Generation Initial Training Program

PJM Reserve Market

PJM State & Member Training Dept.

Objectives

Students will be able to:

- Describe the types of Reserves that are maintained in PJM
- Describe the Reserve Markets and Participation Requirements
- Define the PJM Reserve Zone and Subzone(s)
- Identify the Reserve Market timelines
- Explain the Reserve participation response verification process

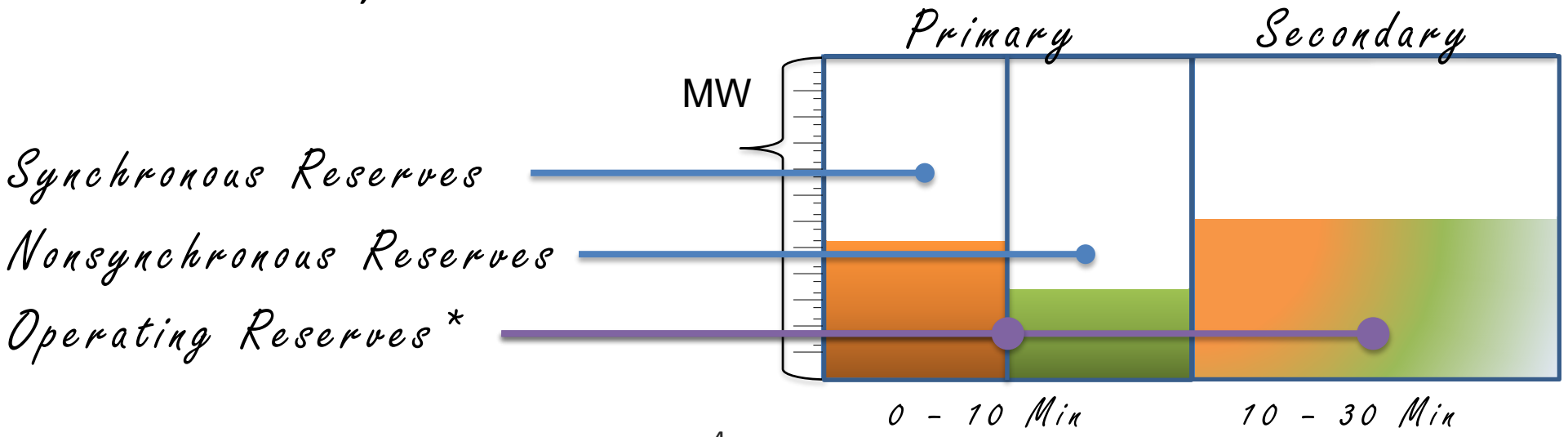
Reserves Overview

What are Reserves?

- Reserves are additional generation capacity above the expected load
  - Protects the power system against the uncertain occurrence of future operating events:
    - Loss of generation or load forecasting errors

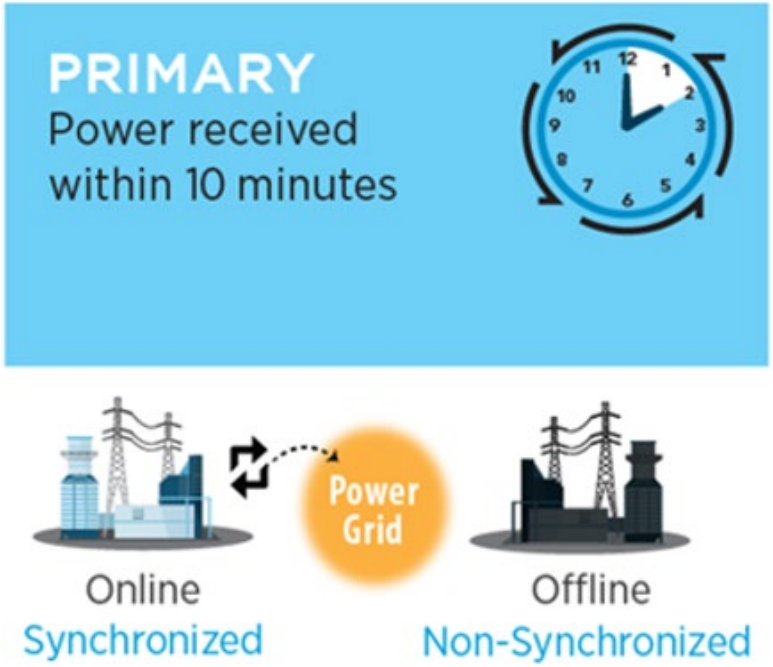
Reserve Monitoring

- Reserves are additional capacity above the expected load
- Used to protect the system against uncertain occurrences
  - Loss of capacity
  - Load forecasting errors
- Compliance with NERC, SERC and RF BAL standards



Primary Reserve

- NERC term is Contingency Reserves
  - On or off-line reserves available within 15 minutes
- **PJM Primary Reserves**
  - Reserves which can be converted fully into energy or;
  - Load that can be removed from the system within 10 minutes of the request from the PJM Dispatcher
- NERC and PJM terms are interchangeable
- Primary (Contingency) Reserves are subdivided two categories:
  - Synchronized Reserves
  - Non- Synchronized (Quick Start) Reserves



Synchronized Reserves

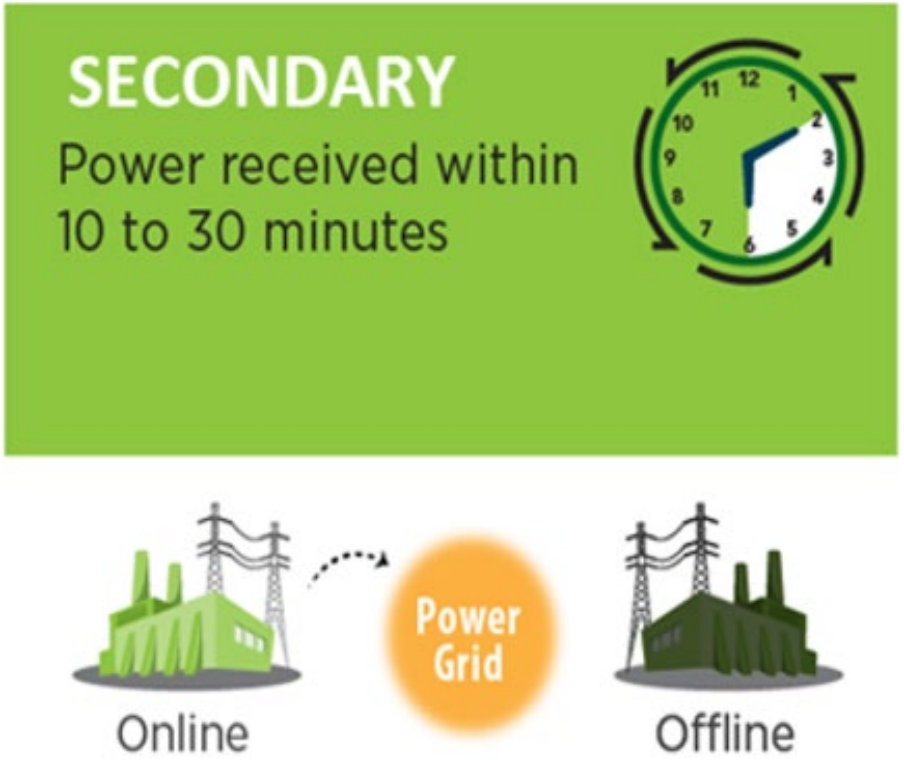
- Reserve converted fully into energy or load removed from the system within 10 minutes of the request
- Must be provided by equipment electrically synchronized to the system
- Includes:
  - increase in the output of a synchronized generator
  - reduction in load from a synchronized resource such as the load of a pumped hydro resource currently synchronized in the pumping mode and capable of being shut down
  - the maximum output energy level that could be attained on a resource operating as a synchronous condenser

