PJM Ancillary Services

Ukrainian Delegation

Columbus, Ohio

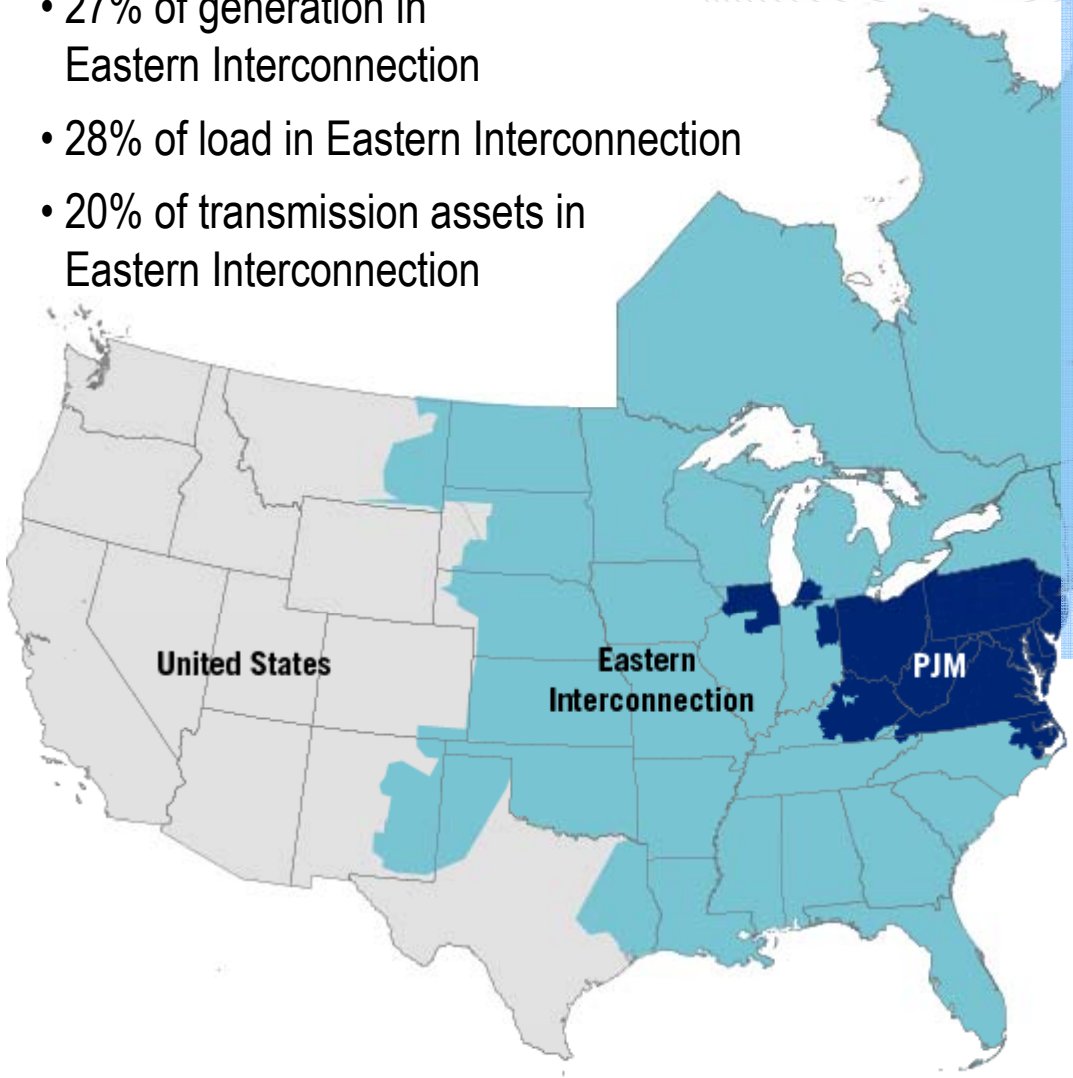
November 7, 2013

Objectives

- What are Ancillary Services (AS)?
- Why Procure Ancillary Services?
- When to Procure Ancillary Services and What Quantity?
- Technical Requirements to Provision of Ancillary Services
- Resources Eligibility and Qualification Process
- Ancillary Services Cost Development and Business Rules
- Resources Data and Timeline
- Procurement Process, Mitigation, Pricing, Communication
- Service Provision, Monitoring and Verification Process
- Penalties for Improper Provision of Ancillary Services
- Ancillary Services Settlement

PJM as Part of the Eastern Interconnection

- 27% of generation in Eastern Interconnection
- 28% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection



KEY STATISTICS	
PJM member companies	850+
millions of people served	61
peak load in megawatts	165,492
MWs of generating capacity	183,604
miles of transmission lines	62,556
2012 GWh of annual energy	793,679
generation sources	1,376
square miles of territory	243,417
area served	13 states + DC
externally facing tie lines	191

21% of U.S. GDP produced in PJM

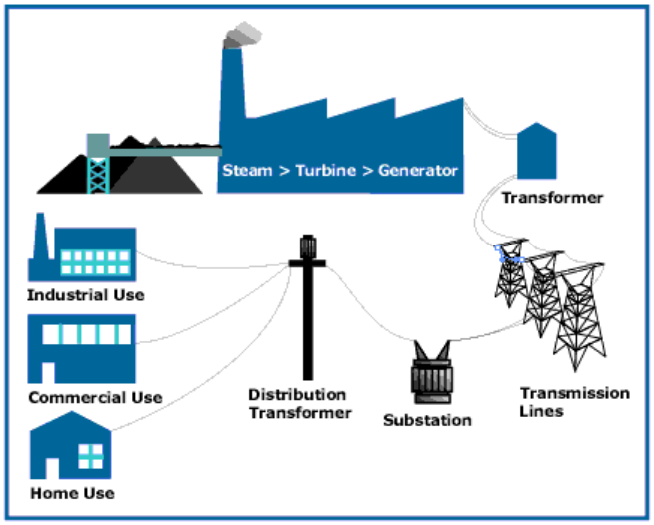
As of 7/1/2013

PJM – Focus on Just 3 Things

What are Ancillary Services?

- Ancillary Services -Those services that are necessary to support the transmission of energy from resources to loads, while maintaining reliable operation of the Transmission Provider's Transmission System in accordance with Good Utility Practice.

- PJM's Regulation and Synchronized Reserve are market based.



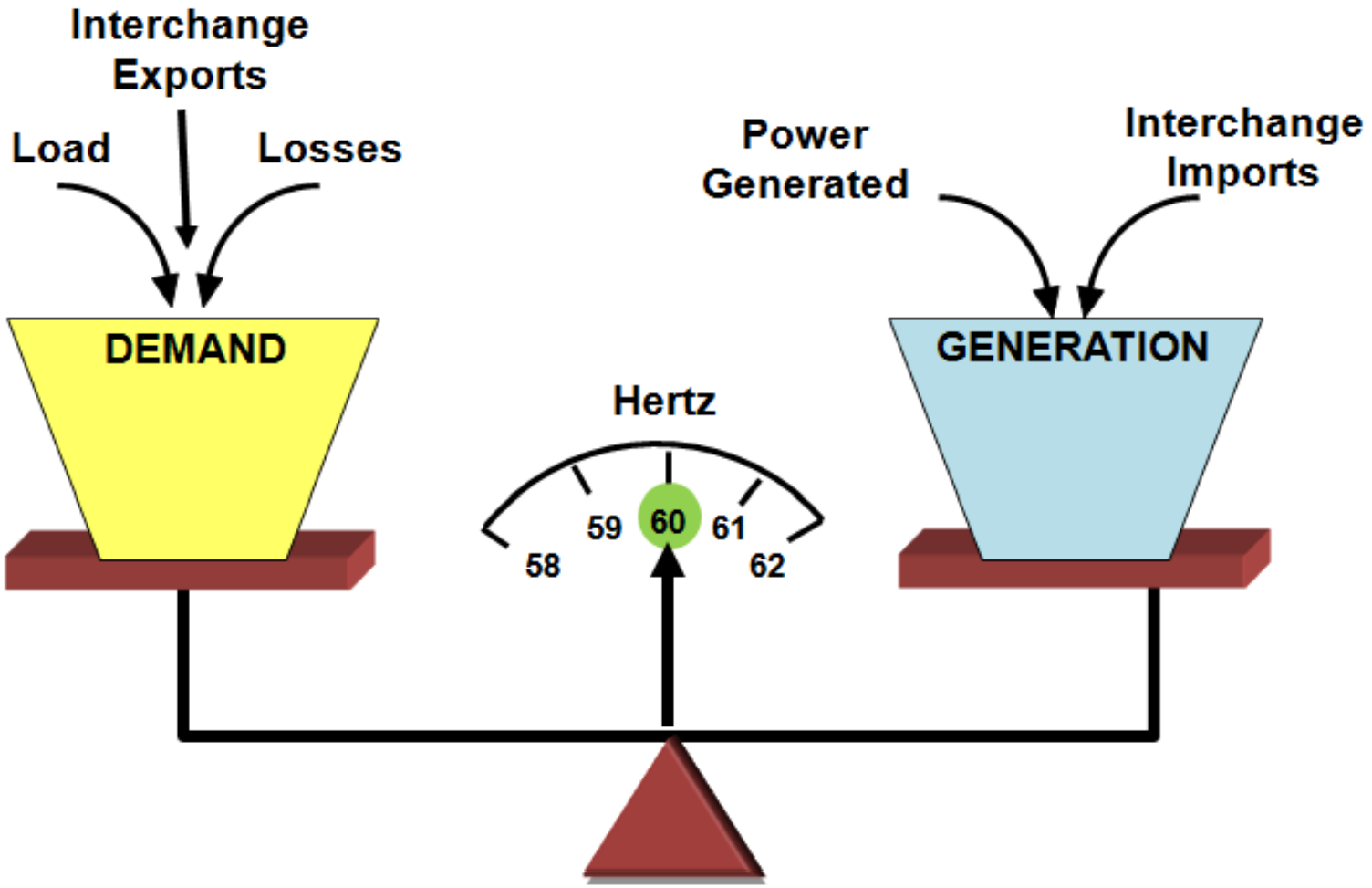
Topics

- Regulation
  - Performance Based Regulation
- Reserves
  - Primary Reserves
    - Synchronized Reserve
    - Non-Synchronized Reserve
  - Secondary and Supplemental Reserve
    - Day-Ahead Scheduling Reserve
- Other Ancillary Services
  - Reactive Supply and Voltage Control
  - Black Start Service

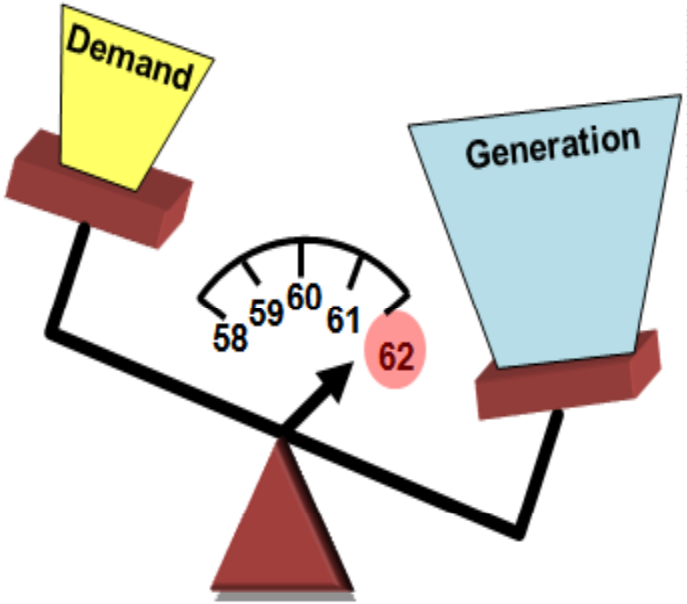
Regulation

- Definition and Requirement
- Eligibility and Qualification Process
- Operation and Market Clearing Process
- Regulation Market Settlement

