Operating Reserve Clarification for Resources Operating as Requested by PJM:
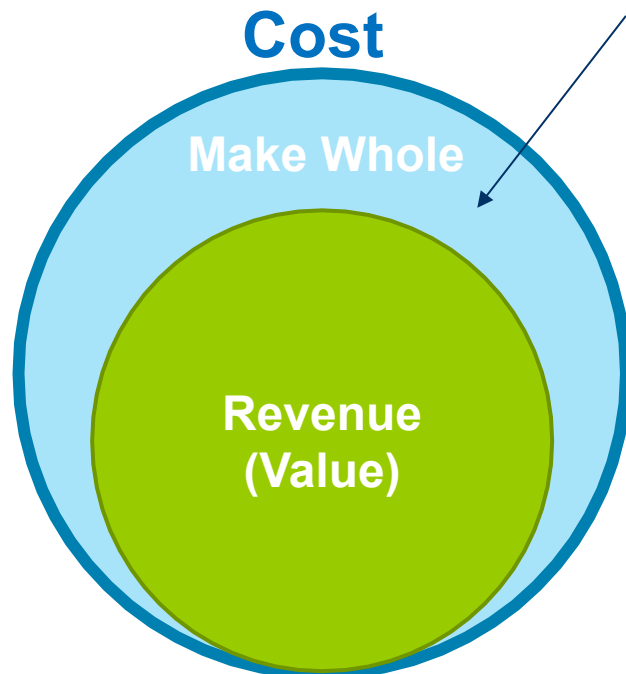
PJM Incentives to Follow Dispatch

May MIC

- Uplift payments are intended to function as one of the incentives for generation owners to offer their energy to the PJM energy market for dispatch based on short run marginal costs and to operate their units as directed by PJM operators.

- Balancing Operating Reserve credits, which are one component of uplift in the PJM market, are a primary means of ensuring resources are not economically disadvantaged for following operating instructions in the real-time energy market.

- Balancing Operating Reserve deviation charges further incent generators to follow PJM real-time dispatch instructions

- Recap how the balancing make whole credit calculation creates an incentive to operate as requested by PJM

- Understand how balancing operating reserve generator deviation charges create an incentive for following dispatch.

- Understand the parallels between the balancing operating reserve make whole credit calculation and the generator deviation charge calculation.

Make whole credits are paid for pool scheduled resources when their revenues do not cover the costs represented in their offers.

Make Whole Credit = Cost minus Value (floored at zero)

Cost

Make Whole

Revenue (Value)

Cost = Total resource offer amount for generation, including startup and no-load costs as applicable

Value = Amounts credited in the energy markets and net profit from the ancillary services markets

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Make Whole Credit	=	Cost			-	Value										
↳	=	RT MW Used	*	$/MWh Offer	-	(Balancing Value MW Used	-	DA MW)	*	RT LMP	+	DA Revenue	+	DA Operating Reserve Credit		
↳	=	Min(Operating Reserve Desired MW, RT MW)	*	$/MWh Offer	-	(Max (Min(DA MW, Op Res Desired MW), RT MW)	-	DA MW)	*	RT LMP	+	DA MW * DA LMP	+	DA Operating Reserve Credit		

This minimizes the cost that can be recovered through the make whole calculation to no more than the MW actually desired by PJM

This maximizes the positive value that can be used to offset any costs, reducing the uplift when the resource over generates.

Similarly, when the resource generates below the desired MW, it excludes any negative buy out from the resource's DA position beyond that which was the result of PJM's dispatch instructions, thus reducing uplift and shifting the cost responsibility to the generator.

Opportunity for cost recovery is maximized when a resource follows dispatch

PJM conducts Balancing Operating Reserve Cost Analysis to determine reason why Operating Reserve credit is earned so charges can be properly allocated

- Total daily cost of operating reserve in balancing market related to resources identified as **Credits for Reliability** is allocated based on regional shares of real-time load (without losses) plus exports

- Total daily costs of BOR related to resources identified as **Credits for Deviations** is allocated based on regional shares of real-time locational deviations from day-ahead scheduled or otherwise desired quantities
  - **Cleared generation offers not following PJM dispatch instructions**
  - Cleared Demand Resources not following cleared Day-Ahead offer
  - Cleared INC offers and external purchase transactions
  - Cleared demand bids, DEC bids, UTCs, and external sale transactions

