Reserve Market Enhancements
Filing Summary

Energy Price Formation Senior Task Force

March 14, 2019

Ground Rules/Purpose of Meeting

- Special Session is intended to:
  - Facilitate understanding of proposed language for Section 206 filing on Energy Price Formation
    - Understanding of new terminology and concepts
    - Identify areas where more clarity is needed
  - Afford the opportunity for stakeholder questions on the proposed tariff language
- Not intended to allow debate over what is included in the PJM proposal
- Proposed tariff revisions are subject to additional editing – the current version should not be construed as final

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	Synchronized Reserve	Non-Synchronized Reserve	Secondary Reserve
General Market Description	1.7.19A	1.7.19A.01	1.7.19A.02
Must Offer	1.10.1A (j) (i) (1, 2)	1.10.1A (j) (i) (1, 2)	1.10.1A (m) (i) (1, 2)
Eligibility	1.7.19A	1.7.19A.01	1.7.19A.02
Offer Parameters			
Offer Price	1.10.1A (j) (i) (3)	1.10.1A (j) (i) (4)	1.10.1A (m) (i) (3)
SR Offer Price Calculation	1.10.1A (j) (i) (3)	N/A	N/A
SR Offer Price Cap Calculation Transition Plan	1.10.1A (j) (i) (3)	N/A	N/A
Econ LR Offers	1.10.1A (j) (iv)	N/A	1.10.1A (m) (iii)
Ability to Self-Schedule	1.10.3 (e)		

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	Synchronized Reserve	Non-Synchronized Reserve	Secondary Reserve
Updating Parameters in Real-time		1.10.9A(b); 1.10.9B	
Reserve Capability	1.10.1A (j) (ii) (1, 2, 4)	1.10.1A (j) (iii) (1, 2)	1.10.1A (m) (ii, iii)
ORDC		3.2.3A.02	
Market Clearing (commitment of resources)	1.11.4A (b)	1.11.4B (b)	1.11.4C (b)
Shortage Pricing	2.5 (d) DA: 2.6; RT: 2.5 (d)	2.5 (d) DA: 2.6; RT: 2.5 (d)	2.5 (d) DA: 2.6; RT: 2.5 (d)