Quick Start (non-synchronized) Reserves

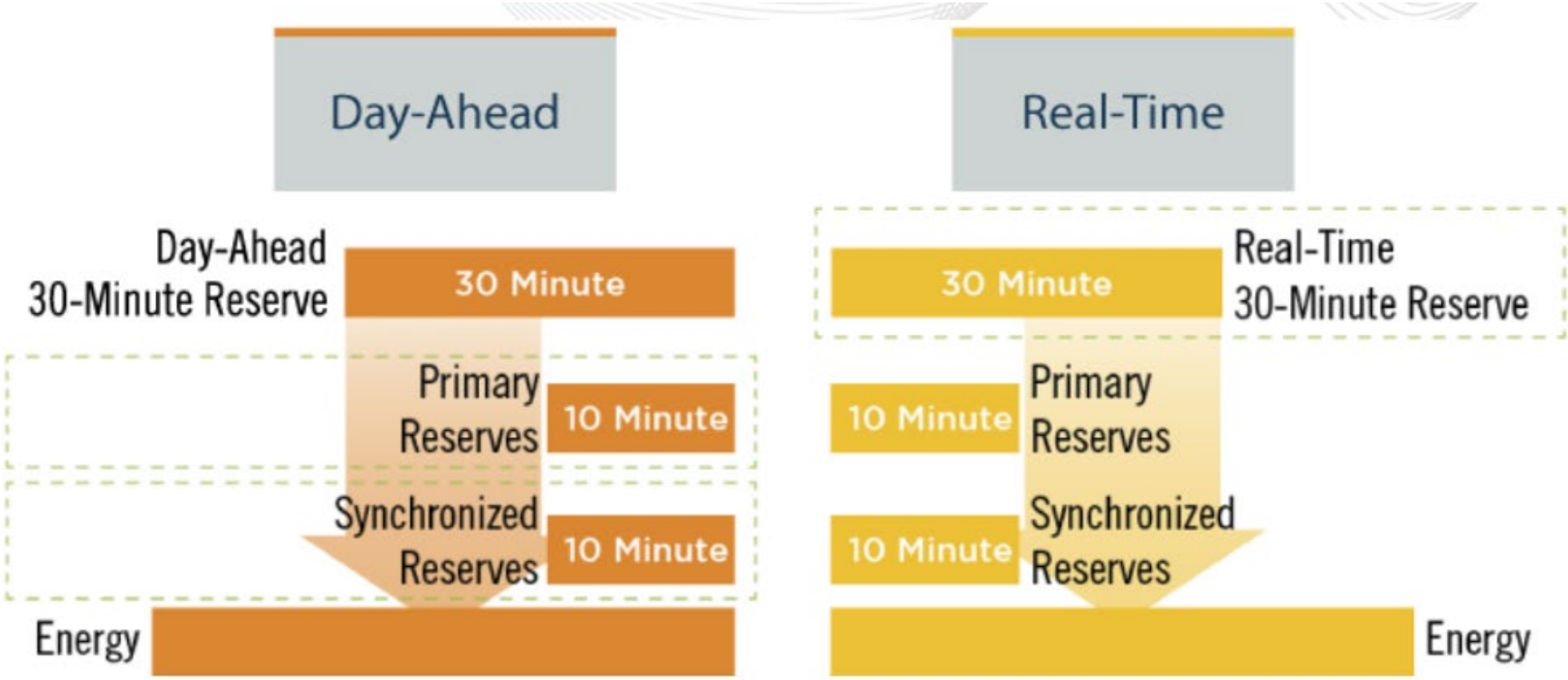
- Reserve fully converted into energy or load removed from the system within 10 minutes of the request
- Provided by equipment not electrically synchronized to the system
- Examples:
    - run-of-river hydro
    - pumped hydro
    - industrial combustion turbines, jet engine/expander turbines
    - Diesels

Secondary Reserve

- Reserve capability converted into energy or load removed from the system within a 10-to-30 minute timeframe
- These resources do not have to be electrically synchronized to the system



Day-Ahead and Real-Time Reserve Alignment



Solidify financial incentives to provide reserves when assigned due to day-ahead financial commitment.
Remove modeling differences between Day-Ahead and Real-Time Energy Markets.

Primary Reserve Requirement

- The Primary Reserve Requirement is defined as the amount of 10-minute reserve that must be available
- May be met with Synchronized and NSR Resources
- RTO reserve zone requirement is a dynamic number that is equal to the sum of:
  - 150% of the output of the largest online single contingency unit(s) in the PJM footprint
  - an extended requirement of 190MW
  - any additional reserve MW's called on in real-time to cover operational uncertainty during emergency conditions, cold weather alerts, or hot weather alerts
- Sub-zone requirement is a dynamic number equal to the sum of:
  - 150% of the output of the largest online contingency unit(s) in the Reserve Subzone
  - an extended requirement of 190MW
  - any additional reserve MW's called on in real-time to cover operational uncertainty during emergency conditions, cold weather alerts, or hot weather alerts

*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
- RTO reserve zone requirement is a dynamic number equal to the sum of:
  - The MW output of the largest online contingency unit(s) in the RTO Synchronized Reserve Zone
  - an extended requirement of 190MW
  - any additional reserve MW's called on in real-time to cover any operational uncertainty during emergency conditions, hot weather alerts, or cold weather alerts
- Sub-zone requirement is a dynamic number equal to the sum of:
  - The MW output of largest online contingency unit(s) in the Reserve sub-zone
  - an extended requirement of 190MW
  - any additional reserve MW's called on in real-time to cover operational uncertainty during emergency conditions, cold weather alerts or hot weather alerts

*Any reserves committed in the Dominion zone will be used to meet the Reserve Sharing Group (RSG) commitment

