



Recent Shortage Pricing Efforts

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Update to PJM Reserve Certainty Senior Task Force

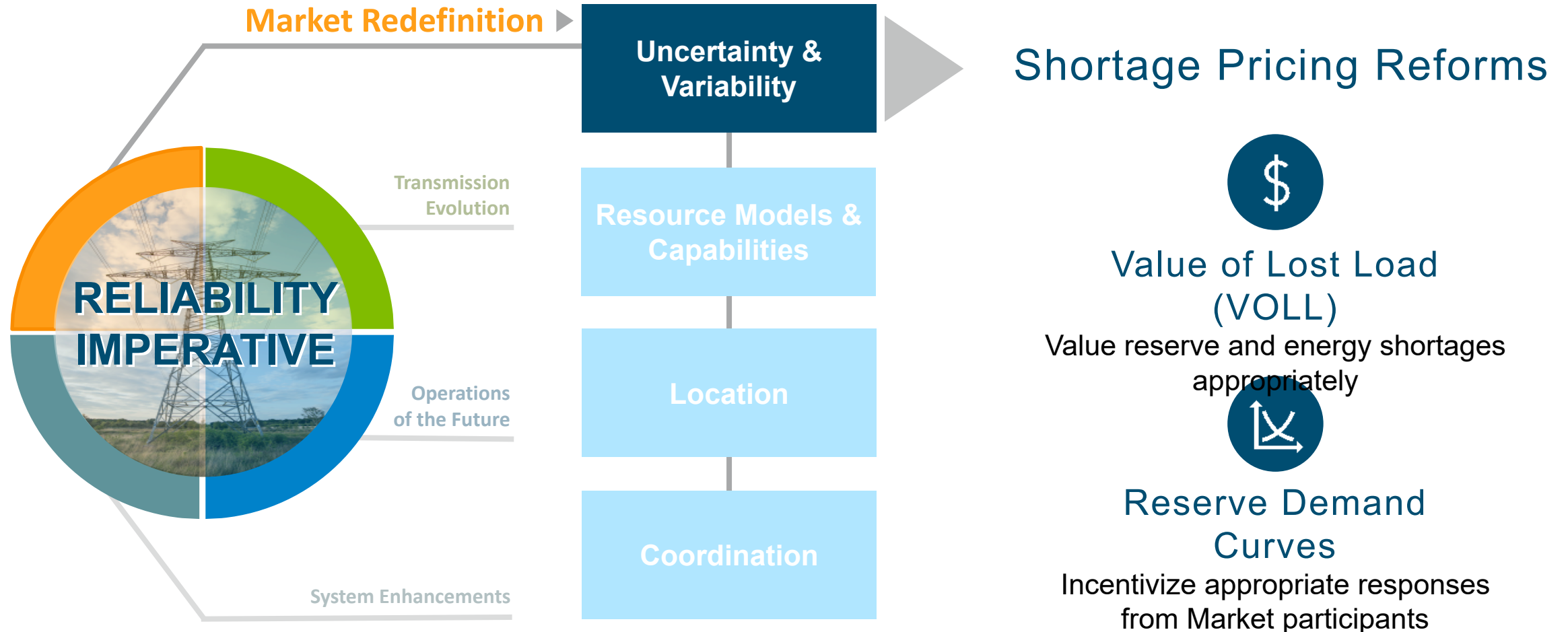
November 13, 2024

Executive Summary



- MISO is focusing on key construct changes to enable and manage the evolving fleet through capacity and energy market reforms
- MISO has identified the need to improve price formation during shortages, which increases price transparency, better reflects marginal costs of serving load, and further aligns with reliable operation of the system
- MISO has worked with stakeholders to develop its proposed updates to the Value of Lost Load (VOLL) and the Operating Reserve Demand Curve (ORDC), which also aligns with IMM recommendations
 - MISO's proposal also includes market pricing "circuit breaker" for extended duration shortage conditions to mitigate financial risks
- MISO is targeting the end of October to make a FERC filing for the proposed changes to VOLL and ORDC with a target implementation by the end of Q3 2025

