MARKET SURVEILLANCE COMMITTEE

Scarcity pricing background discussion

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Topics

Reserve shortage pricing mechanics

Summary observations on trends

ISO reserve shortage pricing designs

Concluding observations

Reserve shortage pricing mechanics

Reserve shortage pricing

Real-time reserve shortage pricing as implemented by most North American ISOs has two elements: real-time co-optimization of energy and ancillary service schedules and the use of penalty prices for reserve shortages.

- With real-time co-optimization of energy and ancillary service schedules, when the system is short of reserves the dispatch of generation to meet an incremental megawatt of load will reduce the level of reserves by one megawatt.
- If a penalty price is associated with reserve shortages, the change in production costs from meeting a megawatt of load will be the sum of the energy offer price and the penalty price for an incremental megawatt of reserve shortage (if the ISO allows a real-time offer price the price would reflect any avoided costs reflected in the offer price).

Reserve shortage pricing

Thus, if the transmission system were short of 10 minute reserves with a penalty price of $500, and the lowest cost resource that could be dispatched to meet load had an energy offer price of $125, the price at that location would be set at $625.

- Software vendors have used penalty prices associated with constraint violations since the 1980s to ensure that dispatch software violated constraints in a defined sequence.
- Until 2005 these penalty prices were set at arbitrarily large values to ensure that the software exhausted all options for satisfying the constraints before violating them.
- When all of the constraints could not be satisfied, the constraints would be relaxed (set at a value at which the system can be dispatched so that they should just barely not be violated) in a sequence consistent with the penalty prices. Market prices would be set by the offer price of the incremental resource dispatched to meet load when the constraint is relaxed.

Reserve shortage pricing

Instead of relaxing constraints (setting them at values such that the system can be dispatched so that they will just barely not be violated) when they cannot be satisfied, reserve shortage pricing allows constraints to be violated and sets penalty prices for these violations at values that reflect the estimated reliability cost of violating the constraints.

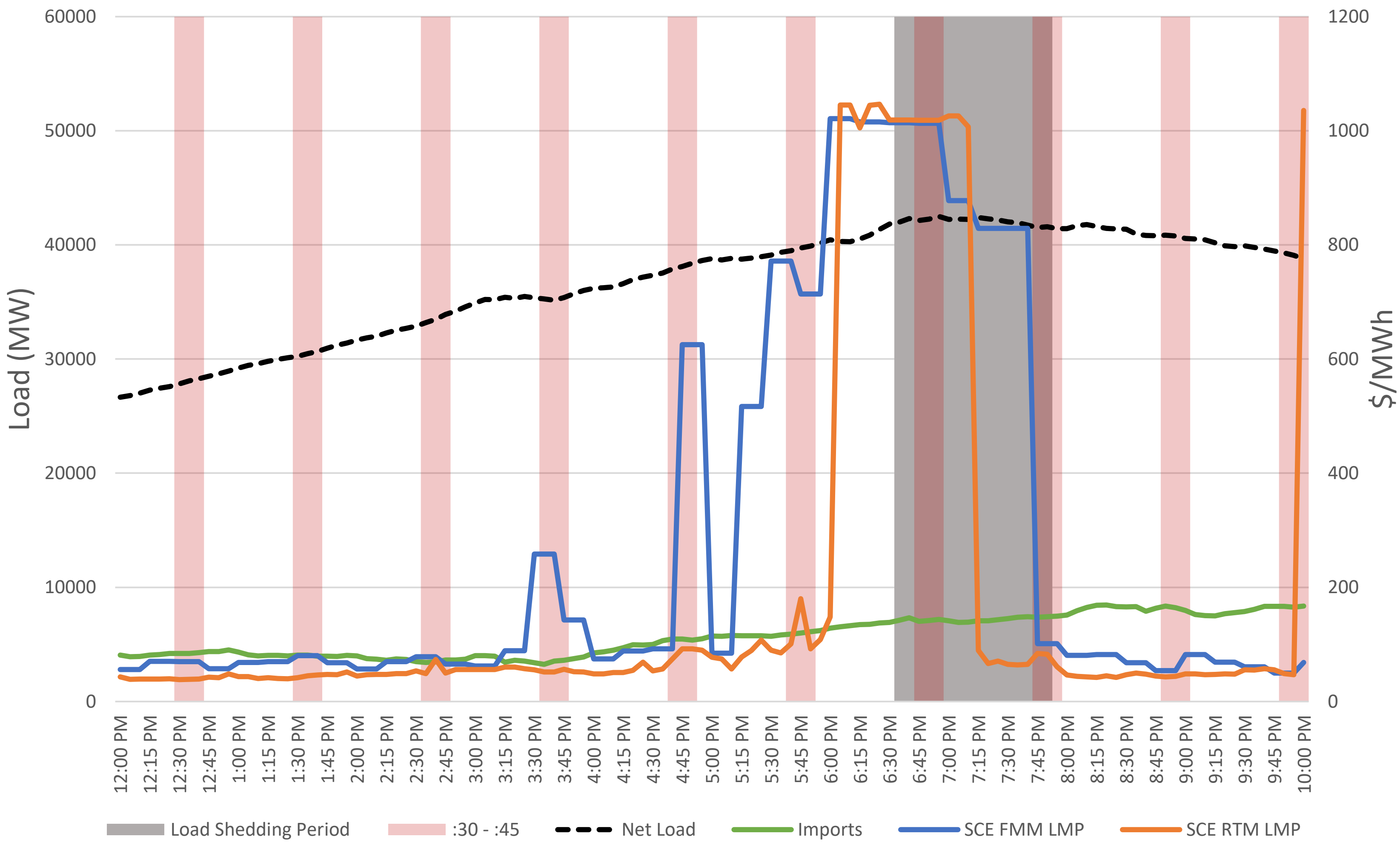
- With such a design, the dispatch software will incur production costs up to the penalty price to satisfy the reserve constraint, and if the reserve constraint cannot be satisfied at the cost set by the penalty price, the dispatch software will violate the constraint.
- When the dispatch software violates a reserve constraint, it will set both energy and reserve prices at levels that reflect the penalty cost of violating the reserve constraint.
- The dispatch could use two sets of penalty prices, a higher set in the pass that determines schedules or dispatch instructions and a lower set of penalty prices in the pass that determines prices.

Reserve shortage pricing

The CAISO day-ahead market and real-time software uses penalty prices in this manner, with higher penalty prices used in the scheduling pass than in the pricing pass.

- However, the CAISO currently enforces reserve requirements with arbitrarily large penalty prices in the real-time dispatch, so that instead of going short of reserves to balance load and generation, there will normally be a power balance violation.
- With this design, ramp constraints can result in power balance violations in the CAISO real-time dispatch, although the power balance constraint could have been satisfied by dispatching capacity scheduled to provide reserves.
- It is not clear what occurred on August 14 to allow prices to be set at levels that did not reflect a power balance violation when the CAISO was in a stage 2 emergency and presumably therefore short of reserves.

Reserve shortage pricing? August 14



Reserve shortage pricing

Reserve shortage penalty prices can be used to ensure that dispatch and scheduling software respects mandatory reserve requirements to the extent possible and appropriately prices violations of these requirements.

- Reserve shortage prices can also be used to cause the dispatch and scheduling software to meet other discretionary reserve targets at lower penalty prices.
- The CAISO software already models the flexiramp constraint in this way. The penalty price for the flexiramp constraint is set at values that vary from $0 to $247 depending on the amount that fleixramp procurement falls short of the target.
- As has been discussed in the flexiramp improvements stakeholder process, however, flaws in the flexiramp implementation have resulted in the outcome in which the constraint is almost always satisfied in the flexiramp evaluation, even when less than the target amount of capacity can actually be dispatched to meet CAISO net load uncertainty.

Summary observations on trends

Observations on trends

1. There has been a trend towards increasing 30 minute reserve targets (NYISO, Ontario and ISO New England) or the introduction of 30 minute reserves targets (PJM and MISO) over the past 8-10 years.
2. There has been a trend towards higher shortage pricing levels either directly reflected in reserve shortage prices (NYISO, ISO New England and PJM and under consideration in MISO) or through pay for performance pricing incentives (PJM and ISO New England).[1]
3. There has been a trend towards either defining reserve penalties as continuous penalty curves (ERCOT and PJM, MISO considering), or introducing more steps in the penalty functions (NYISO 30 minute reserves).

1. This has also occurred in ERCOT but ERCOT is less comparable to the CAISO because ERCOT operates an energy only resource adequacy design.