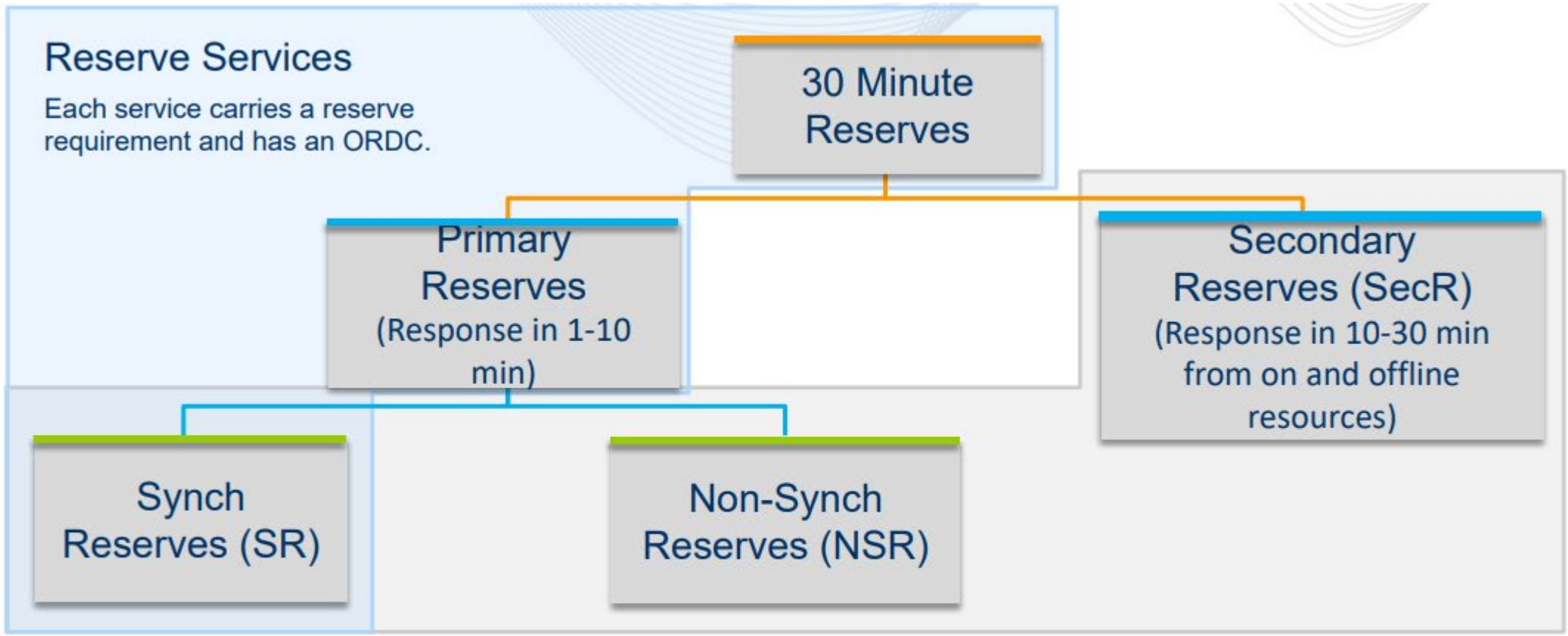
Synchronized Reserve Obligation

- Who must acquire Reserves?
  - All Load Serving Entities (LSE)
  - Obligation determined from real-time load ratio share
  - Obligation is by reserve location

Resource Obligations and Benefits

- Resources obligated to respond to PJM instructions during a Synchronized Reserve Event
- Resources compensated at the applicable clearing price for assigned MW amount
- Face penalty if the resource does not respond during an event
- Expected Benefits:
  - More accurate reserve calculations that require less operator intervention
  - More reliable reserve assignments that will improve Synchronized Reserve performance
  - Consistent compensation and penalties for all resources providing the same service
  - More accurate energy and reserve pricing due to improved Synchronized Reserve measurement

Reserve Markets



Clearing Price represents procurement of the Synch Reserve requirement	Clearing price represents procurement of the balance of the Primary Reserve Requirement not met by Synch Reserves	Clearing price represents procurement of the balance of the 30 Min Requirement not met by Synch and Non-Synch Reserves

Identical Clearing Mechanism in DA and RT Markets

Reserves and energy will be co-optimized the same way in DA and RT	• The two-stepped ORDC will be implemented in DA and RT: generally, same reserve requirements; penalty factors will be identical for DA and RT • Same reserve zone configuration in DA and RT unless there is an operational emergency requiring it to be changed in RT

There will be differences in cleared MW and prices between DA and RT markets

Day Ahead Reserve Assignments Carried to Real-Time

Condensers and Inflexible Economic Load Response resources that are cleared day-ahead will have their commitments carried to real-time	
Need to have a min run time no greater than one hour and notification time between ten and thirty minutes	Commitment is carried over unless in real-time the resource is committed to provide energy or another reserve product

Synchronized Reserve Product

- Tier 1 and Tier 2 reserve products consolidated into one Synchronized Reserve product
  - Similar to old Tier 2
- Resources:
  - obligated to respond to PJM instructions during Event
  - compensated at applicable clearing price for assigned MW
  - face the existing penalty if does not respond

- Benefits:
  - Accurate reserve calculations
  - Reliable reserve assignments
  - Improved Synchronized Reserve performance
  - Consistent compensation and penalties for all resources
  - More accurate energy and reserve pricing