The increasing risk and complexity MISO faces require significant transformational changes to our grid, markets, operations and technology



By modernizing its shortage pricing, MISO can better manage emergency grid operations and ensure fair market outcomes for all participants

MISO is proposing
to update its shortage
pricing methodology to:

- 1 Reflect the true cost of lost load through a revised VOLL
- 2 Improve the ORDC to accurately represent cost of reserve shortage
- 3 Enhance price transparency and market efficiency

Updates to MISO's shortage pricing mechanisms will promote greater market efficiency and grid reliability



Value of Lost Load (VOLL)

*The price that demand is willing to pay to avoid loss of
or disruption to service.*

- The Value of Lost Load serves four functions in Day-Ahead and Real-Time markets
- The **\$3,500 cap** and hasn't changed since 2007
 - As a **price cap**, it can curtail valid market prices and isn't sufficiently high to encourage full participation
 - As an **administrative price** during load shedding, it is below industry-accepted willingness to pay studies



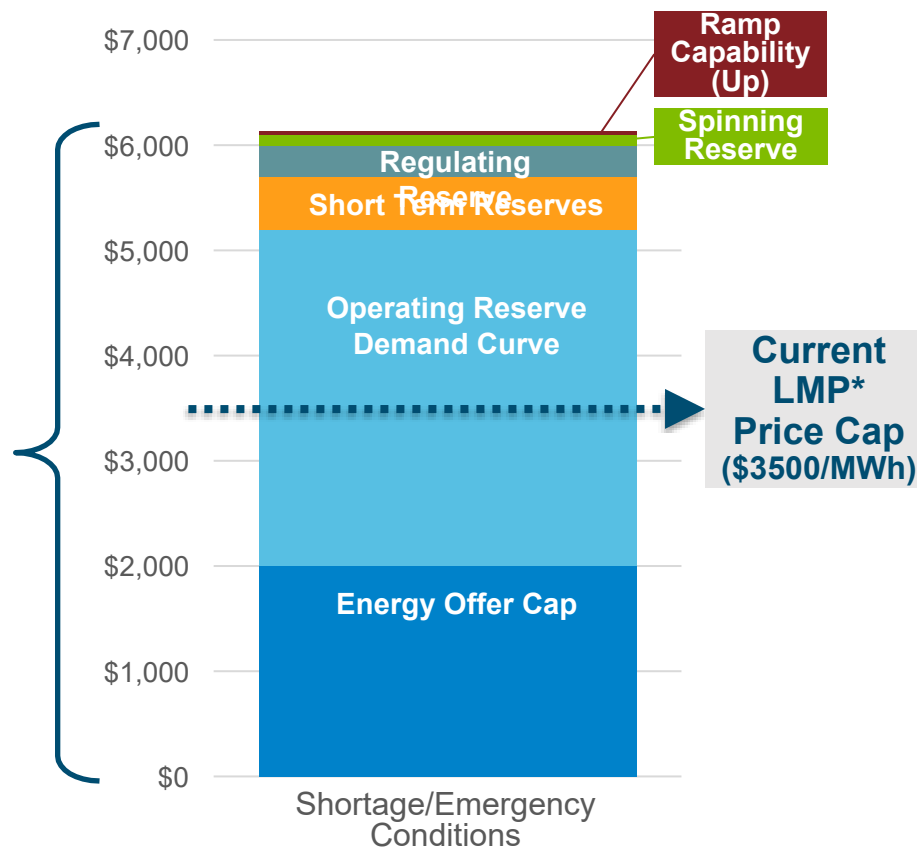
Operating Reserve Demand Curve (ORDC)

*Used to establish the price of energy and reserves when there is insufficient supply to satisfy requirements.**

- The current ORDC curve:
 - Does not adequately reflect the increasing reliability risks of declining reserves
 - Hinders congestion management during smaller operating reserve shortages

The demand curves that make up the Marginal Energy Component can exceed the LMP cap during extreme shortage conditions

The **Marginal Energy Component (MEC)** is made up of the Energy Offer plus the shadow price of the reserve products



The existing pricing parameters have positive and negative impacts on the signals to the market.