Observations on trends

4. There has been a trend in the last few years towards co-optimizing energy and ancillary services in both the day-ahead market and real-time dispatch among the ISOs that did not already do this.
   - NYISO has done this since 2005, and MISO since 2009.
   - PJM will introduce co-optimization in both day-ahead market and real-time for all reserve products in 2022.
   - The IESO will introduce co-optimization in a day-ahead market, as well as in real-time, with its Market Renewal Design.
   - ERCOT is moving forward with introducing co-optimization in real-time as well as in the day-ahead market.
   - The introduction of real-time co-optimization requires that the ISO have methods or systems that avoid scheduling reserves at locations where they will be bottled.

Observations on trends

5. There has been a trend towards replacing reserve requirements managed through ad hoc operator actions with explicitly modeled reserve requirements.
   - NYISO SENY reserve target 2015, New York City reserve target 2019.
   - MISO short-term reserves (2021 implementation).
   - CAISO contingency modeling enhancements, to be implemented.
6. There is a trend towards ISOs taking on the additional complexity associated with dynamic locational reserve targets, or at least to begin consider taking that step.
7. There has been a concern in several markets (MISO, NYISO and PJM in particular) with the potential for inflexible demand response to impact price signals during shortage conditions in a way that could deter other supply responses. This concern has been or is in the process of being addressed in different ways ("scarcity pricing" in NYISO, "emergency pricing" in MISO and "closed loop interface pricing" in PJM.)

Reserve shortage pricing designs

- New York ISO
- ISO New England
- MISO
- PJM
- SPP
- IESO
- ERCOT

Reserve shortage pricing designs

This section reviews the reserve pricing designs of most North American ISOs and discusses some of the evolution in these designs with the goal of providing an understanding of where these designs are headed.

- All of these designs other than that of ERCOT are based on real-time co-optimization of energy and ancillary service schedules and prices.
- The ERCOT design dates back to when ERCOT envisioned that prices in its energy only market would be set by hockey stick bids during shortage conditions, so ERCOT does not currently co-optimize energy and ancillary service schedules.
- With the introduction and refinement of the ORDC, ERCOT no longer relies on hockey stick bids to set prices during shortage conditions. ERCOT is now moving towards implementing co-optimization of energy and ancillary service schedules.

Reserve shortage pricing designs

This review will start with the reserve shortage pricing design of the New York ISO.

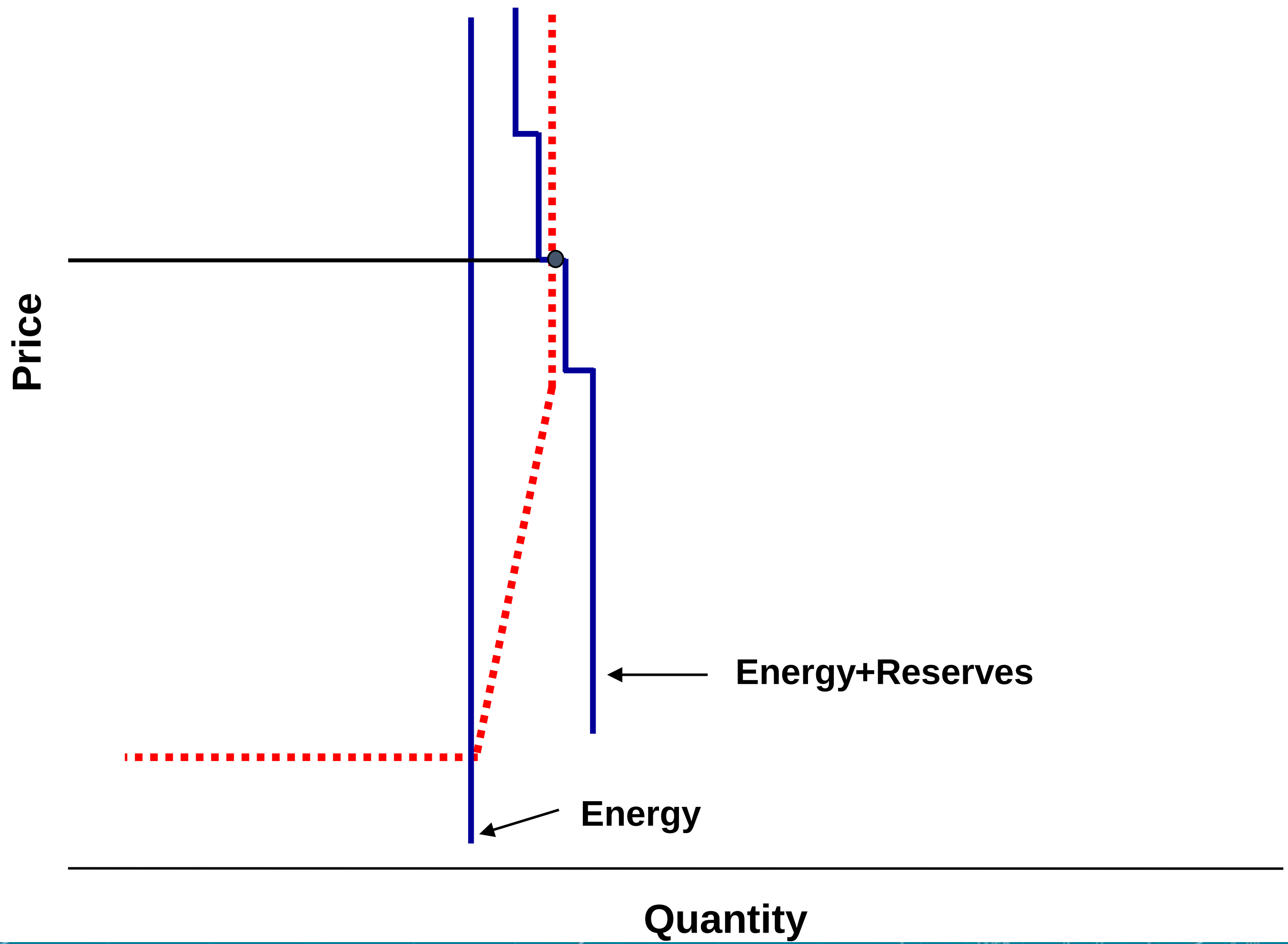
- The New York ISO design provides a good starting point because the concept of reserve shortage pricing originated in the New York ISO and the New York ISO shortage pricing design has gone through several rounds of refinement that are useful in illustrating the evolution of the design concept.
- The slides then review the designs of the other North American ISOs, illustrating both variations on the New York ISO design and common design elements and evolving goals.

NYISO reserve and regulation shortage pricing

New York ISO 2002

The New York ISO uses the term "shortage pricing" to refer to prices set by the penalty prices for shortages of reserves or regulation.

- The New York ISO uses the term "scarcity pricing" to describe the pricing rules that are applied when the NYISO activates demand response.
- This presentation will focus on what the NYISO calls "shortage pricing."


Price
Energy+Reserves
Energy
Quantity

New York ISO 2002

The New York ISO implemented what was in effect a demand curve for 30-minute reserves during summer 2002.

- The amount of 30-minute reserves purchased was reduced both day ahead and in the real time interchange scheduling and unit commitment process (called BME) by:
  - 200 MW if the shadow price of reserves exceeded $50/MW.
  - By another 200 MW if the shadow price exceeded $100/MW.
  - And by another 200 MW (to zero) if the shadow price of 30-minute reserves exceeded $200/MW.

The reserve shortages did not set prices directly in the real-time dispatch which did not enforce the 30-minute reserve constraints, but when the New York ISO scheduling software did not schedule very high cost imports (which would be price taking in real-time) to maintain 30-minute reserves, real-time prices tended to rise when the NYISO went short of 30-minute reserves.

New York ISO 2002

The NYISO implemented this demand curve for 30-minute reserves while complying with NPCC and NERC reserve requirements by identifying recallable exports as reserves in amounts corresponding to the reduction in internal reserves.

- With this design, the NYISO would continue to identify 1,800 MW of 30-minute reserves, but as little as 1,200 MW might be available internally.
- This design was the first step towards use of a reserve demand curve and gave the NYISO experience to point to when it took the next step.

New York ISO 2005

New York ISO Reserve Shortage Values 2005 – March 2011	
Regulation Shortages	
< 25MW	$250/MW
25-80MW	$300/MW
More than 80MW	$400/MW
Total Spinning Reserves	$500/MW
Eastern 10-Minute Reserves	$500/MW
Total 10-Minute Reserves	$150/MW
Total 30-Minute Reserves	$50/100/200/MW
Eastern Spinning Reserves	$25/MW
Eastern 30-Minute Reserves	$25/MW
Long Island Spinning Reserves	$25/MW
Long Island 10-Minute Reserves	$25/MW
Long Island 30-Minute Reserves	$300/MW

New York ISO 2005

The NYISO SMD2 design, implemented February 1, 2005, drew upon these initial steps to introduce explicit shortage pricing for 30-minute, 10-minute total and 10-minute spinning reserves, as well as regulation, in the day-ahead and real-time markets.