Reserve Zone Structure

One Reserve Zone: RTO Reserve Zone

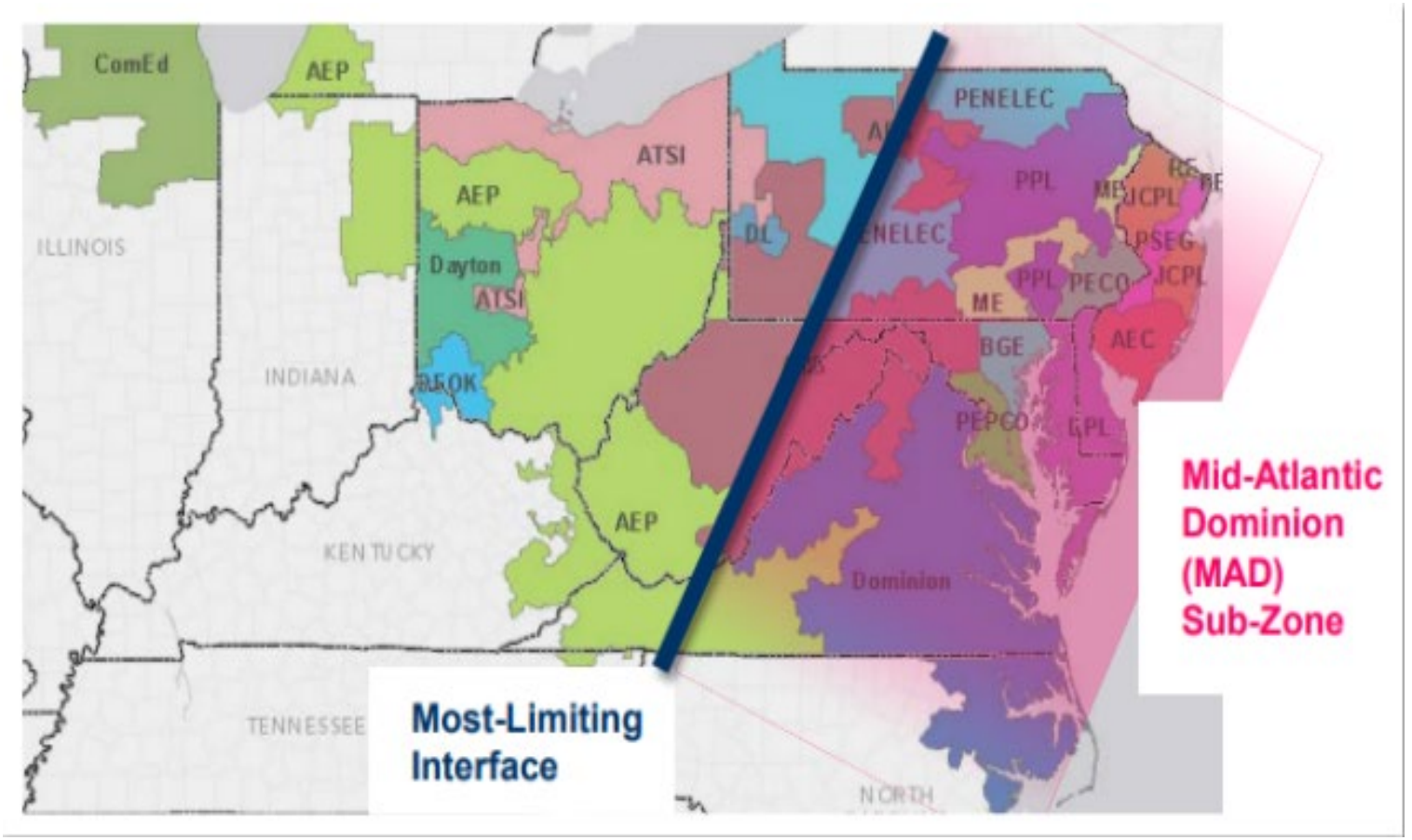
- Currently, two (2) sub-zones due to potential deliverability issues
  - Mid-Atlantic Dominion (MAD)
  - Baltimore, PEPCO, Dominion (BPD)

Creation of New Reserve Subzones

- New reserve subzones defined as far in advance as possible
- Cannot be created on a same-day basis
- Defined for constraints in these three categories:
  - Reactive transfer interfaces (AP South, BEDBLA, etc.)
  - >= 230 KV actual overload constraint (i.e. Conastone-Peach Bottom 500kV actual overload)
  - Contingency overload exceeding load dump limit on 230kV or above facility

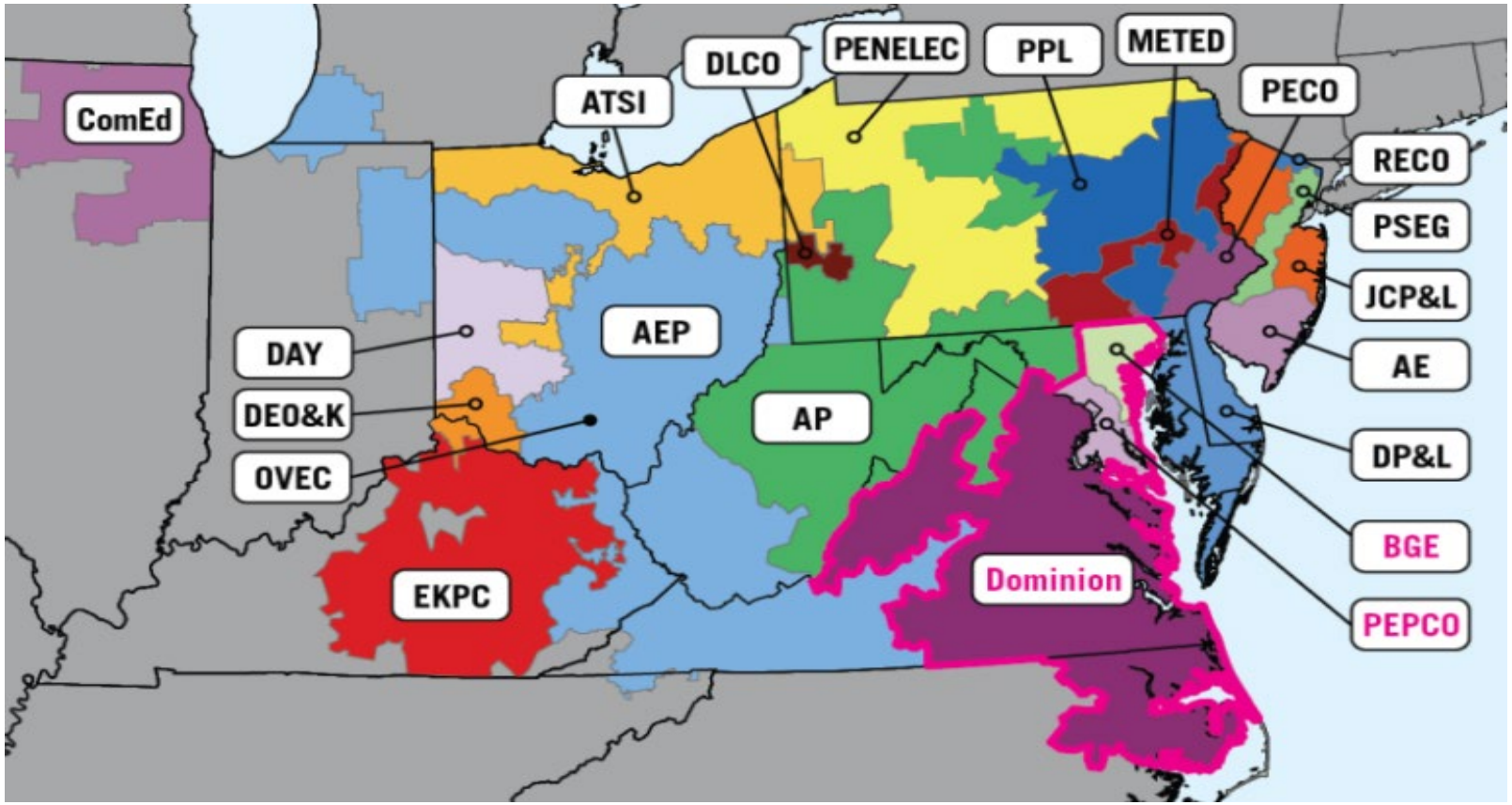
Mid-Atlantic Dominion (MAD) Reserve Subzone