The Energy Balance - Balancing Authority's Goal

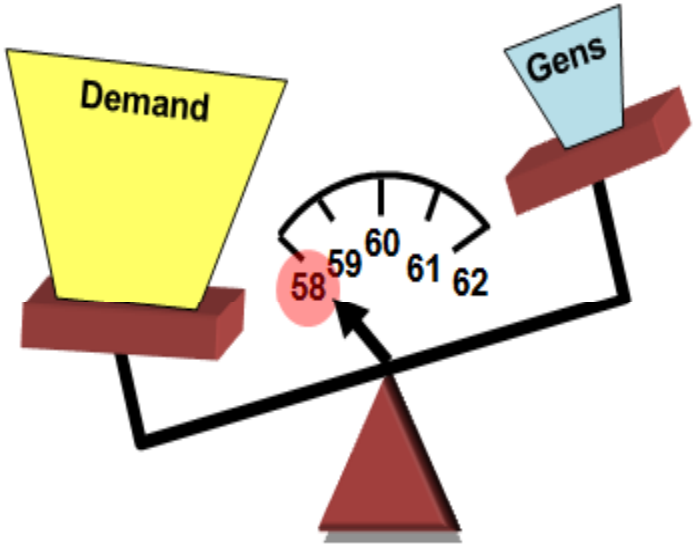


Imbalance Conditions



Over-generation

- Total Generation > Total Demand
- Frequency > 60 Hertz
- Generators momentarily speed up



Under-generation

- Total Generation < Total Demand
- Frequency < 60 Hertz
- Generators momentarily slow down

What is Regulation?

Regulation is:

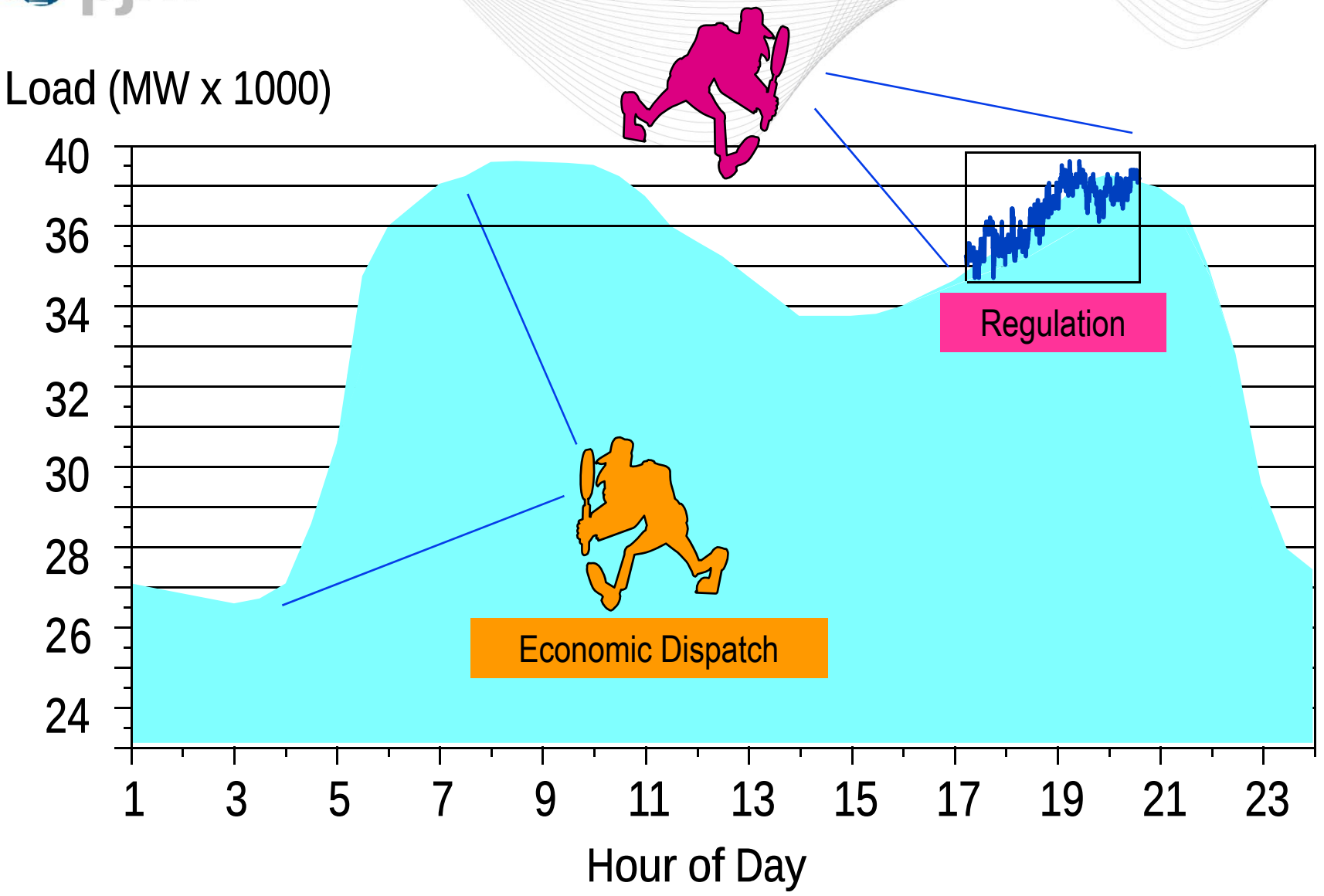
- A variable amount of generation energy under automatic control
- Independent of economic cost signal
- Obtainable within five minutes
- Responds to frequency deviations

- These generating units or Demand Response (DR) resources provide fine tuning that is necessary for effective system control
- Governors respond to second-to-second changes in load
- Regulating units correct for small load changes that cause the power system to operate out of balance (measured as “Area Control Error - ACE”)

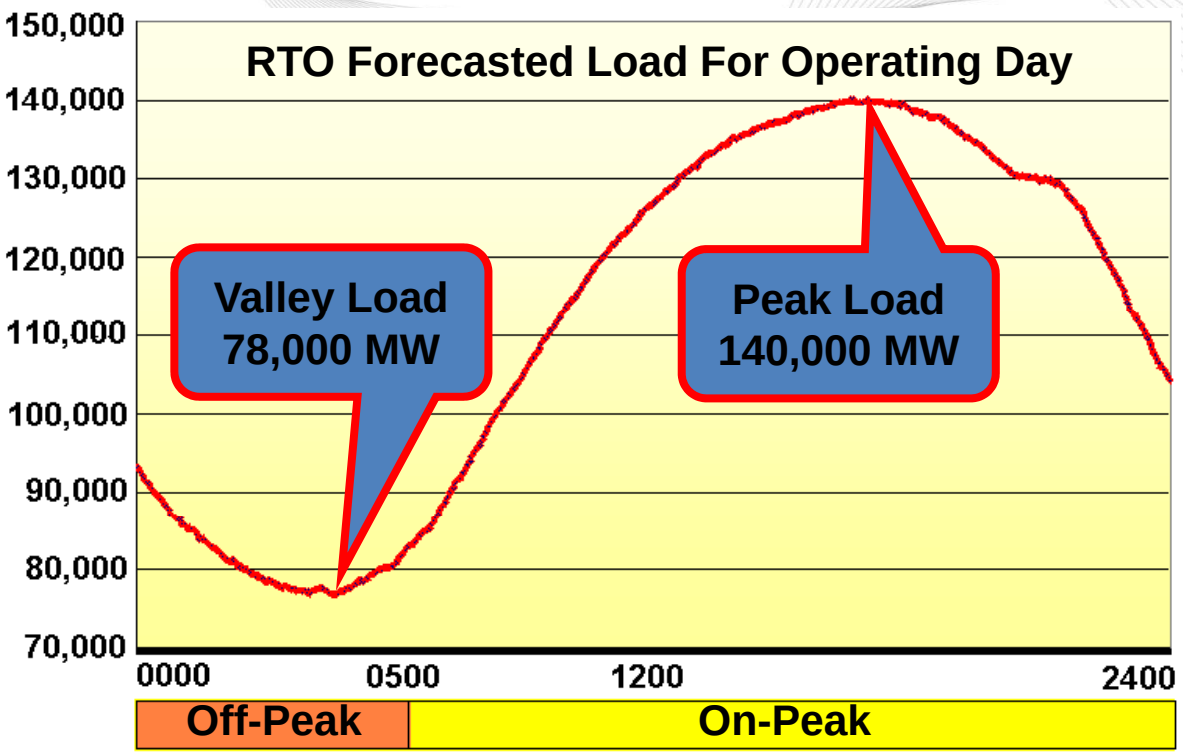
Regulation Overview

- The PJM Regulation product provides for market-based compensation to resources that have the ability to adjust output or consumption in response to an automated signal
  - Helps to maintain interconnection frequency
  - Help to track moment-to-moment fluctuations in customer loads
  - To correct the unintended fluctuations in generation
  - Manage differences between actual and scheduled power flow between control areas
  - Match generation to load within a control area
- Service can be provided by resources equipped with automatic generation control (AGC)
  - Generator,
  - Energy storage, or
  - Load (Demand Response)
- The Regulation service is a reliability product procured by the transmission provider on behalf of the load to ensure reliable system operation

Regulation vs. Economic Dispatch



PJM's Regulation Requirement (Example)



Off-Peak Regulation Requirement

Valley Load Forecast	*	0.7%	=	Regulation Requirement
78,000 MW	*	0.7%	=	546 MW

On-Peak Regulation Requirement

Peak Load Forecast	*	0.7%	=	Regulation Requirement
140,000 MW	*	0.7%	=	980 MW

Regulation Technical Requirement

- Regulation offers may be submitted only for those resources electrically within the PJM RTO.
- Generation resources must have a governor capable of AGC control.
- Resources must be able to receive an AGC signal.
- Resources must demonstrate minimum performance standards, as set forth in the PJM Manual
- New resources must pass an initial performance test (minimum of 75% compliance required). PJM will rely on owner‘s data for initial qualification. – section 4 of manual12
- Resources must exhibit satisfactory performance on dynamic evaluations.
- Resources MW output must be telemetered

Regulation Qualification Test

- Resource owner may contact PJM at RegulationTesting@pjm.com at least a day prior to testing following guidelines as described in section 4.5 of manual 12 (Balancing Operations) and also indicate the following:
  - Resource name and id
  - Date and Time of test
  - Regulation Test MW
  - Regulation Signal type
- Resources must meet the following criteria:
  - Pass three consecutive tests with a performance score of 75% or better
  - The resource will follow the RegA or RegD signal for 40 minutes using sample operation signal as in http://www.pjm.com/markets-and-operations/ancillary-services/mkt-based-regulation.aspx
    - Resources may complete one self-test and two PJM administered tests
    - Or three PJM administered tests
    - No more than one test may be scheduled in a day
    - Resources can dual qualify for RegA and RegD by completing additional tests
- Resources that wish to qualify for RegD must contact RealTimeDataManagement@pjm.com and ask that the RegD signal, TREGD, AREGD be added to its ICCP/DNP link
- PJM Performance Compliance will score the test using the Performance Score Calculator with results available in 3 business days for initial qualification and 1 business day for qualified MW uprate

What types of Resource can provide regulation:

- *Generation* : Steam, Hydroelectric, Combustion Turbines, Combined Cycle
- *Grid Energy Storage* : Batteries, Flywheels
- *Behind-the-meter Storage*: Water Heaters, Plug-in Hybrid Electric Vehicles
- *Demand Response* : Variable Speed Pumps, Ceramic Thermal Storage

Real-Time Regulation Data/Terms

PJM >> Member

AReg – Assigned Regulation

- Static for hour as a result of market
- Sent by PJM for each resource capable of regulation

RegA – Regulation Control Signal

- Automated Generator Control signal sent by PJM to Resource owner
- Sent every 2 seconds
- Bounded by TReg

RegD – Fast Regulation

- Automated Generator Control signal sent by PJM to Resource owner
- Dynamic signal moves with the frequency deviation component of ACE
- Increases the “utilization” of the energy storage devices

Member >> PJM

TReg – Total Regulation

- Resource owner sends one number for the fleet regulation capability

CReg – Current Regulation

- Calculated value where fleet is operating relative to regulation band
- Fleet-wide value sent from Resource owner to PJM
- Sent every 4 seconds

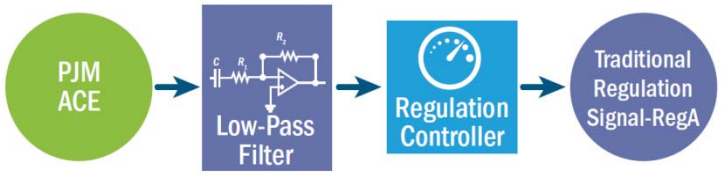
Unit Reg – Resource allocation

- Allocation should be sent as percent allocation for each individual regulating resource of the resource AReg.

