Updated Shortage Pricing White Paper: Value of Lost Load, Operating Reserve Demand Curve, and Pricing VOLL Circuit Breaker

November 2024

Highlights

- MISO has identified the need to improve price formation during reserve and energy shortages, to increase price transparency, better reflect marginal costs of serving load, and further align prices with reliable operation of the system
- MISO recommends a Pricing VOLL of $10,000/MWh, with a Circuit Breaker mechanism that can ultimately reduce the Pricing VOLL to $2,000/MWh during prolonged capacity emergencies which include MISO-directed load-shedding
- MISO recommends an updated Operating Reserve Demand Curve, utilizing a System VOLL of $35,000/MWh, that better aligns economic market signals with the magnitude of reserve shortages
- MISO recommends removing the $2,000/MWh Day-Ahead Price-Sensitive Demand Bid and Day-Ahead Virtual Demand Bid Caps
- MISO recommends decoupling the EDR Offer Cap from the VOLL to a fixed $3,500/MWh

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Acronyms

ASM	Ancillary Services Market
C&I	Commercial and Industrial [loads]
CB	[Market Price] Circuit Breaker
DA	Day-Ahead (market)
DAMAP	Day-Ahead Margin Assurance Payment
DER	Distributed Energy Resource
DRR	Demand Response Resource
EDR	Emergency Demand Response
EEA	Energy Emergency Alert (NERC). EEA-Level 3 involves firm load-shedding.
ELMP	Extended Locational Marginal Pricing
GSF	Generator Shift Factor
IMM	Independent Market Monitor
LBA	Load Balancing Authority
LBNL	Lawrence Berkeley National Labs
LMP	Locational Marginal Price
LMR	Load Modifying Resource
LOLP	Loss Of Load Probability
LSE	Load Serving Entity
MCC	Marginal Congestion Component (of LMP)
MCP	Market Clearing Price
MEC	Marginal Energy Component (of LMP)
MLC	Marginal Loss Component (of LMP)
MRD	Manual Redispatch
ORDC	Operating Reserve Demand Curve
RT	Real-Time (market)
SMP	System Marginal Price
SOM	State of the Market, as in IMM SOM Report
TCDC	Transmission Constraint Demand Curve
TOD	Time Of Day
VOLL	Value of Lost Load
WTP	Willingness to Pay

Purpose Statement

MISO continues to make significant efforts in the Reliability Imperative. Market Redefinition focuses on improvements needed to reliably manage the transmission system while the resource portfolio evolves. Shortage pricing improvements will establish appropriate price signals before and during reserve shortage conditions to increase energy production and reduce consumption.

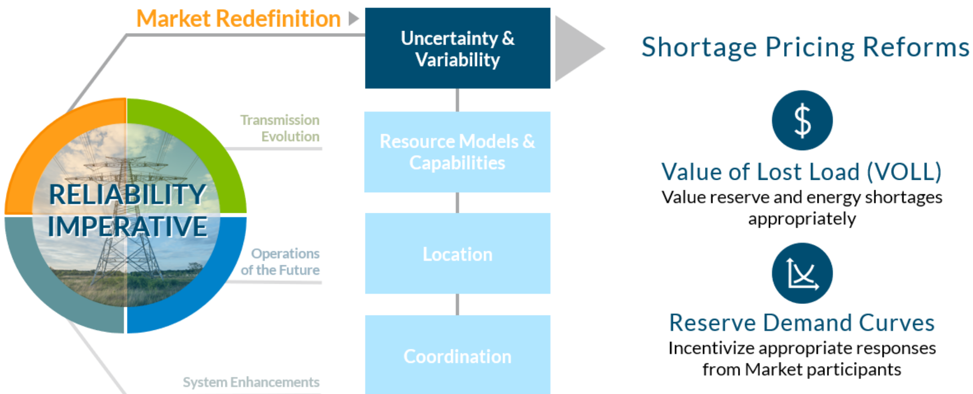

Figure 1: Shortage[1] pricing reforms as part of MISO's Reliability Imperative

Since 2020, many improvements have been made to emergency and shortage pricing. Through 2025, MISO's focus is on the Value of Lost Load (VOLL), demand curves and Forced-off Assets (Figure 2).

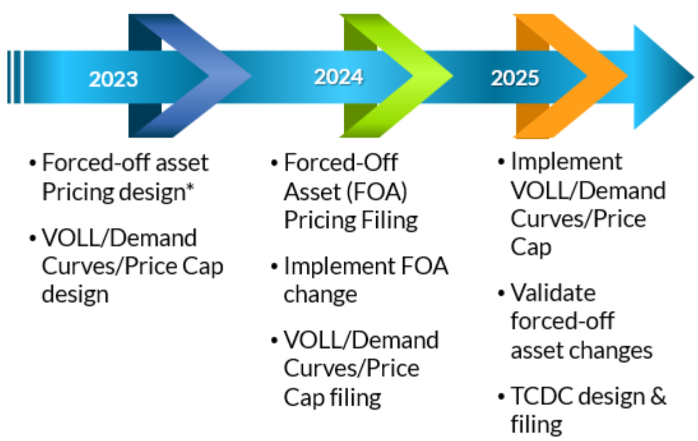

Figure 2: Shortage pricing roadmap

This updated conceptual design white paper further clarifies the proposed VOLL and Operating Reserve Demand Curve modifications to shortage pricing, originally published in March 2024[2]. It follows the *Scarcity Pricing Evaluation Paper* published in May 2021[3] and the earlier *Emergency Pricing Evaluation Paper*[4] published in September 2020.

[1] "Shortage" and "scarcity" are often used interchangeably, but in this white paper, MISO favors the term "shortage".
[2] MISO's Scarcity Pricing White Paper: Value of Lost Load and Operating Reserve Demand Curve, March 2024
[3] MISO's Scarcity Pricing Evaluation paper, May 2021
[4] MISO's Emergency Pricing Evaluation Paper, September 2020

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1. Executive Summary

Shortage pricing refers to the notion of increasing Day-Ahead and Real-Time Locational Marginal Prices (LMPs) of energy above the incremental cost of the marginal resource under conditions when the system is short on generation capacity. This initially manifests itself as the inability of MISO to procure sufficient reserves, and ultimately as the inability of MISO to serve firm customer demand. MISO Market signals are the most effective and efficient mechanism to incentivize resource behaviors that promote reliability on the Bulk Electric System under shortage conditions.

Previous improvements to the shortage pricing design did not update the key Value of Lost Load (VOLL) parameter. Shortage pricing design in 2024 focused on the VOLL, and parameters closely coupled to the VOLL, including the Operating Reserve Demand Curve (ORDC) and the Emergency Demand Response (EDR) Offer Cap.

The determination of VOLL has employed Lawrence Berkley National Labs (LBNL) studies, which estimate the impact of service interruption to end-use customers based on factors such as the season and outage duration. End Use customer classes include Residential, Small Commercial & Industrial (Small C&I), and Large Commercial & Industrial (Large C&I). In 2007, the MISO VOLL was determined to be $3,500/MWh based on a combination of the one-hour, off-peak summer Residential and Small C&I values[5].

MISO refreshed the underlying VOLL components in 2023, utilizing updated economic and electrical usage data. Based on these values, MISO proposes to establish two VOLL types: (1) a Pricing VOLL of $10,000/MWh; and (2) a System VOLL of $35,000/MWh.

The Pricing VOLL represents the price consumers are willing to pay to avoid an interruption of electrical service and is based primarily on consumers with the *lowest willingness to pay*. It will be used as a market price cap and for fixed administrative pricing in extreme EEA-Level 3 energy shortage conditions. The Pricing VOLL recognizes that firm load-shedding will tend to be focused on the Residential class (85%), which has the lowest 1-hour-outage Summer VOLL of $4,337/MWh, but that other higher-valued load classes (15%) would inevitably be dropped during such an event. These weights were used in the original VOLL calculation of $3,500/MWh, and now yield a potential value of $13,640/MWh. However, MISO proposes to utilize a more conservative $10,000/MWh value for the Pricing VOLL.

The System VOLL represents the composite price that consumers are willing to pay to avoid an interruption of electrical service. The System VOLL calculation uses weights based on a load-ratio share[6] of all load classes, yielding a raw value of $36,889/MWh. MISO proposes a System VOLL of $35,000/MWh, which will be used for scaling the Loss of Load Probability Curve portion of the new Operating Reserve Demand Curve.

Experience and planning studies both indicate that MISO energy shortage events are likely to be rare and of limited duration (minutes-to-hours). Following discussion with Market Participants, however, MISO agreed that the proposed Pricing VOLL could increase financial risks, while

[5] Docket No. ER07-1372, which established the Ancillary Services Market in 2009

[6] 34% Large C&I, 31% Small C&I, 35% Residential

providing marginal benefits during an extended energy shortage situation. Thus, in forced load interruptions lasting hours-to-days, MISO developed a Pricing VOLL Circuit Breaker that limits the financial impact of extended high shortage prices. The timing and magnitude of the reduced Pricing VOLL was based on the same MISO-updated LBNL demand interruption studies used to establish the default values of the Pricing VOLL and System VOLL. At a high level, the Circuit Breaker works as follows:

- First, at the end of four (4) hours of real-time EEA – Level 3 load-shedding in a Max Gen Emergency, the real-time Pricing VOLL is reduced from $10,000 to $5,000/MWh.
- Second, when the shortage conditions that led to a Max Gen Emergency with EEA – Level 3 persist when the Day-Ahead Market closes at 1030 Eastern Prevailing Time ("EPT"), the day-ahead and real-time Pricing VOLLs shall be set to $5,000/MWh for the next Operating Day.
- Third, when the shortage conditions that led to the Max Gen Emergency continues to any additional Day-Ahead Market closings, the day-ahead and real-time Pricing VOLLs shall be set to $2,000/MWh for the next Operating Day.

MISO also proposes changing the relationship of the VOLL to the ORDC (see Figure 3). MISO agrees with the Independent Market Monitor's recommendation (2016-1) made in their State of the Market report to define the ORDC based on a loss of load probability calculation, scaled to reflect the cost of shedding firm load. MISO proposes to scale the LOLP curve with a System VOLL of $35,000/MWh.

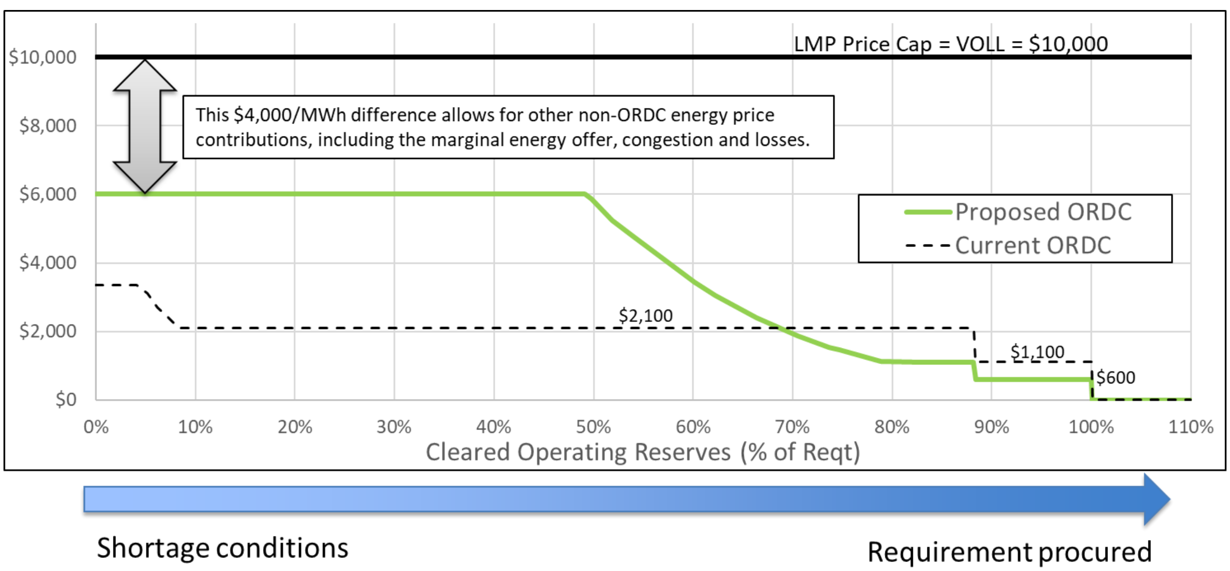


Figure 3: Current and proposed Operating Reserve Demand Curve

Next, MISO proposes a $6,000/MWh ORDC upper limit to allow prices to appropriately rise towards VOLL as Operating Reserves are depleted. The ORDC should have a substantial impact during shortage conditions, but there are other components that also impact energy prices, such as generator offers, four other reserve demand curves, congestion, and losses. A $6,000 ORDC cap allows sufficient room for these other pricing components to function ahead of any MISO-directed load-shedding (NERC EEA-Level 3), at which time prices would be administratively set to the Pricing VOLL.

MISO also proposes a two-step floor for the ORDC ($600 and $1,100), using the same NERC-defined Most Severe Single Contingency (MSSC) breakpoint as the current ORDC. This is lower than the current $1,100 and $2,100/MWh ORDC steps and will help MISO better manage congestion for small Operating Reserve shortages, while clearing nearly all the available reserve supply. Congestion management is enhanced by the lower ORDC floor, because the market can send better pricing and dispatch signals to resources that are contributing to binding transmission constraints.

The ORDC floors were also selected to prevent undesirably low prices during declared system emergencies and when Short-Term Reserves (STR) are scarce. The STR demand curve can reach $500, which is also the value of the Tier 1 Emergency Offer Floor. The $600 step ensures the Operating Reserves price does not fall below these values for small Operating Reserve deficits, when considering the $100 Contingency Reserve Offer Cap. Similarly, the $1,100 step ensures that the Operating Reserves price does not drop below the Tier 2 Emergency Offer Floor (plus the Contingency Reserve Offer Cap).

MISO also recommends the removal of the $2,000/MWh DA demand bid caps. Supply-side offer caps will be unchanged, as established by FERC Order 831. These modifications allow DA Price-Sensitive Demand Bids and DA Virtual Demand Bids to clear at prices between $2,000/MWh and $10,000/MWh, which are possible Real-Time prices for the upcoming Operating Day.

Finally, MISO proposes the removal of the direct link between the VOLL and the EDR Offer Cap. EDRs can be called upon during NERC Energy Emergency Alert 2 (“EEA-Level 2”), Alert 3 (“EEA-Level 3”), or any other type of emergency event, although EDRs have only been called upon once by MISO Operations. The EDR Offer Cap is currently set to the VOLL of $3,500/MWh. After considering Stakeholder feedback, MISO is recommending that the EDR Offer Cap be decoupled from the VOLL and fixed at $3,500/MWh.

MISO is actively working with stakeholders to improve how additional demand response can effectively be offered/utilized during emergency shortage conditions. As part of that improvement, MISO is contemplating the eventual removal of the EDR category, which is recommended by the IMM.

2. Introduction

MISO published an *Emergency Pricing Evaluation Paper* in September 2020 and a *Scarcity Pricing Evaluation Paper* in May 2021. Several of the emergency pricing recommendations have been implemented, such as clearing the Short-Term Reserve, removing the $200 step from the ORDC, and moving from a single-step demand curve to a multi-step demand curve for Ramp Capability and Short-Term Reserves. Using Stakeholder feedback and lessons learned following Hurricane Laura, MISO also developed and implemented a "Forced-Off Asset (FOA)" methodology for pricing disconnected nodes under emergency conditions[7].

As a part of next phase of Shortage Pricing reforms, MISO is focusing on the following outstanding market-wide recommendations:

- Recommend a new VOLL with the objective of ensuring that optimal market prices reflect customers' willingness to pay to avoid curtailments
- Recommend a new ORDC to ensure the proper valuation of Operating Reserves during shortages
- Recommend whether the market price cap for Locational Marginal Prices (LMPs) and Market Clearing Prices (MCPs) should be changed

In 2016, the IMM State of the Market (SOM) report recommended that MISO adopt an improved ORDC reflecting the VOLL. The SOM recommendation was considered in the development of alternatives to address the outstanding shortage pricing issues.

Figure 4 captures the planned pricing reforms, designed to provide greater transparency and improved market incentives for the changing fleet.

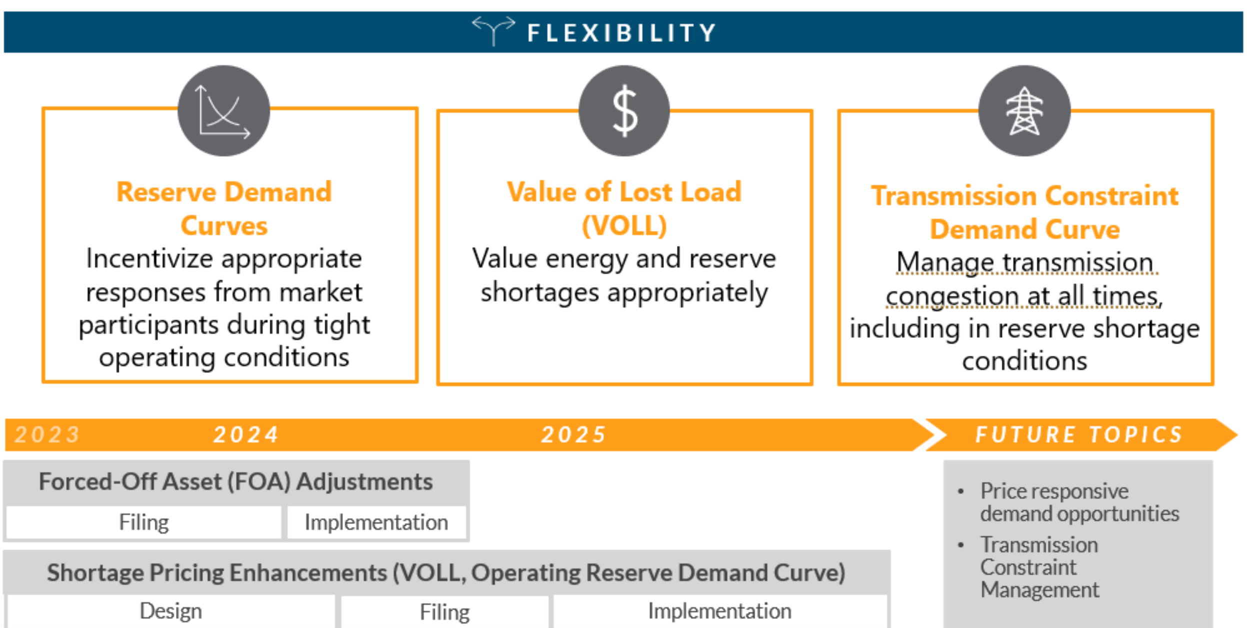


Figure 4 Planned shortage pricing reforms

[7] FERC Docket No. ER24-1191-001 ER24-1191-000, Order accepting Tariff revisions 2024-05-31.