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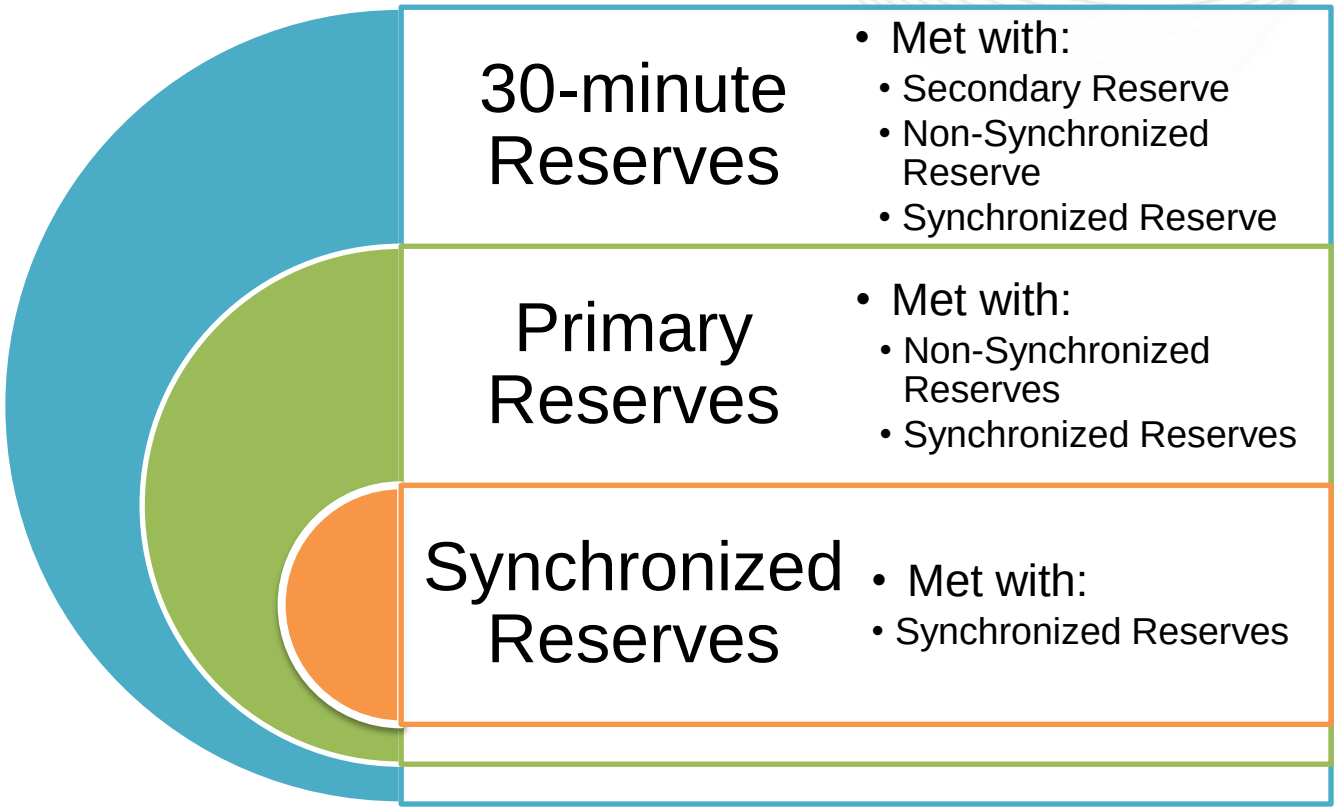
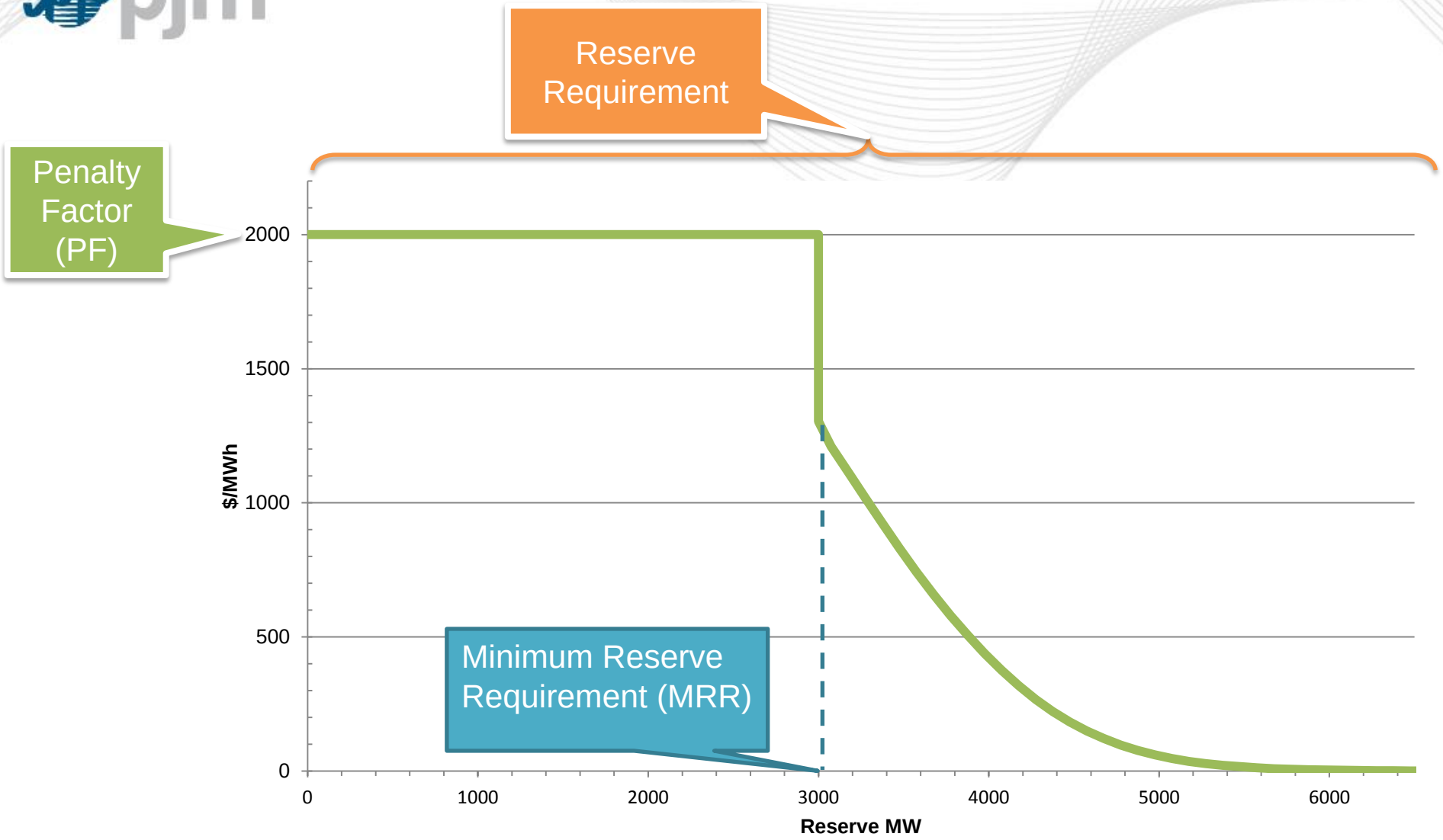
	Synchronized Reserve	Non-Synchronized Reserve	Secondary Reserve
LMP Calculations & Interaction with ORDC			
Day-ahead	2.6 (b)		
Real-time	2.5 (b)		
Calculation of Clearing Prices	3.2.3A (d)	3.2.3A.001 (c)	3.2.3A.01 (e)
Opportunity Cost used in clearing prices	3.2.3A (e)	3.2.3A.001 (d)	3.2.3A.01 (f)
Settlements			
LSE Charges	3.2.3A (a, h)	3.2.3A.001 (a, f)	3.2.3A.01 (a,)
Resource Credits	3.2.3A (b, f)	3.2.3A.001 (b)	3.2.3A.01 (b, c, d, g)
Non-Performance Penalties	3.2.3A (j, k, l)	3.2.3A.001 (g, h)	3.2.3A.01 (h)
Locational Reserve Zone Modeling	1.7.19A (b)	1.7.19A.01 (b)	1.7.19A.02 (b)

Defined Terms



- 30-minute Reserve: reserve capability of resources that can be converted fully into energy within 30 mins
- Primary Reserve: reserve capability of resources that can be fully converted into energy within 10 mins (can be Synch or Non-Synch)
- Secondary Reserve: reserve capability of resources that can be fully converted into energy within 30 mins less Primary Reserve capability

Defined Terms



General Revisions

- Energy Storage Resources are included in references to generation except where specifically addressed
- Demand Resource changed to Economic Load Response Participant Resource
- Reinstated Pre-Emergency / Emergency DR strike price language that was inadvertently removed through compliance filings for Order 831
  - Also made changes to static values rather than formulaic values based on penalty factors (1.10.1A(d))

Evolved Concepts

- The following areas have evolved subsequent to previous Stakeholder discussion:
  - Capping DR procurement at 50% of Synchronized Reserve and Secondary Reserve Minimum Reserve Requirement (MRR)
  - Reflection of EFORds in the ORDC
  - Calculation of LOC for Offline Resources
  - Self-scheduling availability for Secondary Reserves
  - Real-time treatment of inflexible resources with a DA reserve commitment
  - Secondary Reserve Non-Performance Penalty
  - Balancing Reserve Market Settlements
- Supporting slides are/will be posted to provide the rationale for the evolution