- Default subzone
- Defined by the most-limiting reactive transfer interface
  - Procure reserves that will not overload critical constraints when reserves are deployed



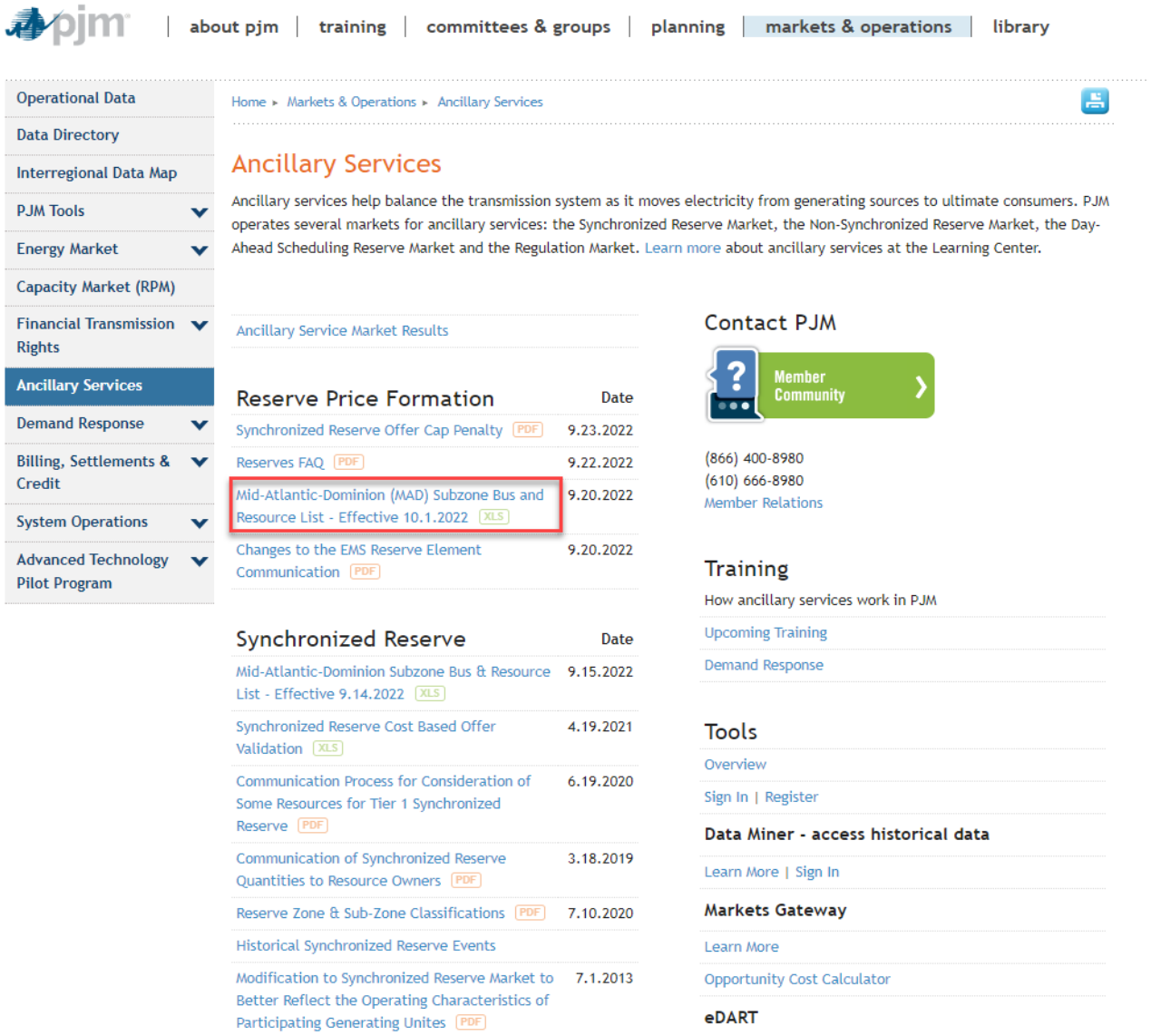
Baltimore, Pepco, Dominion (BPD) Reserve Subzone

- Used during the heavy North-South flow or during a specific transmission outage