2.1 Shortage Pricing Objectives

MISO balances energy supply and demand in the energy markets. If surplus supply dwindles, operating reserve shortages will begin, preceding potential energy deficiencies. Shortage pricing utilizes "demand curves" to provide a price for the reserve shortage(s) to signal the tight conditions to market participants.

At a high-level, shortage pricing solutions should satisfy these objectives:

- Market prices should reflect real-time operating risks as Operating Reserves diminish to incent proper market participant real-time actions (e.g. adjust supply and demand).
- Shortage pricing should encourage anticipatory behaviors (e.g., greater Day-Ahead market participation, fuel purchases) that help MISO avoid potential shortage conditions, particularly in the days and hours leading up to the real-time interval.
- To a lesser degree, proper Day-Ahead/Real-Time shortage prices may also inform longer-term market participant operational decision making, such as maintenance scheduling, addition of new supply resources, or the deferral of generator retirements.
- Shortage pricing must consider multiple reserve demand curves, floors and caps. In particular, the market must simultaneously balance reserve shortages along with congestion management.

MISO's short-term and long-term market price signals help inform market participant operational and investment decisions.

- Short-run market efficiency involves resources operating according to their marginal costs in the Day-Ahead and Real-Time markets.
- Medium-run market efficiency involves outage scheduling, fuel procurement and other operational planning decisions for resources.
- Long-run market efficiency involves optimal investments in upgrading, maintaining, and building new capacity. While MISO's market prices are not the only factors considered in long-run investment decisions, they are still critical for signaling the value of grid services and providing incentives for development.

2.2 Current Shortage Pricing Limitations

Several limitations have been identified with the current MISO shortage pricing methods:

- As a price cap, the VOLL (a) can curtail valid market prices and (b) is not sufficiently high to encourage full participation of supply and demand resources and interchange during shortage conditions.
- As an administrative price applied during MISO-directed load-shedding, the VOLL is below the industry-accepted willingness-to-pay studies. The $3,500/MWh VOLL has not been updated since 2009, at the launch of the Ancillary Services Market.
- The current ORDC does not properly increase for greater Operating Reserve shortages and reduces congestion-management effectiveness for small Operating Reserve shortages.
- As an offer cap for Emergency Demand Response, the VOLL may overstate their relative value.

3. MISO's Shortage Pricing Proposal

The VOLL presently serves four functions in MISO's Day-Ahead and Real-Time markets (see Figure 5): energy and reserve price cap, administrative price during capacity emergency load-shedding, a reference point for the top the ORDC, and the Emergency Demand Response Offer Cap.

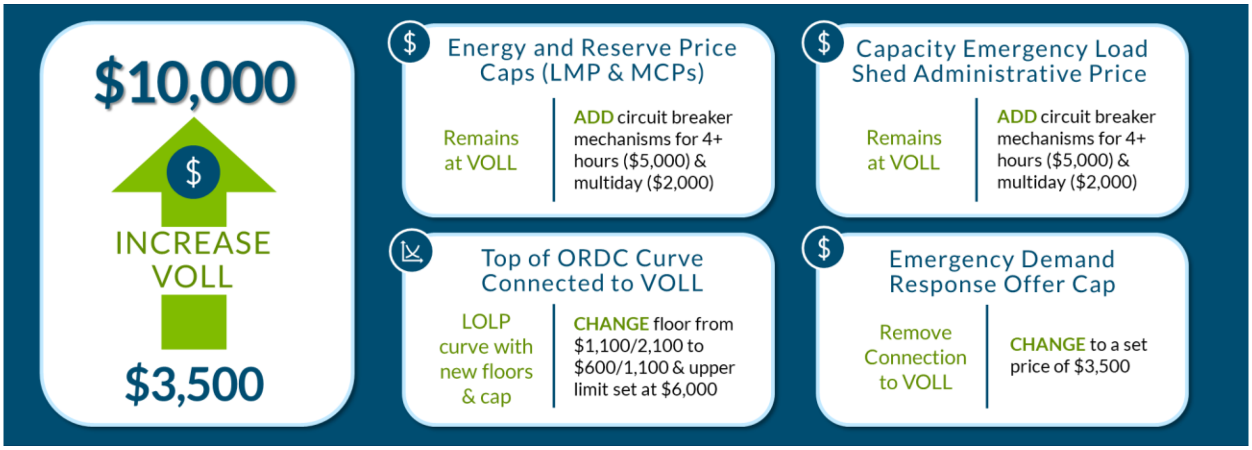


Figure 5 The VOLL is connected to four items in the Tariff, and MISO proposes adjustments to some of these relationships

After considering shortage pricing objectives, as well the limitations of current MISO shortage pricing, MISO proposes several enhancements. These include updating the VOLL that is used as a price cap and for administrative load-shed pricing, updating the ORDC to better reflect the degree of reserve shortages, and to remove the direct link of the EDR Offer Cap to VOLL. MISO is also proposing a market pricing circuit breaker mechanism which is triggered by long-duration energy shortage events lasting hours-to-days.

3.1 Value of Lost Load

The Value of Loss Load (VOLL) represents the price that demand is willing to pay to avoid loss of service. In this section, MISO addresses the following:

- Updating the VOLL components
- Determining the Pricing VOLL
- Determining the System VOLL

3.1.1 Updating the VOLL components

The VOLL represents the value of uninterrupted service, and can vary due to several factors, such as market segment, geographic location, temporal factors (time of day, season), duration, frequency, and amount of advanced notification.

MISO has updated VOLL calculations using recent econometric results, which delineate multiple load characteristics. These analyses utilized Lawrence Berkeley National Labs (LBNL) meta-analyses with MISO-specific drivers, which is both consistent with MISO's original approach in

2009 and the approach utilized in the IMM's SOM recommendation 2016-1[8]. This approach uses two-step regression models to estimate statistically significant outage cost functions.

The resulting 2023 nominal values (MISO-wide, load-weighted) are summarized in the following table:

Load Class	1-hr outage	2-hr outage	4-hr outage	8-hr outage	12-hr outage
Residential	$4,337	$2,420	$1,477	$1,013	$832
Small C&I	$80,965	$50,277	$37,006	$33,271	$31,098
Small C&I, Services #	$66,354	$41,227	$30,328	$27,267	$25,486
Large C&I	$29,472	$20,391	$18,194	$21,859	$24,054
System VOLL *	$36,889	$23,545	$18,342	$18,309	$18,342
Pricing VOLL using 2007 weightings (85% Residential / 15% Services)	**$13,639**	**$8,241**	**$5,804**	**$4,951**	**$4,530**

Basis of $10,000 VOLL for EEA events < 4 hrs (1-hr and 2-hr outage)

Basis of $5,000 VOLL for EEA3 events >=4 hrs (4-hr, 8-hr and 12-hr outage)

* Inter-class weights: 34% Large C&I, 31% Small C&I, 35% Residential
# Value reduced by 18% if only considering "Services" sub-category of Small C&I

Figure 6: MISO load class VOLL ($/MWh) components, for multiple outage durations

The proposed Pricing VOLL, System VOLL, and Pricing VOLL Circuit Breaker mechanisms are derived from these results.

3.1.2 Determining the Pricing VOLL

The Pricing VOLL represents the price consumers are willing to pay to avoid an interruption of electrical service and is based on consumers with the *lowest willingness to pay*. It will be used as a market price cap and also for fixed administrative pricing in extreme EEA-Level 3 energy shortage conditions. The Pricing VOLL recognizes that firm load-shedding will tend to be focused on the Residential class (85% weight), which has the lowest 1-hour-outage Summer VOLL of $4,337/MWh, but also recognizes that other higher-valued load classes (15% weight) would inevitably be dropped during such an event. These weights were used in the original VOLL calculation of $3,500/MWh, and now yield a potential value of $13,640/MWh. However, MISO proposes to utilize a more conservative $10,000/MWh value for the Pricing VOLL.

Currently, the Tariff defines the VOLL to be $3,500/MWh. MISO proposes defining a Pricing VOLL to be $10,000/MWh based on updated willingness to pay calculations, as well as these considerations:

- As MISO residential load comprises 35% of the total load and has a markedly lower VOLL than commercial and industrial loads, it should be the primary target for MISO

[8] See Appendix H: Updated 2023 Value of Lost Load Calculations for additional VOLL calculation information.

directed load-shedding. A $10,000 Pricing VOLL recognizes, however, that some non-residential loads will inevitably also be shed along with residential loads.

  - Based on Figure 6, a weighted 1-hour Summer VOLL of $36,889/MWh could be argued. Alternatively, a VOLL of $13,639/MWh could be justified, if MISO were to apply the same load class weights used for the current $3,500/MWh VOLL. Instead, MISO is recommending a more conservative $10,000/MWh, as this will generate appropriate pricing signals without being excessive or punitive.

- The Pricing VOLL allows market prices to exceed the willingness to pay threshold for many loads, providing a financial incentive to reduce consumption.
- The Pricing VOLL is large enough to incent the establishment of more price-sensitive demand, incremental emergency supply from all resource types, as well as interchange with neighboring markets.
- This increased level of potential real-time pricing will encourage greater participation in the Day-Ahead market, particularly when tight operating conditions are anticipated.
- The Pricing VOLL, combined with an appropriately designed ORDC, provides room for all pricing components, including Marginal Energy Component (MEC), Marginal Congestion Component (MCC) and Marginal Loss Component (MLC) to function before prices are capped.
- The higher Pricing VOLL would expose MPs to greater financial risk during periods of extended VOLL pricing; however, stronger economic incentives should result in those risks materializing less often. Nevertheless, this financial risk of longer-duration events will be mitigated with a Pricing VOLL Circuit Breaker (Section 3.2).

The Pricing VOLL will be used for these two purposes:

- **Energy Locational Marginal Price (LMP) Cap and Reserve Market Clearing Price (MCP) Cap**: The Tariff defines the LMP Cap and MCP Cap to be the [Pricing] VOLL in the Ex-Ante and Ex-Post processes. If reserve requirements are not fully satisfied, while several transmission constraints are binding, the LMP may naturally exceed the [Pricing] VOLL. The LMP and MCP Caps serve as a backstop to prevent excessive market prices. These caps are utilized in both the DA and RT markets.
- **Administrative Capacity Emergency Load-Shed Price**: During the last step of a real-time capacity emergency event, MISO will issue an Energy Emergency Alert (EEA - Level 3) to warn that load shed is imminent. Once load is shed, market prices would likely reduce as the available supply is now able to meet the load. However, these lower prices do not reflect the incremental cost of the desired demand (i.e., non-interrupted demand). MISO administratively sets the LMPs and MCPs to the [Pricing] VOLL across the MISO Balancing Authority Area or Sub-Area for the duration of the load shed event (*MISO Tariff section 40.2.20.b.iii*). In a similar fashion, the [Pricing] VOLL is used to set DA prices in the hours in which offered supply cannot satisfy fixed demand bids plus fixed export schedules (*MISO Tariff section 39.2.10.b*).

3.1.3 Determining the System VOLL

The System VOLL represents the composite price that consumers are willing to pay to avoid an interruption of electrical service. In an event of a pervasive system outage, all customer classes would be affected. The System VOLL calculation uses weights based on a load-ratio share[9] of all load classes, yielding a raw value of $36,889/MWh (see Figure 6).

MISO proposes a System VOLL of $35,000/MWh, which will be used for scaling the Loss of Load Probability Curve portion of the new Operating Reserve Demand Curve (see section 3.3 below).

3.2 Pricing VOLL Circuit Breaker

This section begins by examining the frequency and duration of likely shortage conditions, and the existing Capacity Emergency and Emergency Pricing mechanisms. Then the proposed Pricing VOLL Circuit Breaker mechanism is presented.

3.2.1 Analysis of Energy and Reserve Shortages

MISO historical and planning analyses support the notion that future reserve and energy shortage conditions are likely to be of short duration. However, MISO also believes that high shortage prices should not be enforced at levels that are no longer needed to enhance reliability, and that it would be prudent to establish appropriate pricing phase-down regimes for such potential long-duration events.

To inform Pricing VOLL Circuit Breaker reductions, it is instructive to examine historical Operating Reserve and Energy shortage conditions.

- As detailed in *Appendix E: Analysis of Operating Reserve Shortages*,
  - RT OR shortages are rare (about 1 out of 3,300 5-minute RT intervals)
  - 85% of OR shortages last only 1 or 2 intervals.
  - The longest OR shortage lasted seven intervals (35 minutes).
  - When short of OR, MISO cleared an average of 92% of the OR requirement.
  - The minimum amount of RT cleared OR was 52% of the requirement.
- The MISO DA Market has never cleared an hour with an OR shortage
- Real-Time EEA-Level 3 (Max Gen Event Step 5) capacity emergency events, which involve MISO-directed load-shedding, have also been rare in MISO:
  - During Hurricane Laura in 2020, a capacity emergency was declared for a load pocket in the South Region. Under current rules and procedures, however, a similar occurrence would now be classified as a Transmission System Emergency.
  - During Winter Storm Uri in 2021, MISO ordered off 700MW in the South Region for about 2 hours (see *Appendix K: Winter Storm Uri Case Study*).

In addition to the market history, future-facing planning studies illustrate that energy shortage intervals are likely be infrequent and of short duration. Figure 7 shows results from the recent

[9] 34% Large C&I, 31% Small C&I, 35% Residential

MISO Loss of Load Expectation (LOLE) studies. These studies quantify the duration of potential unserved energy events.

These LOLE studies utilized 7,500 one-year Monte Carlo runs, which generated the following unserved energy event statistics:

- Mean outage event lasted 2.55 hours
- 60% of outage events were 1-2 hours
- 96% of outage events were <= 6 hours
- Longest outage event was 10 hours

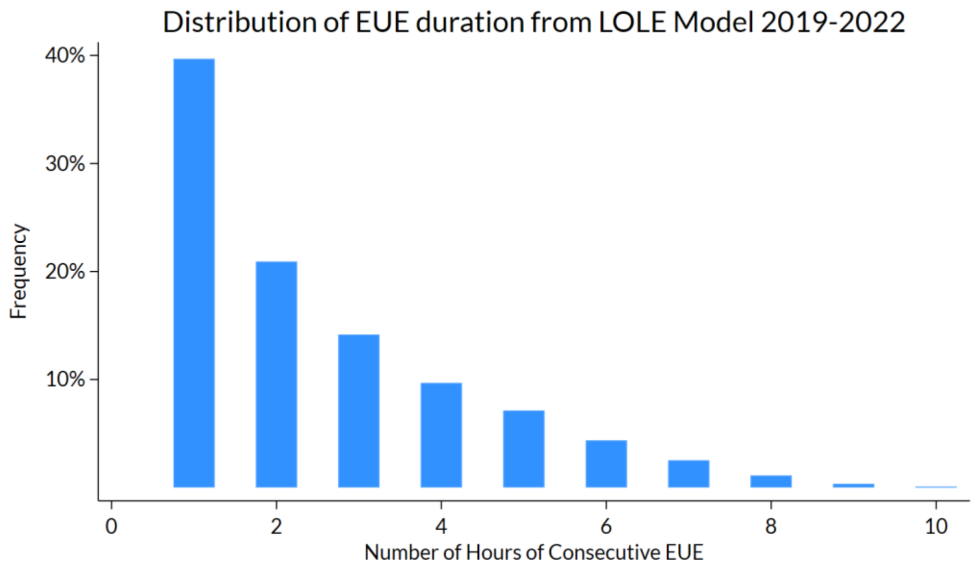


Figure 7 LOLE studies quantity the duration of potential unserved energy events

3.2.2 Review of MISO Emergency Pricing and Capacity Emergency Stages

Before proceeding to the proposed circuit breaker mechanism, it is worthwhile to review the existing MISO Emergency Pricing mechanisms, and the stages of a MISO Capacity Emergency (see Figure 8). A Max Gen Emergency is any stage above a Capacity Advisory, including Alert, Warning and Event Steps. MISO-directed firm-load shedding occurs at Event Step 5, which is also referred to as an EEA – Level 3 condition.

MISO Emergency Pricing uses Extended Locational Marginal Pricing ("ELMP") to better reflect system needs during Max Gen Emergencies. There are multiple tiers of pricing impacts, depending on the declared level of the Capacity Emergency:

- Beginning at the Max Gen Alert level, MISO implements Emergency Pricing Tier 0, which allows ELMP to adjust prices to include the commitment costs for Emergency Operations Resources, which have up to *four-hour* start-up times and minimum run times of less than *four hours*. Under normal conditions, ELMP does not consider resources with lead times greater than one hour.