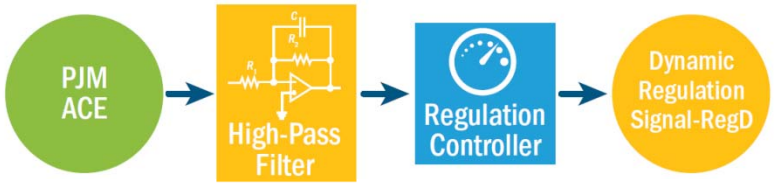
Load BP – Operational Midpoint

- The point around which the regulating resource (unit, plant or registration) operates.

- Traditional Regulation Signal (REGA)
  - A function of slow filter of RTO Area Control Error (ACE)
  - Can remain full raise or lower for extended periods



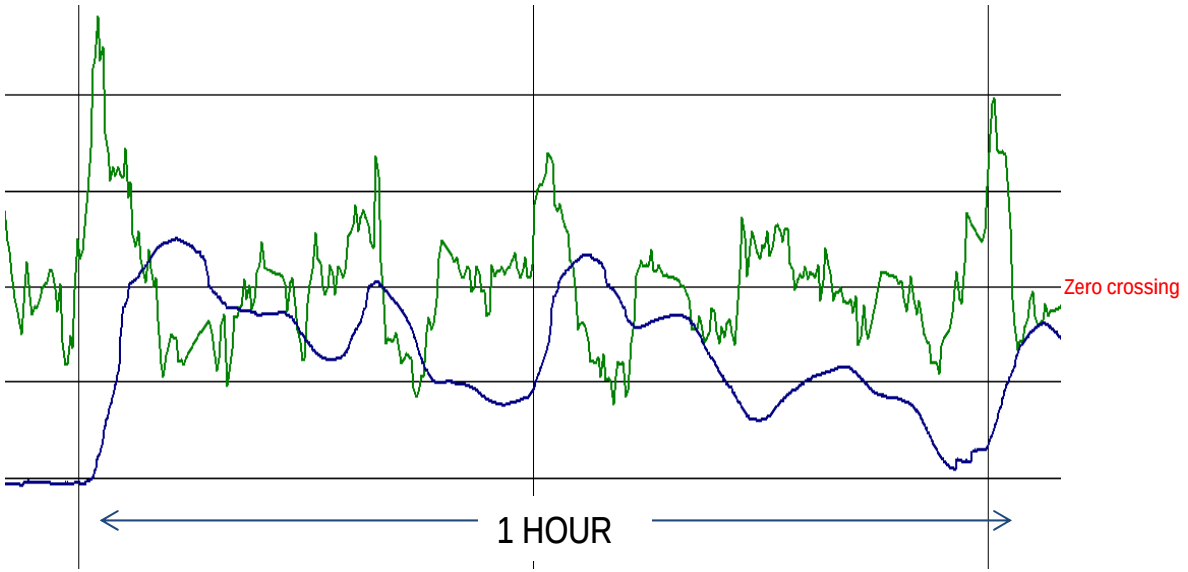
- Dynamic Regulation Signal (REGD)
  - A function of fast filter of RTO ACE
  - Increases the amount of time the REGD signal opposes the ACE during a deviation



Regulation Signals

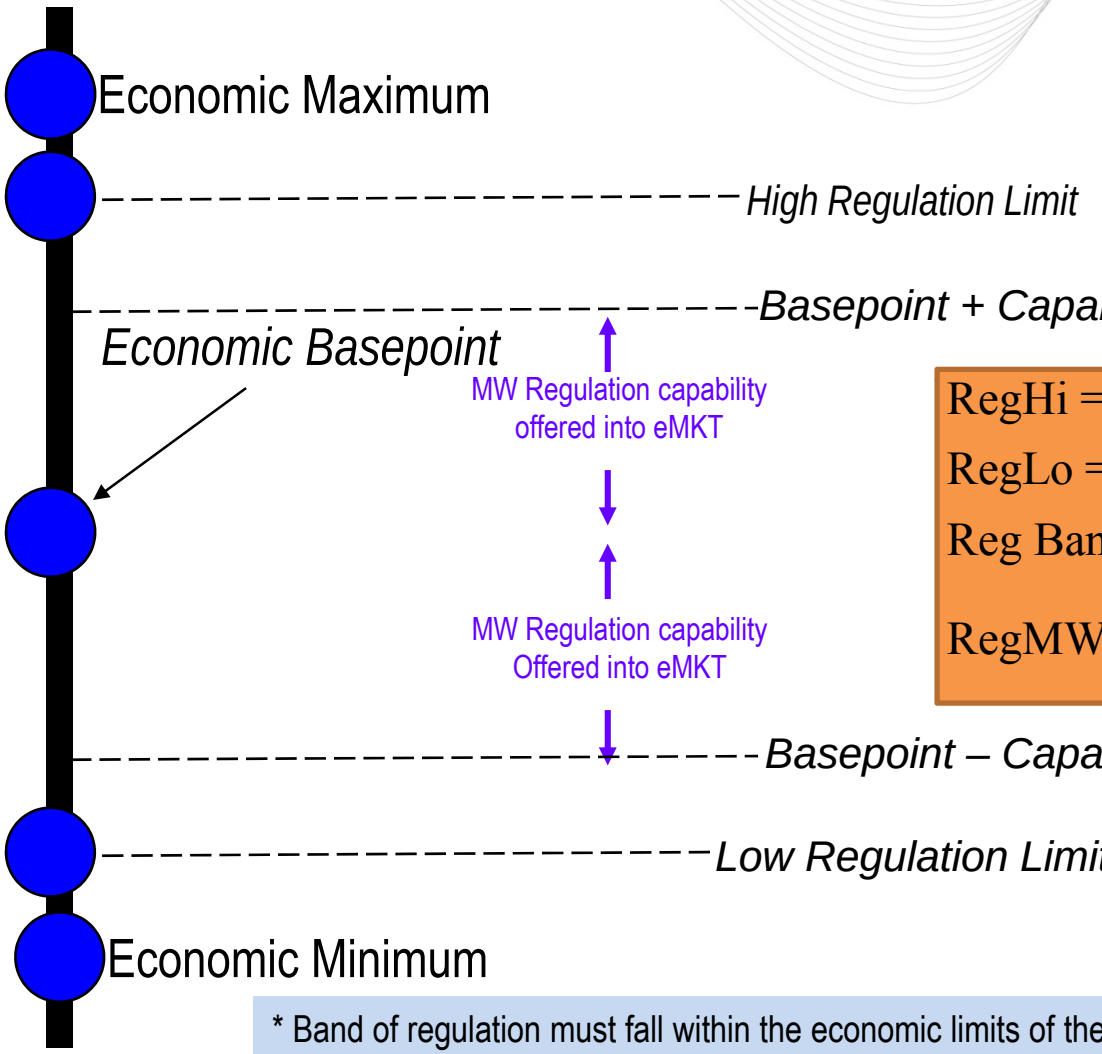
RegA (blue) - fleet level regulation signal sent by PJM to traditional units (some CTs, CC's, steam)

RegD (green) –fleet level regulation signal sent by PJM to fast moving units (energy storage, hydro, some CT's



The RegD (D for Dynamic) has different time constants which speeds up the signal for resources that can move faster, allowing them to cross 0 more frequency and prevent excess discharge.

Band of Regulation for Generator



RegHi = min(EcoMax, RegMax);

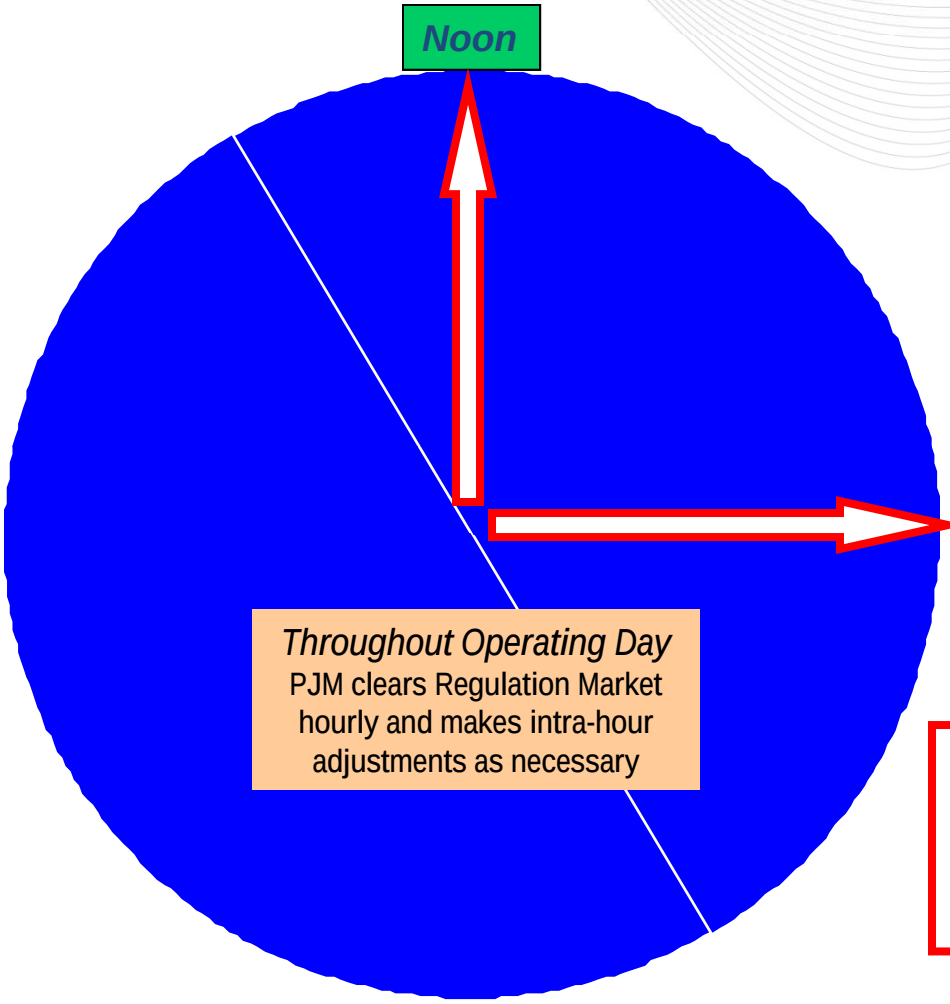
RegLo = max(Ecomin, RegMin);

