortfall due to failure to provide assigned capability during a synchronized reserve event (plus opportunity cost, energy use costs, and startup costs incurred, for generators), as applicable.
Response Calculation / Verification

- Resource responses are verified by the PJM Performance Compliance Dept following each event.
- Actual responses compared to assignments at start of Synchronized event used to determine penalties.
Monitoring and Verification

• The magnitude of each resource’s response to a synchronized reserve event (both Tier 1 and Tier 2) 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.

• In order to allow for small fluctuations and possible telemetry delays, resource output at the start of the event is defined as the lowest telemetered output between one (1) minute prior to and one (1) minute following the start of the event.

  – Similarly, a resource’s output ten minutes after the event is defined as the greatest output achieved between nine (9) and eleven (11) minutes after the start of the event.
Monitoring and Verification

Integrated Response

MW₀ is the highest load at T₀ (start) +/- one minute
MW₁ is the lowest output at T₁ (10 minutes, or event end, if sooner) +/- one minute
T₂ is the end of the event or 30 minutes past the start of the event
Questions?