- At higher Max Gen Emergency levels, MISO establishes Emergency Offer Floors ("EOFs") to assign Proxy Offers for Emergency resources, to prevent price suppression within ELMP. Relevant Emergency resources include External Resources that qualify as Planning Resources, Generators' Emergency Capacity, Load Modifying Resources, Emergency Demand Resources and Emergency Energy Purchases.
- At the Max Gen Warning level, the Tier I EOF is established as the minimum of $500 or the highest available economic offer in the Energy Emergency Area. At the Max Gen Event Step 2 level, the Tier 2 EOF is established as the minimum of $1,000 or the highest available economic or emergency offer in the Energy Emergency Area. As a further bulwark against price suppression, Tier II accounts for the possibility that an Emergency Offer may be higher than an economic Offer due to Emergency dispatch range release.

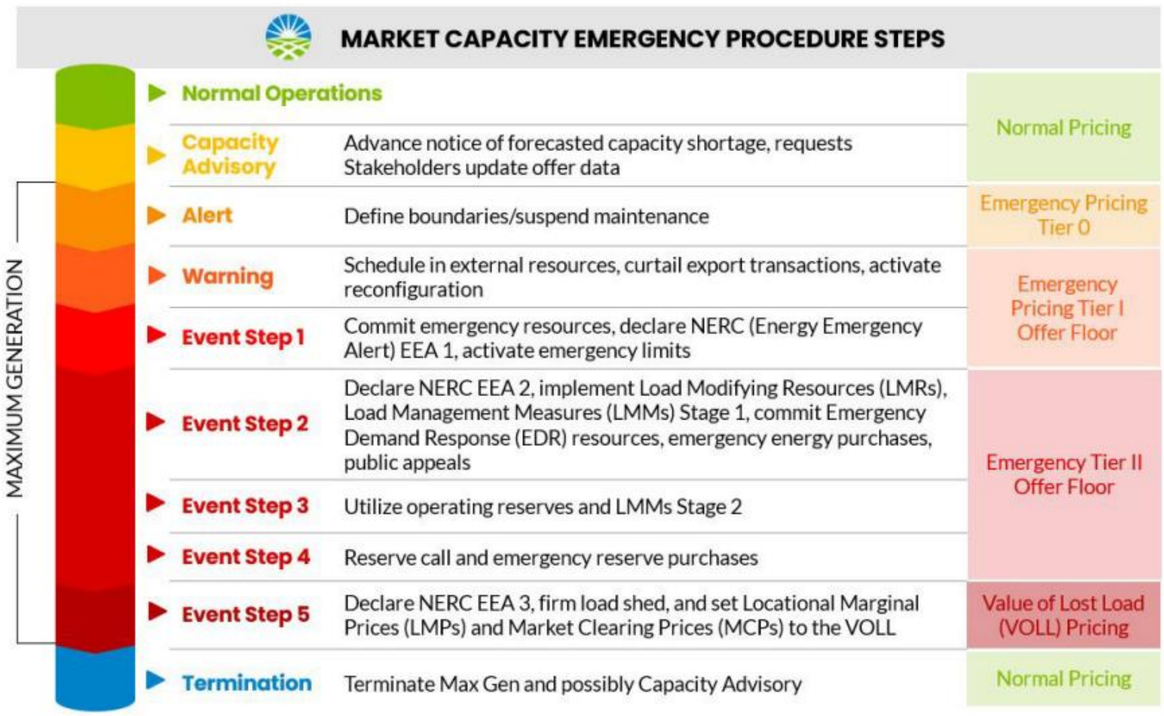


Figure 8 MISO Market Capacity Emergency Procedure Steps (SO-P-EOP-00-002)

3.2.3 Proposed Pricing VOLL Circuit Breaker Mechanism

MISO's recommended shortage pricing constructs will generate appropriate pricing signals during short-term energy shortage events, typically lasting minutes-to-hours. If high market prices do not resolve extreme shortage conditions in a timely manner, then the market design should consider the potential financial impacts to Market Participants. In addition, the Value of Lost Load (VOLL) calculations (Figure 6) support the notion that interruption costs are less for longer events.

MISO recommends creating a market price circuit breaker mechanism (Figure 9), which gradually reduces the Pricing VOLL during longer-duration energy shortages:

- First, at the end of four (4) hours of real-time EEA – Level 3 load-shedding in a Max Gen Emergency, the real-time Pricing VOLL shall be reduced from $10,000 to $5,000/MWh.

This is consistent with the updated VOLL studies (Figure 6), which show that outages lasting 4-12 hours had outage costs consistently in the $5,000/MWh range.

- Second, when the shortage conditions that led to a Max Gen Emergency with EEA – Level 3 persist when the Day-Ahead Market closes at 1030 Eastern Prevailing Time ("EPT"), the day-ahead and real-time Pricing VOLLs shall be set to $5,000/MWh for the next Operating Day. This approach synchronizes pricing regimes between the Day-Ahead and Real-Time Markets, when this emergency event extends into the next Operating Day.
- Third, when the shortage conditions that led to the Max Gen Emergency continues to any additional Day-Ahead Market closing, the day-ahead and real-time Pricing VOLLs shall be set to $2,000/MWh for the next Operating Day. The $2,000/MWh pricing level is only activated for an extreme multi-day load-shedding event and is consistent with the Energy Offer Resource Hard Price Cap, established by FERC Order 831.

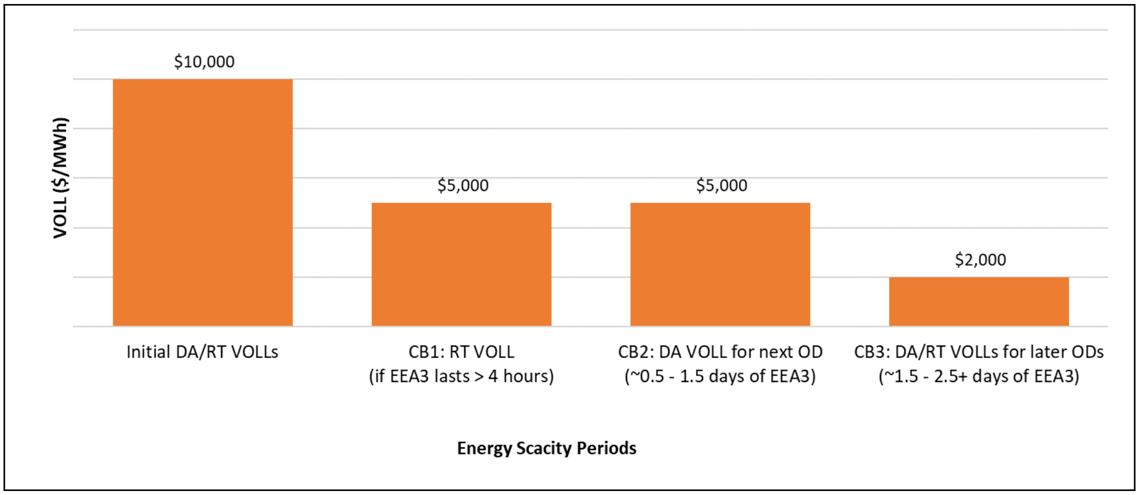


Figure 9. Timeline of Pricing VOLL Circuit Breakers

Circuit Breaker Termination: When the day-ahead and/or real-time Pricing VOLLs have been reduced by a circuit breaker, they shall cease to apply after MISO has terminated the Max Gen Emergency and thereby declared that the shortage conditions have ended. At that point, the Pricing VOLL, as a potentially applicable administrative price, shall be reset to $10,000/MWh. Furthermore, if the Max Gen termination occurs before 1030 EPT, the Pricing VOLLs, as potentially applicable administrative prices, are reset to $10,000/MWh at the end of the current Operating Day. If the Max Gen termination occurs after 1030 EPT, the Pricing VOLLs, as potentially applicable administrative prices, are reset to $10,000/MWh at the end of the next Operating Day. These termination rules ensure that the Day-Ahead and Real-Time Pricing VOLLs remain consistent as the market transitions back to normal conditions.

The Pricing VOLL Circuit Breaker has these additional features:

- In the case where there are multiple EEA – Level 3 periods within a single declared Max Gen Emergency, the cumulative EEA – Level 3 time determines the transition to the next stage of the RT Pricing VOLL.

- Even if the Max Gen Emergency is declared for only a portion of the MISO market, the Pricing VOLL Circuit Breaker will be applied *across the entire market*. In other words, there is a single RT Pricing VOLL that is applied both as a market-wide price cap and as the administrative price for declared EEA – Level 3 areas.

For an example timeline of a Pricing VOLL Circuit Breaker event, see *Appendix M: Example of a Long-Duration Shortage Pricing Event.*

3.3 Operating Reserve Demand Curve

MISO has created five reserve products to help ensure that reliability of the grid. The original three products were Regulation, Spinning and Supplemental Reserves. In recent years, the Ramp Capability and Short-Term Reserve products were added. For more details, please refer to *Appendix D: Summary of MISO Reserve Products.*

For each reserve product, MISO specifies a target requirement which can vary at different times or conditions. In most intervals, there is sufficient supply to satisfy these reserve requirements, and a Market Clearing Price (MCP) is established using provided offers and/or lost opportunity costs. When there is insufficient supply to satisfy the requirement, then a price is established using a "demand curve." The demand curve should reflect the increased reliability risk for that reserve shortage, while considering the relative (and sometimes cumulative) risks of other reserve shortages.

The ORDC is important as it reflects the combined need of Regulating, Spinning and Supplemental Reserves. These products must be deliverable within 10 minutes (or less for regulating reserves) to ensure the grid can withstand the loss of the largest supply source, and thus, an extended deficiency of OR must be avoided. The ORDC has the highest potential prices of any reserve demand curve, as it is used to escalate prices towards VOLL (the price cap) as cleared Operating Reserves are depleted.

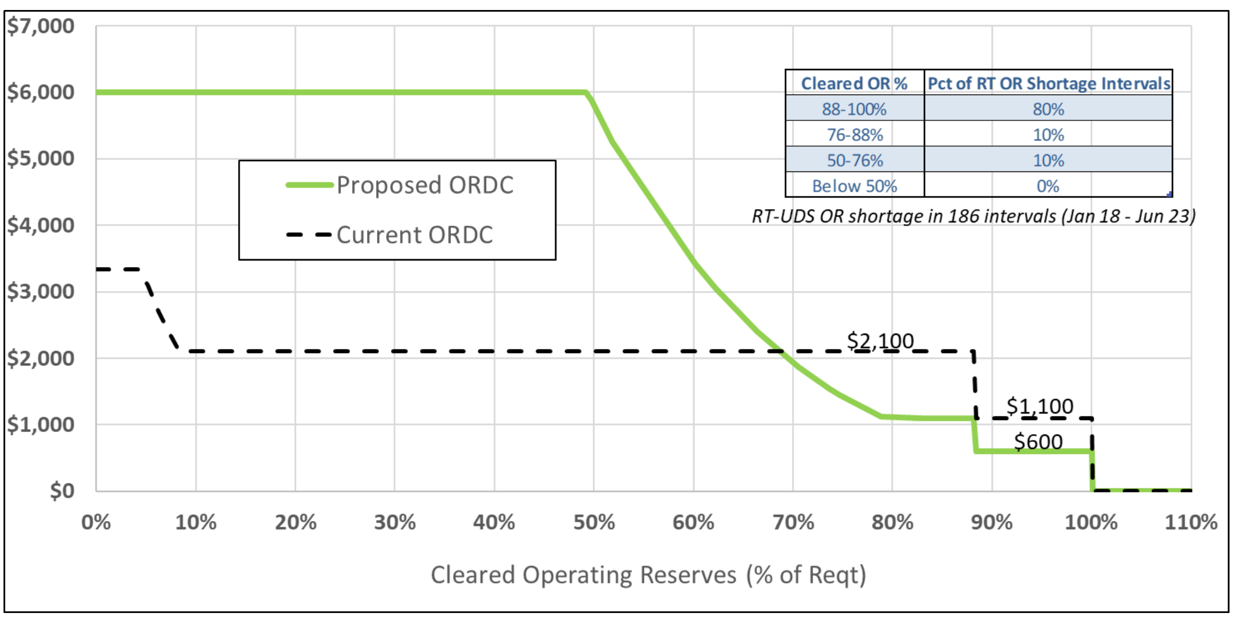


Figure 10 MISO Proposed Operating Reserve Demand Curve (ORDC)

The current ORDC does not fully reflect the reliability conditions of the grid. It is largely defined by two steps ($1,100 and $2,100) and does not increase as the Operating Reserve deficiency worsens, not considering the most extreme of deficits. The first $1,100 step can also provide challenges for congestion management, even for small Operating Reserve deficits.

To address these limitations, MISO is proposing an update to the ORDC (see Figure 10). The ORDC will be discussed below in three parts: 1) the general shape of the curve, 2) the lower bounds for the curve and 3) an upper bound for the curve.[10]

3.3.1 Loss of Load Probabilities Drive the ORDC Shape

As Operating Reserves are reduced, there is an increasing chance for customer demand to exceed supply. It is possible to estimate the cost of a given Operating Reserve shortage, by computing the probability of losing load at that level of Operating Reserves, and then multiplying that by the economic value of the unserved load. In contrast to a relatively flat ORDC define primarily by a fixed $2,100/MWh step, this approach increases the demand curve as cleared Operating Reserves decrease (note that upper and lower bounds for the demand curve are needed to satisfy other price formation objectives, as discussed later).

This ORDC is constructed by first developing a loss-of-load-probability curve that quantifies the risk of losing load for decreasing amounts of Operating Reserves.[11] MISO's approach compares historical Look Ahead Commitment (LAC) and Real-Time Security Constrained Economic Dispatch (SCED) cases to capture Net Load and Gen Outage/Derate uncertainties within a 10 to 30-minute lead time. Then, a Monte Carlo simulation generates the Loss of Load Probability (LOLP) distribution, for varying contingency reserve levels.

Next, the LOLP curve is scaled by the System VOLL of $35,000/MWh,[12] which reflects the financial impact of shedding load across all customer classes (residential, small, and large commercial and industrial). This value is higher than the $10,000/MWh Pricing VOLL used as the price cap and administrative pricing during load-shedding, which prioritizes residential loads.

This higher System VOLL is also consistent with the actions taken by MISO Operations during increasing Operating Reserve deficits, as prolonged deficits below the Most Severe Single Contingency (MSSC)[13] of ~88% brings firm load-shedding decisions into play.[14] The following chart (Figure 11) illustrates how the ORDC shape changes for different values of the System VOLL. Note that the bottom "$10K*LOLP" curve is quite shallow and only reaches ~$1,600/MWh at a 50% Operating Reserve shortage. That pricing is too low given the priorities and actions that would be taken by MISO operations during such shortages. The $35,000/MWh scaling (orange curve), established using the VOLL calculations above, escalates Operating Reserve shortage

[10] MISO performed extensive studies for December 23, 2022 (Winter Storm Elliott), to see how real-time dispatch and prices would react to different Operating Reserve Demand Curves.
[11] "Addressing Uncertainties Through Improved Reserve Product Design," Y. Chen, IEEE Transactions on Power Systems, Vol. 38, No. 4, July 2023, pp. 3911-3923.
[12] The composite MISO VOLL considering all customer classes (1-hour, summer, off-peak) is $36,888/MWh.
[13] The default MISO MSSC is 1,732 MW, which is loss of all interconnections with Manitoba Hydro. This equates to ~88% of the MISO Operating Reserve Requirement.
[14] MISO Market Capacity Emergency (EOP-002). Step 4.2.9.4 states "IF Contingency Reserves fall below minimum required (MSSC) for greater than 30 minutes and NO reasonable actions exist to restore within 90 minutes, THEN DECLARE an EEA-Level 3."

pricing more appropriately. At the same 50% Operating Reserve shortage, the ORDC now reaches ~$6,000/MWh (see Figure 10), reflecting the severity of imminent operator actions.