Reg Band (or Range) = RegHi - RegLo;

$$\text{RegMW} \leq \frac{\text{RegBand or (RegHi - RegLo)}}{2}$$

* Band of regulation must fall within the economic limits of the generating resource

Regulation Market Data and Time Line



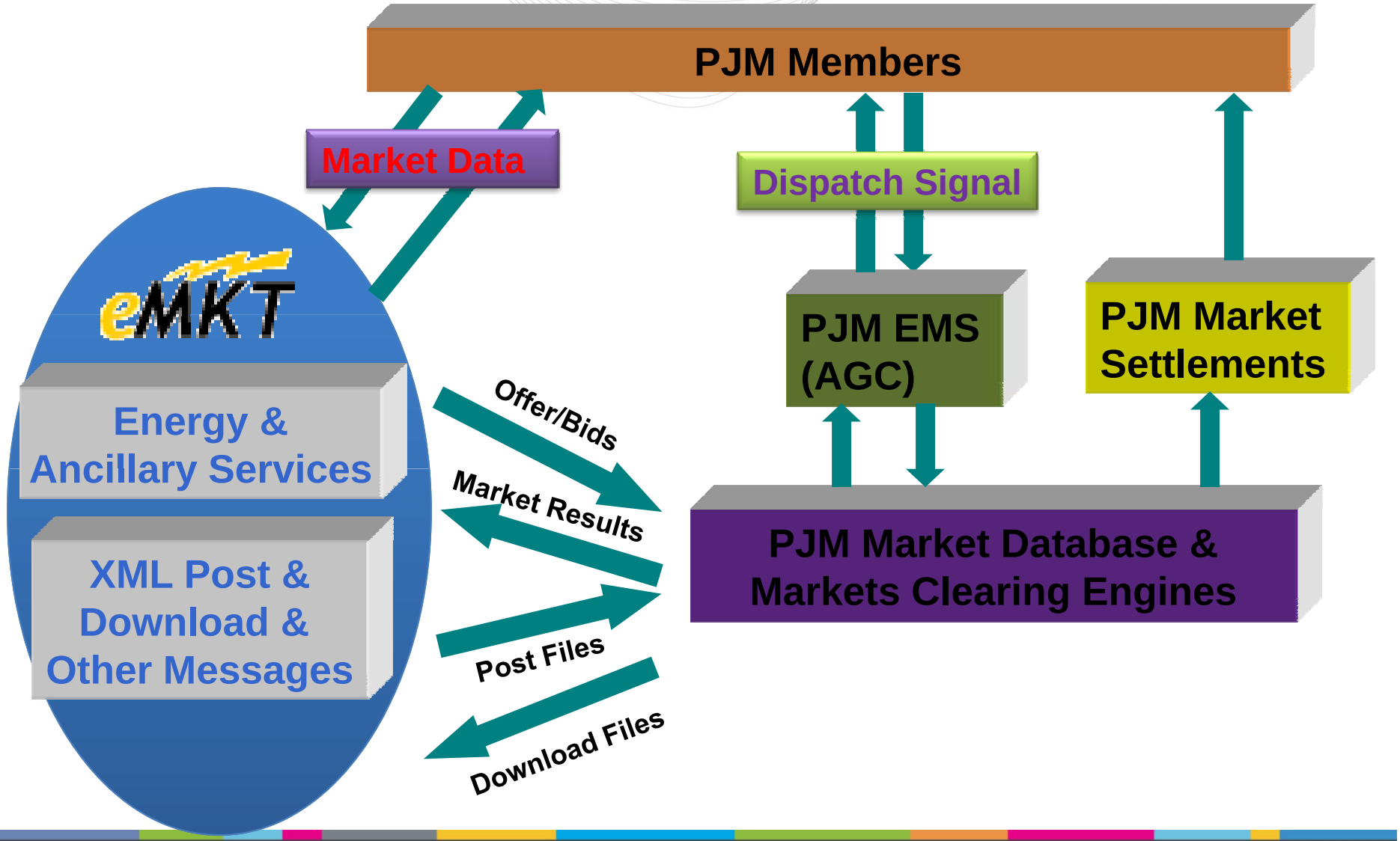
Regulation Offers (price and cost data only) due by 1800 EPT for next operating day

- Energy cost schedule* is due by 12 noon a day ahead of the operating day;
- Regulation price and cost related data must be supplied by 6:00 PM a day ahead and is applicable for the entire 24 hour period for which they are submitted.
- All other regulation data can be revised up till 60 minutes before the operating hour
- * - for LOC calculation for qualify units

is an internet application that allows PJM Market participants to participate in PJM's Energy and AS markets

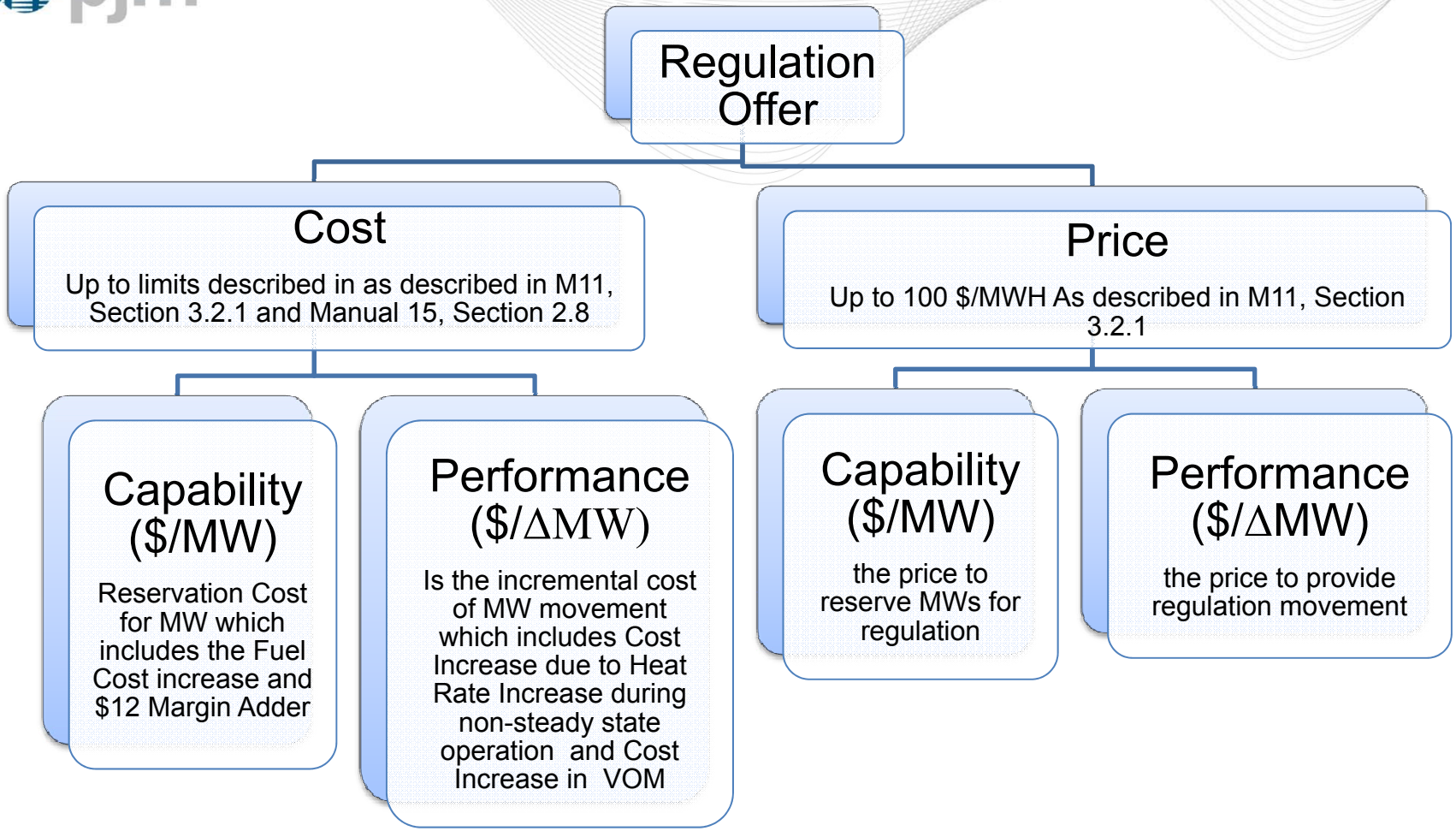
https://esuite.pjm.com/mui/

Ancillary Services Subsystem



- Cost-Based Regulation Offer is split into two portions and is mandatory to clear in the market even when self scheduled.
  - Capability portion ($/MW)
    - Fuel Cost Increase
    - Unit Specific Heat Rate Degradation due to Operating at Lower Loads
    - $12 margin adder
  - Performance portion ($/ΔMW)
    - Cost Increase due to Heat Rate Increase during non-steady state operation
    - Cost Increase in VOM
    - The $/ΔMW will be multiplied by the ratio of ΔMW/MW to convert to ($/MW)
- Price-Based Regulation Offer is capped at $100/MW, and its submission is optional. It is split into:
  - Capability ($/MW) the price to reserve MWs for regulation
  - Performance ($/ΔMW) the price to provide regulation movement
    - The $/ΔMW will be multiplied by the ratio of ΔMW/MW to convert to ($/MW)