- Shortage values were set at $25 for reserve targets that reflected operator practice, rather than any New York State, NPCC or NERC requirement.
- The NYISO attempted to set other shortage values at levels consistent with the cost of the actions operators would take to meet these targets.
- The shortage values were additive.
- Since a shortage of spinning reserve could not persist unless the NYISO were also short of 10-minute and 30-minute reserves, a statewide spinning reserve shortage would result in prices in excess of $850/MWh ($200 +$150 + $500), without regard to the level of energy offer prices.

New York ISO 2011

New York ISO Reserve Shortage Values 2005 – March 2011	
Regulation Shortages	
25MW	$80/MW
25-80MW	$180/MW
More than 80MW	$400/MW
Total Spinning Reserves	$500/MW
Eastern 10-Minute Reserves	$500/MW
Total 10-Minute Reserves	$450/MW
Total 30-Minute Reserves	$50/100/200MW
Eastern Spinning Reserves	$25/MW
Eastern 30-Minute Reserves	$25/MW
Long Island Spinning Reserves	$25/MW
Long Island 10-Minute Reserves	$25/MW
Long Island 30-Minute Reserves	$25/MW

New York ISO 2011

In 2011, the NYISO implemented several changes to the initial reserve[1] shortage values that had been in place since February 1, 2005.

- Raised the shortage value for total New York Control Area 10-minute reserves (previously $150 per megawatt) to $450 per megawatt, to better reflect the cost of converting 30-minute reserves to 10-minute reserves by starting 30-minute gas turbines.
- Reduced the shortage value for Long Island 30-minute reserves (previously $300 per megawatt) to $25 per megawatt.
- Reduced the penalty prices for going short on regulation capacity by 180 megawatts or less, enabling the dispatch to balance generation and load when ramp constraints bound.

1. See NYISO filing in Docket ER11-2454-000, December 21 2010

New York ISO 2015

New York ISO Reserve Shortage Values 2015 to 2020	
Regulation Shortages	
25MW	$25/MW
25-80MW	$400?MW
More than 80MW	$775/MW
Total Spinning Reserves	$775/MW
Eastern 10-Minute Reserves	$500/MW
Total 10-Minute Reserves	$750/MW
Total 30-Minute Reserves	$25/100/200/750/MW
Eastern Spinning Reserves	$25/MW
Eastern 30-Minute Reserves	$25/MW
SENY 30-Minute Reserves	$25/$500MW
Long Island spinning Reserves	$25/MW
Long Island 10-Minute Reserves	$25/MW
Long Island 30-Minute Reserves	$25/MW

New York ISO 2015

In 2015, the NYISO implemented several refinements to the reserve shortage values implemented in 2011.[1]

1. The NYISO modified its regulation shortage prices to make some capacity reserved to provide regulation available to balance generation and load in the dispatch at a low price ($25/MW), while raising the penalty price for large regulation shortages to reduce the potential for the NYISO to go short on regulating capacity to support incremental exports.
2. The NYISO raised the shortage price for total spinning reserves, total 10 minute reserves, east 10 minute reserves and for large shortages of 30 minute reserves.

1. See NYISO February 18, 2015 filing in Docket ER15-1061.

New York ISO 2015

3. The NYISO increased its 30-minute reserve target from 1965 MW to 2620 MW and limited the amount of reserves located on Long Island that would count towards meeting this target.
4. The NYISO implemented a 30-minute reserve requirement for SENY (South East New York) to price a reserve requirement that had previously been managed through operator actions.
   - This penalty price was initially set at $25/MW when these changes were implemented on November 4, 2015 but rose to $500/MW on June 1, 2016 when other market design changes were implemented. [1]
   - The $500/MW shortage value was set to be consistent with the cost of demand response activation that NYISO operators would take to avoid shortages of SENY reserves.

1. See Potomac Economics, 2016 State of the Market Report for the New York ISO Markets, May 2017, Analytical Appendix p. A-130

New York ISO 2015

	2005-2011	2011-2015	2015-2019
Regulation Shortage			
< 25 MW	$250	$80	$25
> 25 MW; < 80	$300	$180	$400
> 80 MW	$400	$400	$775
Eastern Spinning Reserves			
	$25	$25	$25
Long Island Spinning Reserves			
	$25	$25	$25
Total Spinning Reserves	$500	$500	$775

New York ISO 2005-2019

	2005-2011	2011-2015	2015-2019
Ten Minute Reserves			
east	$500	$500	$775
Long Island	$25	$25	$25
Total	$150	$450	$750
30 Minute Reserves			
east	$25	$25	$25
SENY	n.a.	n.a.	$25/$500
Long Island	$300	$25	$25
Total	$50/100/200	$50/100/200	$25/100/200/750

New York ISO 2019

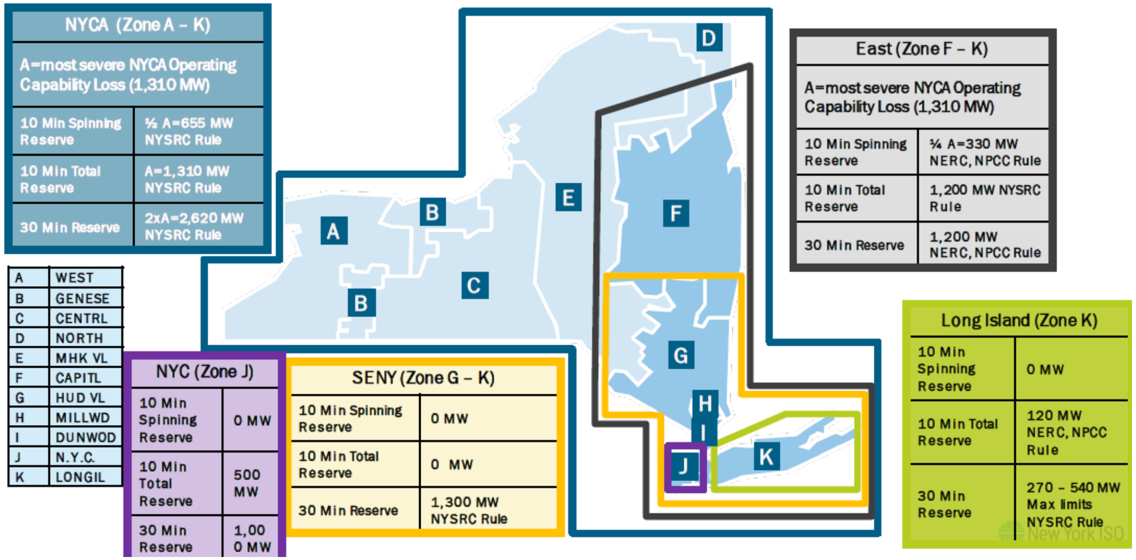
In 2019, the NYISO implemented a reserve zone for New York City with initial penalty prices of $25/MW for shortages of 10 minute total and 30 minute reserves. [1]

- The penalty prices were initially set low pending development of additional market design elements and software to take account of the shift to second contingency dispatch during thunderstorm alerts. [2]

1. NYISO filing in Docket ER19-1678, implemented June 26, 2019
2. We do not go into these issues in this presentation because they arise from particular operational practices in the NYISO and are not related to reserve pricing design in the CAISO

New York ISO 2020

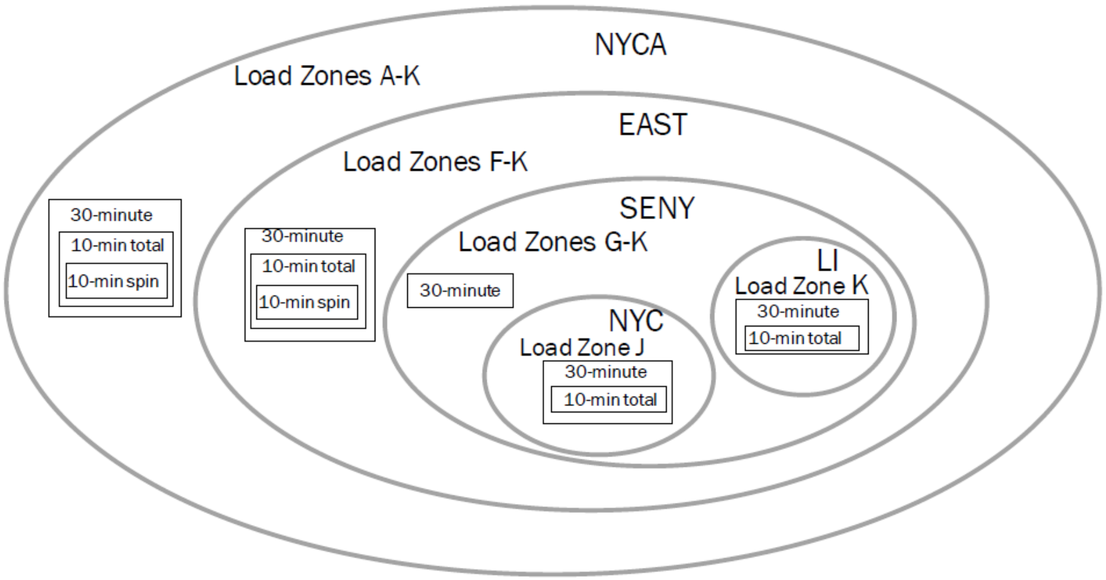
NYISO Reserve Zone Design 2020



Source: New York ISO, Ancillary Services Shortage Pricing, April 7, 2020 p. 15

New York ISO 2020

NYISO Reserve Zone Nesting Design



Source: New York ISO, Ancillary Services Shortage Pricing, April 7, 2020 p. 12

New York ISO Dynamic Reserve Targets

In addition to the nested locational reserve requirements the NYISO has imposed limitations on the amount of 30-minute reserves that can be scheduled on Long Island. This limit is intended to avoid scheduling reserves that would be bottled by transmission limits on exports from Long Island.