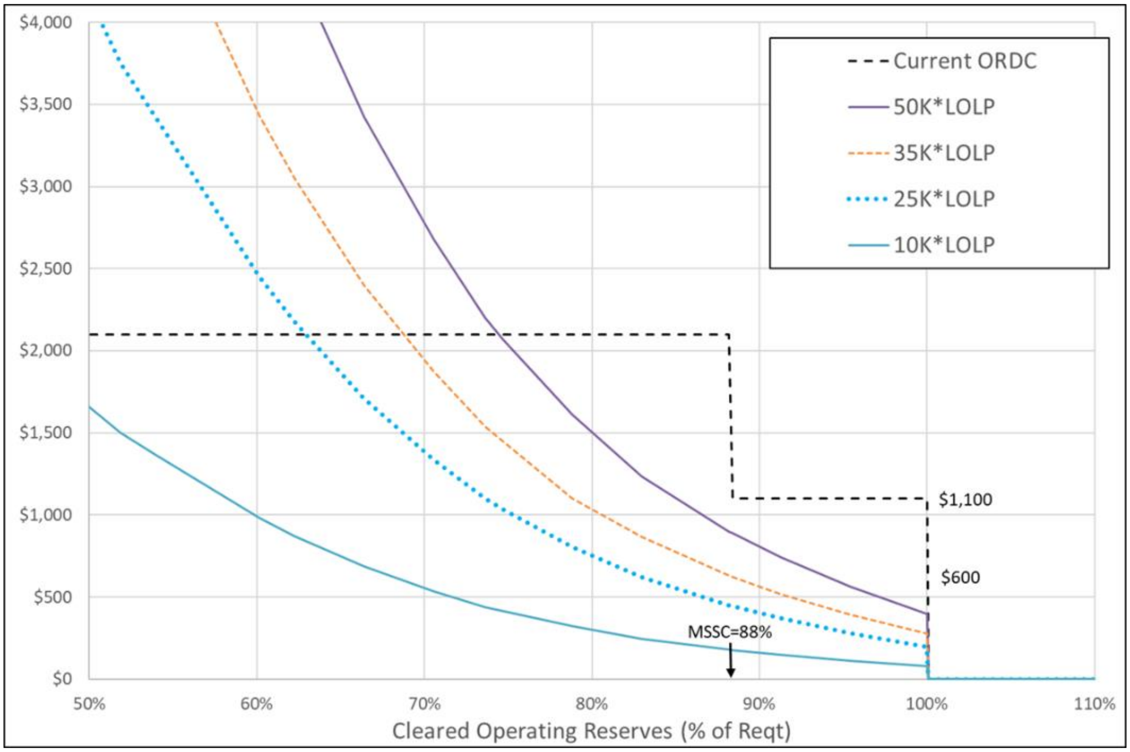


Figure 11 Comparing the impact of alternative System VOLLs ($/MWh)

3.3.2 Establishing Lower Limit(s) for the ORDC (Small Reserve Deficits)

Since the launch of the Ancillary Services Market in 2009, the lower bound(s) for the ORDC have been adjusted several times by MISO:

- Originally, the ORDC had a single $1,100 floor, which ensured that all available Operating Reserves were cleared considering the Energy Offer Cap of $1,000/MWh along with the Contingency Reserve Offer Cap of $100/MWh [Docket ER07-1372].
- It was then determined that the $1,100 floor was too high for certain short-term economic shortages, so a $200/MWh step was added for small deficits (0-4%) [Docket ER13-921-000].
- With the implementation of FERC Order 831, the Energy Offer Hard Price Cap increased to $2,000/MWh, so an additional $2,100/MWh step was added below the MSSC [Dockets ER18-622-004, ER19-328-000, and ER20-11-000].
- More recently, it was determined that the $200/MWh step was no longer needed [Docket ER21-2797], due to the introduction of the Ramp Capability Product, and changes to the emergency pricing algorithms.

These changes illustrate the desire of MISO to balance pricing signals with the associated reliability risks. When establishing the latest proposed ORDC floor(s), MISO has considered several competing factors:

- Attempting to always clear 100% of available reserve capacity would require a very high ORDC floor of $2,100/MWh, and this would lead to inefficient price swings for small Operating Reserve deficits. Rather, it is more prudent to set the lower bound(s) high enough to clear the majority of the available Operating Reserves for small Operating Reserve deficits, and to rely on the increasing ORDC to clear additional Operating Reserve capacity for larger Operating Reserve shortages.
- The Ramp Capability Product helps MISO avoid spurious Operating Reserve shortages by better positioning of the generation fleet to respond to potential short-term ramping needs. Since there are fewer transient ramping shortages, MISO does not need to create an extremely low ORDC step, such as the previous $200/MWh step.
- Emergency pricing logic (discussed in Section 3.2.2) employs Emergency Offer Floors ($500 and $1,000) to prevent energy prices from collapsing when emergency capacity is deployed. The market should avoid going short on Operating Reserves if that would allow prices to fall below one (or both) of these offer floors. This can be accomplished by setting ORDC floors sufficiently high.
- The Short-Term Reserves (STR) product helps to reduce the potential of Operating Reserve shortages by ensuring that adequate capacity is committed to mitigate potential uncertainties in the upcoming 30-minute to 3-hour timeframe. This product has its own demand curve, which can reach $500/MWh. As the same resource capacity can simultaneously be cleared for Short-Term Reserves <u>and</u> one of the other reserve products (e.g., Reg, Spin, Supp, or Ramp Capability), the current $1,100 step may be too high as the first step given the additional $500 potential impact of a concurrent STR shortage. Thus, when STR is not short, a small Operating Reserve shortage is likely a transient one and will be priced accordingly. But when STR is short, it's additional shortage price will complete the pricing signal.

More recently, MISO and the Independent Market Monitor (IMM) have recognized that the ORDC can impact the effectiveness of congestion management. (See *Appendix G: IMM State of the Market Recommendation 2022-1 with MISO Response*). Operating Reserve shortages impact energy prices through the Marginal Energy Component (MEC), which can make congestion management more challenging due to comparatively smaller Marginal Congestion Components (MCC). A constrained resource will come unbound once its Locational Marginal Price (LMP) exceeds its Energy Offer, which is more likely to happen as the MEC increases during Operating Reserve shortage. This can cause transmission constraint violations, which may then trigger Manual Redispatches (MRDs), leading to increases in make-whole payments. See *Appendix I: Example Illustrating the Potential Impact of Operating Reserve Shortage on Day-Ahead Margin Assurance Payment (DAMAP).*

Further research regarding Transmission Constrained Demand Curves (TCDCs) and congestion management are underway, but it is important to recognize that reductions in the ORDC for small shortages will improve MISO's ability to manage congestion during tight operating conditions.

With that background, MISO proposes an ORDC floor of $600/MWh when cleared Operating Reserves are above the MSSC (88%), and $1,100/MWh when cleared OR is below the MSSC (Figure 12).

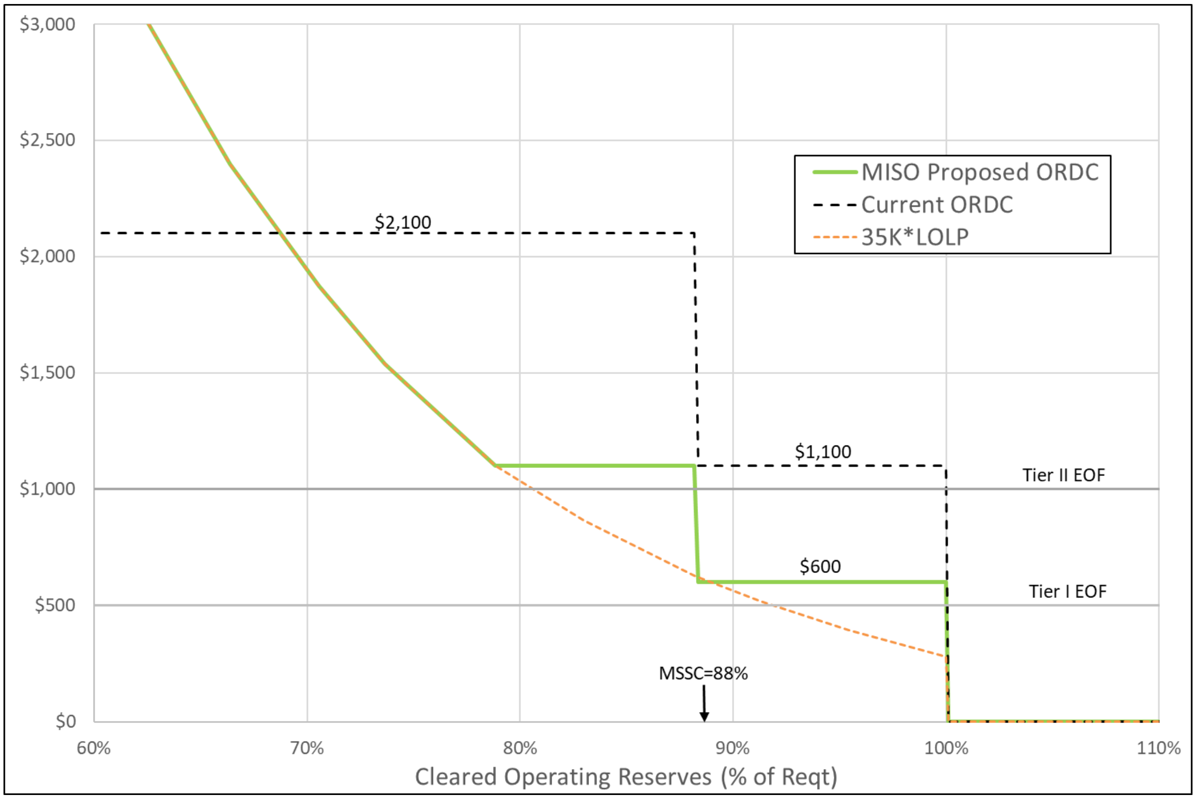


Figure 12 The proposed MISO ORDC employs $600 and $1,100 lower bounds

The $600 ORDC lower bound was selected for the following reasons:

- When MISO declares a Max Gen Warning or Maximum Generation Event Step 1, the market solution should not violate the Operating Reserve requirement to avoid clearing resources offered at the minimum Tier I EOF. This is accomplished by setting the floor to be the sum of:
    - the minimum Tier I Emergency Offer Floor of $500/MWh and
    - the Contingency Reserve Offer Cap of $100/MWh.
- This floor greatly reduces OR "economic shortages" compared to an even lower floor ($200/MWh).[15]
- Acknowledges the potential combined pricing impact of Operating Reserve and STR shortages (i.e., the impact of concurrent Operating Reserve and STR shortage could reach the current $1,100 ORDC step).
- By reducing the first step from $1,100 (Current ORDC) to $600, MISO can better manage congestion during small Operating Reserve shortages.

[15] MISO studied Winter Storm Elliott (12/23/22) and compared the current $1,100 ORDC floor with lower $600 and $200 values. The $200 ORDC floor would have caused Operating Reserve shortage in 24 additional intervals, with an average 160MW deficit. The proposed $600 floor would have results in only 5 additional shortage intervals, with an average 14MW deficit. Thus, the $500 MW reduction from $1100 to $600 had significantly less impact on the amount of cleared Operating Reserves compared to the lower $200 ORDC floor.

The $1,100 ORDC lower bound was selected for the following reasons:

- This second step increases the pricing when cleared Operating Reserves fall below the Most Severe Single Contingency, used in EOP-002 Step 4.2.9.4.
- When MISO declares a Max Generation Event Step 2, the market solution should not violate the Operating Reserve requirement to avoid clearing resources offered at the minimum Tier II EOF. This is accomplished by setting the floor to be the sum of:
  - the minimum Tier II Emergency Offer Floor of $1,000/MWh and
  - the Contingency Reserve Offer Cap of $100/MWh.
- By reducing the second step from $2,100 (Current ORDC) to $1,100, MISO can better manage congestion during small Operating Reserve shortages.

3.3.3 Establishing Upper Limits for the ORDC (Large Reserve Deficits)

During extreme Operating Reserve shortages, high energy prices will incentivize beneficial demand response, increased imports, and additional energy production. As VOLL is administratively applied during MISO-directed capacity emergency load-shedding, prices should approach VOLL before load-shedding begins. This is accomplished by ensuring that the ORDC escalates appropriately when deficits become severe, and that the ORDC upper bound is set sufficiently high.

Additionally, the ORDC upper limit should allow sufficient room for other MEC contributions (i.e., marginal energy offers and shadow prices from other reserve products) as well as LMP congestion and loss components. The current ORDC is very close to VOLL, which curtails many valid LMPs during tight operating conditions.

MISO proposes a $6,000/MWh[16] upper bound for the ORDC (refer to Figure 10):

- During severe reserve shortages, the energy prices will approach VOLL to encourage proper response from market participants.
- This ORDC upper bound also provides up to $4,000 for other MEC and LMP contributions to the energy prices, before the VOLL Price Cap is applied. For example, marginal energy offers can reach $2,000/MWh, and the STR Demand Curve has a $500 upper limit. There are other smaller reserve product demand curves to also consider. The separation between the upper limit of the ORDC ($6,000/MWh) and the Pricing VOLL ($10,000/MWh) is illustrated in the right-side of Figure 12. With the current shortage mechanism (left-side), the VOLL price cap can truncate valid signals in the energy LMPs.
- In addition, the selection of this upper ORDC limit recognizes that firm load-shedding may be avoided even when minimal reserves are being cleared. MISO and IMM studies showed that the Loss of Load Probability ("LOLP") curve only reached up to ~60%, as cleared operating reserves approach zero. Thus, it is reasonable that the ORDC should not exceed 60% of $10,000/MWh (the "Pricing VOLL"), even when cleared reserves are minimal, as MISO-directed load-shedding might not occur.

[16] Note also that the $6,000/MWh upper bound is consistent with the LOLP curve increasing to ~61% when Operating Reserves are completely depleted ($10K * .61 = $6,100).

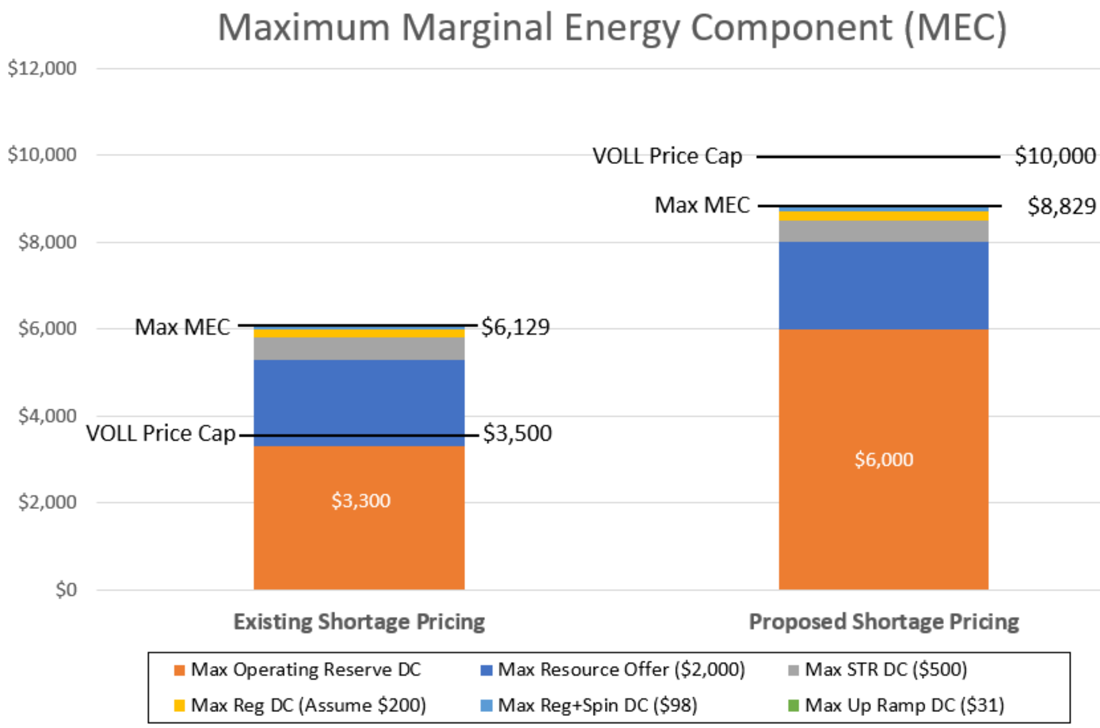


Figure 13: Maximum Marginal Energy Component (MEC) for Existing and Proposed Shortage Pricing

3.4 Day-Ahead Demand Bid Cap Removal

MISO considers it unnecessary and inappropriate to apply the Energy Offer Hard Price Cap to Day-Ahead Price-Sensitive Demand Bids and Virtual Demand Bids. The cap was applied as part of the momentum in complying with Order No. 831. However, before Order No. 831, there were no day-ahead bid caps in the MISO Tariff. The application of this bid cap prevents Day-Ahead Price Sensitive Demand from specifying a value between $2,000/MWh and the Pricing VOLL (to be $10,000/MWh). In contrast, Fixed Demand Bids will clear at any price, up to the Pricing VOLL. There is no viable policy reason not to allow Day-Ahead Price Sensitive Demand to likewise bid beyond the $2,000/MWh price cap.

3.5 Emergency Demand Response (EDR) Offer Cap

The EDR Offer Cap is defined to be VOLL in Schedule 30 of the Tariff. EDRs can be called upon during NERC Energy Emergency Alert 2 ("EEA-Level 2"), Alert 3 ("EEA-Level 3"), or any other type of emergency event.

This is the status of the EDR product:

- There is a limited MW volume of registered EDRs, often totaling <500MW from a handful of MPs, with notification times averaging >4 hours. Also, EDR offers must be entered prior to the operating day, reducing their flexibility in real-time.
- EDRs have only been deployed once (9/24/2014).

- EDRs are managed on a standalone system (separate from Day-Ahead/Real-Time and Demand Side Resource Interface).
- EDR settlement is a manual process.
- More details can be found in *Appendix J: Emergency Demand Response (EDR) Background*.

Given the proposed increases to the Pricing VOLL, MISO has concerns that such potential offers overstate their relative value, compared to other supply resources.

MISO has conducted internal and external discussions to identify potential solutions, as well as the broader considerations for the EDR product. To date, three broad solutions have been discussed:

1. Retain the existing EDR infrastructure and set the EDR Offer Cap to a fixed value, such as $3,500/MWh, or the Energy Offer Hard Cap of $2,000/MWh.
    a. This requires minimal effort.
2. Utilize the same offer validation process as for other resources, established by FERC Order 831.
    a. The system and infrastructure requirements to accomplish this are to be determined and may require significant effort.
    b. The Independent Market Monitor verifies all offers above $1,000 soft cap.
    c. Verified offers above $2,000 (hard cap) are potentially eligible for make whole payments but cannot set Market Clearing Prices.
3. Retire and/or replace the EDR instrument.
    a. Encourage use of existing Load Modifying Resource and Demand Response Resource functionality, as well as future DER capabilities (FERC Order 2222).
    b. Retiring the product requires little effort.
    c. Consider increasing the DRR hard cap, so verified offers could clear and set price above $2,000/MWh. Current EDRs could transition to the DRR1 resource model and participate during emergencies.