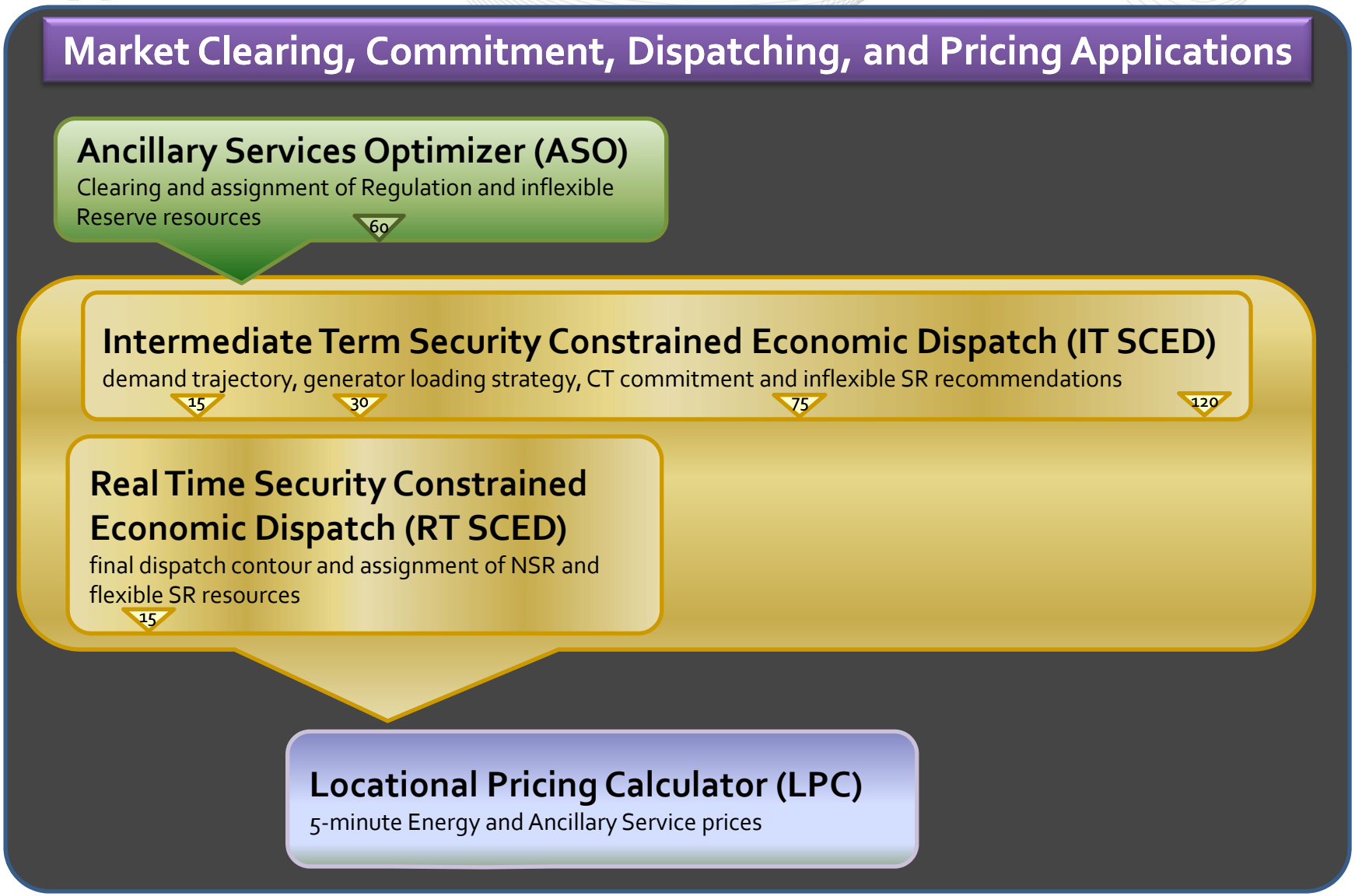
Regulation Offers – Cost and Price



- The $/ΔMW will be multiplied by the ratio of ΔMW/MW to convert to ($/MW)
- Participant supplies PJM with Performance Offer, Capability Offer, and MW Offer

- PJM clears regulation an hour ahead of real-time and on an hourly basis.
- Regulation pricing is done in real-time every five minutes.
- Resources have the opportunity to *self-schedule* or offer into the market and be assigned economically (*market scheduling*)
  - Assignments and clearing prices and are co-optimized along with energy, synchronized, and non-synchronized reserves using Ancillary Service Optimizer (ASO) and Intermediate-Term Security Constrained Economic Dispatch (ITSCED)*
    - Minimize Production Cost
    - Meet requirement
    - Regulation Three Pivotal Supplier Test to mitigate market power
  - Clearing prices include opportunity cost
- Multiple constraints respected in market clearing
    - Resource, Transmission, etc.
    - Resources cannot be committed for more than one of the non-synchronized reserve, synchronized reserve, or regulation products during the same interval

Market Clearing Engines



Regulation Three Pivotal Supplier (RegTPS) Test

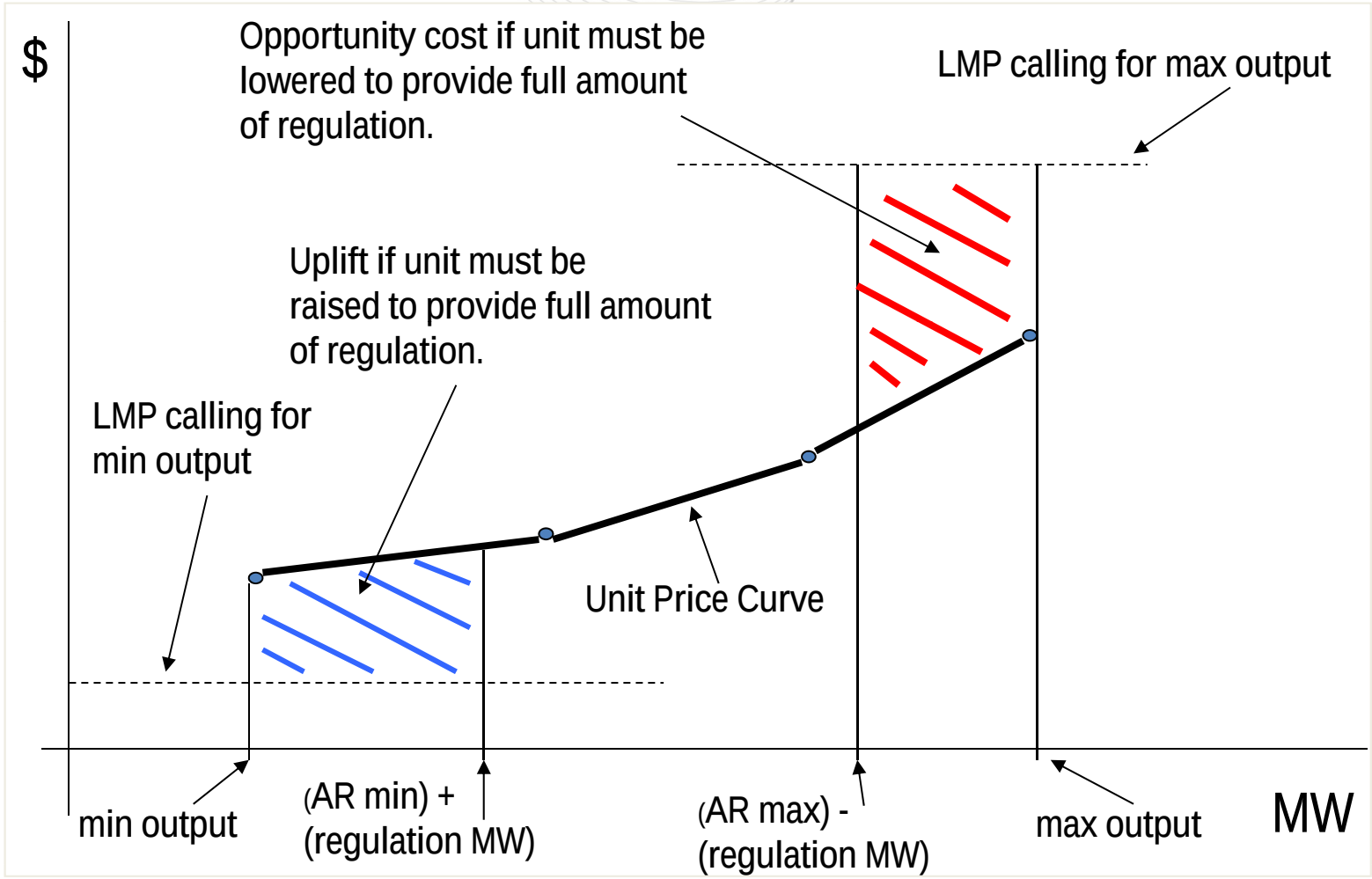
- Utilized to mitigate Regulation market power as detailed in section 3.2.2A.1 of the PJM Tariff;
- Conducted for each Regulation clearing hour
- Applied on a Regulation supplier basis (not a resource by resource basis)
- Performed on all supply within 150% of cost-based RMCP – eligible to clear resources
- A Regulation supplier fails the RegTPS test in any hour in which such Regulation supplier and the two largest Regulation suppliers are jointly pivotal.
- When RegTPS score is less than or equal to 1.0 , then the three suppliers are jointly pivotal and fail the RegTPS
  - Any resource owner failing the Reg TPS Test will be offer-capped
  - Resources are offer-capped at the lesser of their adjusted cost-based or adjusted market-based regulation offer price
- Resources that do not submit a cost-based regulation offer price cannot provide regulation

$$\mathrm{Re}\,gTPS\_Score = \frac{TotalCompetiveSupply - (Supplier1 + Supplier2 + SupplierN)}{\mathrm{Re}\,gulation\,\mathrm{Re}\,quirement}$$

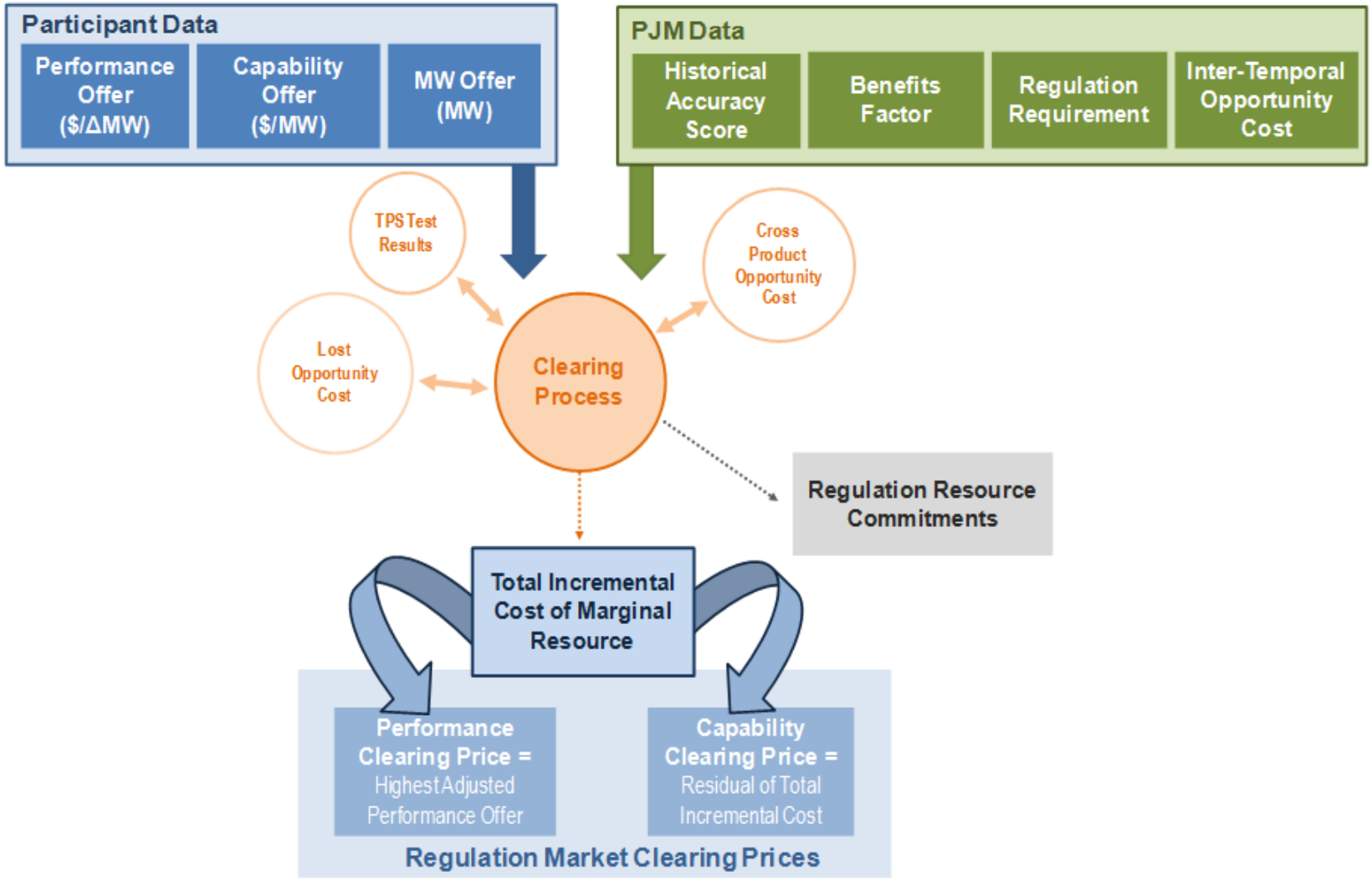
- RegLOC – is the foregone revenue or increase in costs relative to the energy market for providing regulation.
  - Calculated only for pool scheduled generators
  - Is $0 for DSR and self-scheduled generators
  - In the clearing process - RegLOC is calculated using forecasted energy market conditions and the lesser of
    1. the price-based energy offer, or,
    2. the most expensive, available, cost-based energy offer
  - In the pricing – RegLOC is calculated as the difference between Real-Time LMP and marginal cost to provide regulation
  - The operating rate is used to determine the LOC energy schedule

$$\text{Operating rate} = \frac{(\text{Area Under Curve} + \text{No Load})}{\text{Ecomax}}$$