Total MW Deviations of Participant (by Region)

✖

Regional Rate for BORs for Deviations

$$\frac{\text{Total BOR Credits for Deviations}}{\text{Total Deviation MW}}$$

- RTO region defined as East region, West region, & exports that are at interfaces or hubs not completely contained in either East or West region

- West region defined as AEP, AP, ATSI, ComEd, DEOK, DUQ, Dayton, & EKPC transmission zones

- East region defined as AE, BGE, DOM, Penelec, PEPCO, Meted, PPL, JCPL, PECO, Delmarva, PSEG, & Rockland transmission zones

- Dispatchable pool-scheduled generation resources and dispatchable self-scheduled generation resources that **follow** dispatch **are not** assessed balancing Operating Reserve deviations.

- Generation resources that **do not** follow dispatch **are** assessed balancing Operating Reserve deviations.
  - The deviation MW used to assess deviation charges is calculated by comparing the resource's real-time output to the desired MW level, which in most cases is based on real-time prices and dispatch instructions.
  - This creates greater incentive for generators to follow PJM real-time dispatch instructions rather than their day-ahead schedule.

- The deviation charge calculation recognizes that generators are not able to follow the dispatch signal perfectly and excuses small deviations.
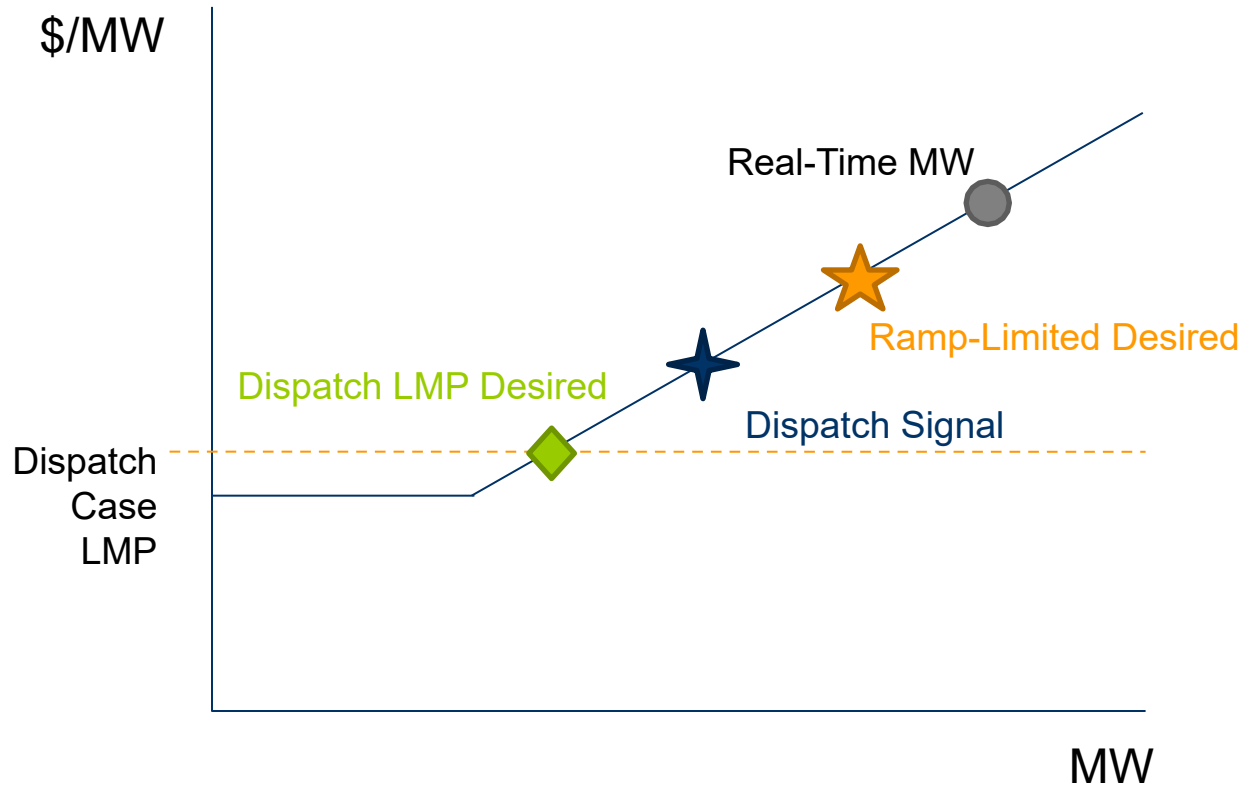
There are several MW values used in the determination of generator deviations. Many of these are also used in the Desired MW value in the balancing make whole credit calculation.