Following the April 2024 MSC meeting, MISO requested stakeholder feedback about Option 1, with a fixed $3,500/MWh EDR Offer Cap. All feedback supported this approach, at least until further market improvements can determine whether or not emergency demand response can be a more useful tool for MISO System Operations.

4. Conclusion

To increase the market's effectiveness at managing congestion and transparency, key shortage pricing parameters and relationships described in the Tariff should be modified to send appropriate incentives to market participants.

The Pricing VOLL should be increased to $10,000/MWh. This will continue to be used as a price cap for energy and reserve prices, and as the administrative price applied during MISO-directed capacity emergency load-shed events.

In the unlikely occurrence of an extended-duration energy shortage event, a Pricing VOLL Circuit Breaker is also proposed. This mechanism allows the Pricing VOLL to be successively lowered to $5,000/MWh, and then to $2,000/MWh for energy shortage events lasting hours-to-days.

The ORDC should be modified to better reflect the reliability conditions of the grid. This is accomplished by developing a loss-of-load-probability curve to quantify the risk of losing load for decreasing amounts of Operating Reserves. This curve is scaled by the System VOLL of $35,000/MWh, which reflects the financial impact of dropping load across all customer classes. An ORDC floor of $600 balances potential "economic shortages" with the increased burdens on congestion management of Operating Reserve shortages. An $1,100 ORDC step also helps clear additional reserves below MISO's Most Severe Single Contingency. An ORDC ceiling of $6,000 allows market prices to appropriately approach VOLL during severe Operating Reserve shortages and prevents the overshadowing of other important pricing components (e.g., other reserve product shortages, marginal fuel costs, congestion and losses).

MISO proposes to remove the $2,000/MWh cap for Day-Ahead Price Sensitive Demand Bids and Virtual Demand Bids. Removing these bid caps would allow day-ahead demand to clear energy above $2,000/MWh, but below the Pricing VOLL of $10,000/MWh.

The Emergency Demand Response (EDR) Offer Cap should no longer be directly tied to the VOLL. Appropriate alternatives could include simply setting the EDR Offer Cap to some fixed value, utilizing the same FERC Order 831 offer cap process used for other resources or retiring the EDR product.

Appendix A: Market Design Guiding Principles

FERC Price Formation Goals (Docket AD14-14)

- Maximize market surplus for consumers and suppliers;
- Provide correct incentives for market participants to follow commitment and dispatch instructions, make efficient investments in facilities and equipment, and maintain reliability;
- Provide transparency so that market participants understand how prices reflect the actual marginal cost of serving load and the operational constraints of reliably operating the system; and,
- Ensure that all suppliers have an opportunity to recover their costs.

MISO Market Vision Guiding Principles[17]

1. Support an economically efficient wholesale market system that minimizes cost to distribute and deliver electricity.
2. Facilitate non-discriminatory market participation regardless of resource type, business model, sector or location.
3. Develop transparent market prices reflective of marginal system cost and cost allocation reflective of cost-causation and service beneficiaries.
4. Support market participants in making efficient operational and investment decisions.
5. Maximize alignment of market requirements with system reliability requirements.

These were presented as part of an August 24, 2023, Market Subcommittee presentation.

[17] https://www.misoenergy.org/markets-and-operations/market-roadmap/#:~:text=Five%20principles%20serve%20as%20guideposts%20for%20progressing%20toward,reflective%20of%20cost-causation%20and%20service%20beneficiaries%20More%20items

Appendix B: Key MISO Market Dates and Recent Shortage Pricing Efforts

MISO Market Key Dates

- 2001: First FERC-approved RTO
- 2005: Day-Ahead/Real-Time market launch
- 2009: Ancillary Service Market
- 2011: Reserve Procurement Enhancement for zonal reserves
- 2014: SRPBC for Energy (South Region integration)
- 2015: Emergency Pricing Construct
- 2016: Ramp Capability Product
- 2018: SRPBC for Reserves
- 2021: Emergency Pricing minimum floors ($500 and $1000)
- 2021: Short-Term Reserve (STR) Product Go Live
- 2022: STR and RCP Up Ramp demand curves updated
- 2024: Forced-Off Asset (FOA) Settlement Adjustments

Figure 14: MISO Market Key Dates

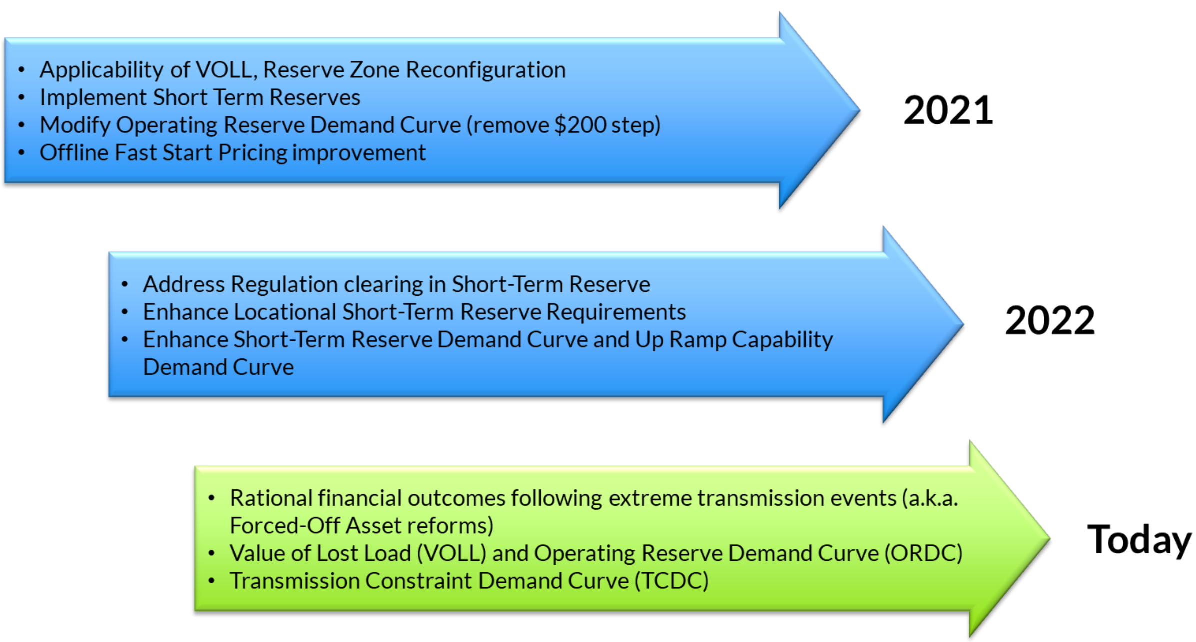


Figure 15: Recent Updates to Emergency Pricing and Shortage Pricing

Appendix C: Other ISO/RTO Approaches for Shortage Pricing

PJM Reserve Demand Curves and Caps for Energy and Reserve Prices

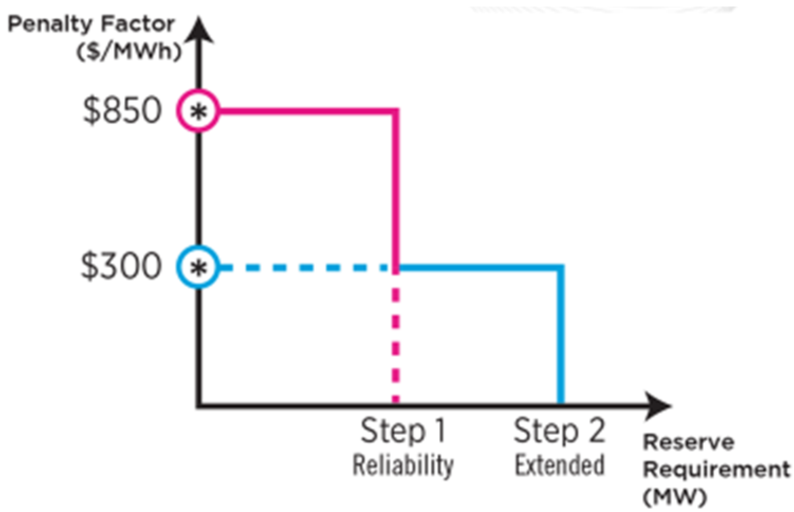


Figure 16: PJM Reserve Demand Curves

Market Product	Price Cap	Notes
System Energy LMP	$3,700	Analogous to MISO MEC
Nodal LMPs	-	Congestion and losses are added to SE-LMP
Synchronized Reserve*	$1,700	Two step demand curve ($300, $850)
Primary Reserve	$1,275	Two step demand curve ($300, $850)
30–Minute Reserve	$850	Two step demand curve ($300, $850)
Regulation	Not co-optimized with energy in real-time (no explicit shortage pricing mechanism)	

*Additional punitive charges can be assessed for under-performance following a Synchronized Reserve deployment event.

Note that PJM System Energy LMP is analogous to MISO Marginal Energy Component, or MEC (MW-weighted average of load LMPs).

In 2024, PJM's Reserve Certainty Senior Task Force will begin discussions, to potentially update these curves/caps.

SPP Reserve Products are similar to MISO

Market Product*	Price Cap	Notes
Energy (LMP, MEC)	none	MEC effectively limited to $3,900
Regulation Up #	$1,900	Multi-step demand curve, first (base) step updated monthly, max $600
Spinning Reserve #	$1,300	Will relax spin requirement based on $200 violation relaxation limit (VRL)
Supplemental Reserve #	$1,100	Contingency Reserve Demand Curve has 3 steps ($275, $550 and $1100)
Ramp Capability Up Reserve	$23 now	Multi-step demand curve up to estimated cost of unit start-up (min $10)
Uncertainty Reserve	$113 now	Multi-step demand curve (min $10) [July 2023 go-live]

#Formulated similar to MISO (e.g., Reg >> Spin >> Supplemental, shadow prices are additive).

*Focusing on just upward-ramping reserve products (e.g., not Reg Down).

Appendix D: Summary of MISO Reserve Products

MISO Reserve Products address uncertainty in several timeframes

Product	Time Horizon	Uncertainty Addressed
Regulating Reserves	Seconds (0-5 minutes)	Uncertainty between real-time dispatch and actual load – intended for normal imbalance within 5-minute intervals
Contingency Reserves (Spin & Supplemental)	10 minutes post-contingency event	Uncertainty caused by contingencies that create significant & immediate imbalances – NERC required recovery in 15 min.
Ramp Capability Product	10-25 minutes	Uncertainty in upcoming intervals due to net load uncertainty and contingencies
Short-Term Reserve	Intra-day > 30 min, up to 3 hrs	Intra-day uncertainty caused by net load uncertainty and contingencies

MISO Operating Reserves have a prioritization hierarchy

- Terminology
  - *Contingency Reserves = Spinning Reserves + Supplemental Reserves*
  - *Operating Reserves = Regulating Reserves + Contingency Reserves*
- Operating Reserves are prioritized
  - *Regulation >> Spin >> Supplemental*
  - *"Higher quality" reserves will not have lower prices (MCPs)*
  - *"Higher quality" reserves can be used to satisfy "lower quality" reserve requirements*
- Three system-wide constraints are enforced in the clearing engines:
  - *(Reg) Reserves ≥ (Reg) Requirement*
  - *(Reg + Spin) Reserves ≥ (Reg + Spin) Requirement*
  - *(Reg + Spin + Supp) Reserves ≥ (Reg + Spin + Supp) Requirement*

MISO Reserve Product Mathematical Formulation

Resource *i* and time interval *t* with ramp rate of *RR (MW/min)* and cleared energy $Energy_{i,t}$

	Operating Reserve			Ramp	Short-Term Reserve
	Regulating Reserve	Contingency Reserve		Ramp capability up product (ignore down ramp)	Short term reserve (STR) Online & offline
		Spinning Reserve	Supplemental Reserve Online & offline		
Delivery time	5 min	10 min	10 min	10-25 min*	30 min – 3 hour*
Resource Offers	$O\_Reg_{i,t}$	$O\_Spin_{i,t}$	$O\_Supp_{i,t}$	n/a	$O\_Str_{i,t}$ (n/a for online STR)
Variables	$reg_{i,t}$	$spin_{i,t}$	$supp_{i,t}$	$rcup_{i,t}$	$str_{i,t}$
Ramp constraint	$reg_{i,t} \leq 5 \cdot RR_{i,t}$	$spin_{i,t} \leq 10 \cdot RR_{i,t}$	$supp_{i,t} \leq 10 \cdot RR_{i,t}$ for online resources	$rcup_{i,t} \leq 10 \cdot RR_{i,t}$	$str_{i,t} \leq 30 \cdot RR_{i,t}$ for online resources
Resource limit constraints	$Energy_{i,t} + reg_{i,t} + spin_{i,t} + supp_{i,t} + rcup_{i,t} \leq EcoMax_{i,t}$ (1) $Energy_{i,t} + str_{i,t} \leq EcoMax_{i,t}$ (2)				

STR is cleared alongside other reserves (i.e. a MW of capacity can clear both STR and another reserve type)

Reserve Product Requirements

- *Regulation*: 300, 400 or 500 MW (hourly)
  - Increased in June 2024: 500 – 800 MW (hourly)
- *Spin*: 900 or 1,200 MW (hourly)
- *Supplemental*: 1,110 MW
- *Up-Ramp*: 1,075MW + forecasted 10-min ramp
- *Short-Term Reserve*: Hourly requirements for normal and emergency conditions; always >= 3,000 MW

Reserve Product Offer Caps

- *Regulation*: $500/MWh
- *Spin/Supplemental*: $100/MWh
- *Up-Ramp*: No offer (prices based lost opportunity costs)
- *Short-Term Reserve*: No offer for on-line; $100/MWh for off-line units

Reserve Product Demand Curves

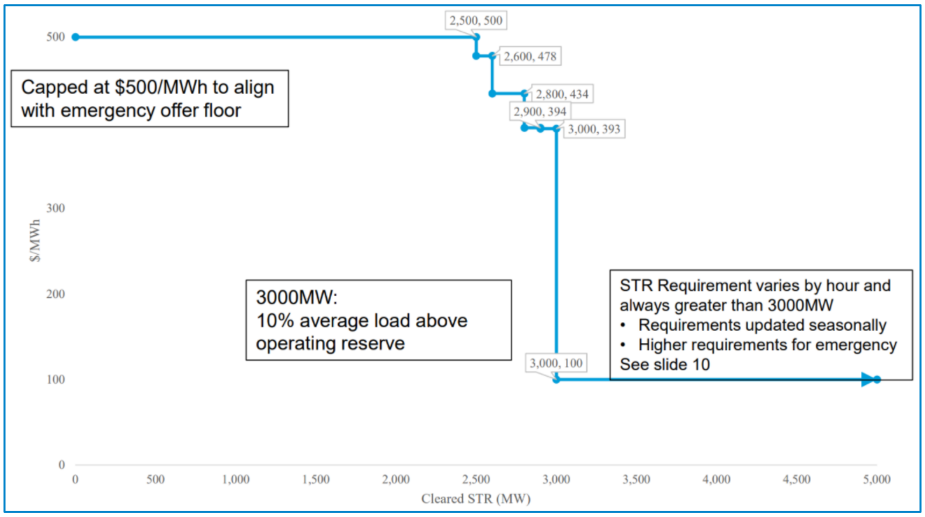


Figure 17: Short-Term Reserves (STR) Demand Curve

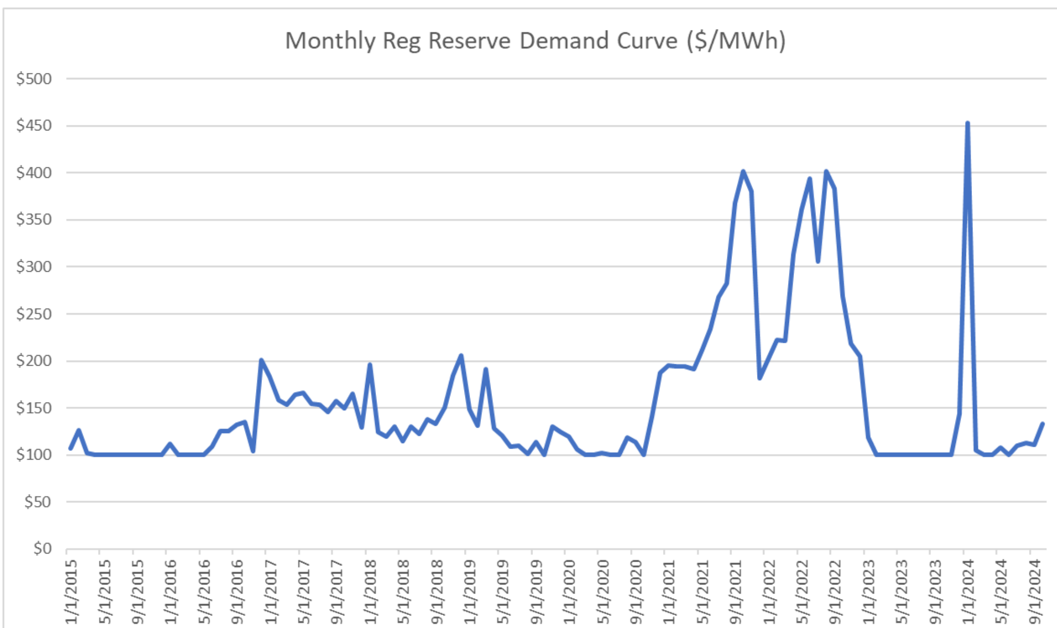


Figure 18: Regulation Demand Curve (single value, updated monthly)