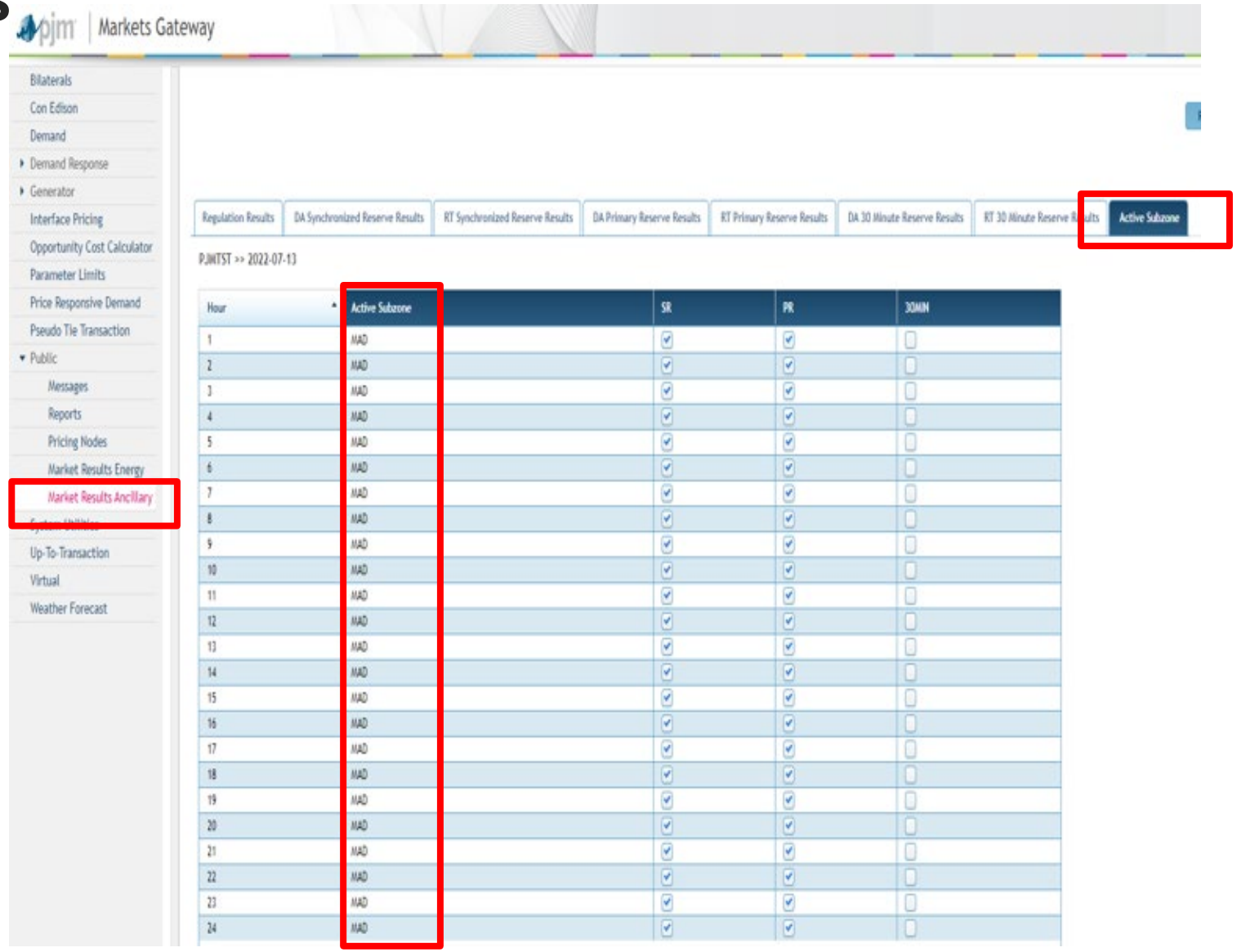
Reserve Subzone Composition

- Reserve subzones defined as all buses with 3% or greater (raise-help) distribution factor on associated transmission constraint
- Definitions will be reevaluated and published quarterly or coincide with the network model build
- Definitions posted on Ancillary Services page of pjm.com



Flexible Reserve Subzones

- Dynamically adjust reserve subzone to reflect system conditions
- Better enable reliable operations and result in market results more consistent with system operations
- Only one subzone active at any given time
  - Communicated in Markets Gateway



Note: Changes to the active reserve subzone can be made in real-time intraday on an exception basis

Reserve Market Resource Eligibility

- Generation and Economic Load Response resources are eligible to provide Synchronized Reserves, Non-Synchronized Reserves, and Secondary Reserves unless:
  - Resource is not within the metered boundaries of PJM
  - Entire output is offered as Emergency Only
  - Resource type includes: Nuclear, Wind, or Solar, unless exception approved
  - Resource is not available to provide energy or reduce load
- Following resources <u>not eligible to provide Non-Synchronized</u> Reserves:
  - Economic Load Response
  - Energy Storage Resources enrolled in ESR participation model

Fulfilling Obligation: Purchasing from Market

- Participant may fulfill their respective Reserve Obligations by:
  - Self-scheduling from own generation resources
  - Entering bilateral arrangements with other market participants
  - Purchasing the applicable Reserves quantity from the market
- LSE Reserve Obligation equal obligation load ratio share times amount Reserve assigned for Reserve Zone or active Reserve Sub-zone

Must Offer Requirement

- Any generation capacity resource (RPM or FRR) must offer their 10-minute and 30-min reserve capability
  - Unless on outage
- If a resource chooses not to make its capability available will be defined as violating the reserve must offer requirement
- All other generation resources eligible to provide reserves and submitted energy offers are considered offered into the reserve markets
  - Hydro, ELR and ESR not considered available by default
    - Must submit specific reserve offers
- Can request reduced Synch/Secondary Reserve Max due to physical limitations

Reserve Offers

- Consist of three elements:
  - Availability
  - Offer MW
  - Offer price

<table>
<tr><th></th><th colspan="5">Resource Type</th></tr>
<tr><th>Reserve Market</th><th>Condensers</th><th>Other Gen</th><th>Wind/Solar/ Nuclear</th><th>ESR/Hydro</th><th>Load Response</th></tr>
<tr><td>SR</td><td rowspan="3" colspan="3">Set through energy offer</td><td colspan="2">Specify availability separately</td></tr>
<tr><td>NSR</td><td>N/A for ESR; Specify availability separately for hydro</td><td>N/A for NSR</td></tr>
<tr><td>SecR</td><td colspan="2">Specify availability separately</td></tr>
</table>

- If Hydro, ESR, and ELR unable to participate in any given hour during Operating Day:
  - Set Offer MW = 0
  - Set to “Not Available”
  - Done in Markets Gateway sixty-five (65) minutes prior to the operating hour

Synchronized Reserve Offers

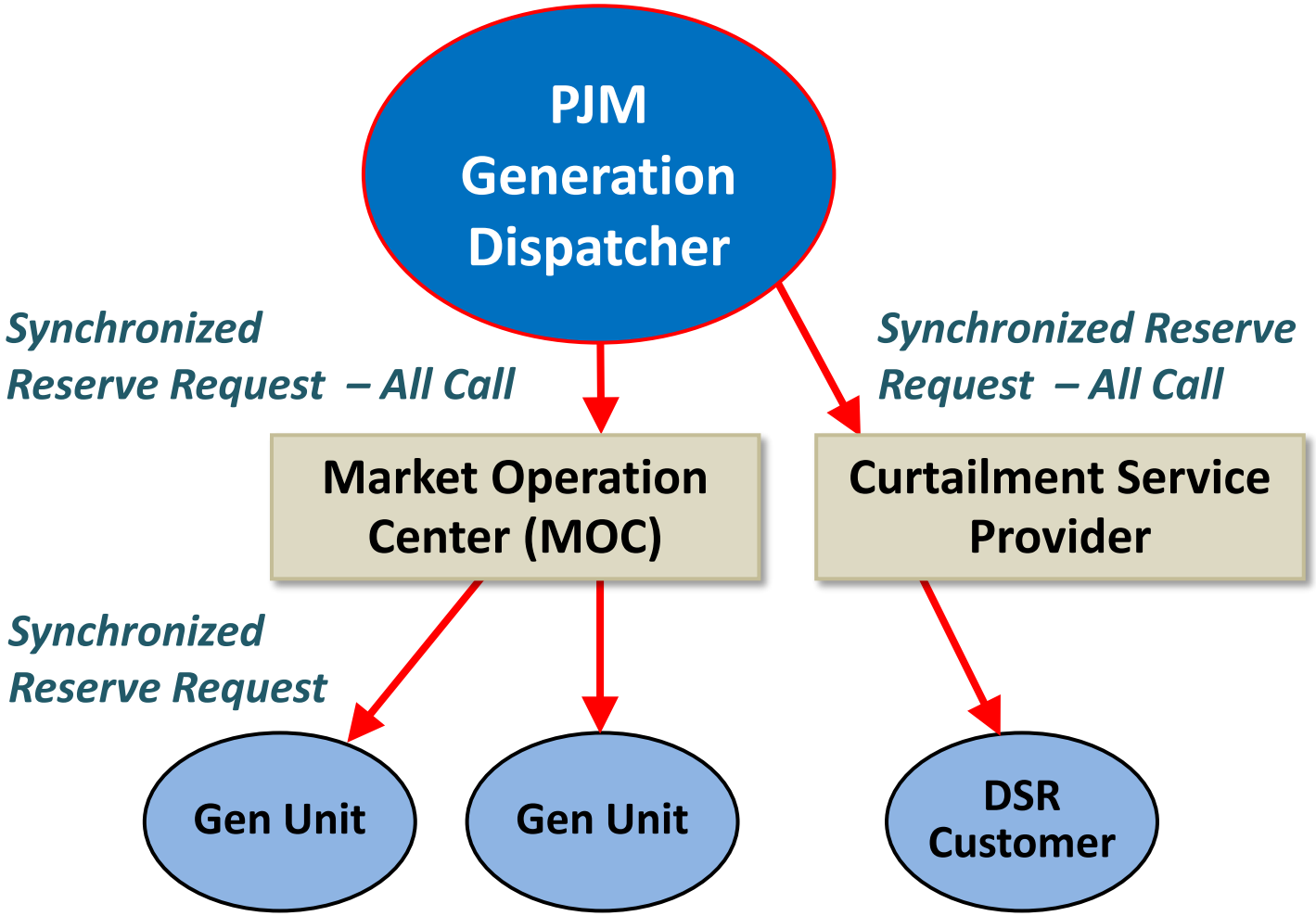
- All resources may specify a Synchronized Offer Price ($/MWh)
  - Synchronized Reserve offer prices must be cost-based
  - Capped at the Expected Value of Synchronized Reserve Penalty.
  - Offer Price cannot be a negative value
  - All resources listed as available for Synchronized Reserves with no Offer Price are set to $0.00/MWh.