PROS

- Existing pricing structure provides consistent and clear price signal during normal conditions
- Reserve prices reflect priority of the product

CONS

- Price cap hides the true price signal during shortages
- Small operating reserve shortages increase MEC by \$1100
- Regulating Reserve and Spinning Reserve MCP increase by \$1100 for small operating reserve shortages

An Introduction to MISO Reserve Products

MISO reserve products address uncertainty in different 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

Operating Reserves have a prioritization hierarchy

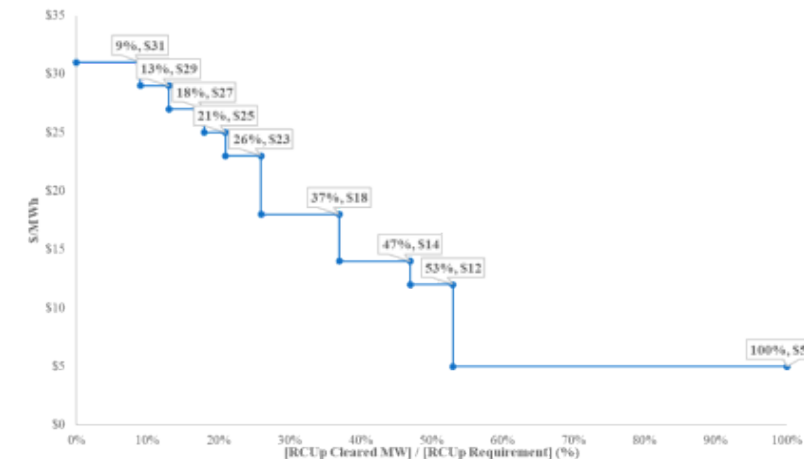
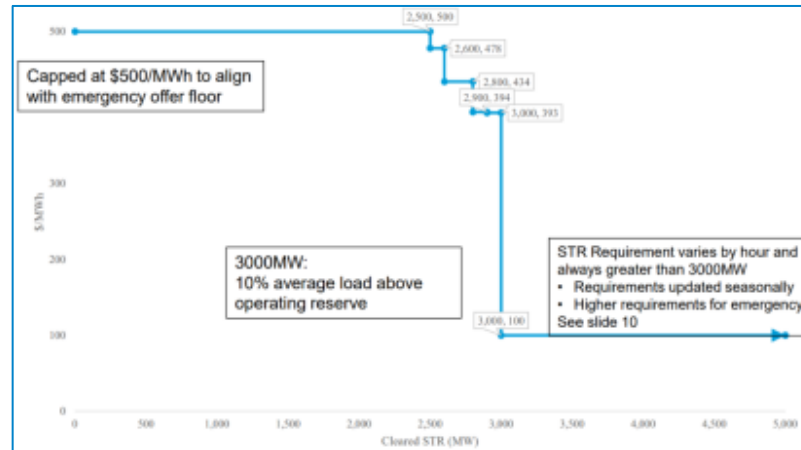
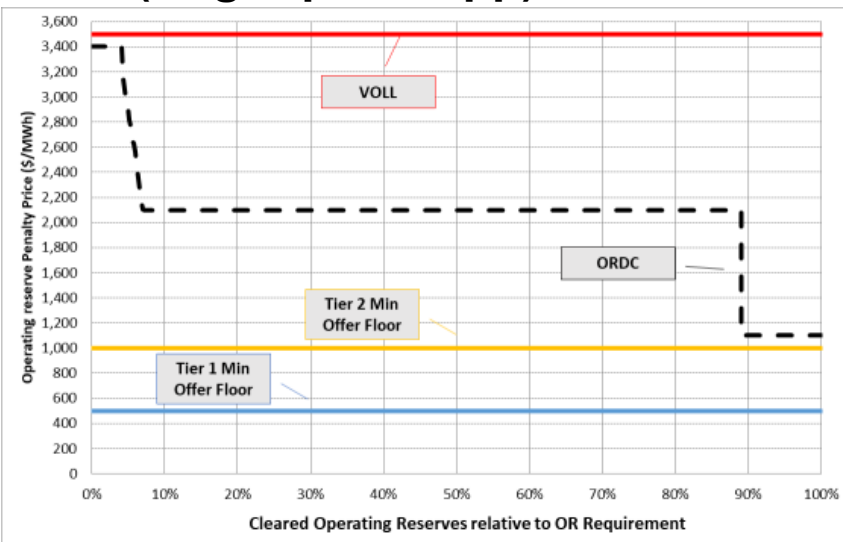
- Terminology
 - *Contingency Reserves = Spinning Reserves + Supplemental Reserves*
 - *Operating Reserves = Regulating Reserves + Contingency Reserves*
- Operating Reserves are prioritized
 - ***Regulation >> Spin >> Supplemental***
 - *“Higher quality” reserves will not have lower prices (MCPs)*
 -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