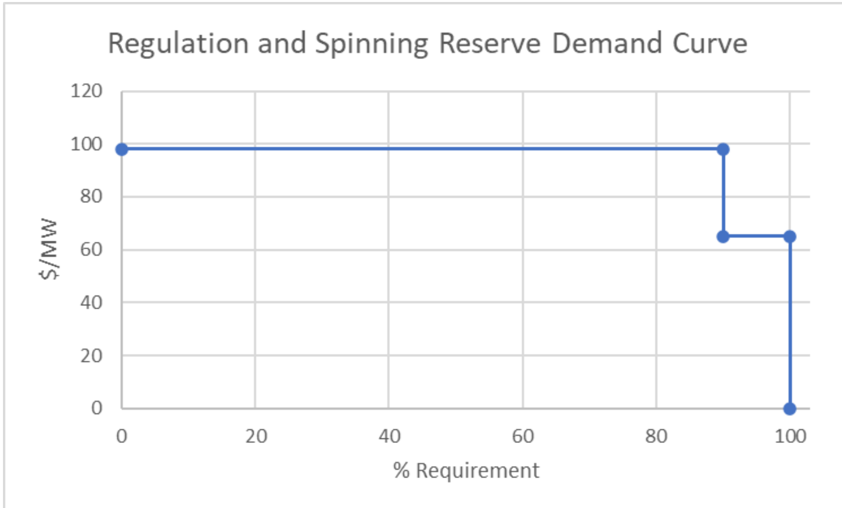


Figure 19: Regulation + Spin Demand Curve

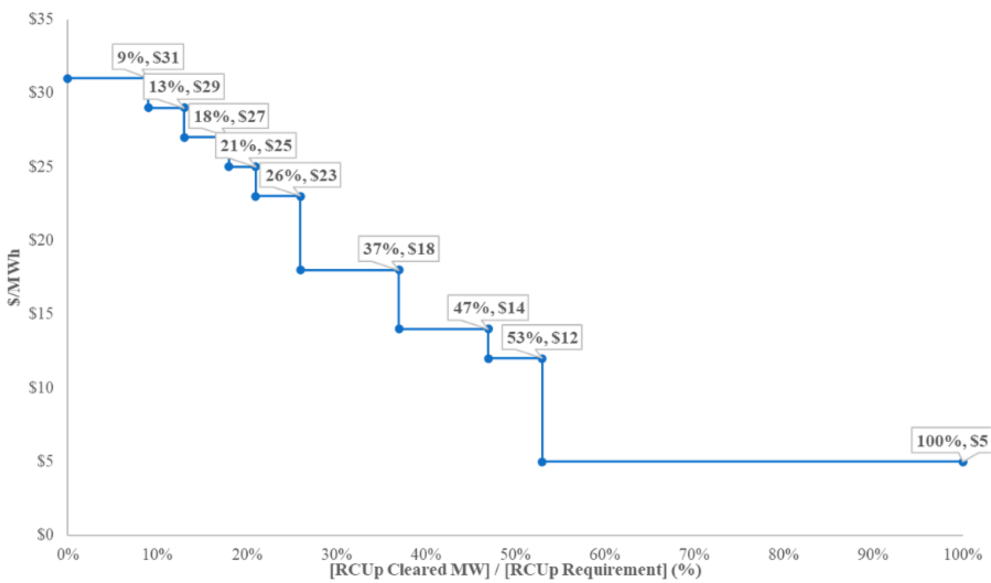


Figure 20: Up-Ramp Capability Demand Curve Up-Ramp Capability Demand Curve

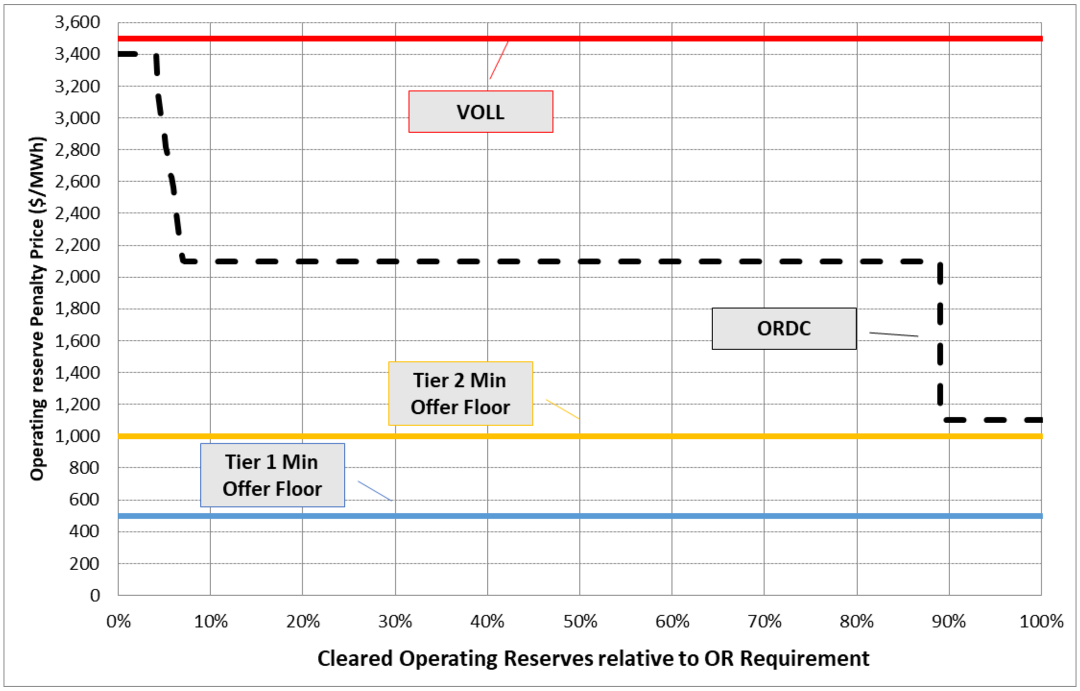


Figure 21: Current Operating Reserve Demand Curve

Appendix E: Analysis of Operating Reserve Shortages

The hierarchy of Regulation, Spin and Supplemental reserves implies that all "Operating Reserve" shortages will be appear as a Supplemental Reserve shortage (the lowest quality product).

Between January 1, 2018, and May 20, 2024 (~6.5 years), there were 203 5-minute RT intervals with Operating Reserve shortages. Note that the $200 Operating Reserve Demand Curve step was removed in December 2021, and that one-third of the 2022 Operating Reserve shortages occurred on December 23, 2022.

RT OR shortages are rare (about 1 out of 3,300 5-minute RT intervals). 85% of OR shortages last only 1 or 2 intervals. The longest OR shortage lasted seven intervals (35 minutes). When short of OR, MISO cleared an average of 92% of the OR requirement. Finally, the minimum amount of RT cleared OR was 52% of the requirement.

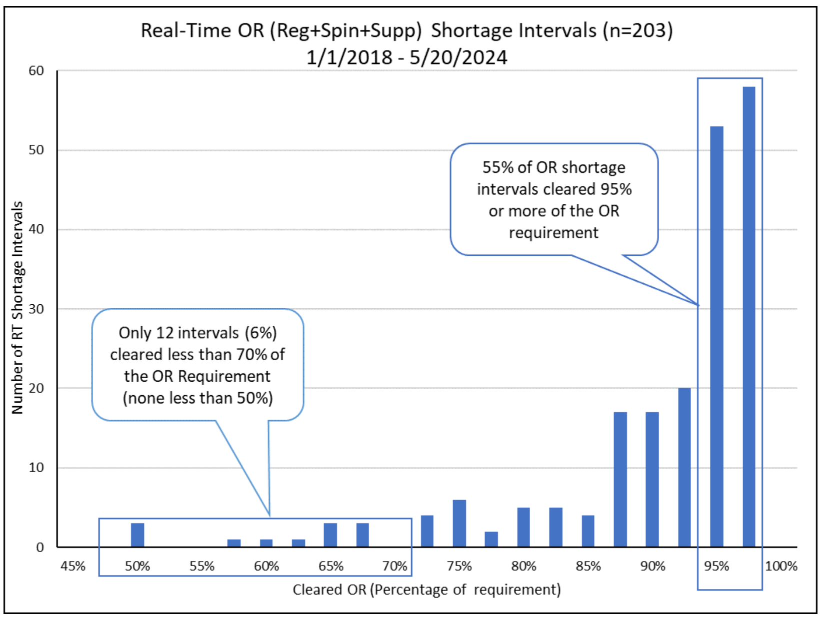


Figure 22: Real-Time OR (Reg+Spin+Supp) Shortage Intervals

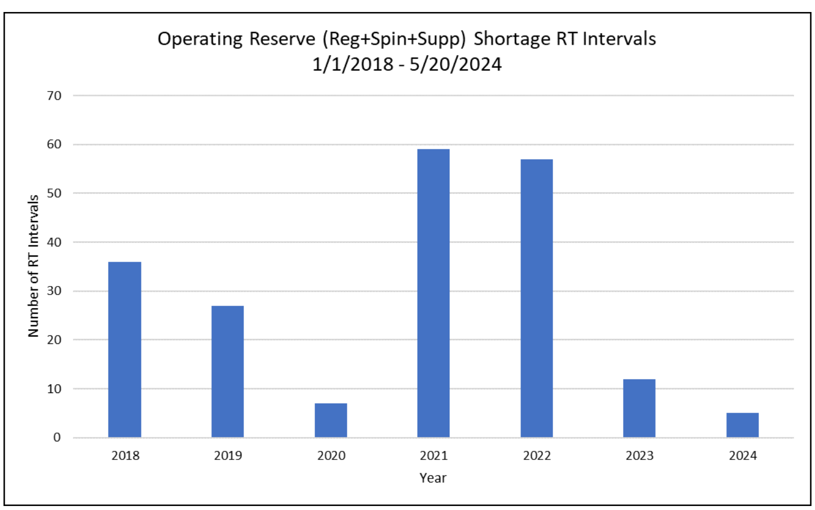


Figure 23: Operating Reserve (Reg+Spin+Supp) RT Shortage Intervals

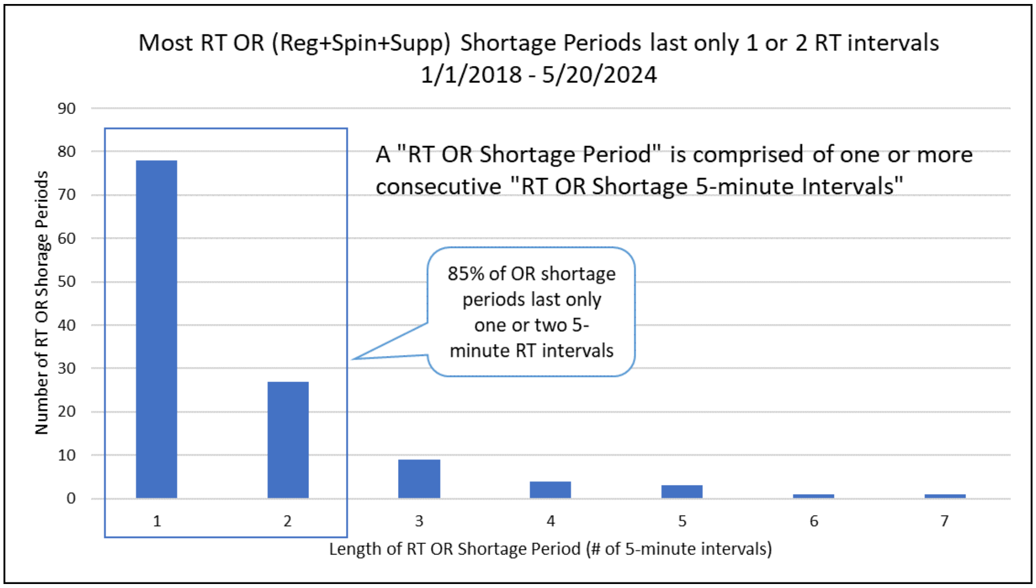


Figure 24: Most OR shortage periods last only 1 or 2 RT intervals

The following chart shows that most Operating Reserve shortage intervals cleared more than 88% of the Operating Reserve requirement, and that there were no shortage intervals clearing below 50%.

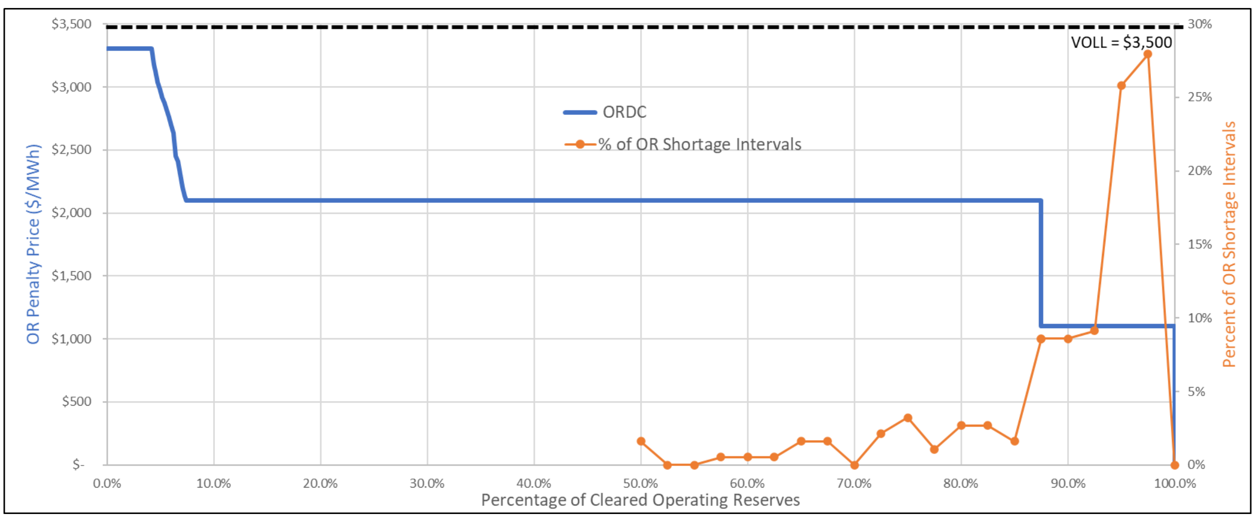


Figure 25: Most OR shortage intervals clear more than 88% of the OR requirement

Appendix F: IMM State of the Market Recommendation 2016-1 with MISO Response

2016-1: Improve shortage pricing by adopting an improved Operating Reserve Demand Curve (ORDC) reflecting the expected value of lost load

<u>Independent Market Monitor (IMM) Recommendation:</u>

Efficient shortage pricing is the primary incentive for both dispatch availability and flexibility. As the primary determinant of shortage pricing, the ORDC must accurately reflect the value of reliability. An optimal or "economic" ORDC would reflect the "expected value of lost load", equal to the product of: (a) probability of losing load and (b) the value of lost load (VOLL). Such an ORDC will track the escalating risk of losing load as shortfalls increase.

The shortage prices will send more efficient signals for participants to take actions in response to the shortage and help maintain the reliability of the system. Additionally, as MISO integrates larger quantities of renewables, the ORDC will be pivotal in compensating flexible resources that can start quickly and ramp rapidly to manage the uncertain output of intermittent resources.

MISO's current ORDC does not reflect the reliability value of reserves, overstating the reliability risks for small, transient shortages and understating them for deep shortages. Additionally, PJM's pay-for-performance rules price modest shortages as high as $6,000 per MWh (sum of the shortage pricing and capacity performance settlement), which will lead to inefficient imports and exports when both markets are tight.

Hence, we recommend MISO reform its ORDC by updating its VOLL assumption and determine the slope of the ORDC based on how capacity levels affect the probability of losing load. We have estimated that a reasonable VOLL for MISO would exceed $30,000 per MWh. Although the ORDC should be based on this VOLL, it would be reasonable to cap the ORDC at a lower price level for deep shortages, such as $10,000 per MWh. Almost all of MISO's shortages are likely to be in ranges that would establish shortage prices between $100 and $2,000 per MWh.

<u>MISO Response and Next Steps:</u>

MISO agrees with the IMM's description of this issue, and also generally supports the IMM's proposed solution. Initial review and planning started in late 2019. MISO filed in October 2019 to accelerate implementation of FERC Order 831 that increased the Energy Offer Cap to $2,000 or above and introduces a third step to MISO's ORDC at $2,100/MWh above the existing second step ($1,100/MWh) and first step ($200/MWh) for less severe reserve shortages.

MISO began reviewing several aspects of scarcity and emergency pricing with stakeholders in 2020 (see MISO Dashboard MSC-2019-1 Continued Reforms to Improve Scarcity Pricing and

Price Formation). MISO published a Scarcity Pricing Evaluation Paper[18] in May 2021. Key items evaluated in the paper included: (1) the IMM's methodology to create the loss-of-load probability curve for different reserve levels and proposed modifications; and (2) establishing a reasonable cost of shedding firm load (a.k.a. Value of Lost Load).

In 2021, MISO filed with FERC to remove the first $200 step of the ORDC to align with the costs of emergency actions taken to avoid Operating Reserve shortages.

In 2023, MISO focused on designing a settlement-based solution for forced off assets and implemented this functionality in the first half of 2024.