- However, since Long Island is typically importing a substantial amount of power, up to 1000 megawatts or so, reserves on Long Island could often be used to replaced outages of upstate generation by reducing imports.
- The NYISO Market Monitor, Potomac Economics, has been urging the NYISO to implement a dynamic limitation that would take account of the level of power imports for several years (recommendation 15-16). [1]
- This recommendation has not yet been acted upon but has been expanded to recommend that the NYISO implement a number of other dynamic reserve targets that would reduce the cost of meeting load. [1]

1. See Potomac Economics, 2019 State of the Market Report for the New York ISO, May 2020, pp. 117-118.

New York ISO 2020

The NYISO is in the process of developing and implementing another round of improvements in its reserve shortage pricing design. [1]

- A key change will be to introduce many more steps into the 30-minute reserve demand curve. This change will reduce price discontinuities and provide a better price signal for imports and other supply and demand side actions.
- These changes will be accompanied by higher shortage prices for shortages of NYISO wide 30-minute reserves in excess of 500 megawatts.
- The shortage price for some reserve targets reflecting operator preferences will rise from $25 to $40.

1. See Pallavi Jain, New York ISO, "Ancillary Services Shortage Pricing," ICAPWG/MIWG October 16, 2020 pp. 23

New York ISO 2020

Reserve Region	Reserve Product	Reserve Reqt.	Demand curve ($/MWh)		Rationale
			Current	Proposed	
NYCA	30-minute	2,620 MW	300 MW at $25/MWh	200 MW at $40/MWh	Allow a portion of the 30 minute total reserves to be forgone against price volatility
			-	125 MW at $100/MWh	Facilitate reduction of unnecessary price volatility by further graduation of the NYCA 30-minute reserve demand curve
			355 MW at $100/MWh	55 MW at $175/MWh	Consistent with cost of operator actions to maintain 30-minute reserves (GT OOMs)
			-	55 MW at $225/MWh	Consistent with cost of operator actions to maintain 30-minute reserves (SREs)
			300 MW at $200/MWh	55 MW at $300/MWh	Facilitate reduction of unnecessary price volatility by further graduation of the NYCA 30-minute reserve demand curve
			-	55 MW at $375/MWh	Represents a value aligned with the average cost of 99% of the resource costs observed for historic SRE and OOM commitments
			-	55 MW at $500/MWh	Consistent with cost of activating SCR/EDRP resources to maintain reserves
			-	55 MW at $625/MWh	Facilitate reduction of unnecessary price volatility by further graduation of the NYCA 30-minute reserve demand curve
			1,665 MW at $750/MWh	1,965 MW at $750/MWh	Consistent with cost of operator actions to replenish by converting 30 min GTs to energy
NYCA	10 minute total	1,310 MW	$750/MWh	$750/MWh	Consistent with cost of operator actions to replenish by converting 30 min GTs to energy
NYCA	10 minute spin	655 MW	$775/MWh	$775/MWh	Provide scheduling priority to NYCA 10-minute total and NYCA 30-minute reserves
EAST	30-minute	1,200 MW	$25/MWh	$40/MWh	Facilitates distribution of reserves throughout NYCA
EAST	10 minute total	1,200 MW	$775/MWh	$775/MWh	Recognizes equal importance with NYCA 10-min spinning reserves
EAST	10 minute spin	330 MW	$25/MWh	$40/MWh	Facilitates distribution of reserves throughout NYCA

Source: Pallavi Jain, New York ISO, “Ancillary Services Shortage Pricing,” ICAPWG/MIWG October 16, 2020 pp. 23

New York ISO 2020

Reserve Region	Reserve Product	Reserve Reqt.	Demand curve ($/MWh)		Rationale
			Current	Proposed	
SENY	30-minute	1,550 MW or 1,800 MW	250 MW or 500 MW at $25/MWh (proposed; pending stakeholder review/approval)	250 MW or 500 MW at $40/MWh (only if SENY incremental reserves proposal is approved by stakeholders)	supplemental reserves to facilitate returning transmission assets to Normal Transfer Criteria following a contingency (see Reserves for Resource Flexibility project)
			1,300 MW at $500/MWh	1,300 MW at $500/MWh	Consistent with cost of activating SCR/EDRP resources to maintain reserves
NYC	30-minute	1,000 MW	$25/MWh	$25/MWh	Facilitates distribution of reserves throughout NYCA
NYC	10-minute total	500 MW	$25/MWh	$25/MWh	Facilitates distribution of reserves throughout NYCA
LI	30-minute	270-540 MW	$25/MWh	$25/MWh	Facilitates distribution of reserves throughout NYCA
LI	10-minute total	120 MW	$25/MWh	$25/MWh	Facilitates distribution of reserves throughout NYCA

Source: Pallavi Jain, New York ISO, “Ancillary Services Shortage Pricing,” ICAPWG/MIWG October 16, 2020 pp. 23

ISO New England Reserve and Regulation Shortage Pricing

ISO New England 2020

ISO-NEW ENGLAND RESERVE SHORTAGE VALUES (RCPF)	
Total New England 10-Minute Spinning Reserves	$50/MW
Total New England 10-Minute Reserves	$1500/MW[4]
Total New England 30-Minute Operating Reserves	$1000/MW [1]
New England Replacement Reserves	$250/MW [3]
Local 30-Minute Operating Reserves	$250/MW [2]

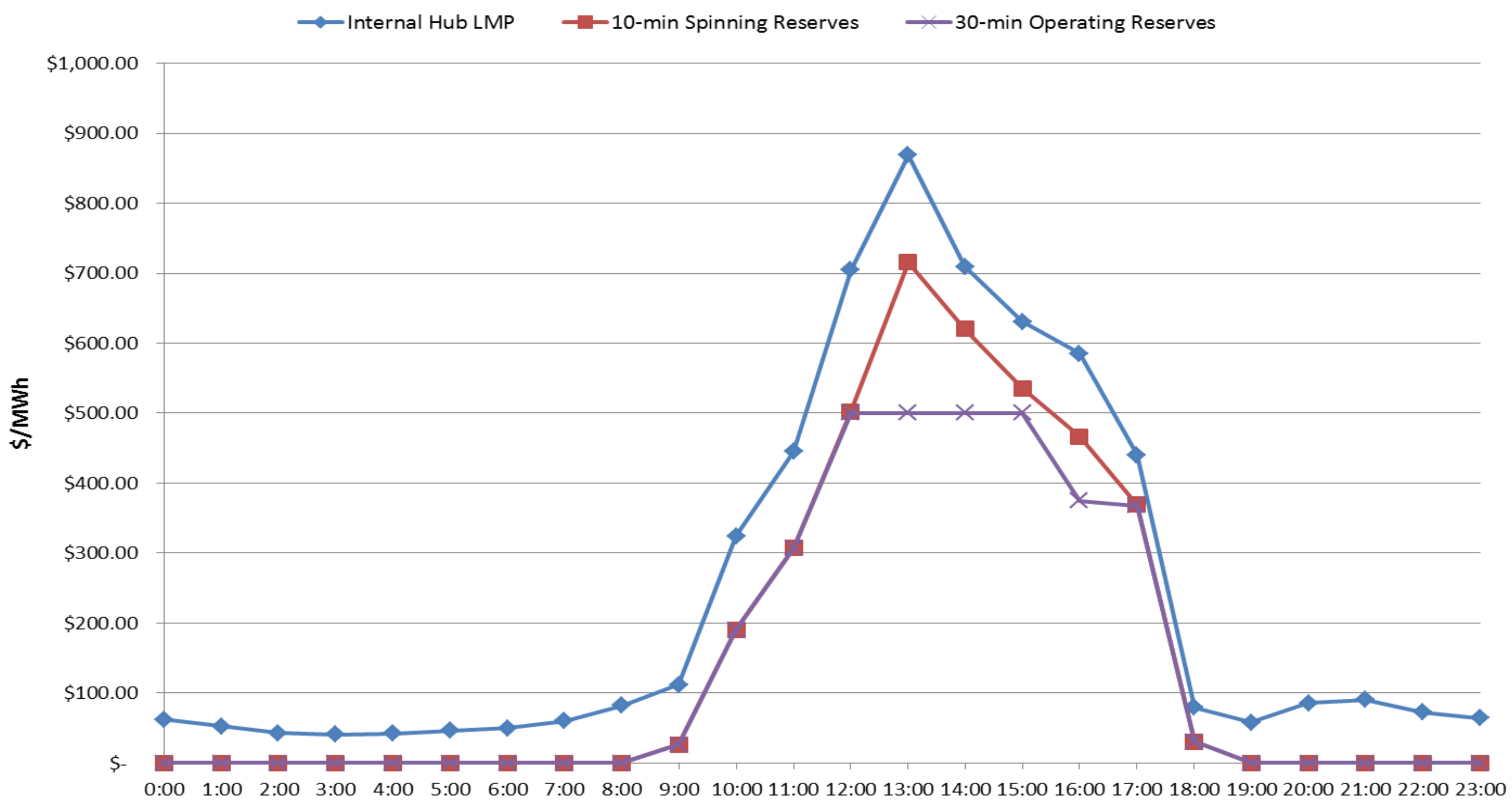
1. Raised from $100 to $500 effective June 1, 2012, then to $1000 effective December 3, 2014.
2. Raised from $50 to $250 effective January 1, 2010.
3. Target Established October 1, 2013, see filing in Docket ER 13-1736-000, June 20, 2013.
4. Raised from $850 to $1500 effective December 3, 2014.