Reserve Requirements balance reliability benefits and costs to the Markets

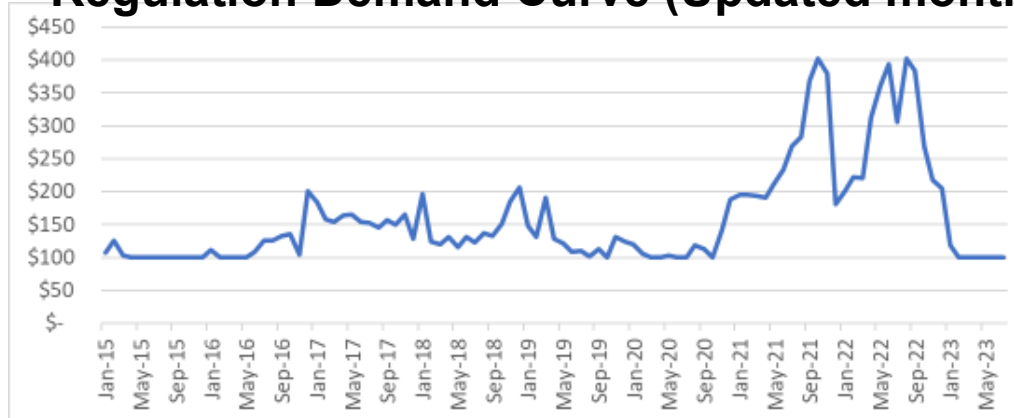
- *Regulation*: 500 – 800 MW (hourly)
- *Spin*: 900 or 1,200 MW (hourly)
- *Supplemental*: 1,110 MW
- *Up-Ramp*: 1,075MW + forecasted 10-min net load ramp
- *Short-Term Reserve*: Hourly requirements for normal and emergency conditions; always $\geq 3,000$ MW

MISO Market-Wide Reserve Demand Curves

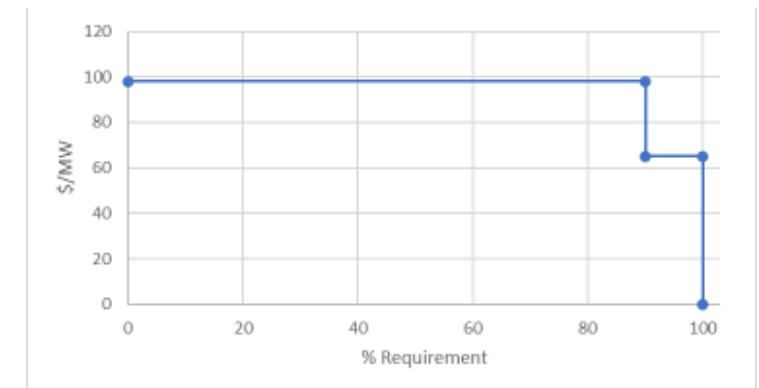
OR (Reg+Spin+Supp) Demand Curve Short-Term Reserve Demand Curve Up Ramp Capability Demand Curve