Regulation Lost Opportunity Cost (RegLOC) Calculation

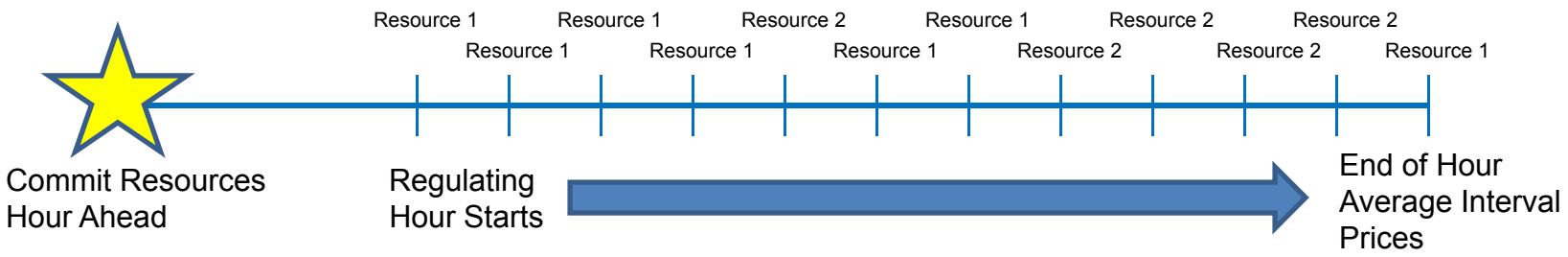


Market Clearing Process



LOC and 5 Minute Co-optimization

- Under 5 Minute Co-optimization, resources still clear in the hour ahead regulation market.
- Intra-hour, any one of the cleared resources may set the 5 minute regulating market clearing price (RMCP). For each 5 minute interval three prices are calculated:
  - Regulation Market Performance Clearing Price (RMPCP)
  - Regulation Market Capability Clearing Price (RMCCP)
- All 5 minute interval for a total of 12intervals are averaged for the hourly prices (RMPCP and RMCCP).



Clearing Price Example

	Adjusted Capability Offer Price ($/MW)	Adjusted Performance Offer Price ($/MW)	Adjusted Lost Opportunity Cost ($/MW)	Rank Price ($/MW)	Benefits Factor	Performance Score	Reg Assigned MW	Reg Effective MW
Resource 5	0.38	1.19	0.38	1.95	2.77	95%	2	5.3
Resource 8	0.81	2.5	0.4	3.71	2.61	95%	1	2.5
Resource 6	0.42	5.26	0.42	6.1	2.48	94%	1	2.3
Resource 2	4.08	2.12	1.02	7.22	1	97%	10	9.7
Resource 3	1.54	7.98	1.54	11.06	1	66%	35	23.1
Resource 4	3.33	8.64	1.67	13.64	1	60%	12	7.2
Resource 7	11.76	1.22	1.18	14.16	1	85%	-	-
Resource 1	6	6.22	2	14.22	1	50%	-	-
						Total Reg Effective MW		50.1

Rank Price = Adjusted Capability Offer Price + Adjusted Performance Offer Price + Adjusted Lost Opportunity Cost

Reg Effective Mw = Reg Assigned MW * Benefit Factor * Performance Score

- The Regulation Market Clearing Price (RMCP) is the highest rank price of the cleared resource = $13.64
- The highest adjusted performance offer from the set of cleared resources, which is $8.64 sets the Regulation Market Performance Clearing Price (RMPCP)
- The Regulation Market Capability Clearing Price (RMCCP) is a residual;

  RMCCP = RMCP – RMPCP = $13.64- $8.64 = $5

Disqualification and Requalification

- Regulating resources that have not met performance thresholds will be disqualified and must re-qualify to offer into the regulating market
- The disqualification threshold is based on a 100 hour rolling average with an average performance score below 40%
- When a regulating resource falls below the threshold PJM will notify the resource owner and the resource will no longer be eligible to offer into the regulation market for the applicable signal type
- Upon successful completion of requalification, the regulating resource performance score starts a new rolling average without any hours from the previous period counting towards the current period's rolling average

Fulfilling Regulation Obligation

- All Load Serving Entities have hourly Regulation Obligation
  - pro rata share of PJM Regulation assigned for hour
    - based on LSE total real time hourly load
- Obligation can be satisfied by:
  - self-scheduling own resources
  - enter bilateral transactions with other participants
  - purchasing from PJM Regulation Market

Fulfilling Obligation: Bilateral Transactions

- Entered by Buyer using eMKT
  - Entered as a MW amount to be transacted
- Confirmed by Seller on eMKT
- Data entered and confirmed no later than 1600 day after transaction starts
  - Transaction that have been reported and confirmed may not be changed; they must be deleted and re-reported
  - Deletion of a reported transaction after its start time has passed will result in a change in the end time to the current hour
  - Confirmation after 1600 will default the transaction to starting the day of confirmation

Regulation Settlements

- Regulation Capability Clearing Price Credit =

  Hourly-integrated Regulation MW x Actual Performance Score x Marginal Benefits Factor x RMCCP

- Regulation Performance Clearing Price Credit =

  Hourly-integrated Regulation MW x Actual Performance Score x Marginal Benefits Factor x RMPCP

- Regulation Market Clearing Price Credit =

  Regulation CCP Credit + Regulation PCP Credit

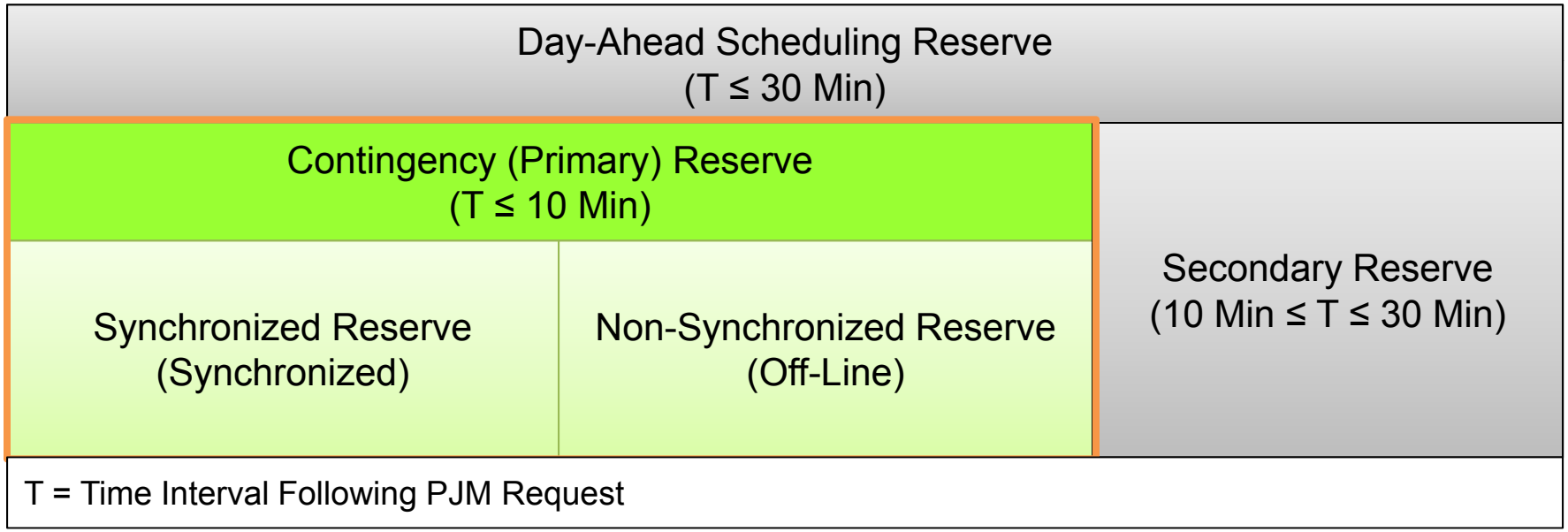
From Manual 28 – Operating Agreement Accounting, Section 4.2 Regulation Credits

Synchronized Reserve

- Definition and Requirement
- Resource Classification
- Operation and Market Clearing Process
- Synchronized Reserve Event Response / Verification
- Synchronized Reserve Market Settlement

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.