ISO New England

ISO-New England implemented real-time shortage pricing covering 30-minute operating reserves, 10-minute reserves and 10-minute spinning reserves, effective October 1, 2006.

- Reserve shortage prices were raised in 2010 and 2012 and again on December 3, 2014.
- A category of replacement reserves, additional 30-minute reserves in excess of the NPCC requirement, was added effective October 1, 2013.
- An important innovation by ISO New England was the use of dynamic targets for local reserves, taking account of unloaded capacity into the regions.

ISO-NE Internal Hub LMP and Rest of System Reserves, 7/19/2013



Note: Reserve Prices presented are for the Rest of System reserve zone.

Sources: ISO-NE Final Real-Time LMPs and Final Hourly Reserve Zone Prices and Designations: http://www.iso-ne.com/markets/hst_rpts/hstRpts.do?category=Hourly

ISO New England

The increase in the shortage value for thirty minute reserves to $500 in 2012 provided a more efficient price signal during shortage conditions.

- The subsequent increase in the shortage value for thirty minute reserves to $1000 and 10-minute reserves to $1500 on December 3, 2014 has provided strong incentives for improved generator performance during stressed system conditions.
- The increase in reserve shortage prices in December 2014 has also incented load serving entities to more fully hedge their expected load in the day-ahead market to avoid being exposed to very high real-time prices.

ISO New England

ISO New England's current reserve shortage prices can result in prices in excess of $2800/MW hour.

- The large steps in the reserve shortages can result in large price discontinuities from incremental import supply or the commitment of additional generation.
- The introduction of ISO New England's pay for performance capacity market design provides additional strong incentives for increased supply from generators or importers during shortage conditions.

MISO Reserve and Regulation Shortage Pricing

MISO

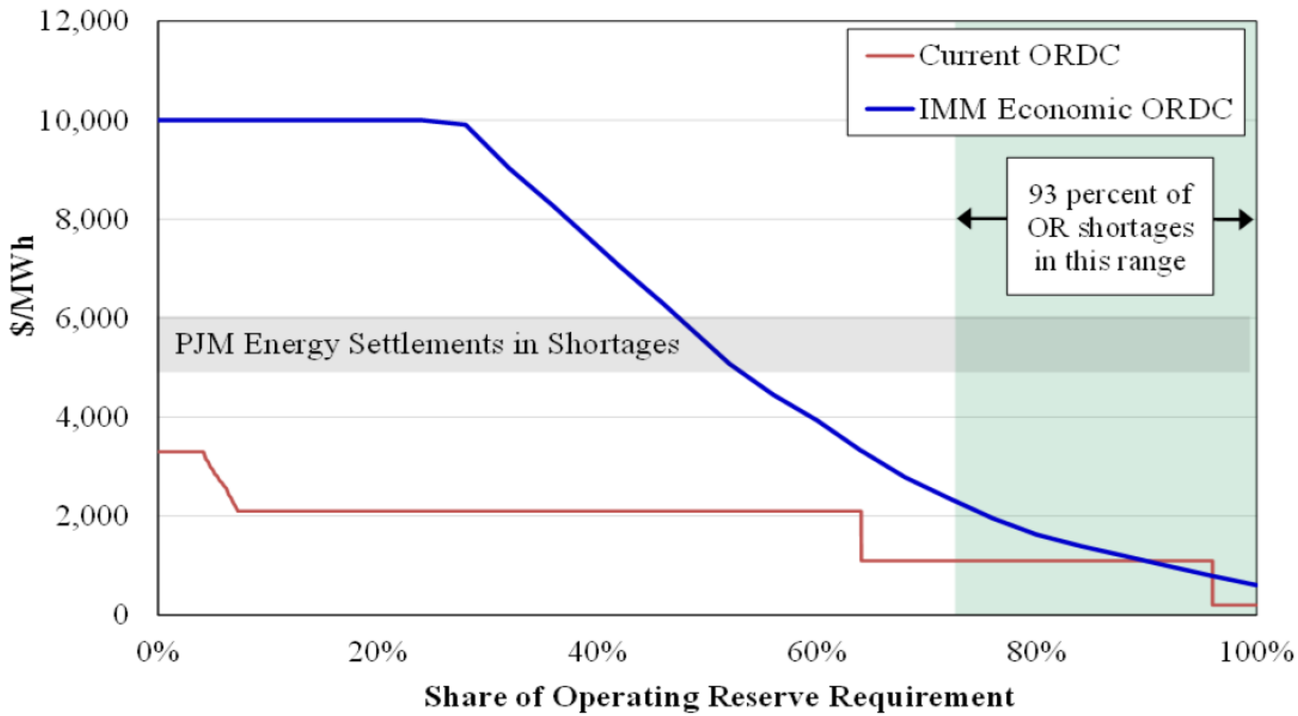
The MISO implemented shortage pricing for total operating reserves with its ancillary services market in January 2009.

- The MISO's operating reserve shortage values for total 10-minute reserves are much higher than in New York or New England.
- The MISO operating reserve demand curve currently starts at $200 per megawatt, rises to $1100, then to $2100, then to the estimated value of lost load, currently $3,500.
- The MISO is currently discussing increases in the value of lost load used to cap the operating reserve demand curve as well as potential changes in the shape of the ORDC.[1]

1. See MISO, "Scarcity Pricing Analysis and Proposals, Market Subcommittee, December 3, 2020.

MISO

The MISO independent market monitor has proposed that the MISO shift to an ORDC based on a $23,000 per megawatt hour value of lost load.



1. See Potomac Economics, 2019 State of the Market Report for the MISO Electricity Market, June 2020 p. 27.

MISO

An important limitation of the current MISO ORDC are the large steps in the demand curve that result in large discontinuities in energy and reserve prices.

- The large drop from a shortage price of $1100 per megawatt to $200 per megawatt will cause MISO commitment software to incur large commitment costs to eliminate shortfalls priced at $1100 per megawatt.
- These commitments can appear highly uneconomic when the shortage price declines to $200 per megawatt when the additional capacity comes on line or price taking imports are scheduled.

MISO

The Midwest ISO implemented shortage pricing for spinning reserves in 2012 with a shortage price of $65/megawatt for shortages of 150 megawatts or less and a shortage price of $98/megawatt for shortages of more than 150 megawatts. [1]

The MISO also has a regulation shortage price that is set each month as a function of gas prices and a calculated proxy heat rate for a peaking unit. It tends to range between $100 and $200. [2]

1. See MISO filing in Docket ER12-1185-00 March 1, 2012. 139 FERC ¶ 61,081 April 30, 2012, see also MISO Tariff, schedule 28.
2. MISO Tariff schedule 28.

MISO

The MISO has been experiencing price formation issues during potential shortage conditions.