Regulation Demand Curve (Updated monthly)



Regulation+Spin Demand Curve



Summary of MISO reserve products

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	$Energy_{i,t} + reg_{i,t} + spin_{i,t} + supp_{i,t} + rcup_{i,t} \leq EcoMax_{i,t} \quad (1)$ $Energy_{i,t} + str_{i,t} \leq EcoMax_{i,t} \quad (2)$				

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

MISO's Recent Shortage Pricing Recommendations

MISO Shortage Pricing Objectives

- Send shortage price signals that reflect the risks of diminishing reserves, to incent proper market participant real-time actions
 - MISO reserve shortages are infrequent and often of brief duration (details in the August 24th, 2023 [MSC presentation](#))
- To encourage behavior that helps avoid potential scarcity conditions, particularly in the days/hours leading up to the Real-Time operating interval (e.g. Day-Ahead market participation, fuel purchases)
- To a lesser degree, proper DA/RT scarcity pricing may also inform longer-term market participant operational decisions, such as maintenance scheduling

MISO recommends changes for all four Value of Lost Load relationships in the Tariff anchored by a price increase from \$3,500 to \$10,000



\$ Energy and Reserve Price Caps (LMP & MCPs)

Remains at VOLL	ADD circuit breaker mechanisms for 4+ hours (\$5,000) & multiday (\$2,000)
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\$ Capacity Emergency Load Shed Administrative Price

Remains at VOLL	ADD circuit breaker mechanisms for 4+ hours (\$5,000) & multiday (\$2,000)
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⌵ Top of ORDC Curve Connected to VOLL

LOLP curve with new floors & cap	CHANGE floor from \$1,100/2,100 to \$600/1,100 & upper limit set at \$6,000
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\$ Emergency Demand Response Offer Cap

Remove Connection to VOLL	CHANGE to a set price of \$3,500
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MISO proposes a base VOLL of **\$10,000/MWh** as a price cap, and for administrative pricing during load-shed events*

- \$10K is a low-end estimate of the negative financial impacts associated with MISO-directed firm load-shedding
 - Since residential load has a markedly lower VOLL than commercial and industrial loads, LBAs often prioritize them earlier in their load-shedding plans
 - Price recognizes that some commercial/industrial loads will inevitably be shed, too
- Allows market prices to provide a clear financial incentive to reduce consumption
- Incentivizes incremental emergency supply from resources and interchange
- This VOLL, combined with the redesigned ORDC, provides room for all pricing components (MEC, MCC and MLC) before price capping

MISO further recommends a market pricing “circuit breaker” for longer-duration energy shortage conditions