Call for Synchronized Reserve

Loading of Synchronized Reserve is a Reliability Service!

- The resource owners implement the requested percentage of Synchronized Reserve:
  - Without regard to price and as quickly as possible
- Continue to implement Synchronized Reserve until directed by PJM dispatcher to discontinue

At most, one level of operator intervention between PJM and customer reducing load



Non-Synchronized and Secondary Reserve Offers

- Offer prices for Non-Synchronized Reserve and Secondary Reserve are $0.00/MWh
- Not able to be submitted in Markets Gateway
- Shutdown Cost ($/MWh)
  - Cost Economic Load Response incurs when reducing load in response to a reserve event
  - If a non-zero value, must be approved by PJM and the IMM

Reserve Market Timeline

*

Due day ahead of operating day by 11:00 a.m.

- Set through energy offer
- SR Offer capped at Expected Value of SR Penalty
  - No offer price submitted = $0
- Offer prices for Non-Synchronized Reserve and Secondary Reserve are $0.00/MWh
  - Cannot be submitted in Markets Gateway

*

Real-time offers due day ahead by 2:15 p.m.

*

Up to 65 min prior to the operating hour

- Availability
- Offer MW
- SR Offer Price*
- SR Self-Scheduled Status

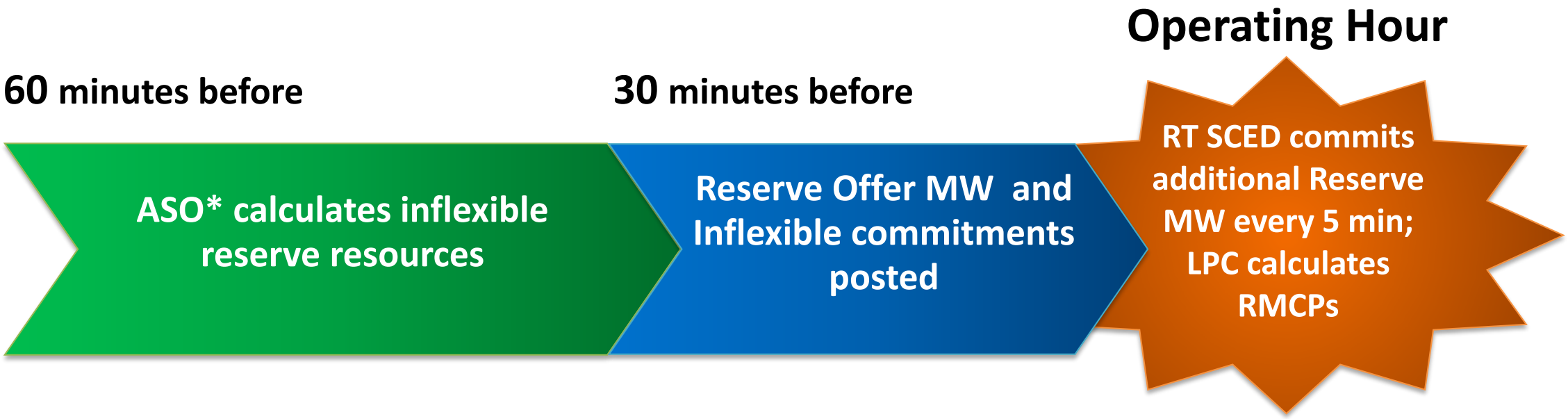
*subject to intraday offer rules

Data submitted to Markets Gateway

*Times are in Eastern Prevailing Time (EPT)