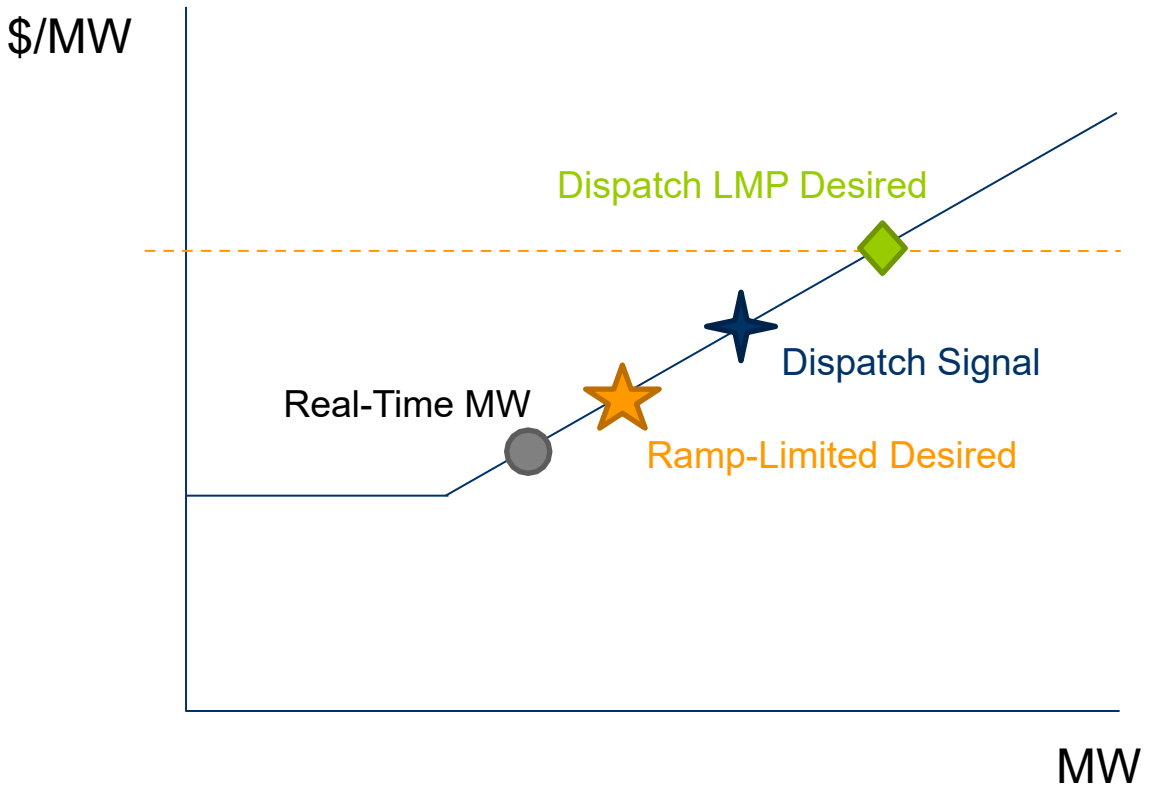
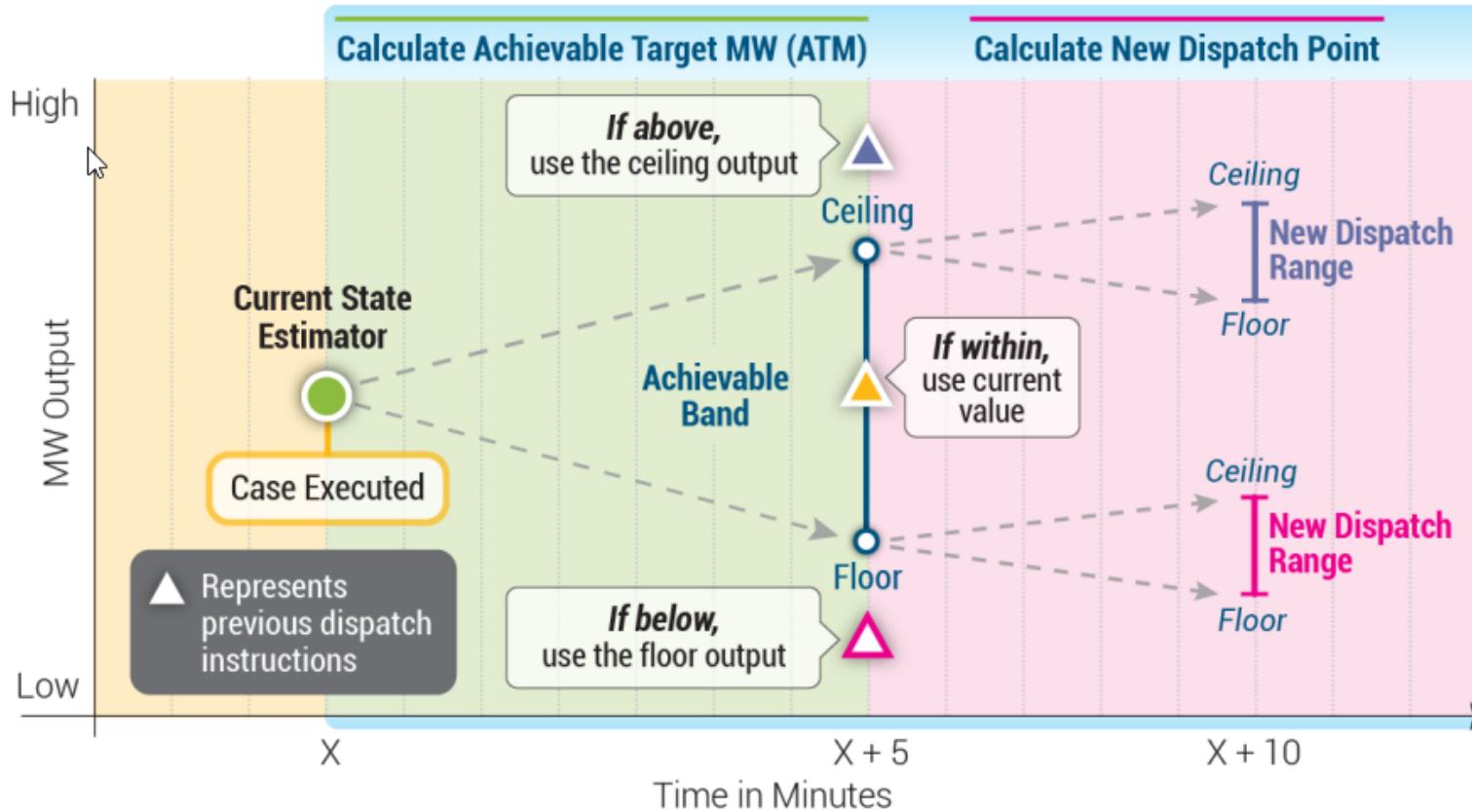| Desired MW Type	Explanation
Ramp-limited Desired (RLD)	Output level that a resource should have achieved between dispatch signals based on submitted ramp rate and dispatch instruction.
Dispatch signal or UDS Basepoint	Output level requested via the dispatch basepoint issued by PJM's real-time dispatch tools. This value is time-weighted based on how long the dispatch signal is effective.
Dispatch LMP Desired	Output level desired based on the intersection of dispatch LMP and the incremental offer curve. This value is not ramp limited.
Day-Ahead MW	Generator's day-ahead market schedule