In 2023/24, MISO developed a series of seven MSC presentations related to shortage pricing, which included five stakeholder feedback requests. After refreshing the VOLL calculations, MISO is proposing an updated System VOLL of $35,000/MWh, to be used in conjunction with a new Loss of Load Probability (LOLP) curve to establish the shape of the Operating Reserve Demand Curve. In addition, the ORDC will be lowered for small, transient OR shortages while maintaining a minimum shortage price in alignment with the Emergency Offer Floors. MISO also is proposing a Pricing VOLL of $10,000/MWh, to be used as a market price cap, and as the administrative price imposed during periods of MISO-directed firm load-shedding (a.k.a. EEA-Level 3 Emergency). A market price circuit breaker has also been developed, to mitigate the potential risks of extended-duration EEA-Level 3 Emergencies. MISO posted a new Scarcity Pricing Whitepaper in the April 2024 MSC meeting materials. MISO anticipates filing these proposed enhancements with FERC in Q4 2024.

Status (2022 / 2023): Design / Design. This recommendation is being tracked as MISO Dashboard MSC-2019-1.

MISO Five-Year Action: ***Active***

[18] Available at the below URL: https://cdn.misoenergy.org/20210513%20MSC%20Item%20XX%20Scarcity%20Pricing%20Evaluation%20Paper550162.pdf

Appendix G: IMM State of the Market Recommendation 2022-1 with MISO Response

2022-1: Expand the TCDCs to allow MISO's market dispatch to reliably manage network flows

Independent Market Monitor (IMM) Recommendation:

During a number of recent storm events in 2021 and 2022, MISO has experienced operational challenges requiring extraordinary operator actions to manage network flows. During both transmission and capacity emergencies, the current TCDCs limit the ability of MISO's market dispatch to manage transmission congestion. During capacity emergencies, the value of energy and reserves under the Operating Reserve Demand Curve (ORDC) can prevent the dispatch model from reducing output when needed to manage network flows because the value of managing the transmission constraint is not high enough. Likewise, when the Regional Directional Transfer (RDT) or other constraints are violated, the dispatch model may not move generation as needed to manage the flows over other constraints. This has often compelled MISO operators to manually dispatch generation to reduce flows on overloaded constraints, which is costly and distorts market outcomes.

Therefore, we recommend MISO add higher segments to the TCDCs to allow the dispatch model to limit excessive violations. MISO should also improve its procedures to increase the TCDCs for a constraint when the violations raise reliability concerns or are sustained. Additionally, uncertainty regarding network flows has often caused operators to derate transmission constraints. Adding lower-priced segments to the TCDCs that would account for the value of holding back transmission capability to manage uncertainty could be valuable and we recommend MISO consider this as an alternative to its current approach to lowering transmission limits.

MISO Response and Next Steps:

MISO agrees that potential improvements can be made related to transmission constraint management. MISO has developed comprehensive changes to the ORDC and VOLL (Value of Loss Load) (recommendation 2016-1) which play a role in the effectiveness of TCDCs. MISO has reduced the first two steps of the ORDC, which will improve MISO's ability to control network flows economically when OR shortages are relatively small.

Over the last couple of years, MISO has been more proactive in making TCDC overrides which partially mitigates the congestion management issues highlighted by the IMM. As mentioned in the IMM's Fall 2023 Quarterly Report, "MISO operators took fewer out of market actions to manage difficult constraints, resulting in more efficient market outcomes. Compared to last fall, MISO took 64 percent fewer manual re-dispatch actions, relying instead on 26 percent more transmission constraint demand curve (TCDC) increases to allow the market to secure more congestion relief." MISO is committed to continue working with the IMM staff to effectively utilize TCDC overrides to manage congestion, when appropriate. After its Shortage pricing efforts, MISO plans to design changes needed to the TCDCs to improve congestion management during both transmission and capacity emergencies.

Status and Next Steps: New / Design

MISO Five-Year Action: ***Active***

Appendix H: Updated 2023 Value of Lost Load Calculations

The Value of Lost Load (VOLL) attempts to estimate the value of uninterrupted electrical service, but determining the value to consumers of reliable, uninterrupted supply is non-trivial. Alternatively, determining VOLL can be related to the price at which customers prefer interruption to paying the marginal cost of service. Another approach is to estimate the costs/losses incurred when service is interrupted.

It is important to recognize that VOLL can vary for numerous reasons, including:

- Market segment (residential, commercial, industrial)
- Temporal factors (time of day, season)
- Duration and frequency of outages
- Amount of advance notification before outage

At the end of 2023, MISO updated the VOLL calculations using recent econometric results, delineating multiple load characteristics. These analyses utilized a LBNL meta-analyses with MISO-specific drivers, which is consistent with MISO's original approach in 2009 and the Independent Market Monitor State of the Market (IMM SOM) approach in Rec 2016-1. This approach uses two-step regression models to estimate statistically significant outage cost functions.

Hundreds of values for VOLL were updated, with breakdowns for these aspects (highest VOLL factors are in **bold**):

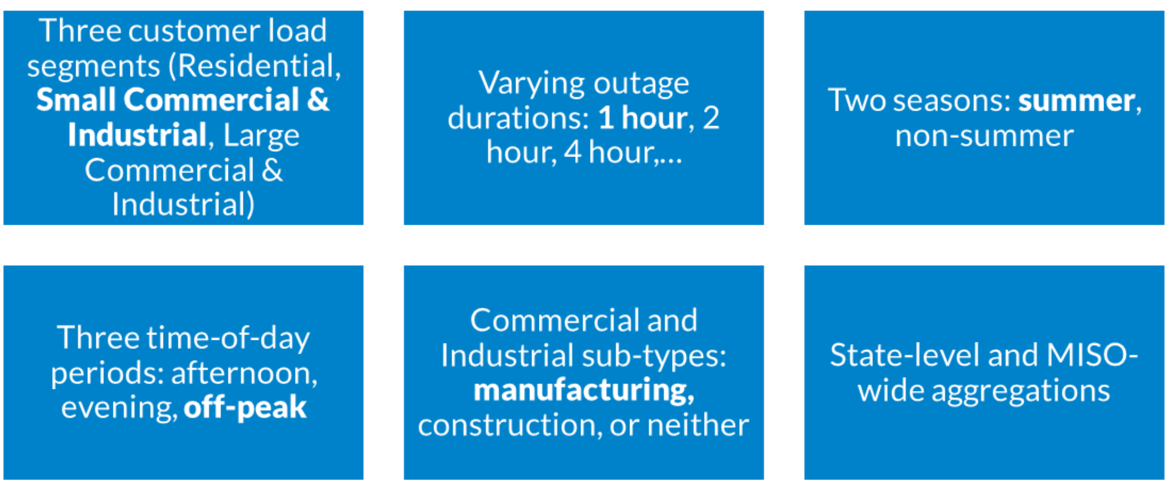


Figure 26: VOLL Calculation Load Characteristics/Classes

Figure 27 shows some of the caveats of establishing any VOLL value.

May not reflect complete economic costs of outages

- *Short-term outage costs and long-term adaptive costs*
- *These estimates are only short-term outage costs*

Outage cost estimates typically are for summer peak conditions

- *As such, reflect 'worst case'*
- *Outage costs vary by TOD and season*

Outage cost estimates are for all sources of failure

- *Probably vary by source of failure*

Outage costs vary over time

- *Decline with more EE measures and DG*
- *Increase with more end-use application requiring higher reliability*
- *Residential customers have becoming willing to pay more to avoid prolonged outages*

Residential Outage costs vary by:

- *Housing type, Family size, Respondent's age, Respondent's gender*

C & I outage costs vary significantly within each sector, by business activity

Figure 27 VOLL Calculation Complications

To perform the MISO Willingness to Pay (WTP) Study, the following information was utilized:

- LBNL Study Tables
  - Medium and Large C&I Table 3-5 GLM Regression
  - Small C&I Table 4-5 GLM Regression
  - Residential Table 5-5 GLM Regression
- Additional Data Sources
  - For ease of comparability to previous results, 2019 was chosen as the base year. Choosing a different base year will cause a slight adjustment to the results. All prices are adjusted to 2023 dollars.
  - Table H-8. Median Household Income by State 1984 to 2022
  - Annual Electric Power Industry Report, Form EIA-861 2022 Detailed Data Files
  - Use Sales to Ultimate Customers and filter for the MISO in BA Code
  - 2019 Base Year Used From FRED

MISO performed the following data cleaning steps:

1. From EIA-861 Data, pull MISO specific footprint from BA Code
2. Excluded OK, KS, and TN due to small samples
3. Calculate Average Monthly Consumption (kWh), Average Price ($/kWh), Average Monthly Bill ($)
4. State level income is adjusted from 2019 levels to 2023 dollars using the FRED adjustment (122.4)
   - This may not correspond to the MISO footprint, but a more detailed study is expected to provide small improvement for a large amount of effort
5. Calculate Avg Annual MWh and apply the appropriate dummy/indicator variables.
6. WTP is calculated as $\frac{e^{\beta' X}}{Avg\ Peak\ Demand\ (APD)}$, APD => Res = 3, Sm C&I = 16, Lg C&I = 401
7. Load ratios applied for system: Res = 0.34, Sm C&I = 0.31, Lg C&I = 0.35

Detailed VOLL component calculations were published in Appendix 2 of the Market Subcommittee presentation from January 18, 2024.

The resulting 2023 nominal values (MISO-wide, load-weighted) were presented earlier in Figure 6, but replicated here as well:

Load Class	*1-hr outage*	*2-hr outage*	*4-hr outage*	*8-hr outage*	*12-hr outage*
Residential	$4,337	$2,420	$1,477	$1,013	$832
Small C&I	$80,965	$50,277	$37,006	$33,271	$31,098
Small C&I, Services #	$66,354	$41,227	$30,328	$27,267	$25,486
Large C&I	$29,472	$20,391	$18,194	$21,859	$24,054
System VOLL *	$36,889	$23,545	$18,342	$18,309	$18,342
Pricing VOLL using 2007 weightings (85% Residential / 15% Services)	**$13,639**	**$8,241**	**$5,804**	**$4,951**	**$4,530**

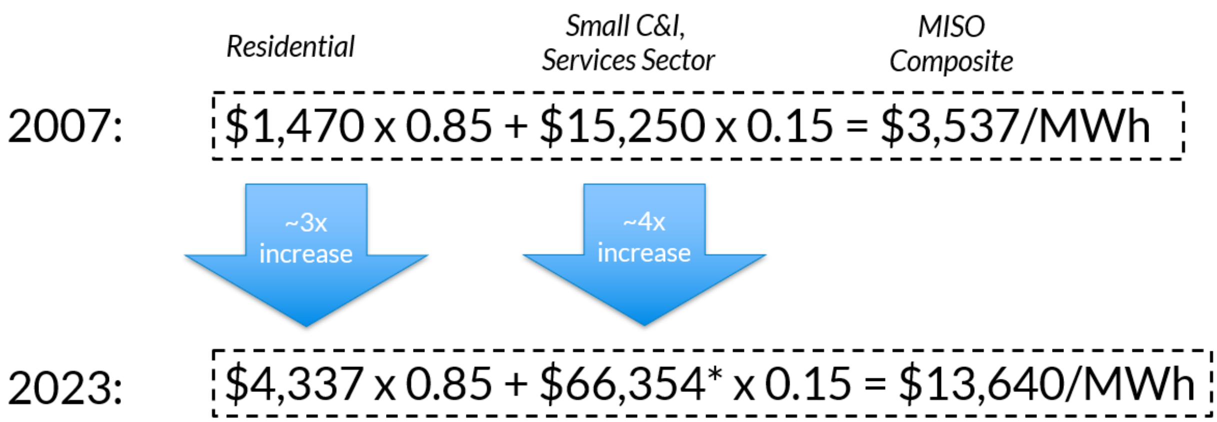
Basis of $10,000 VOLL for EEA events < 4 hrs (1-hr and 2-hr outage)

Basis of $5,000 VOLL for EEA3 events >=4 hrs (4-hr, 8-hr and 12-hr outage)

The rationale for the original $3,500/MWh VOLL was explained in the FERC filing [Docket ER07-1372 Attachment E] which MISO made for the 2009 addition of the Ancillary Services Market. MISO explained that:

- "The Midwest ISO, in determining the VOLL, calculated the median values (and distributions) for residential customers and commercial and industrial customers."
- "The $3,500/MWh number represents an estimate of the VOLL using an average of the median values for the *residential class* [$1,470] and the *lowest median value of the small commercial and industrial class, the service category* [$15,250]."
- "The average was calculated using *weights of 0.85 for residential and 0.15 for small commercial and industrial services*."
- "This estimate of the VOLL represents an estimate for the market segment that values uninterrupted electrical service the least."

Simply updating the 2007 VOLL components (Summer, 1-Hour outage, Off-peak) to 2023 values would support a MISO VOLL increase in the range of 300-400%. This is shown in the following calculation:



* *MISO estimated the Services sector value, which was utilized in the 2007 VOLL calculation.*

Figure 28: Updating the original (2007) MISO VOLL calculations

As recognized from the beginnings of the MISO markets, customer load classes often share the same transmission/distribution circuits. Thus, it is not technically feasible for Load Balancing Authorities (LBAs) to simply target a single customer type (e.g., residential). Their load-shedding plans are reliability-focused and often consider factors beyond their customer priorities, such as their transmission and distribution grid technologies, interruptible rate programs, automated under-frequency load shedding systems, as well as other load characteristics.

MISO load-shedding directives are carried out by the LBAs, and MISO does not specify customer class. A recent MISO LBA survey asked which customer classes would initially be shed in a wide area request (percentage of total load shed):

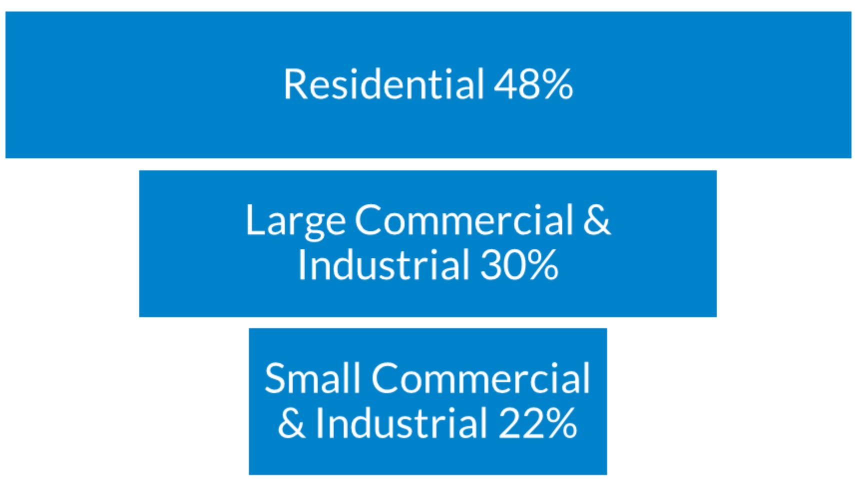
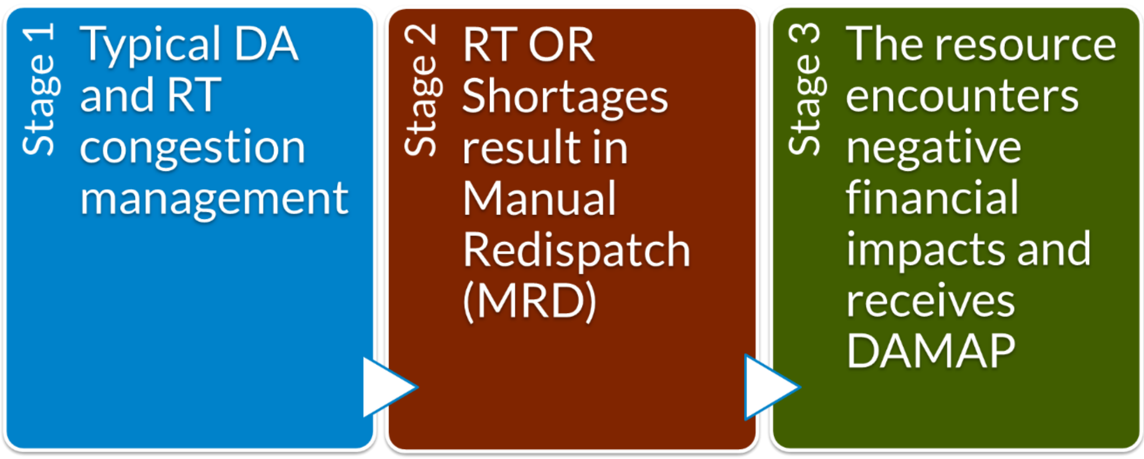


Figure 29: Survey results for LBA initial load-shedding priorities

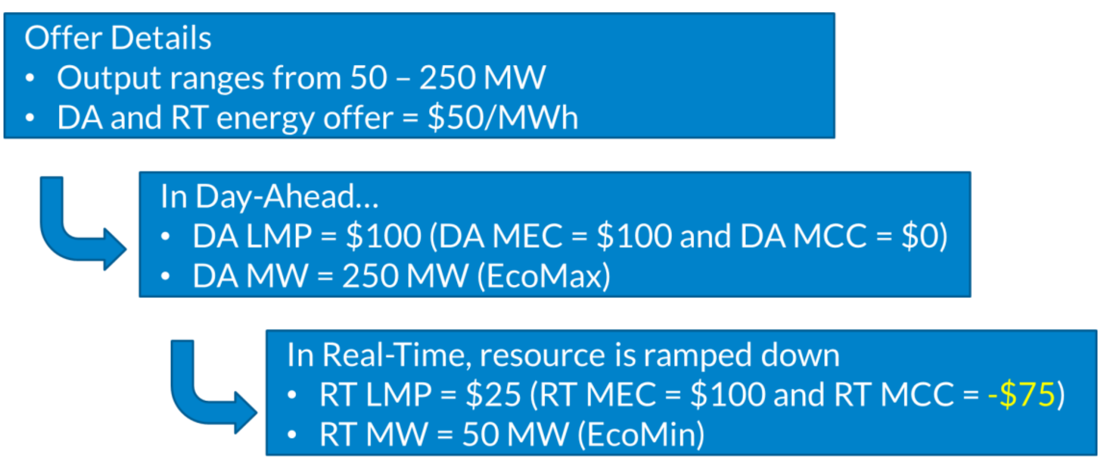
MISO proposes a VOLL of $10,000/MWh to use as a market price cap and for administrative pricing during load-shed events. This recognizes that load-shedding will be focused on the residential class, which has a 1-hour-outage Summer VOLL of $4,337/MWh, but that other load classes would inevitably be dropped during such an event. As shown above, even adding 15% of non-residential load would result in a VOLL of $13,640/MWh. And if load was shed equally across all load types, a VOLL of $36,888 would be justifiable. MISO deems these values to be excessive, however, given the potential financial implications of extended VOLL-pricing.