DR Procurement Cap

- The Board directed PJM to increase the cap on the quantity of Load Response can be assigned as Reserves to 50 percent of the requirement
  - Previously proposed to be capped at 33%
  - 50% Cap applied for Synchronized Reserve and Secondary Reserve
  - Cap applied at the Minimum Reserve Requirement (MRR), not the total cleared
  - Associated revisions are located in OA Schedule 1, sections 1.11.4A(b) and 1.11.4C(b)

Reflection of Forced Outages in the ORDC – New Approach

- PJM has modified its approach to model forced outages based on feedback from Monitoring Analytics (MA)
  - Specifically, PJM has adopted a similar version of the approach used by MA in their presentation to the PJM Board
- Basically, PJM now calculates the amount of forced outages (full and partial) that historically have occurred in 30-min (and 60-min) intervals as reported in eGADS
  - Then this MW quantity is combined with all the other errors measured at that same time T to derive the net-load error for time T

Reflection of Forced Outages in the ORDC - Net Load Error

- The Net-Load Error for time T is calculated per the following formula

Net Load Error = (Actual Load – Actual Wind Output – Actual Solar Output) – (Forecast Load – Forecast Wind Output – Forecast Solar Output) + Forced Outages Thermal Units – Regulation Requirement

Note: The Net Load Error that applies to the derivation of the 30-Minute Reserve ORDC also includes the Net Interchange Schedule Forecast error. Therefore, the formula above as shown in this slide only applies to the derivation of the SR and PR ORDCs

Reflection of Forced Outages in the ORDC - Example

- 30-min Net Load Error calculation for June 30th at 5:30 pm of a given year

Actual Load at 5:30pm: 130,000 MW
Forecasted Load (30-min ahead): 129,400 MW
Actual Wind at 5:30pm: 600 MW
Forecasted Wind (30-min ahead): 500 MW
Actual Solar at 5:30pm: 500 MW
Forecasted Solar (30-min ahead): 550 MW
Forced Outages between 5:00pm and 5:30pm: 300 MW
Regulation Requirement: 525 MW

30-min Net Load Error at 5:30pm = (130,000 – 600 – 500) – (129,400 – 500 – 550)
+ 300 – 525
30-min Net Load Error at 5:30pm = 550 + 300 – 525 = 325 MW

Calculation of LOC for Offline Resources

- Opportunity cost is the forgone energy revenues by a resource that provides ancillary services
- The LOC for offline Resources is $0
  - Consistent with current DASR implementation
  - Will apply to NSR and Offline Secondary Reserve in both DA and RT under this proposal
- DA and RT commitment tools will still take into account the trade off between providing energy and reserves (product substitution cost) when deciding whether to bring the unit online for energy or keep it offline to provide reserve
- Associated revisions are located in OA Schedule 1, sections 1.10.1A(j)(i)(4), 1.10.1A(m)(i)(3)

Comparison of LOC

- Inclusion of LOC in clearing, dispatch and pricing, and settlement

Status	Clearing	Dispatch/Pricing	Settlement
Online Gen	Yes (PSC)	Yes	Yes
Offline Gen	Yes (PSC)	No	No

- PSC – Product Substitution Cost

Calculation of LOC for Offline Resources Example

- Load = 300 MW
- Synchronized Reserve Requirement = 10 MW
- Primary Reserve Requirement = 25 MW

Unit	EcoMax MW	Energy Offer Price $/MWH	Eligible for Offline Reserve	Start up Cost	Reserve Capability MW
A	200	45	Yes	$0	10
B	200	50	Yes	$1000	10
C	500	58	Yes	$0	10
D	300	60	No	$0	10

Calculation of LOC for Offline Resources Example

- Solution with Unit B offline

Unit	Energy MW	EcoMax	SR MW	NSR MW	Energy Offer Price $/MWH	Energy Price $/MWH	SRMCP $/MWH	NSRMCP $/MWH
A	195	200	5	0	45	58	13	13
B	0	200	0	10	50	58	13	13
C	105	500	10	0	58	58	13	13
D	0	300	0	0	60	58	13	13

Unit B has start up cost of $1000

Unit D is not eligible for offline reserve

Total Production Cost = $14,865

Commitment Results from Example

- Unit A is cheapest and should provide EcoMax however unit A is dispatched down to meet Primary Reserve Requirement
- Opportunity cost (Energy Price – Unit A offer price) of $13 /MWH for online unit A is included in Reserve Clearing price
- Unit B looks cheaper based on energy offer price compared to system energy price however it is not cheaper than Unit C from production cost perspective
- Unit B earns more profit by providing offline Reserves rather than being online to provide Energy and Reserve as can be seen in next example
- Commitment tool takes into account product substitution cost to determine the optimal commitment for Energy and Reserve

Calculation of LOC for Offline Resources Example

- Solution with Unit B online

Unit	Energy MW	EcoMax	SR MW	NSR MW	Energy Offer Price $/MWH	Energy Price $/MWH	SRMCP $/MWH	NSRMCP $/MWH
A	195	200	5	0	45	50	5	5
B	105	200	10	0	50	50	5	5
C	0	500	0	10	58	50	5	5
D	0	300	0	0	60	50	5	5

Total Production Cost = $15,025

- Comparison of profit for unit B when the unit is online vs offline

	Unit B Online	Unit B Offline
Revenue	$5300	$130
Production Cost	$6250	$0
Profit	$0	$130

- Unit B will be made whole for $950 to its production cost if online
- Unit B is profitable staying offline which results in lower production cost

No LOC for offline resources

- LMP minus offer price is not a true opportunity cost for offline resources
- Reasons for unit to be offline:
  - Binding Constraints
  - Unit temporal parameters
  - Higher production cost
  - Others
- In RTSCED, PJM can only dispatch units already online
  - When RT LMP exceeds ITSCED LMP (where commitment happens), unit has no opportunity to capture the profit resulting from the higher LMP
    - Time to start
    - Self-scheduling has 20 minute notification requirement