Synchronized Reserve Timing

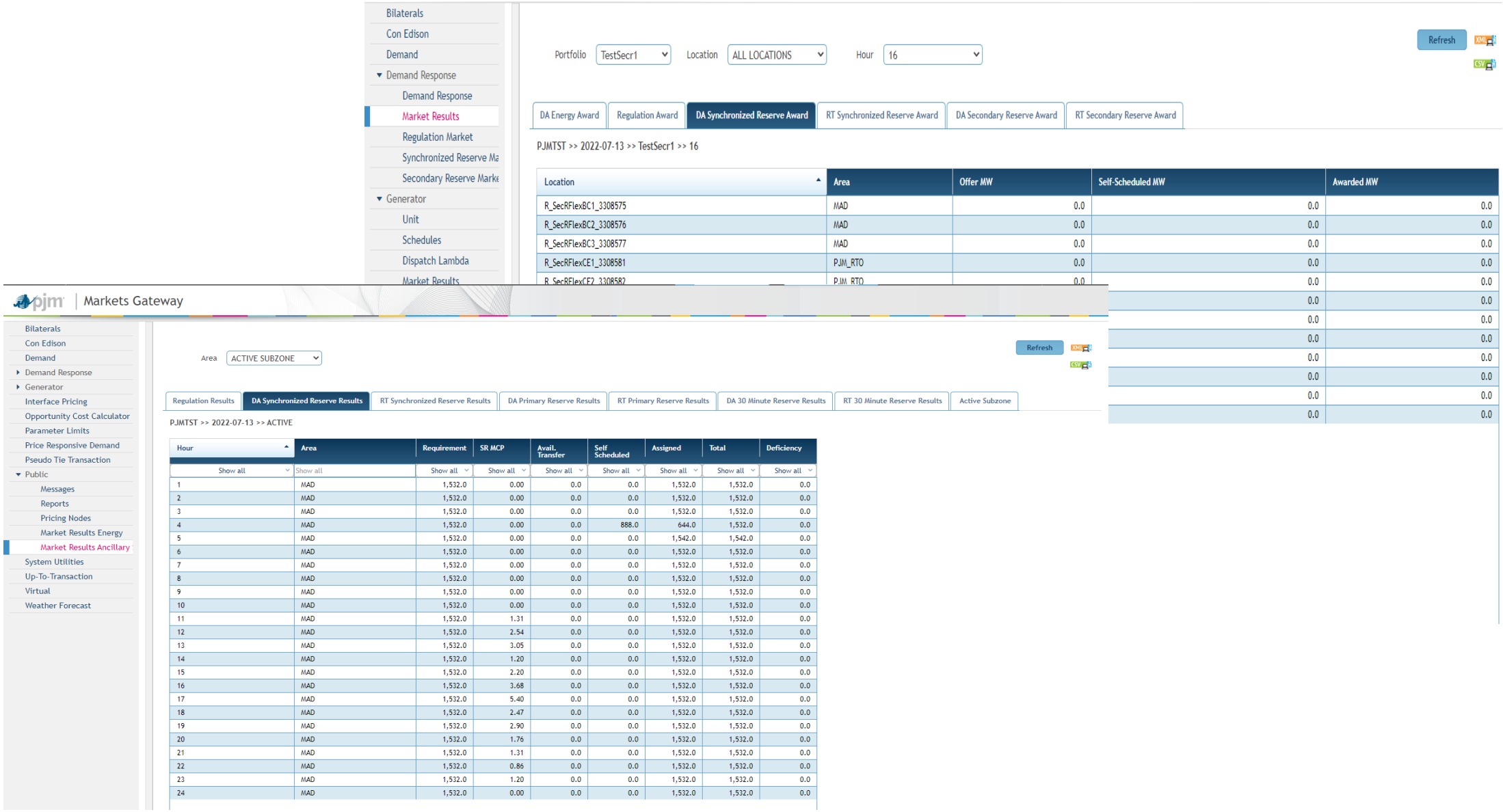
- A forward commitment for reserve resources and all regulation resources will be posted 30 minutes prior to the operating hour
  - Synchronous Condensers and Economic Load Response resources will be considered “inflexible” units and committed on a forward basis



*Ancillary Service Optimizer

Incremental commitments may be made for inflexible units

Reserve Results Posting



Response Calculation / Verification

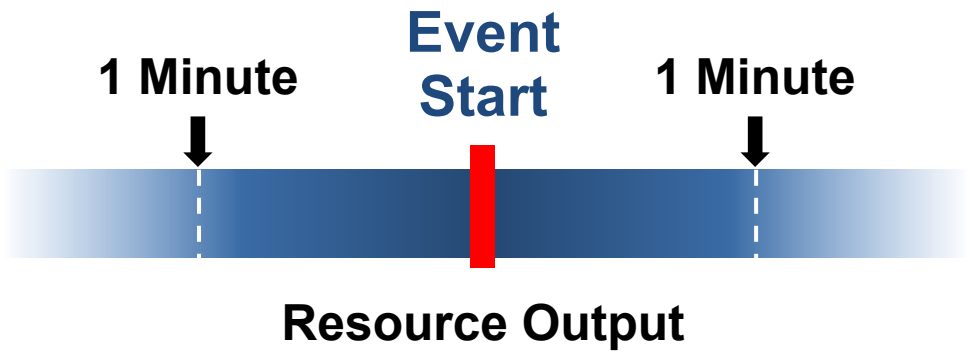
- Resource responses are verified by the PJM Performance Compliance department following each event
- Actual responses compared to assignments during the event are used to determine response and if necessary any penalties

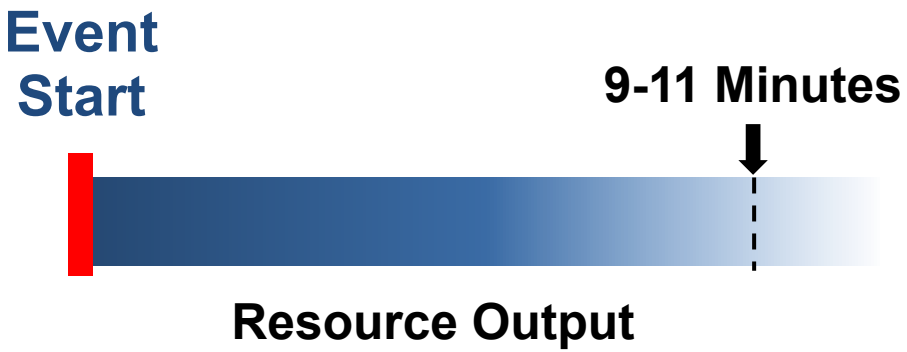
Synchronized Resource Response Measurement

- Resource response to 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 <u>at the start of</u> the event
  - The ***lowest*** telemetered output between 1 minute prior to and 1 minute following the start of the event

- Resource output <u>ten minutes after</u> the event
  - The ***greatest*** output achieved between 9 and 11 minutes after the start of the event





Batch Load ELR Synchronized Resource Response Measurement

- Magnitude of response measured as the difference between resource's consumption at the end of the event and maximum consumption within a ten (10) minute period following the event
  - All subsequent minutes following that minute are no less than 50% of the consumption in that minute
  - Example: Arc Furnace

Non-Synchronized Reserve Resource Response Measurement

- Magnitude of generation resource's response is its output ten (10) minutes after the start of the event.
  - Defined as greatest output achieved between nine (9) and eleven (11) minutes after start of the event
- Below applies to Synchronized and Non-Synchronized Resources
  - Must maintain output level greater than or equal to that achieved as of ten (10) minutes after the event for the duration of the event or thirty (30) minutes from the start of the event, whichever is shorter
  - Event lasts less than ten (10) minutes, resources credited with amount of assigned reserve capacity

Secondary Reserve Resource Response Measurement

- Offline generation resource assigned to provide Secondary Reserve in real-time and dispatched by PJM for Energy during Operating Day required to reach Economic Minimum output within 30 minutes
- ELR resource assigned to provide Secondary Reserve in real-time and dispatched by PJM to provide Energy during Operating Day required to reduce load by at least the Economic Minimum within 30 minutes
  - Greatest telemetered consumption between one minute prior to and one minute following dispatch instruction
  - Ending MW usage shall be the lowest consumption between 29 and 31 minutes after dispatch instruction

Questions?

PJM Client Management & Services

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Toll Free Telephone: (866) 400-8980

Website: www.pjm.com

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