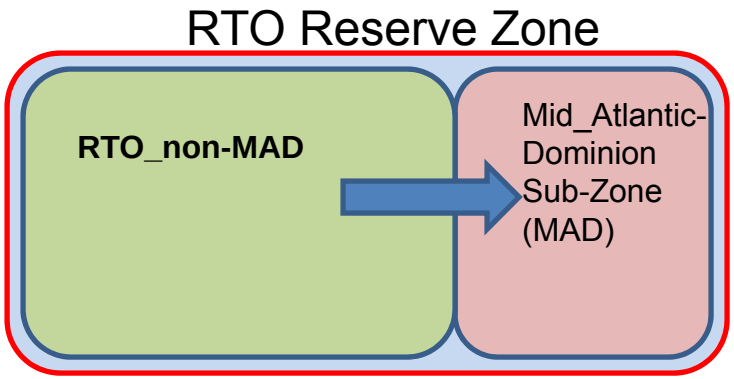


Why Procure Reserves

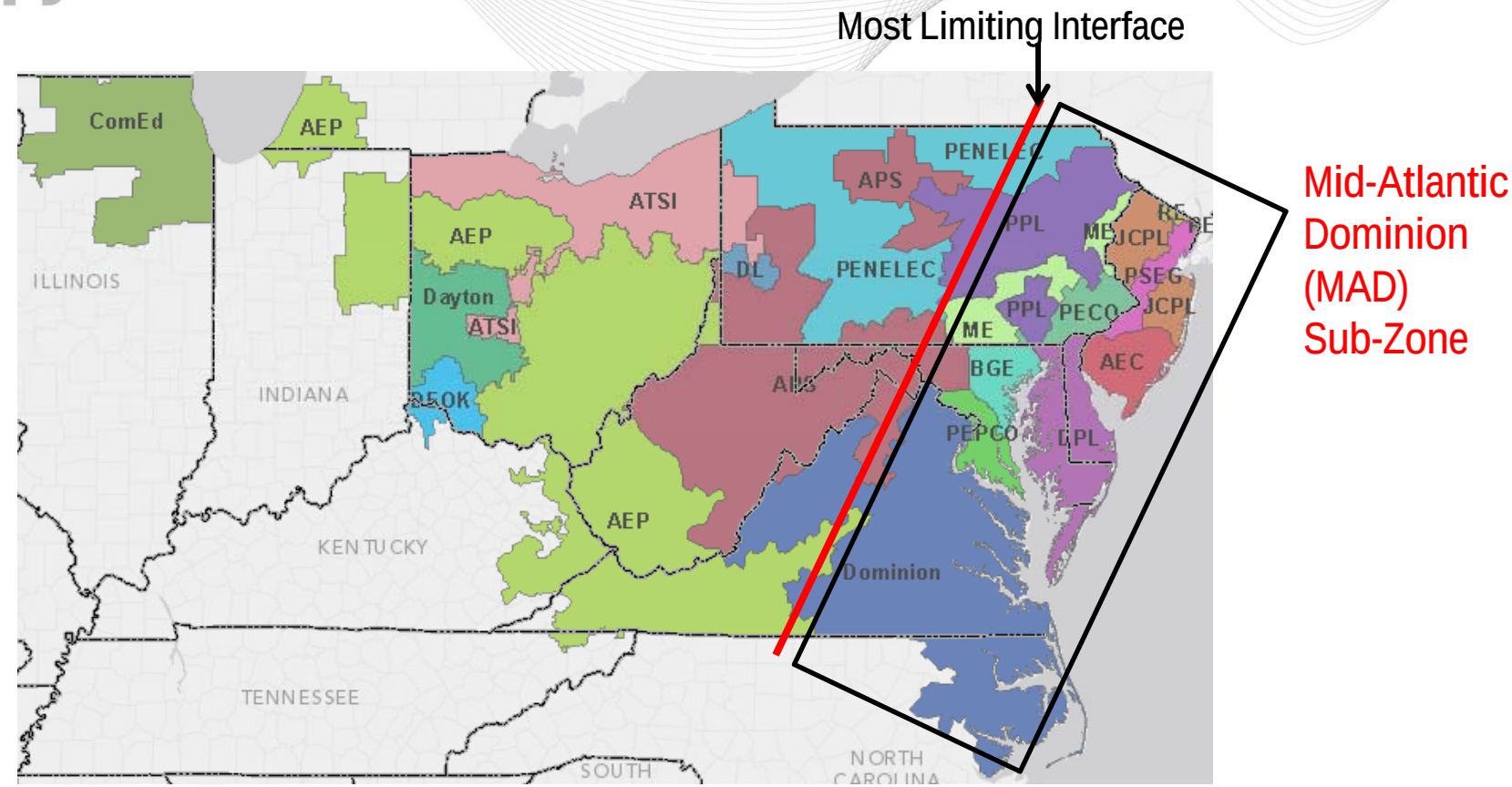
- The main goal of these resources is to recover the ACE back to it's pre-contingency level within the allotted timeframe
- These resources provide a quick boost of generation (or load reduction) to the system to recover ACE after a resource loss, large tie errors, and under frequency conditions
  - SR can not control over-frequency

One Reserve Zone

- Mid-Atlantic Dominion (MAD) sub-zone due to potential reserve deliverability issues
  - ❖ defined based on most limiting transfer interface
  - ❖ Resources with 0% or greater raise help distribution factor on the interface are included in MAD sub-zone



RTO Reserve Zone and Mid-Atlantic Dominion Subzone



Mid-Atlantic Dominion (MAD) sub-zone due to potential reserve deliverability issues

- defined based on most limiting transfer interface
- Resources with 0% or greater raise help distribution factor on the interface are included in MAD sub-zone
- Analysis of most limiting transfer interface coincides with quarterly network model builds
- http://www.pjm.com/markets-and-operations/ancillary-services/synchronized-service.aspx

Primary Reserve Requirement

- The Primary Reserve Requirement is defined as the amount of 10-minute reserve (synchronized or non-synchronized) that must be available
  - Inclusive of the Synchronized Reserve requirement
  - May be met with Tier 1 or Tier 2 resources
- RTO reserve zone requirement is 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 is equal to a static predefined value
    - » Usually 1700 MW

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

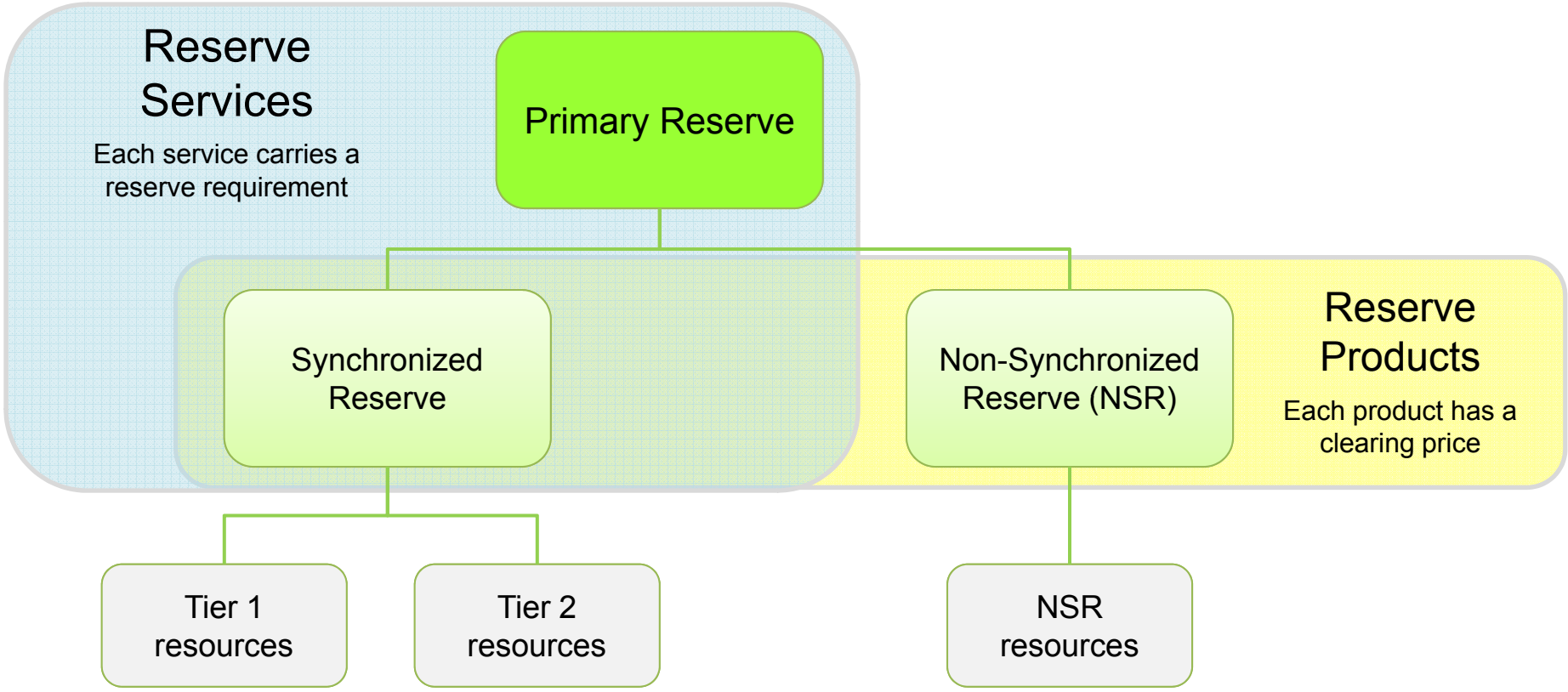
Note 2: PJM must schedule sufficient Contingency Reserves to satisfy the Reliability*First* (RFC) requirements. Contingency Reserves shall not be less than the largest contingency. Contingency Reserves must be made up of at least 50% Spinning Reserves. No more than 25% of Contingency Reserves should be interruptible load. (Standard BAL-002-0, BAL-002-RFC-02)

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

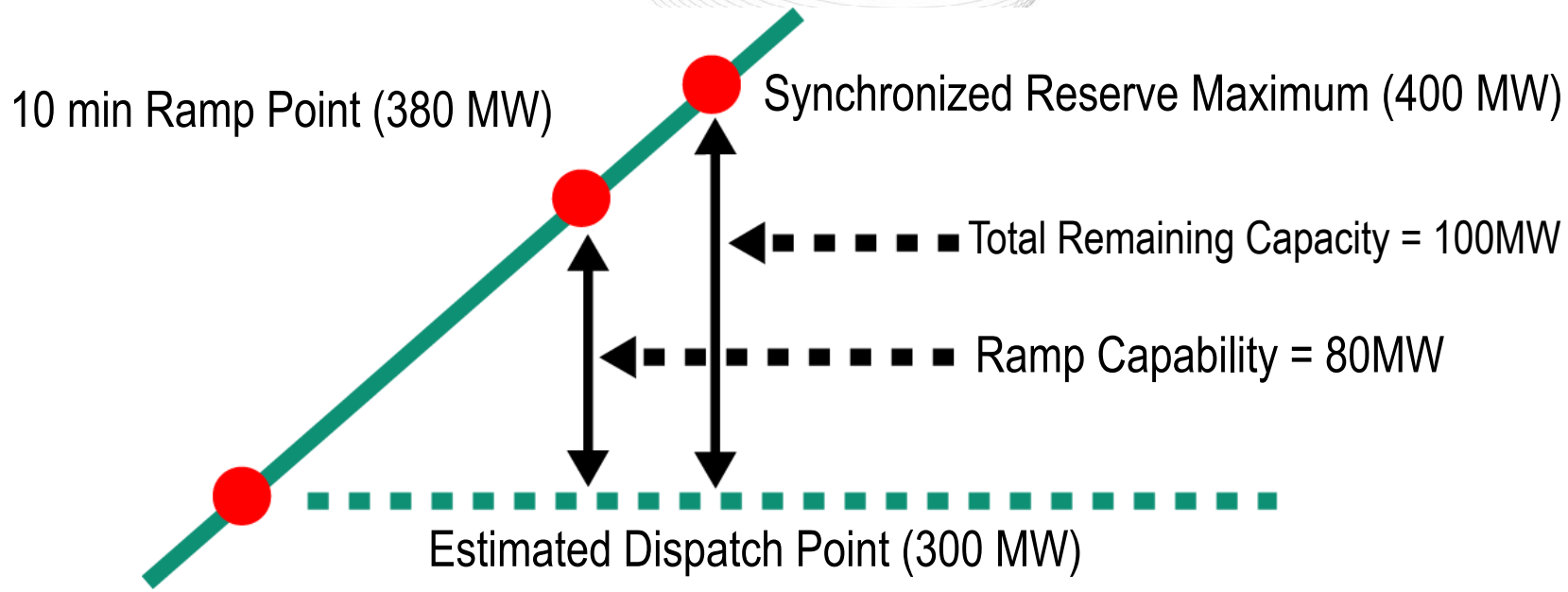
Reserve Markets



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

Tier1 Capability Calculation - Example



Synchronized Ramp Rate = 8 MW/min, therefore max T1 capability = 8 MW/min * 10min = 80 MW