Self-Scheduling in Reserve Markets

- Self-Scheduling permitted in the Synchronized Reserve Market (status quo)
- Self-Scheduling not permitted in the Non-Synchronized Reserve (status quo)
  - Cannot self-schedule a resource to be offline
- Self-Scheduling not permitted in the Secondary Reserve Market
  - Consists of both online and offline resources
    - Cannot self-schedule a resource offline – similar to Non-Synch Reserve
    - For online resources, self-scheduling Secondary Reserves presents a market power concern by withholding additional capability from the energy market
- Associated revisions are located in OA Schedule 1, section 1.10.3(e)

Real-Time Treatment of Inflexible Resources with a DA Reserve Commitment

- Inflexible resources (in the context of reserves) are defined as resources with min run or notification time restrictions
  - Includes synchronous condensers and Load Response
- In Real-Time, these resources are cleared in ASO one hour-ahead rather than every 5 minutes in RTSCED
  - If the forecasted ASO conditions do not support the commitment of the inflexible resource for reserves but actual RT conditions do, the opportunity to commit that resource for reserves has passed
  - Those reserve MWs may be met with other more expensive but flexible resources
  - The cost of this missed commitment is increased by having to make the resource whole for buying out of their DA reserve commitment
- To avoid this additional cost, PJM proposes that if an inflexible resource has an SR or Secondary Reserve assignment in Day-Ahead:
  - The Assignment will carry over into Real-Time
  - The Assignment will remain the same unless the optimization determines that the more economic solution is to dispatch the assigned reserves as energy

Secondary Reserve Non-Performance Penalty

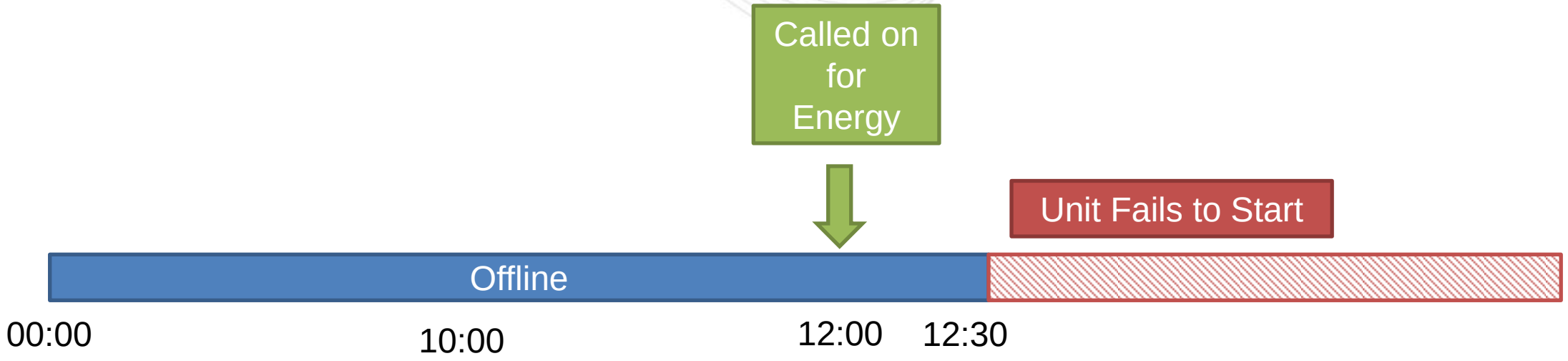
- Resources with Secondary Reserve Assignments must:
  - Come online and reach Economic Min within 30 minutes (offline units)
  - Reduce load up to Economic Min within 30 minutes (Load Response)
  - Follow economic dispatch once online
  - Failure to meet these provisions result in buy back of DA assignment at RT price or forfeiture of RT Secondary Reserve Credits
  - Online resources with Secondary Reserve assignments are not subject to the same non-performance penalty
- Associated revisions will be located in OA Schedule 1, section 3.2.3A.01(h)

Secondary Reserve Non-Performance Penalty – Generation

Offline units assigned Secondary Reserves are evaluated when dispatched for energy

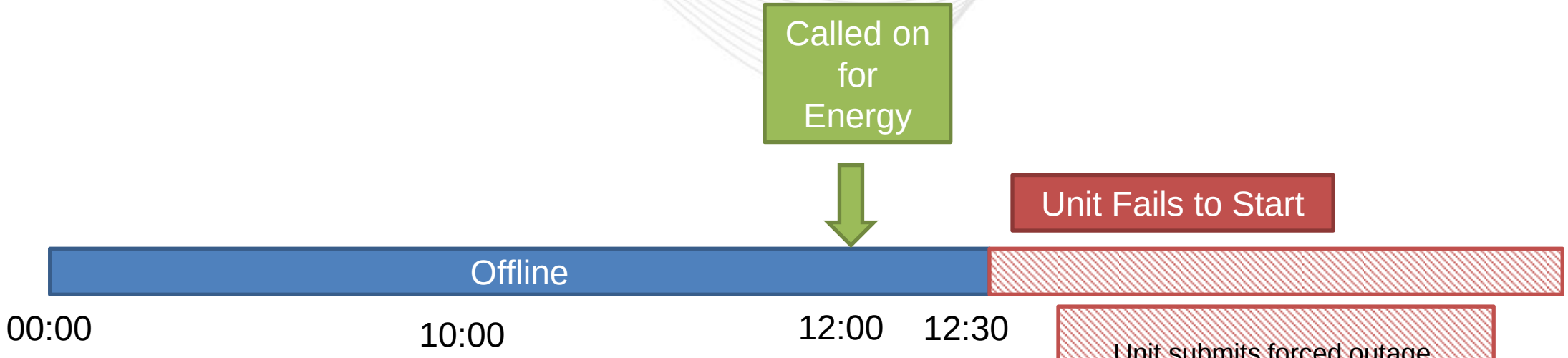
- Must be online and reach Economic Min within 30 minutes
- If unit fails to start within 30 minutes, RT Secondary Reserve assignment is set to 0 MW for all intervals prior* to when it failed, starting at the later of the last time off or the beginning of the day
  - If assigned Day-Ahead Secondary Reserves, results in buying back at RT price
  - If solely assigned in Real-Time, results in $0 Secondary Reserve credit
- *If failure to start, unit will take a forced outage (based on current rules) and will therefore not be considered for Secondary Reserves for subsequent intervals