Achievable Target MW & Impact of Not Following Dispatch

Achievable Target MW, and therefore Ramp Limited Desired, is heavily influenced by SE MW and ramp rate. If a unit does not follow dispatch consistently, the Ramp Limited Desired value will not be reflective of where the unit would have been desired had it been following dispatch. This creates a limit on the amount of deviations that can be assessed, and the desired MW that can be factored into the make whole credit calculation.

Ramp-limited Desired prorates the MW expected from a resource based on how long the dispatch case was in effect.

Ramp-limited Desired is determined as follows:

$$Ramp\_Request_t = {}^{(Dispatchtarget_{t-1} - AOutput_{t-1})}\!\big/\!_{(LAtime_{t-1})}$$

$$RL\_Desired_t = AOutput_{t-1} + (Ramp\_Request_t * Case\_Eff\_time_{t-1})$$

Example:

Ramp Request = (110 MW – 100 MW / 10 minutes)
= 1 MW/min

RL_Desired = 100 MW + (1 MW/min * 5 min)
= 105 MW

Value	Definition	Example
Dispatch target	Dispatch Signal for the previous approved Dispatch case	110 MW
AOutput	Unit's achievable target MW at case solution time	100 MW
LAtime	Dispatch look ahead time	10 minutes
Case_Eff_time	Time between signal changes or between start of case and end of 5 min interval.	5 minutes
RL_Desired	Ramp Limited Desired MW	105 MW

RT MW Influence on Ramp-Limited Desired and Dispatch Signal

Ramp rate = 1MW/Min

5-Minute Interval End	RT Gen (MW)	Ramp Limited Desired	Dispatch Signal		RT Gen (MW)	Ramp Limited Desired	Dispatch Signal
		Dispatch up				Dispatch down	
:05	100	105	110		100	95	90
:10	100	105	110		100	95	90
:15	100	105	110		100	95	90
:20	100	105	110		100	95	90
:25	100	105	110		100	95	90
:30	99	104	109		99	94	89
:35	101	106	111		101	96	91
:40	100	105	110		100	95	90
:45	100	105	110		100	95	90
:50	100	105	110		100	95	90
:55	100	105	110		100	95	90

All other resources are considered to be not dispatchable or dispatchable, but not following dispatch, and will go through the deviation MW calculation.

The desired MW level used to calculate generator deviations varies based on the operational characteristics of the generator and how closely it follows PJM's dispatch instructions. The deviation calculation will be based on one of the following:

Not Dispatchable:
Real-Time MW – Day-Ahead MW

Following Dispatch:
No Deviations

Not Following Dispatch:
Real-Time MW – Ramp-Limited Desired MW OR
Real-Time MW – Dispatch LMP Desired MW

- For generators that are considered not dispatchable,

> **Deviation = Real-Time MW – Day-Ahead MW**

- This applies to:
  - Pool or self-scheduled generators that are not dispatchable in both the Day-Ahead and Real-Time Market (Fixed Gen Flag is used)
  - Generator with a day-ahead schedule that either trips or does not run in real-time
  - Self-scheduled generators with limited dispatchable range
    - Economic maximum limit ≤ 110% of economic minimum limit
  - Self-scheduled generator that is not economic at economic min output
    - Self-scheduled resource not dispatched by PJM above its economic minimum, unless it is lowering its output in accordance with PJM direction in response to minimum generation emergency event (or declaration)

- If deviation MW is within $\pm$5% of day-ahead MW, deviations are set to zero

In order for a generator to be considered following dispatch closely enough to be exempted from the deviation calculations, it must be:

a) A pool-scheduled resource

OR

b) A dispatchable self-scheduled resources dispatched above economic minimum

(self-scheduled, but willing to be dispatched by PJM and economic for the interval)

AND

a) Actual output is between Ramp-Limited Desired MW and Dispatch Basepoint
(within the bounds of what is achievable based on ramp rate and the dispatch basepoint)

OR

a) % off dispatch <= 10%

Some resources providing ancillary services are also excluded from the calculation of BOR deviations.

% Off Dispatch is calculated in reference to the Dispatch Signal and Ramp Limited Desired MW

> **% Off Dispatch = the lesser of the following:**
>
> |Real-Time MW - Dispatch Signal| / Dispatch Signal or
>
> |Real-Time MW - Ramp Limited Desired MW| / Ramp Limited Desired MW

However, if Dispatch Signal or Ramp Limited Desired are unavailable*, % Off Dispatch is determined using Dispatch LMP Desired

> **% Off Dispatch =**
>
> |Real-Time MW - Dispatch LMP Desired MW| / Dispatch LMP Desired MW

*Unavailable means they are unavailable due to technical reasons or a reasonable Ramp Limited Desired or Dispatch Signal cannot be calculated because the Fixed Gen flag is used or Economic minimum and Economic maximum are not at least as far apart in real-time as they are in day-ahead as determined by:

- RT eco min > 105% DA eco min or DA eco min plus 5 MW, whichever is greater
- RT eco max < 95% DA eco max or DA eco max minus 5 MW, which ever is lower

Some resources providing ancillary services are considered following dispatch for this purpose and excluded from the deviation calculation. This is because deviations are potentially created through the provision of the service. Exclusion from deviations reinforces the incentive for them to respond to requests for ancillary services.
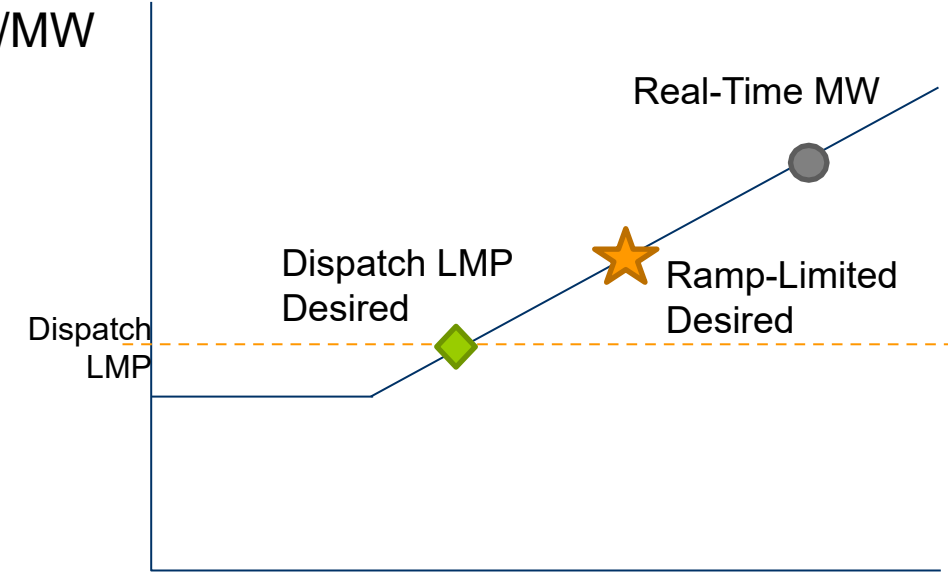
Five-minute intervals during which a generator is assigned by PJM for the following are not assessed deviations:

1. Regulation **OR**

2. Tier 2 Synchronized Reserve (and actual MW are less than day-ahead scheduled MW) **OR**

3. Non-Synchronized Reserve (and actual MW are less than day-ahead scheduled MW) **OR**

4. Tier 1 Synchronized Reserve that responds to a reserve event

Pool-scheduled and dispatchable self-scheduled generators that are deemed to not be following dispatch are assessed deviations based on their % off dispatch.
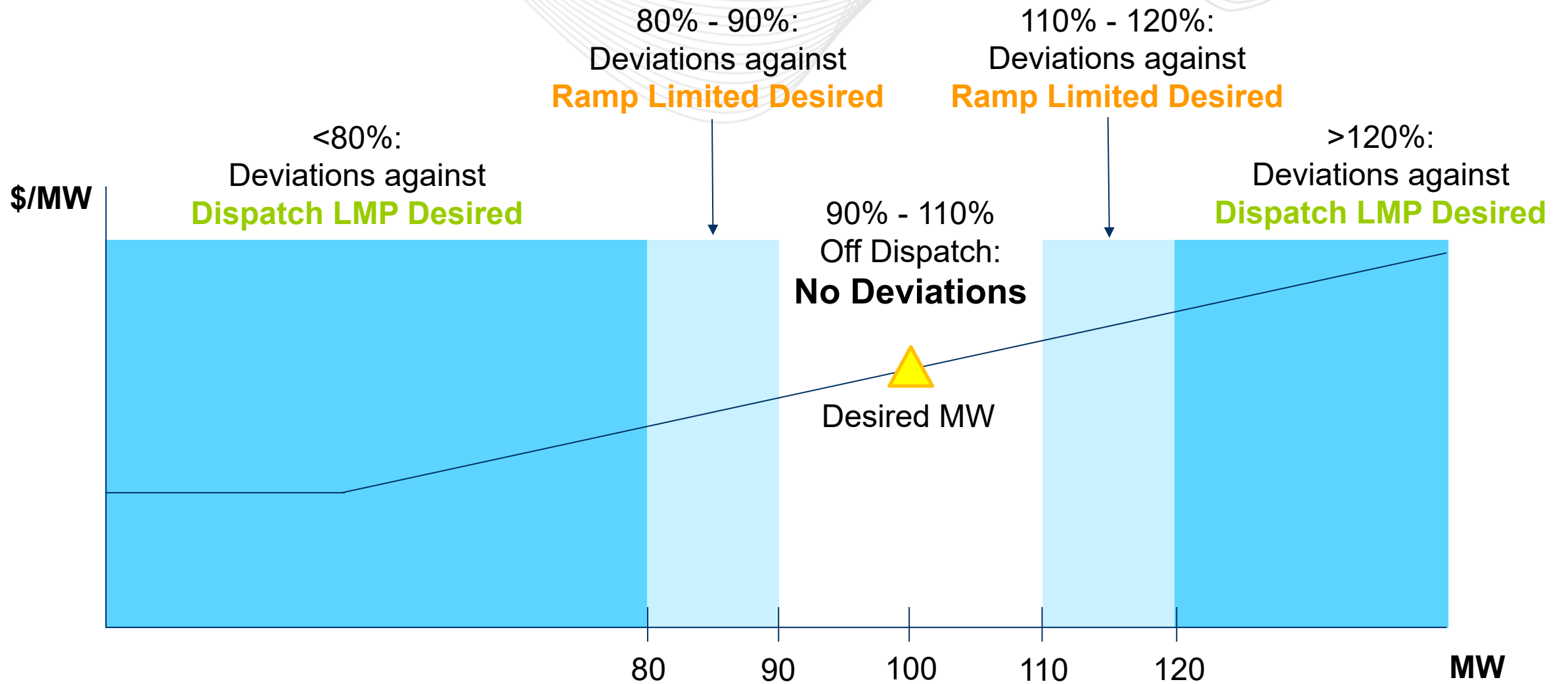
$/MW

When % off dispatch is greater than **10%**:

Deviation MW = Real-Time MW – Ramp-limited Desired MW

When % off dispatch is greater than **20%**:

Deviation MW = Real-Time MW – Dispatch LMP Desired MW

Real-Time MW

Dispatch LMP
Desired

Ramp-Limited
Desired

Dispatch
LMP

As a generator's % off dispatch increases, they are assessed deviations against the Dispatch LMP Desired MW, which is a non-ramp limited value and results in larger deviations. This acknowledges the influence of the generator's RT output and ramp rate on the Dispatch Signal and Ramp-Limited Desired MW values.

80% - 90%:
Deviations against
Ramp Limited Desired

110% - 120%:
Deviations against
Ramp Limited Desired

<80%:
Deviations against
Dispatch LMP Desired

>120%:
Deviations against
Dispatch LMP Desired

$/MW

90% - 110%
Off Dispatch:
No Deviations

Desired MW

80   90   100   110   120   **MW**

- For generators that should be dispatchable, but are not following dispatch because they provided a limited dispatch range in real-time,

> **Deviation = Real-Time MW – Dispatch LMP Desired MW**
>
> Increased deviations for a resource that offers limited flexibility

- This applies to:
  - Generators that were dispatchable day-ahead but use the Fixed Gen flag in real-time
  - Generators that clamp their limits in real-time as compared to day-ahead and it affects their dispatch

    (Unit's real-time economic minimum > Day-ahead Economic Minimum by 5% or 5 MW, whichever is greater **OR**

    Unit's real-time economic maximum < Day-ahead Economic Maximum by 5% or 5MW, whichever is lower)

    AND

    Dispatch LMP Desired MW is either below real-time economic minimum or above real-time economic maximum, respectively

- Generator injections at same bus are electrically equivalent as far as their impact on electric system

- Generators that deviate from real-time dispatch may offset deviations by another generator at same bus