- This is in part because the off-line units that are available to balance load and generation in response to major net load forecast errors tend to be long start units that operators must commit long before it is known how much additional capacity is actually needed.
- Similarly, many MISO demand response resources (load modifying resource –LMRs) have had long notification times that have required that MISO operators activate them long before it is known how much demand reduction is actually needed.[1]

1. See MISO ”Emergency Pricing Analysis and Proposals,” Market Subcommittee, June 11, 2020; See also the MISO filing in Docket ER20-1846 that implemented reductions in the maximum notification period.

MISO

MISO enforces locational requirements for sufficient reserves to replace loss of the largest unit within sub-regions.

- The constraint between MISO north and MISO south has been a particular concern as the penalty price is set at $20-$40 and the need for post contingency reserves in the south region is managed by operators using rough proxies for the actual constraint limits.
- MISO operators will apparently incur costs up to around $500 a megawatt hour, to avoid violating this constraint.
- The MISO is in the in process of adding a category of 30-minute reserves, scheduled for implementation in late 2021, that would explicitly model and price local and regional reserve constraints, reducing the need for ad hoc operator actions. [1]

1. See MISO filing in Docket ER20-42, October 4, 2019

MISO Dynamic Limits

The MISO will enforce the local and sub-regional 30-minute reserve targets with a series of dynamic limits that will be defined as the sum of the unloaded capacity on the constraint and the 30-minute reserves within the sub-region. [1]

- The implementation of these 30-minute reserve targets will incent the construction and retention of generation capable of starting within 30-minutes and also incent the development of demand side resources able to provide these reserves.
- Off line generation resources and demand response resources will be able to submit off prices to provide 30-minute reserves. [2]
- The Penalty price for the local and sub-regional reserves will be tied to the MISO Post Reserve Deployment Constraint penalty prices, which are currently set at $200.

1. See MISO October 4, 2019 filing in docket ER20-42 pp. 17-18.
2. See MISO October 4, 2019 filing in docket ER20-42 p. 21
3. See MISO October 4, 2019 filing in docket ER20-42 p. 24. MISO Tariff Schedule 28C.

MISO Short-Term Reserves

In addition to the local and sub-regional reserve requirements, the MISO will also introduce a market wide target for 30-minute reserves that will have a $100/MW penalty price. [1]

1. See MISO October 4, 2019 filing in docket ER20-42 at p. 23

MISO Emergency Pricing

In addition to its design for reserve shortage prices, the MISO has a design for "emergency pricing." [1]

- The MISO's emergency pricing rules are intended to place a floor under prices when "emergency only" generation or demand response resources are used to meet load.
- Changes to these market rules are also being evaluated by MISO stakeholders.
- These rules, and the incentive issues they can introduce, are not discussed in this presentation.

1. See MISO, Emergency Pricing, Market Subcommittee, November 5, 2020.

PJM reserve and regulation shortage pricing

PJM

PJM uses the term “Primary” reserves to refer to total 10-minute reserves (spinning and non-spinning).

- Tier 1 synchronized reserves are unloaded capacity on generation resources participating in the PJM energy market dispatch that can be converted to energy within 10-minute.
- Tier 2 synchronized reserves are resources that synchronized to the grid and are obligated to increase output in response to PJM instructions but are not on dispatch. Tier 2 resources are allowed to submit offer prices and are typically gas and oil turbines that are able to synchronize with the grid without injecting power.

PJM

- Non-synchronized reserves able to come on line and inject power within 10-minutes can also be used to meet the primary reserve target.
- There is no day-ahead market or offer prices for tier 1 reserves. Until 2012 there was no compensation for tier 1 reserves.

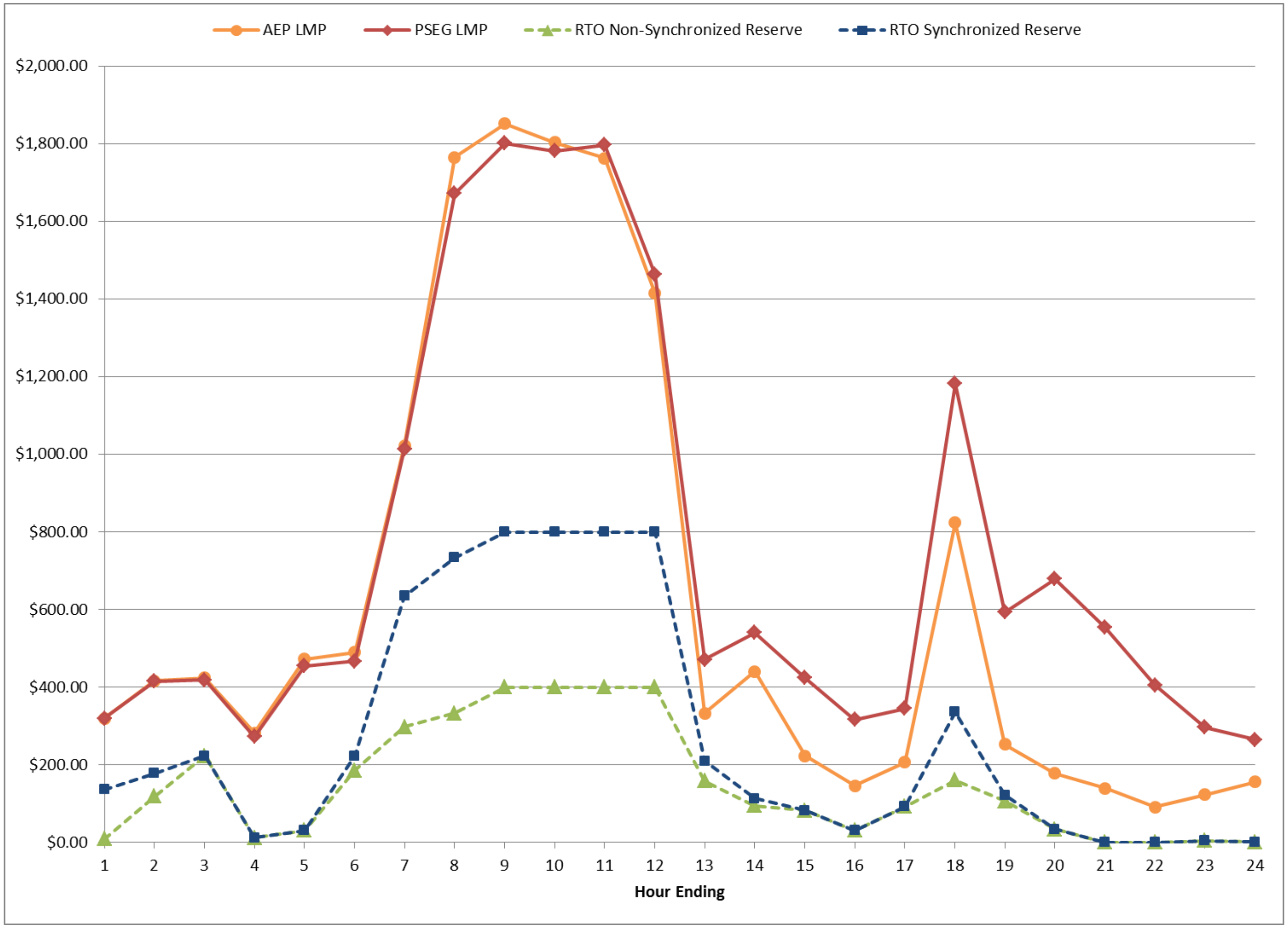
PJM

PJM introduced a market for day-ahead scheduling reserves (DASR) in Docket ER08-780 filed March 31, 2008. [1]

- Day-ahead scheduling reserves are a 30-minute reserve product.
- The target for day-ahead scheduling reserves is around 5% of peak load.
- No 30-minute reserve requirement is enforced in real-time so capacity committed to provide 30-minute reserves day-ahead may be dispatched to support exports or underbid load in real-time without creating any reserve shortage in the pricing system.

1. The day-ahead scheduling reserve market is discussed in the Monitoring Analytics 2019 State of the Market Report for PJM at p. 452

PJM



Source: PJM Daily Real-Time LMP files, containing hourly real-time LMPs and ancillary services prices, are available at http://www.pjm.com/markets-and-operations/energy/real-time/lmp.aspx

PJM

PJM implemented a real-time reserve shortage design on October 1, 2012 after a long wait for FERC approval (ER09-1063).

- Shortage values for non-synchronous and synchronous reserves initially set at $250/MW, rising to $400, $550 and finally to $850 per megawatt on June 1, 2015.
- Two nested reserve zones (RTO and Mid-Atlantic-Dominion Subzone)
- Overall cap of $2700 per megawatt hour on energy prices.