Secondary Reserve Non-Performance Penalty
Example #1: Fail to Start in 30 mins



RT Secondary Reserve Assignment = 10 MW for all intervals from 00:00 – 12:30

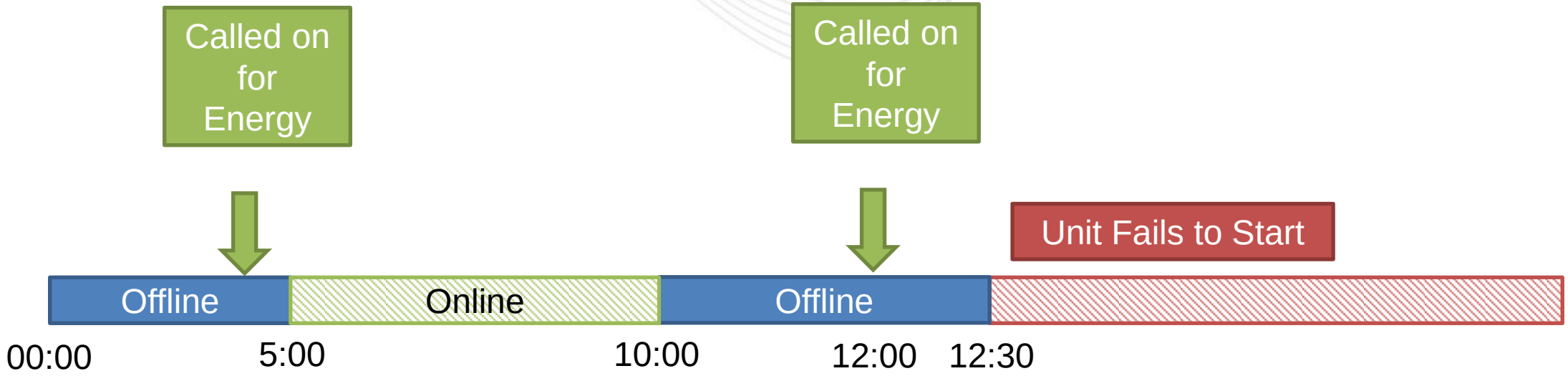
Secondary Reserve Non-Performance Penalty
Example #1: Fail to Start in 30 mins



RT Secondary Reserve Assignment = ~~10~~ MW for all intervals from 00:00 – 12:30

RT Secondary Reserve Assignment set to 0 for all intervals from 00:00 - 12:30

Secondary Reserve Non-Performance Penalty
Example #2: Fail to Start in 30 mins in second Dispatch

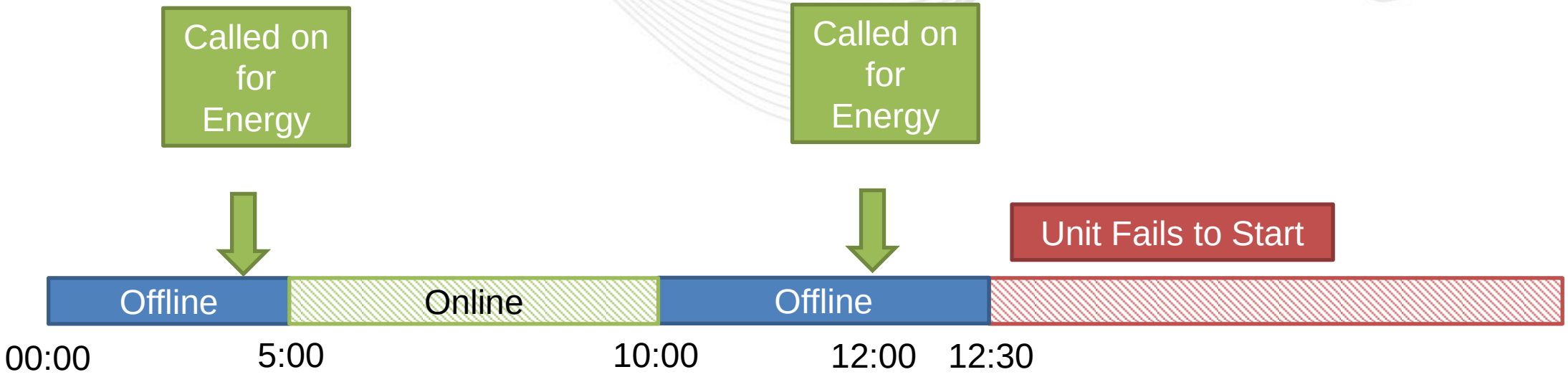


RT Secondary Reserve Assignment

Intervals 00:00 – 5:00 = 10 MW
Intervals 5:00 – 10:00 = 10 MW
Intervals 10:00 – 12:30 = 10 MW*

*Unit received a Day-Ahead Secondary Reserve assignment for these intervals for 10 MW

Secondary Reserve Non-Performance Penalty
Example #2: Fail to Start in 30 mins in second Dispatch



RT Secondary Reserve Assignment

Intervals 00:00 – 5:00 = 10 MW
Intervals 5:00 – 10:00 = 10 MW
Intervals 10:00 – 12:30 = 10 MW*

*Unit buys back 10 MW at the Real-Time price for these intervals

RT Secondary Reserve Assignment set to 0 for previous intervals starting at later of (last time off, beginning of Operating Day)