- For deviations purposes, these two units look like one unit

5-Minute Interval

1. Assess generator eligibility for deviations using current business rules

2. If not dispatchable or not following dispatch, calculate generator deviation MW

3. If generator deviation MW ratio is within 5%, deviations are set to zero.

4. Apply supplier netting for units located at "single bus"

Hour

1. Average the 5-minute generator deviation MW across the hour

2. If average generator deviation <= 5 MW, deviations are set to zero

Day

1. Total Generator Hourly Deviations

Operating Reserve Generator Deviation Example

5-Minute Interval End	DA Cleared (MW)	**OR Desired Gen (MW)**	**RT Profiled Gen (MW)**	Gen Deviation Eligibility	Gen Deviation Ratio	**RT Deviation (MW)**
:05	200	200	0	Yes	100%	200
:10	200	200	0	Yes	100%	200
:15	200	200	0	Yes	100%	200
:20	200	200	0	Yes	100%	200
:25	200	200	0	Yes	100%	200
:30	200	200	0	Yes	100%	200
:35	200	100	100	No	N/A	0
:40	200	98	100	Yes	2%	0
:45	200	40	100	Yes	150%	60
:50	200	150	100	Yes	33%	50
:55	200	200	100	Yes	50%	100
1:00	200	200	100	Yes	50%	100
						126

Hourly average of 5-minute intervals

Table 4-34 Operating reserve rates ($/MWh): 2020 and 2021

if they

Rate	2020 ($/MWh)	2021 ($/MWh)	Difference ($/MWh)	Percent Difference
Day-Ahead	0.012	0.016	0.004	35.8%
Day-Ahead with Unallocated Congestion	0.012	0.016	0.004	35.8%
RTO Reliability	0.030	0.071	0.042	140.6%
East Reliability	0.010	0.013	0.003	27.5%
West Reliability	0.001	0.002	0.001	129.8%
RTO Deviation	0.161	0.268	0.107	66.3%
East Deviation	0.050	0.060	0.010	19.7%
West Deviation	0.006	0.009	0.003	52.6%
Lost Opportunity Cost	0.117	0.139	0.022	18.8%
Canceled Resources	0.000	0.000	NA	N/A
Dispatch Differential Lost Opportunity Cost	NA	0.001	NA	N/A

Source: 2021 PJM State of the Market report

Deviation Charge rates are relatively small given the costs assigned to deviations are spread across all injections, withdrawals and generation deviations.

- The balancing make whole credit and the balancing operating reserve deviation charge calculations both create incentives to operate as requested by PJM.

- Given the relatively low charge rate, generation deviation charges alone are not sufficient to incent resources to follow PJM's dispatch instructions.

- Strengthening the incentives within the balancing make whole credit calculation is most impactful.

  – Parallel changes in the generation deviation charge calculations should be considered given the shared logic around desired MW.

Possible areas of improvement include:

- Ramp Limited Desired

  - An important component in determining make-whole credits and generation deviation charges

  - The degree to which a unit follows PJM's signals can influence the Ramp Limited Desired MW

    - The unit's SE MW can limit the degree to which the dispatch software can move the unit

  - Is there a more appropriate MW value to use as a reference point?

- The practice of setting desired MW equal to actual MW for combustion turbines

  - Means these resources do not incur deviations and are always made whole to actual

  - At the time the rule was implemented, combustion turbines were incapable of following PJM's dispatch signal

  - Provide a better incentive for current technology to follow PJM's dispatch signal

2. Clarify what it means to "operate as requested by PJM" as it relates to the payment of Operating Reserve Credits. This includes but is not limited to:

a) How closely a resource must follow PJM's real-time dispatch signal or other desired MW in order to be considered operating as requested by PJM.

b) How the determination of whether resources are coming on line and going offline, consistent with PJM's operating instructions, is made.

c) How Combustion Turbines (CTs) that do and do not have a dispatchable range are treated in this definition.

d) How the use of the Fixed Gen flag impacts the determination of whether a resource is considered to be operating as requested by PJM or not.

e) Ways in which the definition of "operating as requested by PJM" as it pertains to the calculation of Balancing Operating Reserve Credits may differ from the definition of "following dispatch" that is used for the purpose of calculating Balancing Operating Reserve Deviation Charges.

3. Establish alternative rules addressing the MW level to which Balancing Operating Reserve Credits should be paid to resources found not to be closely following PJM's commitment and dispatch instructions (where needed in order to create strong incentives for resources to operate consistent with such instructions).

4. Clarify the rules and process to disqualify resources from Balancing Operating Reserve Credits when they operate outside of their unit specific parameters and such operation was not the result of an actual constraint.