Beginning on October 1, 2012 tier 1 spinning reserves were paid the tier 2 spinning reserves price so began to receive some compensation.

PJM

In 2015 PJM added extra steps to its primary and synchronized reserve requirements, termed the extended requirement. [1]

- The extended requirement added 190 megawatts to the primary and synchronized reserve requirements at a $300 penalty price.
- PJM was to implement this requirement during cold weather alerts, hot weather alerts or emergency conditions.
- This second step in the PJM reserve demand curves was made permanent, applying to all conditions, in 2017. [2]

1. Docket ER15-643, filed Dec 17, 2014.
2. Docket ER17-1590 filed May 12, 2017.

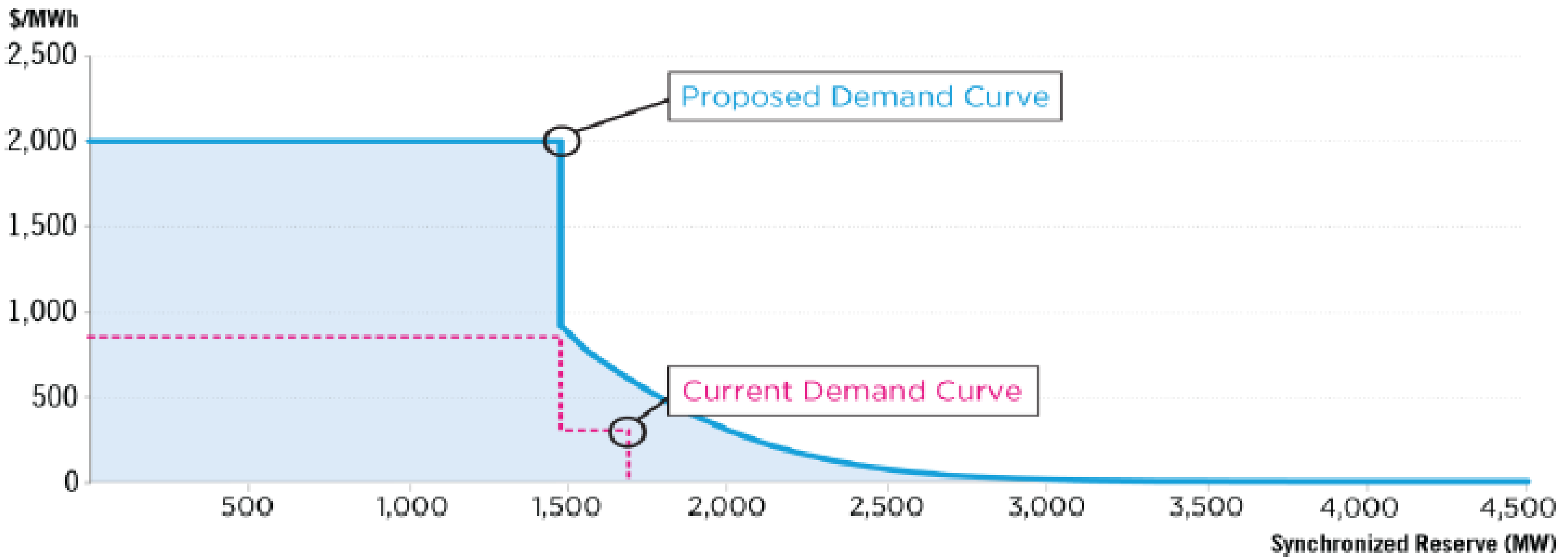
PJM

The PJM energy and ancillary service design appears to be based on a co-optimized energy and ancillary service market design that allows reserves to be dispatched to balance load and generation.

- The PJM market monitor has raised questions about whether this is the case in practice, finding that PJM appears at times to relax the power balance constraint rather than dispatching reserves. [1]

1. See for example, Monitoring Analytics, 2020 Quarterly State of the Market Report for PJM: January through September, November 2020, pp. 188-189.

PJM



Source: See Affidavit of Adam Keech in Docket ER19-1486, March 29, 2019 p. 7

PJM

PJM filed for additional changes to its reserve demand curve in 2019. [1]

- These changes included implementation of a more continuous operating reserve demand curves and pricing and settlement of day-ahead scheduling reserves in real-time.
- The shape of the ORDC in part reflects analysis of the probability of forecast errors larger than the reserve target, and in part assessment of the cost of the actions operators would take to maintain reserves at target levels.[2]
- These changes are scheduled for implementation in 2022.

1. See PJM March 29, 2019 filing in Docket ER19-1486.
2. See Affidavit of Adam Keech in Docket ER19-1486, March 29, 2019 pp. 4-5.

Ontario reserve and regulation shortage pricing

Ontario IESO

The IESO uses the following constraint penalty prices in its constrained and unconstrained schedules. The magnitudes determine the priority for observing the different constraints.

Violation	Penalty Violation Cost
Total Reserve Requirement	$6,000/MW
10-Minute Total Reserve Requirement	$10,000/MW
10-Minute Spinning Reserve Requirement	$12,000/MW
Energy Balance	$30,000/MW
Import/Export Scheduling Limit or Net Interchange Scheduling Limit	$40,000/MW
Security Transmission Limit (Base case or Contingency)	$60,000/MW

The IESO dispatch software has the ability to define and enforce minimums and maximums on the amount of reserves carried within a large number of regions.

- The IESO more typically enforces maximum limits, rather than minimums, to avoid bottling of reserves.
- In practice, this involves limiting the amount of reserves scheduled in Northeast Ontario, Northwest Ontario, or sub regions within the Northeast or Northwest.

SPP Reserve and Regulation Shortage Pricing

SPP

SPP currently has shortage pricing for operating reserves and regulation, with shortage penalties (Violation Relaxation Limit Values) that are set at $200/MW. [1]

1. See SPP OATT, attachment AE, addendum 1.

SPP

SPP currently relaxes the constraint for spinning reserve shortages and for violations of the energy balance constraint.

- The SPP market monitor reported that the market price of spin was often $8 per megawatt hour or less during shortages of spinning reserves. [1]
- “The MMU highly recommends SPP and stakeholders review price formation during scarcity events and establish graduated demand curves that incentivize proper price formation.” [2]

1. SPP Market Monitoring Unit, State of the Market 2019, May 11, 2020 p. 275.
2. SPP Market Monitoring Unit, State of the Market 2019, May 11, 2020 p. 276.

ERCOT Reserve and Regulation Shortage Pricing

ERCOT

On June 1, 2014 ERCOT implemented the Operating Reserve Demand Curve (ORDC) as a key element of shortage pricing in its energy only market.

- The ORDC creates a real-time Price Adder that is intended to reflect the value of available reserves based on the value of lost load and loss of load probabilities for each level of available reserves.
- The overall goal of the ORDC is to improve scarcity pricing, by sending appropriate price signals in the event of reserve shortages.
- Implementation of the operating reserve demand curve eliminated the need for hockey stock bids to set scarcity prices.

ERCOT

The implementation of the ORDC is based on an empirical analysis of the difference between scheduled hour-ahead and real-time reserves.

- The ORDC is constructed as the probability of reserves falling below the Minimum Contingency Level (PBMCL) multiplied by the difference between Value of Lost Load (VOLL) and system lambda.
- The distribution of changes in reserve levels is derived from historical data and used to estimate loss of load probabilities.