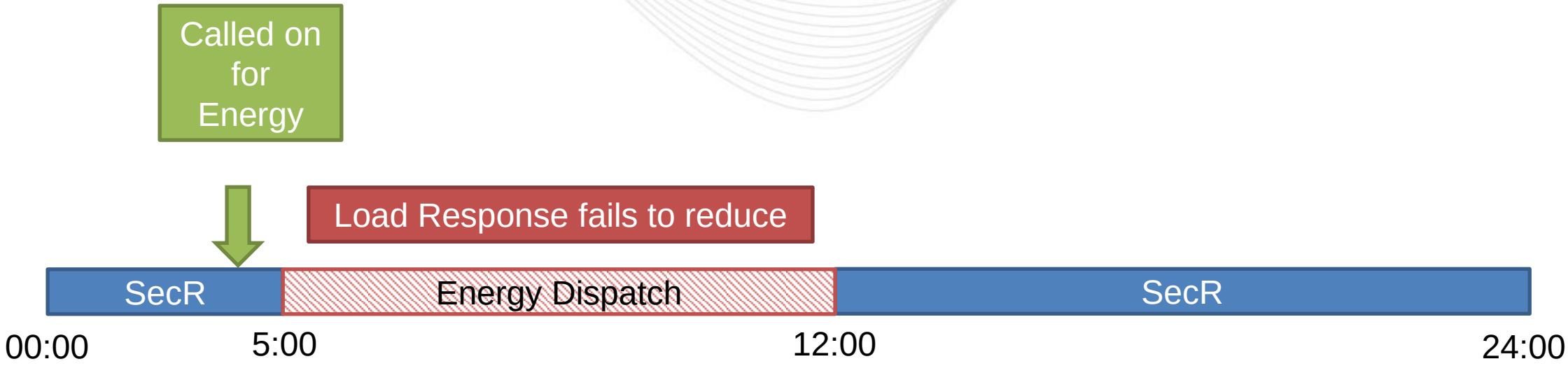
Intervals 00:00 – 5:00 = 10 MW
Intervals 5:00 – 10:00 = 10 MW
Intervals 10:00 – 12:30 = 0 MW

Secondary Reserve Non-Performance Penalty – Load Response

Load Response resources assigned Secondary Reserves are evaluated when dispatched for energy

- Must reduce load by their Economic Min within 30 minutes
- If failure to reduce by at least EcoMin within 30 minutes, RT Secondary Reserve Assignment is set to 0 MW for all intervals:
  - Starting at: the later of the end of the most recent energy dispatch period or the beginning of the Operating day
  - Until: the earlier of the next time the resource has an energy dispatch or the end of the Operating day
- If assigned Day-Ahead Secondary Reserves, results in buying back at RT price
- If solely assigned in Real-Time, results in $0 Secondary Reserve credit

Secondary Reserve Non-Performance Penalty
Example #3: Load Response fails to reduce in 30 mins



RT Secondary Reserve Assignment

Intervals 00:00 – 5:00 = 10 MW*
Intervals 5:00 – 12:00 = 0 MW
Intervals 12:00 – 24:00 = 10 MW

*Resource received a Day-Ahead Secondary Reserve assignment for these intervals for 10 MW

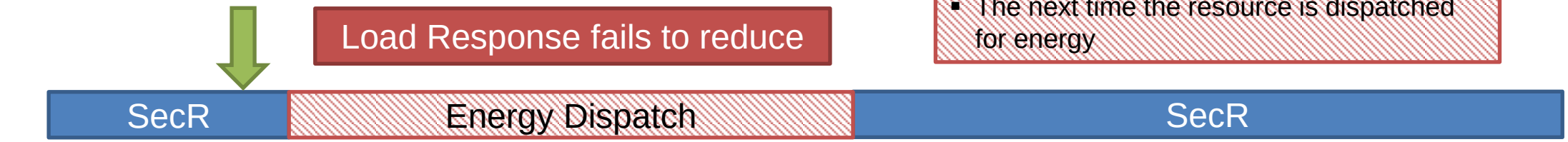
Secondary Reserve Non-Performance Penalty
Example #3: Load Response fails to reduce in 30 mins

Called on for Energy

Load Response fails to reduce

No Forced Outage concept for LR:
Any subsequent assigned Secondary Reserves are set to 0 MW until the earlier of:

- The end of the Operating day OR
- The next time the resource is dispatched for energy



RT Secondary Reserve Assignment

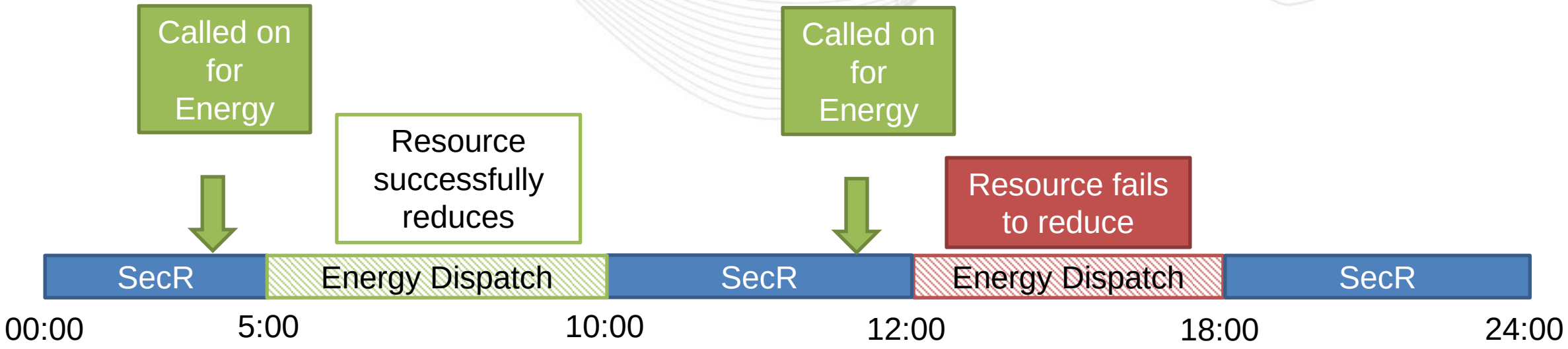
Intervals 00:00 – 5:00 = ~~10~~ MW*
Intervals 5:00 – 12:00 = 0 MW
Intervals 12:00 – 24:00 = ~~10~~ MW

*Resource buys back 10 MW at the Real-Time price for these intervals

RT Secondary Reserve Assignment set to 0 for previous intervals starting at later of (the end of most recent energy dispatch, beginning of Operating Day)