Ramp Rate is more limiting, so T1 capability = 80 MW

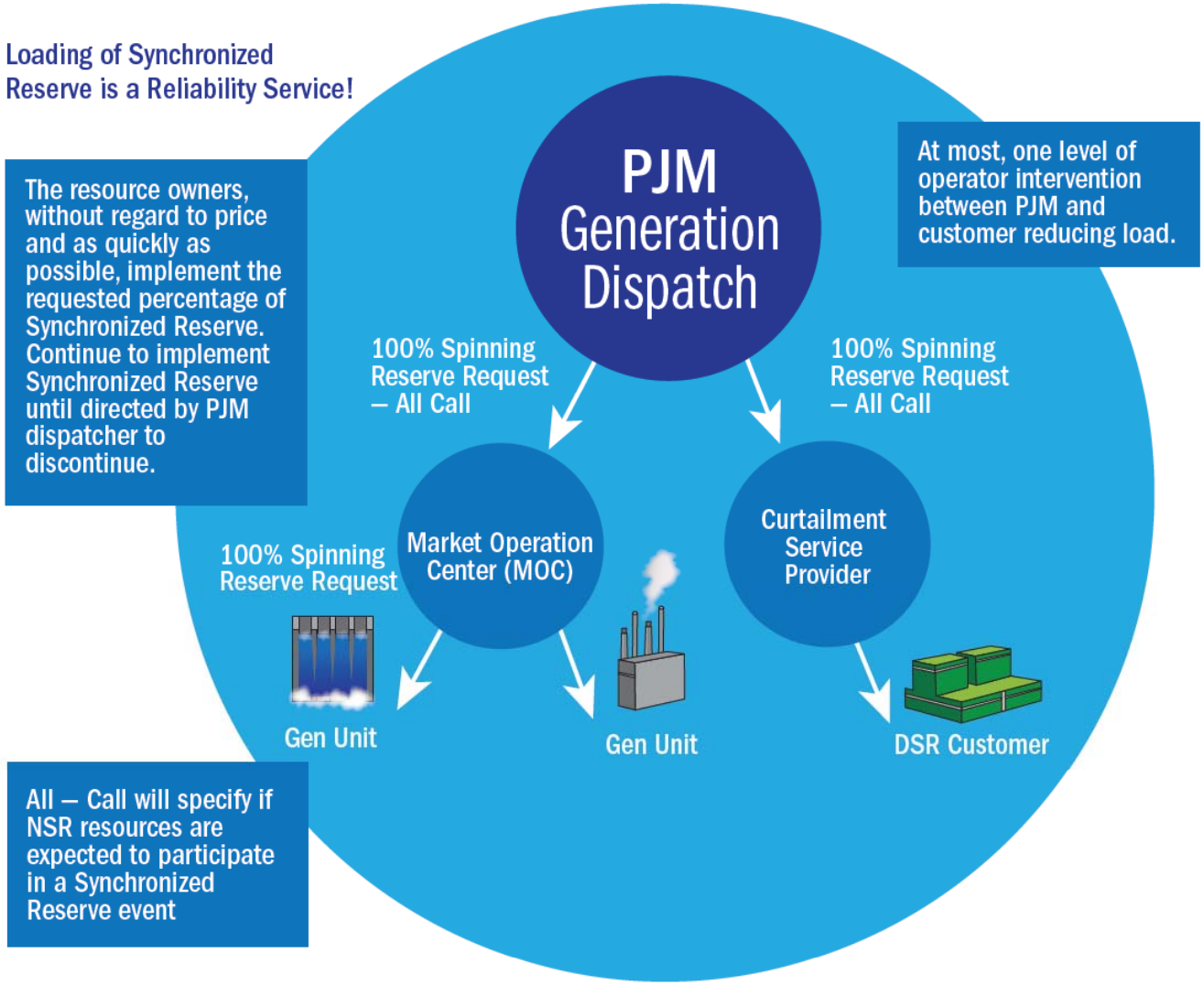
No Tier 1 estimate for Demand Response

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
    - Offer will be rejected by eMKT if greater than cost plus $7.50

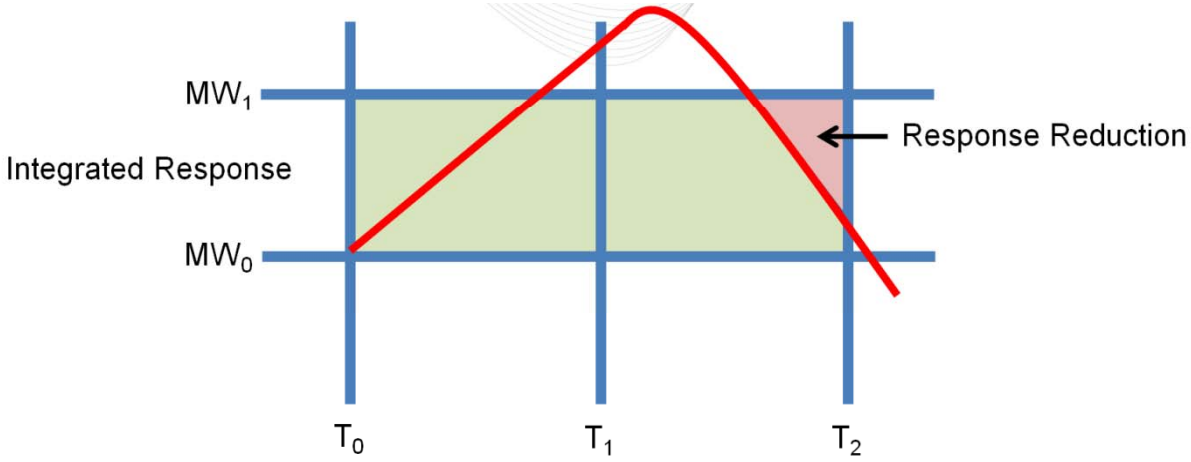
- Tier 2 required based on:
  - Zone Tier 2 Requirement = Zone Synchronized Reserve Requirement minus Tier 1 Estimate minus Available Transfer Capability (Reserve subzones only)
    - If adequate Tier 1 Synchronized Reserve is available (based on Tier 1 Estimate), Tier 2 Requirement is zero
      - SRMCP would be zero for this interval
- Amount of Tier 2 assigned comes from:
  - Tier 2 Assigned = Tier 2 Requirement minus Tier 2 Self Scheduled
    - Tier 2 Assignments are obtained from Synchronized Reserve Market Clearing
  - Resource effective cost includes Tier2 offer plus estimated opportunity cost plus energy usage, if any, plus condense startup costs
  - Condense start-up cost is spread over expected duration of commitment

Call for a Synchronized Reserve Event



Response Calculation / Verification

- Resource responses are verified by the PJM Performance Compliance department following each event
- Actual responses compared to assignments at start of a Synchronized Reserve event are used to determine penalties



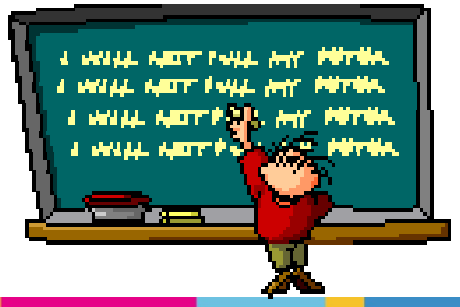
MW0 is the lowest output at T_0 (start) +/- one minute

MW1 is the highest output at T_1 (10 minutes, or event end, if sooner) +/- one minute

T_2 is the end of the event or 30 minutes past the start of the event

Penalties

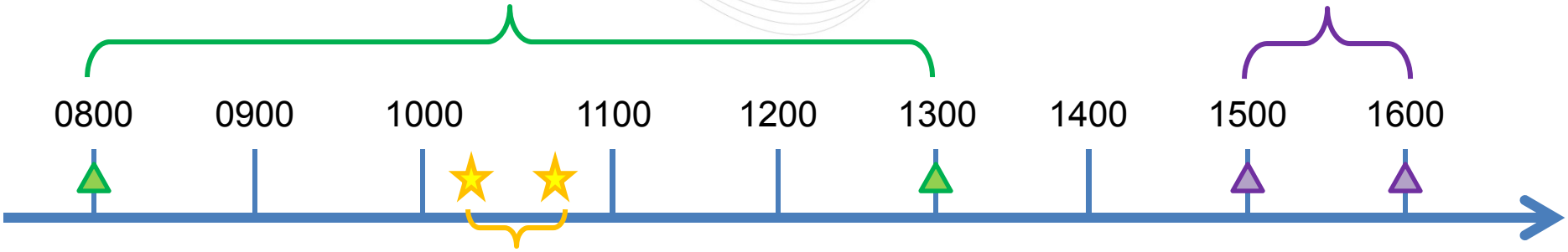
- No penalties exist for Tier 1 (payment made for actual response only)
- Tier 2 units that fail to respond to a Synchronized event when assigned or self-scheduled at the beginning of the event are penalized as follows:
  - Unit forfeits Tier 2 revenue for the amount of non-response over the contiguous hours the unit was assigned Tier 2 when the event occurred
  - The participant incurs a synchronized reserve obligation in the amount of the shortfall for the three (3), consecutive, same-peak days occurring at least three (3) business days following the event. The shortfall is prorated over the minutes of the event
  - Obligation penalty may be offset by over-response from other resources assigned or self scheduled Tier 2



Penalty Example

Unit first assigned 50 MW Tier2 at 0800, assignment continues through 1300

Unit assigned 50 MW of Tier2 again at 1500 through 1600



Synch reserve event occurs from 1015 to 1035
Unit fails to respond by 30 MWh

Unit forfeits 30 MW worth of Tier2 credit from 0800 until 1300

Penalties:

1) Resource will forfeit 30 MW worth of Tier 2 credit from 0800 until 1300

2) Company will incur 10 MW (30MW*20minute event/60 minutes) additional obligation for future three same peak days (Similar profile days)

Synchronized Reserve Obligation

- Who must acquire Synchronized Reserves?
  - All load serving entities (LSEs)
  - Obligation determined from real time load ratio share
  - Obligation is by reserve zone
- Obligation can be satisfied by:
  - enter bilateral transactions with other participants
  - purchasing from PJM Synchronized Reserve Market
    - ❖ Loads located in the MAD sub-zone will pay the MAD SRMCP
    - ❖ Loads located outside the MAD sub-zone will pay the RTO SRMCP

Tier1 Compensation

- Tier 1 Synchronized Reserve resources are compensated at the SRMCP when the NSRMCP is greater than $0
  - Reflects the value of the service provided by Tier 1 resources and the ability for these resources to be counted towards both the Synchronized Reserve and Primary Reserve requirements
- Allocated in proportion to the amount of Tier 1 applied to each participant's obligation

Tier 1 Compensation Details

This chart summarizes when Tier 1 resources will be credited.

Tier 1 Credits are calculated based on MWh * Price

Synch Reserve Event?	Non-Zero NSRMCP?	MWh Used	Price Used	Comment
No	No	N/A	N/A	No credit provided
No	Yes	Tier 1 Estimate	SRMCP	
Yes	No	Tier 1 Actual (capped at110% of the capability)	Premium Price	
Yes	Yes	Min (Tier 1 Actual, Tier 1 Estimate)	SRMCP	Treated like Tier 2 and compensated at SRMCP

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

- Is a market based mechanism for the procurement of supplemental, 30-minute reserves on the PJM System
- Settled through the Operating Reserve Credits and Charge allocation
- Preserves incentive for demand and supply to bid and offer into the day-ahead market based on their actual expectations.
- Preserves incentive for generation to follow real-time dispatch signals.
  - Generation guaranteed to make bid.
- Performed on a daily basis.

❑ Other Ancillary Services

- ➢ Reactive Supply and Voltage Control
- ➢ Black Start

- Purpose: To maintain transmission voltage within acceptable limits

- FERC approves reactive revenue requirements
- PJM calculates zonal rate
- Paid by transmission customers
- Credits go to generation resources and transmission owners

Reactive Supply (Schedule 2)

- Credits
  - Monthly credits are provided to generation and transmission owners with FERC-approved reactive revenue requirements
- Charges
  - Allocated to point-to-point customers based on monthly peak usage
  - Remaining revenue requirements not allocated for each zone are allocated to network customers based on monthly peak load

What is Blackstart Generation?

- Generating Unit that can start and synchronize to the system without having an outside (system) source of AC power
  - Generally Combustion Turbines or Hydro units
  - Critical for System Restoration
    - Starting point for restoring the power system following a complete System Shutdown
    - Used to provide start-up power to non-blackstart units
  - Location-specific
  - Benefits all Transmission Customers
  - Also includes generation that can “self-isolate” from power grid and remain operating
    - i.e. - Trip to house load

Black start (continued)

- Blackstart is a cost-based service - not a market
- Transmission Owners, with PJM identify critical blackstart units
- Restrictions on Blackstart Planned outages
- Generator annual revenue requirements submitted to PJM
- Annual Blackstart testing requirements in place

Questions?