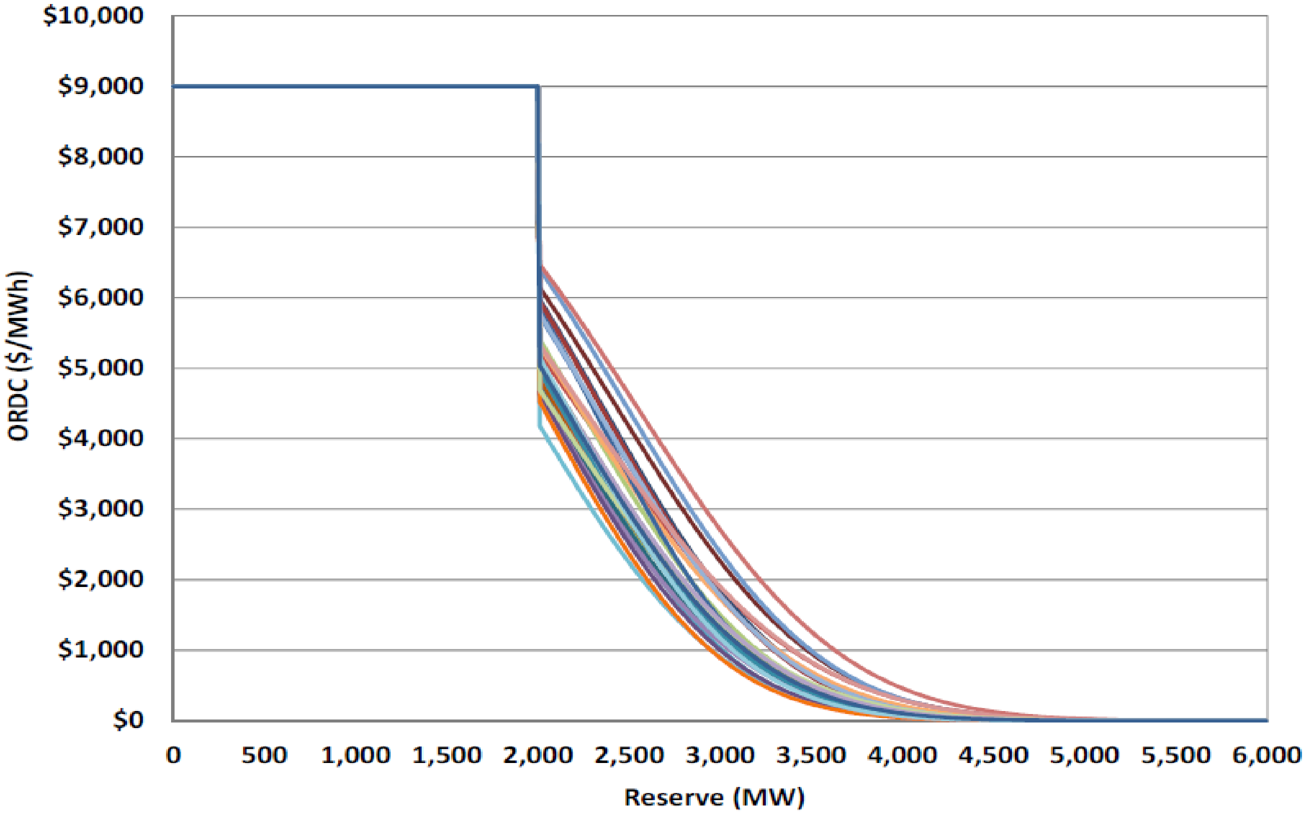
ERCOT

Accurate calculation of the probability of large unforecasted declines in reserves can be very complex.

- The probability of large load forecast errors is not the same over the day or year;
- The probability of large forecast errors that overstate intermittent resource output is not the same over the day or the year and is correlated with the forecast level of intermittent resource output (intermittent resource output cannot decline much if the forecast output is low).
- In regions with material levels of rooftop solar output, large load forecast errors can be correlated with large forecast errors for utility solar output.
- Large drops in net interchange that are a result of excess supply and low prices do not create loss of load risks because they are correlated with high reserve levels.

ERCOT

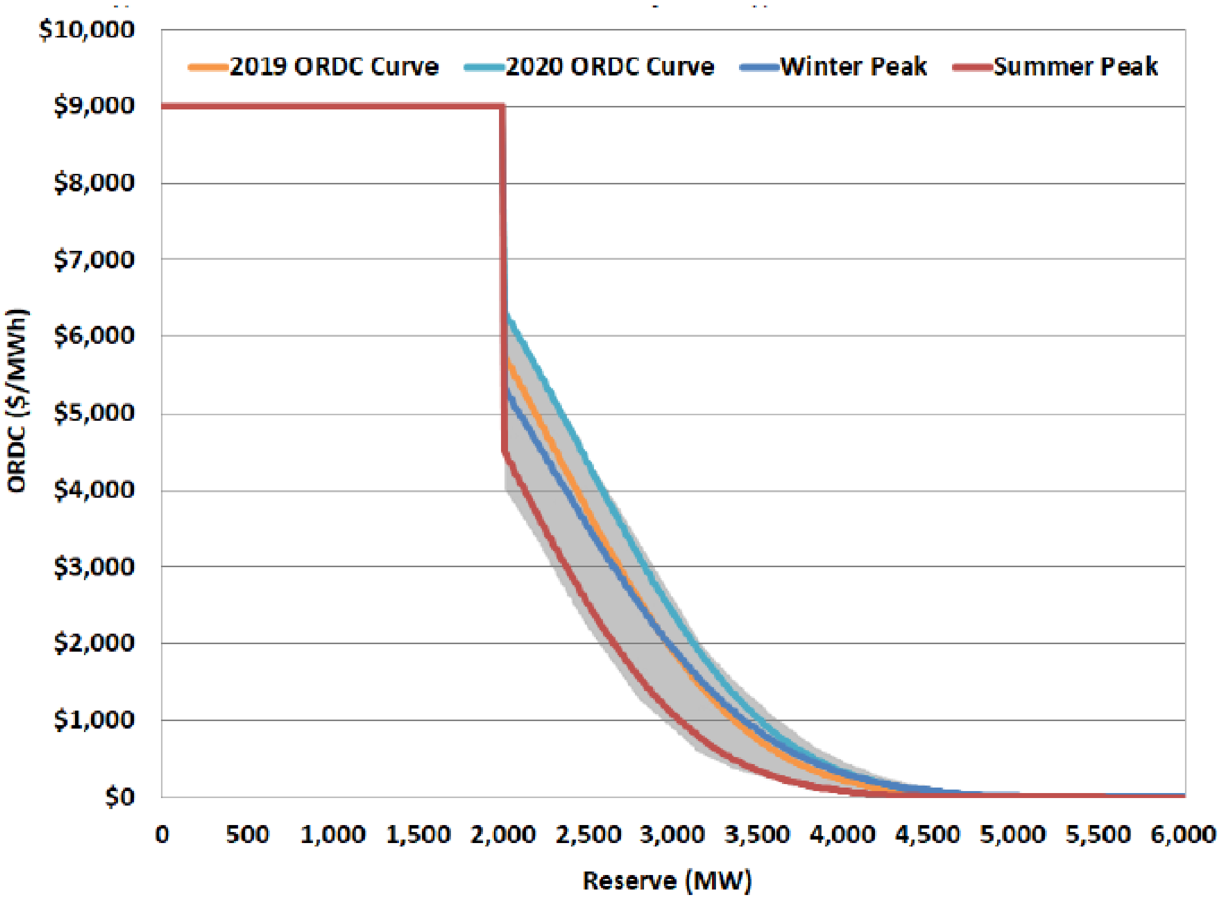
Until 2019, the ORDC was defined for four hour blocks of the day as portrayed by Potomac Economics below.



Source: Potomac Economics, 2017 State of the Market Report for the ERCOT Electricity Markets, June 2019, p. 19 (each line reflects the curve for a distinct 4 hour period, summer and winter).

ERCOT

Beginning in 2019 ERCOT shifted to a single ORDC for each season of the year.



See Potomac Economics, 2019 State of the Market Report for the ERCOT Electricity Markets, June 2020, p. 10

Concluding observations

Concluding observations

1. There are two main views towards defining penalty price for reserve demand curves.

- One view is that the value of reserves should be estimated by the value of lost load and the probability of controlled load shedding being required within that balancing area at some point over the next hour with that level of reserves.
- The second view is that the value of reserves should be estimated by examining the cost of the actions operators would take to maintain that level of reserves.
- The critical flaw of the first approach is that it assumes that the only cost of low reserves is the potential for controlled load shedding. However, an important cost of inadequate reserves, particularly inadequate spinning reserves (and perhaps the larger cost), is the increased potential for uncontrolled load shedding. This flaw could perhaps be addressed by extending the analysis of load shedding costs to include the costs and probability of uncontrolled load shedding.
- The key limitations of the 2nd approach are that the cost of operator actions is often hard to measure in the abstract and neither FERC, NERC nor well has provided clear guidance on what costs balancing areas are required to incur to maintain reserves.

Concluding observations

2. The complexities involved in avoiding scheduling reserves where they will be bottled are likely to increase with increases in intermittent resource output and the potential for a variety of large “contingencies” at a variety of locations.
   - However, there may no longer be a single set of resources that would provide the least cost set of reserves satisfying all large contingencies and ISOs may have no choice but to develop models that account for reserves that would be bottled in meeting particular contingencies.
   - Moreover, operators may no longer be able to define a set of reserves in the day-ahead market or security evaluation that will be deliverable and able to meet the relevant large contingencies in real-time.

Concluding observations

3. With rising intermittent resource output and the likelihood of the location of the largest contingency (which could be a large drop in offshore wind output) shifting over time, it will likely become increasing important to implement energy and reserve co-optimization in real-time.

4. The complexities involved in dynamically determining local reserve requirements and the limited cost savings have deterred development of these designs in the past. With the rising number of potential large contingencies and the likelihood that high output by intermittent resources within constrained regions (becoming the largest contingency) will be accompanied by unloaded transmission lines into the region, ISOs may have no choice but to develop and implement dynamic reserve targets.