Intervals 00:00 – 5:00 = 0 MW
Intervals 5:00 – 12:00 = 0 MW
Intervals 12:00 – 24:00 = 0 MW

Secondary Reserve Non-Performance Penalty
Example #4: Load Response with multiple dispatch periods

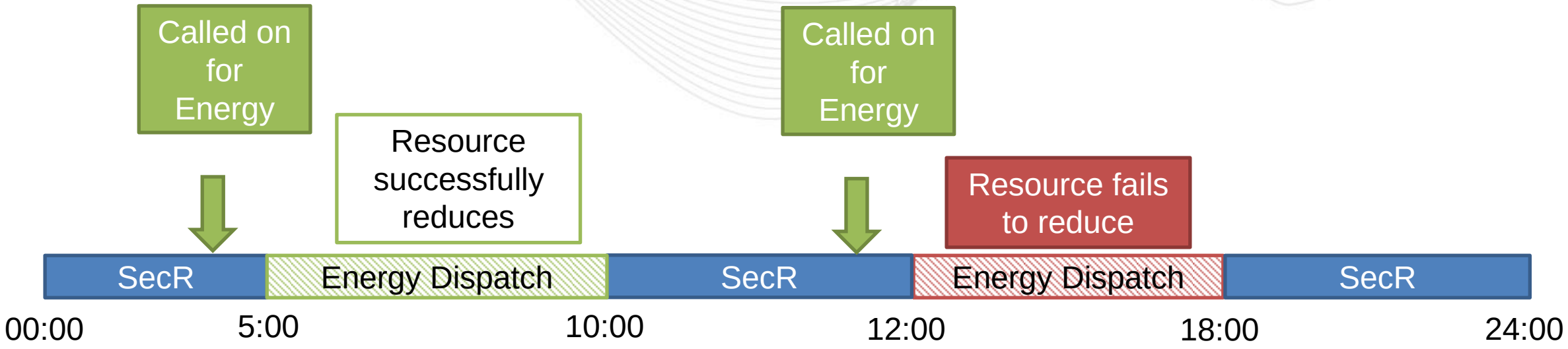


RT Secondary Reserve Assignment

Intervals 00:00 – 5:00 = 10 MW
Intervals 5:00 – 10:00 = 0 MW
Intervals 10:00 – 12:00 = 10 MW*
Intervals 12:00 – 18:00 = 0 MW*
Intervals 18:00 – 24:00 = 10 MW

*Resource received a Day-Ahead Secondary Reserve assignment for these intervals for 10 MW

Secondary Reserve Non-Performance Penalty
Example #4: Load Response with multiple dispatch periods



RT Secondary Reserve Assignment

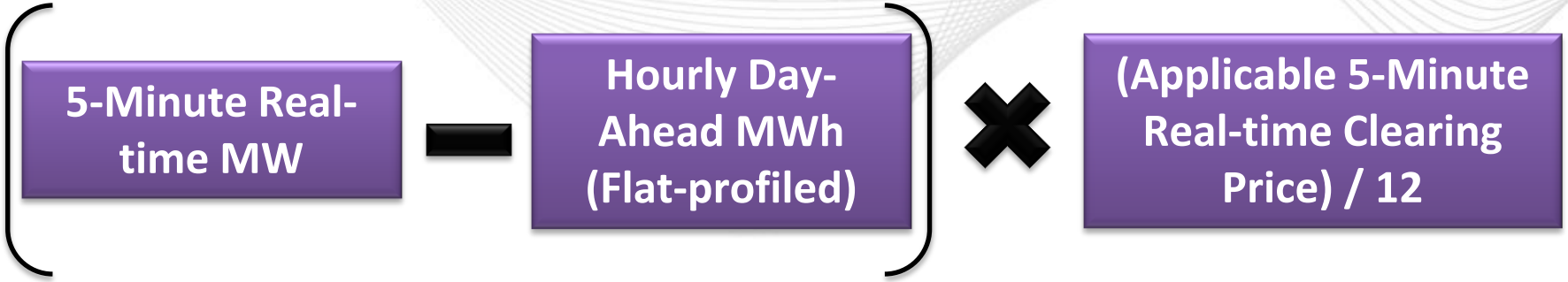
Intervals 00:00 – 5:00 = 10 MW
Intervals 5:00 – 10:00 = 0 MW
Intervals 10:00 – 12:00 = 10 MW*
Intervals 12:00 – 18:00 = 0 MW*
Intervals 18:00 – 24:00 = 10 MW

*Resource buys back 10 MW at the Real-Time price for these intervals

RT Secondary Reserve Assignment
set to 0 for previous intervals AND subsequent intervals

Intervals 00:00 – 5:00 = 10 MW
Intervals 5:00 – 10:00 = 0 MW
Intervals 10:00 – 12:00 = 0 MW*
Intervals 12:00 – 18:00 = 0 MW*
Intervals 18:00 – 24:00 = 0 MW

- Credit Calculations
  - DA Energy = Energy MWh * Total DA LMP
  - DA Sync Reserve = Cleared Sync MWh * DA SRMCP
  - DA Non-Sync Reserve = Cleared Non-Sync MWh * DA NSRMCP
  - DA Secondary Reserve = Cleared Secondary MWh * DA SECMCP



- Credit Calculations
  - Bal Energy = (RT MW – DA MW) * Total RT LMP
  - Bal Sync Reserve = (RT Sync MW – DA Sync MW) * RT SRMCP
  - Bal Non-Sync Reserve = (RT Non-Sync MW – DA Non-Sync MW) * RT NSRMCP
  - Bal Secondary Reserve = (RT Secondary Reserve MW – DA Secondary Reserve MW) * RT SECMCP

Evolved Concept - Credits for Energy and Reserve MWs

- Synchronized and Secondary Reserves
  - Balancing Reserve MW assignment is capped at the lesser of

    Reserve Assignment OR (Eco Max – RT Revenue Data for Settlements value)