Appendix I: Example Illustrating the Potential Impact of Operating Reserve Shortage on Day-Ahead Margin Assurance Payment (DAMAP)

This example was originally presented at the August 24, 2023, Market Subcommittee meeting. It illustrates how undersized Transmission Constrained Demand Curves (TCDCs) can lead to manual redispatches and DAMAP, especially during Operating Reserve shortages.



<u>Stage 1 – Typical Day-Ahead and Real-Time Congestion Management</u>



Stage 2 – Real-Time Operating Reserve Shortage results in Manual Redispatch (MRD)

Operating Reserve Shortage in RT
- RT MEC = $1,400
- RT MCC = TCDC*ShiftFactor = -$2000*25% = -$500

Resource receives new LMP and Dispatch
- RT LMP = RT MEC + RT MCC = 1,400 – 500 = $900
- RT MW = 250 MW (EcoMax)

But higher output results in overloaded constraint
- Resource is manually redispatched (MRD)
- RT MW = 50 MW (EcoMin)

Stage 3 – Resource encounters negative financial impacts and receives large DAMAP

Resource must buy back the 200 MW reduction at high RT prices
- 200 MW * $900 = $180,000

Resource gets Day-Ahead Margin Assurance Payment
- Considers the savings of not producing those MWs
- DAMAP = $180,000 - $10,000 = $170,000

This DAMAP resulted from improper dispatch & prices calculated during reserve shortage conditions
- Solution is an increase to the TCDC

Appendix J: Emergency Demand Response (EDR) Background

MISO EDR Product

- Schedule 30 (EDR instrument) was filed on December 31, 2007 (pre-Ancillary Services Market).
- It was added in response to the capacity shortage events in August 2006 and February 2007.
    - Instituted at stakeholder request and vetted before the Demand Resource Working Group and Market Subcommittee.
    - Emergency pricing not in effect at that time.
    - FERC encouraged MISO to have additional demand response initiatives similar to other ISOs.
- EDR uniqueness compared to Load Modifying Resources (LMRs) and/or Demand Response Resources (DRRs):
    - EDRs can be assets (demand reduction) which, in times of need, can help meet the energy balance, but cannot guarantee availability under all MISO Emergencies (like LMRs) or be available regularly to reduce demand in the energy markets (like DRRs). EDRs increase supply availability.
    - LMR assets that dual register as EDRs can specify the compensation requirements necessary for load reduction (as opposed to LMRs).

Other ISO/RTO EDR Products

- PJM has emergency Demand Response, but it is outside the market (price cannot be set).
    - Non-performance penalties are part of PJM's capacity market pay-for-performance construct.
    - EDR also gets energy payment for any response they provide.
- Electric Reliability Council of Texas (ERCOT) has an Emergency Response Service, which requires response in 10 or 30 minutes, as well as a Firm Fuel Supply Service (FFSS).
    - Neither product can set price.
- NYISO has an EDR program.
    - Deployment does not set price.
    - Settlement is based on system prices, with a $500 cap in certain periods.
- SPP does not have an EDR product as part of its emergency operating plan.

Appendix K: Winter Storm Uri Case Study

The MISO market has implemented firm load-shedding (Max Gen Event Step 5, EEA-Level 3) once, during Winter Storm Uri. During that event, MISO requested 700MW of emergency load reduction in the South Region for over 2 hours in the evening of February 16th, 2021.

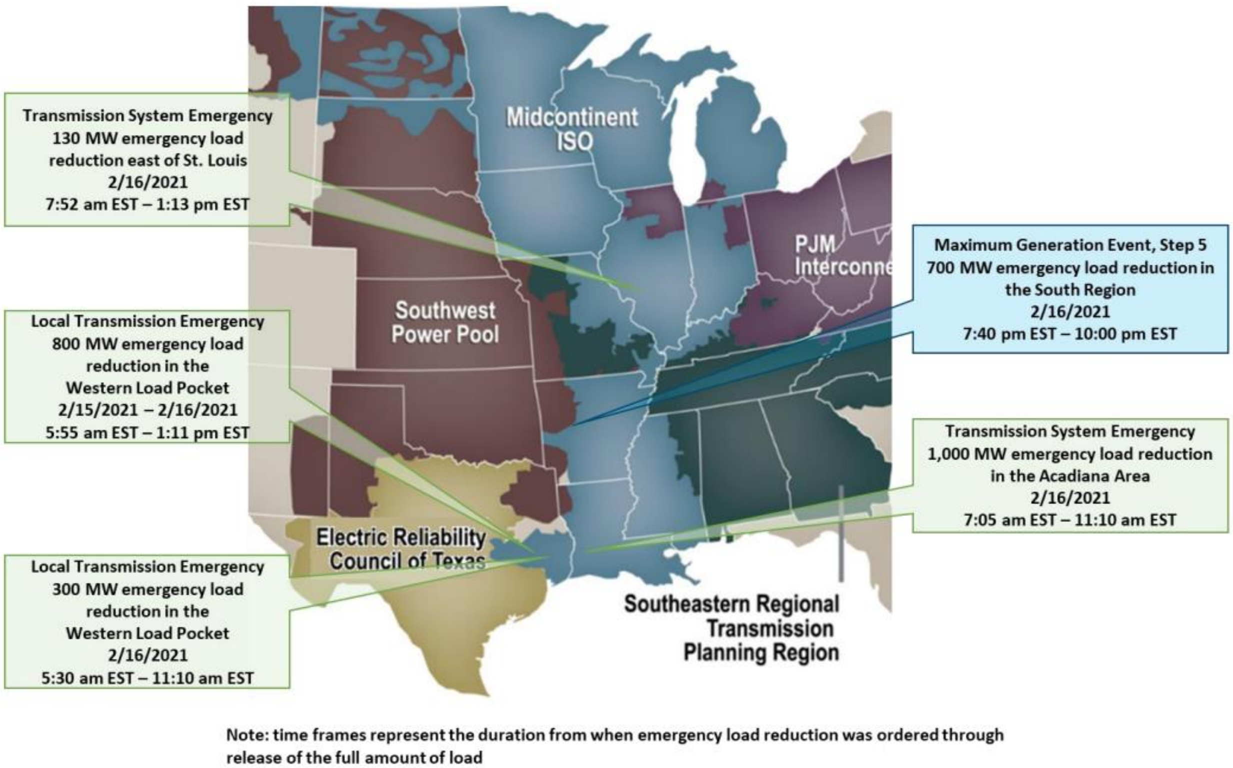


Figure 30: Winter Storm Uri Load Reduction Timeline

The MISO February Arctic Event report[19] detailed the timeline:

- Timeline:
  - **18:35** – Due to generation losses and fuel unavailability, MISO declares Event Step 2c, commitment of Emergency Demand Response resources
  - **18:50** – MISO requested to increase the North-South Regional Directional Transfer Limit from 3000MW to 3700 MW; the request was denied due to neighboring system conditions
  - **19:40** – Maximum Generation Event Step 5 declared, 700 MW emergency load reduction across South regional Local Balancing Authorities
  - **22:00** – Maximum Generation Event Step 5 terminated

[19] https://cdn.misoenergy.org/2021%20Arctic%20Event%20Report554429.pdf

- "During the evening increase in electricity demand on February 16, 2021, multiple generators tripped offline in MISO's South Region. MISO declared a Maximum Generation Event at 6:35 p.m., committing Emergency Demand Response and coordinating with members to issue public appeals for energy conservation. A short time later, at 6:50 p.m.., MISO sought to temporarily increase the North-South Regional Directional Transfer Limit in an effort to transfer more energy to MISO's South region. Unfortunately, the request could not be accommodated due to system overloads in neighboring systems. Realizing the grid's stability was in danger and being unable to move the needed energy to meet demand, at 7:40 p.m. MISO declared a Maximum Generation Event Step 5 and called for a 700 MW pro-rata emergency load reduction across MISO South Local Balancing Authorities. These emergency load reductions ended at 10:00 p.m. There were no further emergency load reductions and the Arctic Event officially ended when the last alert was terminated on February 20."
- "During an EEA-3 event, per the MISO Tariff, prices in the affected area increased to the established Value of Lost Load (VOLL), $3,500/MWh. This value is an estimate of the cost of service interruption to customers and is paid to both supply that increases output and to demand response load that is lowered."

Appendix L: Credit Considerations of Increased Shortage Pricing

Following Winter Storm Uri, MISO identified Credit Policy enhancements to better estimate values for DA/RT exposure following extreme weather/pricing events.

This issue was identified in MISO's February Arctic Event Report:

- "The purpose of MISO's Credit Policy (Attachment L to the MISO Tariff) is to protect its members by preventing losses in the market that are passed onto its members. MISO's credit team typically calculates a participant's credit exposures based on the market participants' forecasted financial obligations from market activity, and then requires that amount be covered by financial security or secured credit as allowed under MISO's Tariff."

- "The Arctic Event caused a significant increase in credit exposure for many market participants. The highest price impact of the event was primarily between February 15 to February 18. However, there was increased pricing and higher demand throughout the week of February 15. Due to the natural delay in forecasting financial obligation and the resulting credit exposure, margin activity didn't spike until the week beginning February 22, resulting in 140 margin calls totaling $325 million. Margin call refers to when a market participant's credit exposure is greater than the financial security and unsecured credit they have in place with MISO, and MISO requests additional collateral or reduced activity in the market. All margin calls were cured by market participants, but some parties indicated a level of financial strain."

- "Several MISO market participants were concerned that credit calculations used to determine credit exposure would result in margin calls in excess of real financial obligations. There was a concern this could create un unnecessary additional financial strain from the Arctic Event."

- "Given how the tariff defined credit exposure calculations, MISO did forecast an over collateral position for some market participants in the coming week. Hence, to prevent additional financial strain on some market participants, MISO sought a waiver[20] from FERC on February 24 to allow adjustments to the credit exposure calculation, which FERC approved on February 25, 2021. In the waiver, MISO obtained approval from FERC to use the best available information for the credit exposure calculations."

- "To better address potential future events, **MISO may seek to revise the Tariff and allow for alternative calculations that may be used in extreme pricing volatility events with appropriate notifications to parties**. This would be more efficient than requesting an emergency waiver from FERC in the middle of an event."

Since then, MISO has addressed credit exposure calculations following extreme pricing events[21].

[20] Docket No. ER21-1200-000
[21] For more details, see Credit Policy Enhancement Task Team (CPETT) meetings in 2023.

MISO's existing Day Ahead-Real Time (DA/RT) estimated calculations work well under normal weather conditions. However, during a short-term extreme weather event, MISO MP's may experience excessive collateral requirements that last up to two weeks after the event occurs. The current calculations use a rolling average based upon the greater of either a 365-day or a 7-day "look-back" on the S7 value. During an event, when prices spike, the collateral requirement typically switches to the 7-day rolling average. Then, when an event is captured in a 365-day rolling average, the event is diluted.

To avoid future emergency filings with FERC, MISO added language to the Tariff that allows for the optionality of using "best available information" during extreme weather/pricing events[22]:

- *New defined term in Module A:*
    - ***Extreme Event:*** An event which includes, but is not limited to, extreme weather events, or other emergency events that have a severe short-term impact on market pricing. Such an event may be declared by the Transmission Provider in its sole discretion and shall affect the applicable Credit Policy calculations as set forth within Attachment L.
- *Addition of language to Attachment L Sections V.A. 1, 2, 4, for Real-Time Energy (PEEE), Day-Ahead Energy (DAEE), and Congestion and Losses (CLEE) Estimated Exposures:*
    - During an Extreme Event, the Transmission Provider reserves the right to use best-available information to calculate PEEE/DAEE/CLEE. Best-available information will be used when the use of the existing calculation will result in potential exposure calculations impacted by Extreme Events that far exceed the expected actual exposure of such entities. When the Transmission Provider implements the use of best-available information: (i) notification will be given to the Market; (ii) the use of best-available information will be used to address a recognized problem; (iii) the time frame for the use of best-available information will be specified in the notice provided to the market; and (iv) the Transmission Provider will continue to ensure sufficient collateralization of its markets.

[22] Docket ER24-1377-000 (filed 3/1/24, effective 5/1/24)

Appendix M: Example of a Long-Duration Shortage Pricing Event

This example was presented at the July and August 2024 Market Subcommittee meetings. It illustrates how the DA and RT Pricing VOLL values would change for an extreme load-shedding event lasting more than a single day.

Scenario: A Max Gen Emergency is declared at 0200 on Day 1, escalating to EEA – Level 3 (Max Gen Event Step 5) at 0800. The MISO-directed load-shedding lasts 24 hours (ends Day 2 0800). The Max Gen Emergency lasts 12 more hours, before it is "terminated" by MISO Operations at 2000 on Day 2. Note that RT and DA pricing will be impacted for three days.

DAY 1

0200: In RT, a MISO declares a Max Gen Emergency (not EEA – Level 3)

0800: Emergency escalates to EEA – Level 3 (Max Gen Event Level 5) and MISO directs load-shedding

- Real-Time LMPs/MCPs are administratively set to the default RT Pricing VOLL ($10,000/MWh)

1030: DA Market closes for MP-submitted offers/bids (EEA – Level 3 continues)

- For the next Operating Day (Day 2), Pricing VOLL is set to $5,000/MWh for both DA and RT Markets
- The Pricing VOLL will be continue to used as the RT price cap, and as the RT Administrative Price during EEA – Level 3 conditions
- DA Demand bids into the DA Market will consider the $5,000/MWh Pricing VOLL for the next Operating Day

1200: RT Pricing VOLL drops to $5,000/MWh, due to 4 hours of EEA – Level 3 load-shedding

- Real-Time LMPs/MCPs are administratively set to $5,000/MWh, for the remainder of the day because EEA – Level 3 conditions persist

DAY 2

0000: EEA – Level 3 load-shedding continues; RT Pricing VOLL kept at $5,000/MWh

- Real-Time LMPs/MCPs are administratively set to $5,000/MWh, while EEA – Level 3 continues

0800: EEA – Level 3 load-shedding ends, but Max Gen Emergency continues

- Real-Time LMPs/MCPs are capped by RT Pricing VOLL of $5,000/MWh

1030: DA Market closes for MP-submitted offers/bids, and Max Gen Emergency continues

- For the next Operating Day (Day 3), lower Pricing VOLL to $2,000/MWh for both DA and RT Markets

- Demand bids into the DA Market will consider the lower $2,000/MWh Pricing VOLL for the next Operating Day

2000: MISO terminates Max Gen Emergency

- Real-Time LMPs/MCPs continue to be capped by RT Pricing VOLL of $5,000/MWh

DAY 3

All Hours:

- RT prices will be capped all day by RT Pricing VOLL of $2,000/MWh because the Max Gen Emergency was terminated yesterday **after** 1030EPT (DA Market close)

1030: DA Market closes

- DA and RT Pricing VOLLs will be $10,000/MWh for the next Operating Day (Day 4)

DAY 4

0000:

- RT Pricing VOLL is reset to $10,000/MWh

<table>
<tr><th>Day</th><th>Time (EPT)</th><th>MISO Max Gen Level</th><th>DA VOLL</th><th>RT VOLL</th><th>Use RT VOLL as RT EEA3 Admin Price?</th><th>Use RT VOLL as RT Price Cap?</th></tr>
<tr><td>1</td><td>0:00</td><td>Normal Ops</td><td rowspan="4">$10,000</td><td rowspan="3">$10,000</td><td rowspan="2">No (no declared EEA3)</td><td rowspan="2">Yes</td></tr>
<tr><td>1</td><td>2:00</td><td>Max Gen (not EEA3)</td></tr>
<tr><td>1</td><td>8:00</td><td rowspan="3">Max Gen Event Step 5 (EEA 3)</td><td rowspan="3">Yes (for declared EEA3 area)</td><td rowspan="3">Yes (for non-EEA3 area)</td></tr>
<tr><td>1</td><td>12:00</td><td rowspan="4">$5,000</td></tr>
<tr><td>2</td><td>0:00</td><td rowspan="3">$5,000</td></tr>
<tr><td>2</td><td>8:00</td><td>Max Gen (not EEA3)</td><td rowspan="4">No (no declared EEA3)</td><td rowspan="4">Yes</td></tr>
<tr><td>2</td><td>20:00</td><td>Normal Ops</td></tr>
<tr><td>3</td><td>All Day</td><td>Normal Ops</td><td>$2,000</td><td>$2,000</td></tr>
<tr><td>4</td><td>0:00</td><td>Normal Ops</td><td>$10,000</td><td>$10,000</td></tr>
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