    * Sync/Secondary Max is used if less than Economic Max

    * Sync Reserves - No capping occurs if there is a Synchronized Reserve Event
  - Eliminates payment for Energy and Reserves for the same MWs

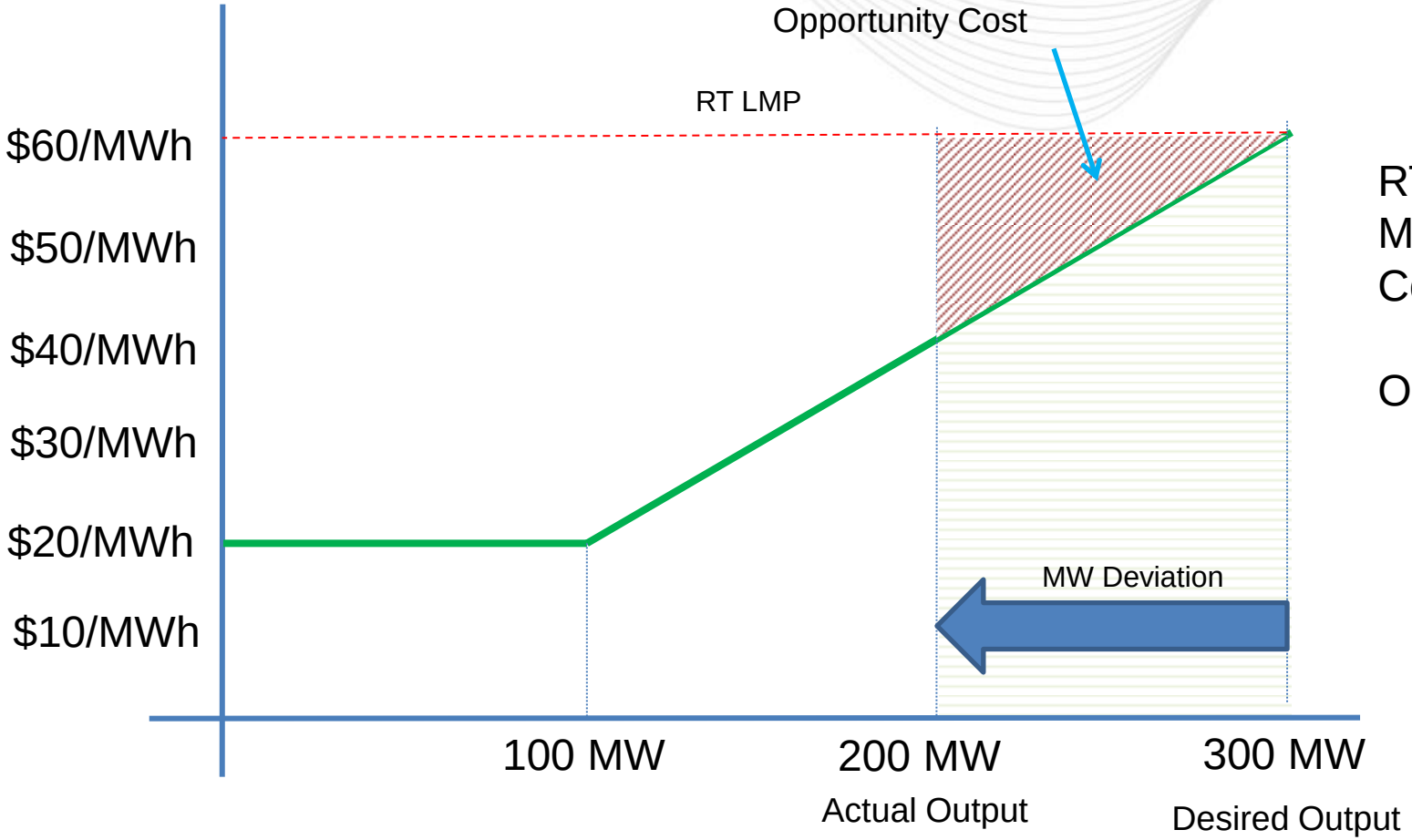
Opportunity Cost Calculation

- Day-ahead and Balancing Opportunity Cost calculated for each reserve market
- A Balancing Opportunity Cost only applies when the RT Reserve assignment is greater than the DA Reserve assignment

- Basic calculation

  (LMP * MW Deviation) – Integrated cost under the offer curve for the MW Deviation

Opportunity Cost Example



RT LMP = $60/MWh
MW Deviation = 100 MW
Cost = $5,000

Opp Cost = ($60/MWh * $100) - $5,000
= $1,000

New Concept - Reserve Market MW Shifts

- Based on Day-ahead and Real-time market clearing, resource MWs can shift between reserve markets or between reserve and energy markets
  - When PJM directs a MW shift between markets, losses created by buying back the DA reserve position are offset by additional profits earned in the other markets
- A shift in MWs can introduce additional revenues above cost that need to be accounted for in the final Lost Opportunity Cost Credit calculation

Lost Opportunity Cost Credit Calculation

Reserve Market Lost Opportunity Cost Credit =

Day-ahead Opportunity Cost +

Balancing Opportunity Cost –

(Day-ahead MCP Credit + Balancing MCP Credit) –

Reserve Market MW Shift Credit

New Concept - Additional Opportunity Cost

- For each reserve market, an additional opportunity cost can occur. Additional cost is included in the Balancing Operating Reserves make whole calculation.
  - For the same assigned reserve MWs in both Real-time and Day-ahead, calculate a Real-time Opportunity Cost in excess of the Day-ahead Opportunity Cost

	Day-ahead	Real-time
LMP ($/MWh)	40	50
SynchReserveMW (MWh)	50	30

$25/MWh Offer Price
Reduced Synch Reserve commitment

Opp Cost = 30 MW * [(RT LMP – Offer) – (DA LMP – Offer)]
= 30 MW * [($50 - $25) – ($40 - $25)]
= 30 MW * $10
= $300

Allocation of Reserve Markets Credits

- Credits allocated as charges to real-time load consistent with current reserve market allocation

- Keeps reserve balancing settlement within the reserve market structure