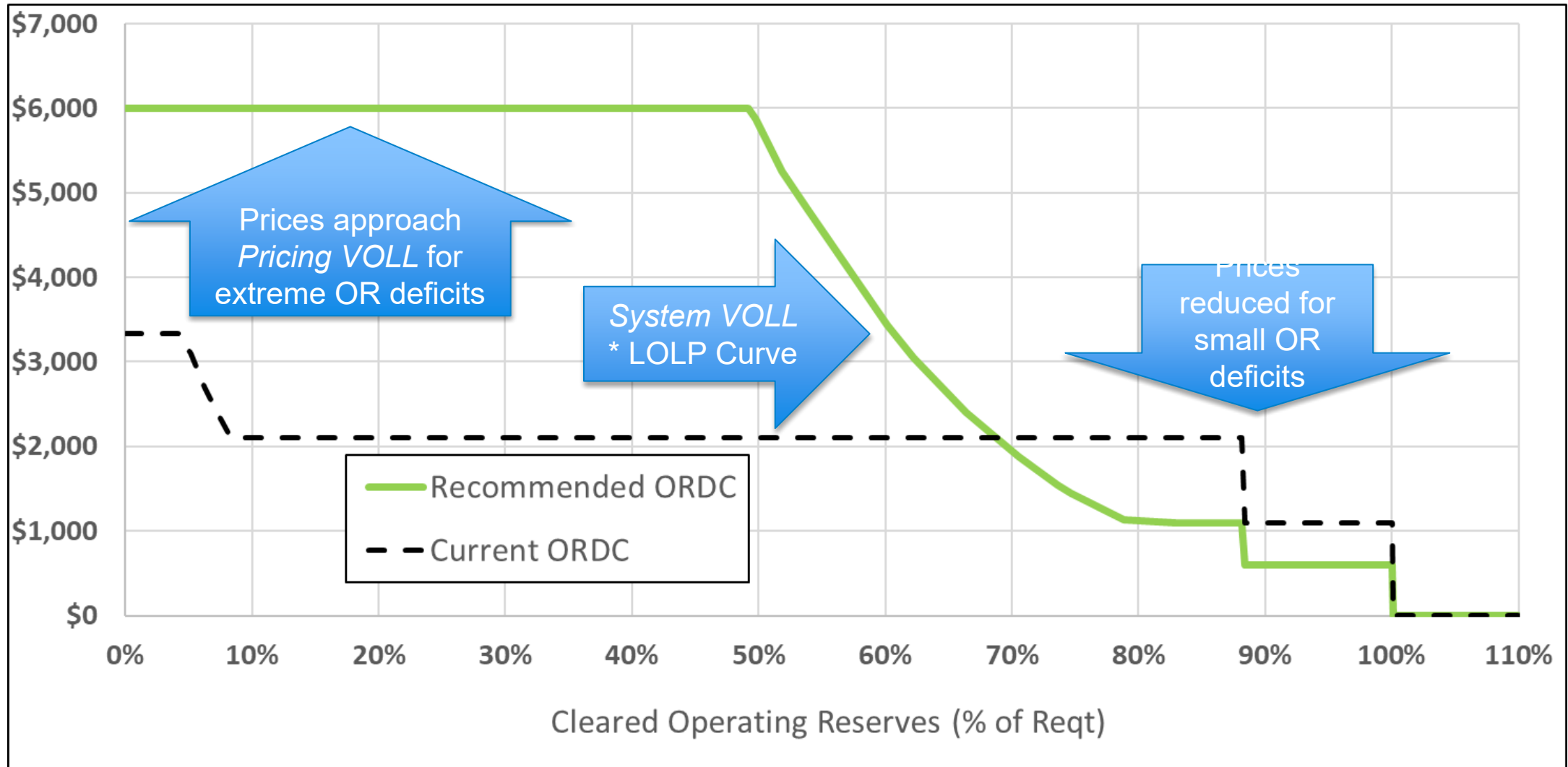
- The MISO recommended VOLL & ORDC changes are appropriate for short-term Operating Reserve and/or energy shortages (minutes-to-hours)
- For extended-duration energy shortage events (hours-to-days), safeguards are warranted to mitigate financial risks
 - Although past market experience and planning studies suggest that energy shortage events will be rare and short, it is prudent to prepare for the possibility of prolonged capacity-related load-shedding emergencies
 - In such situations, the VOLL can be progressively lowered from \$10K to \$5K and then \$2K

Market Price Circuit Breaker mechanisms function by successively lowering the VOLL

- CB1: After a cumulative four hours of RT EEA3 load-shedding in a **Max Gen Emergency**:
- Reduce **RT VOLL** to **\$5,000/MWh** immediately
- CB2: When there is a **Max Gen Emergency with EEA3 Load Shed** at 1030EPT (DA Market bid/offer close):
- Reduce the **DA and RT VOLLs** to **\$5,000/MWh** for the next Operating Day
- CB3: When the **Max Gen Emergency with EEA3 Load Shed** continues to additional Day-Ahead Market bid/offer closings (Day 2 and beyond):
- Reduce the **DA and RT VOLLs** to **\$2,000/MWh** for the next Operating Day

Continue to use RT VOLL as a price cap, and as the Administrative EEA3 price during load-shed

MISO Recommended Operating Reserve Demand Curve



Establishing the Overall ORDC Shape

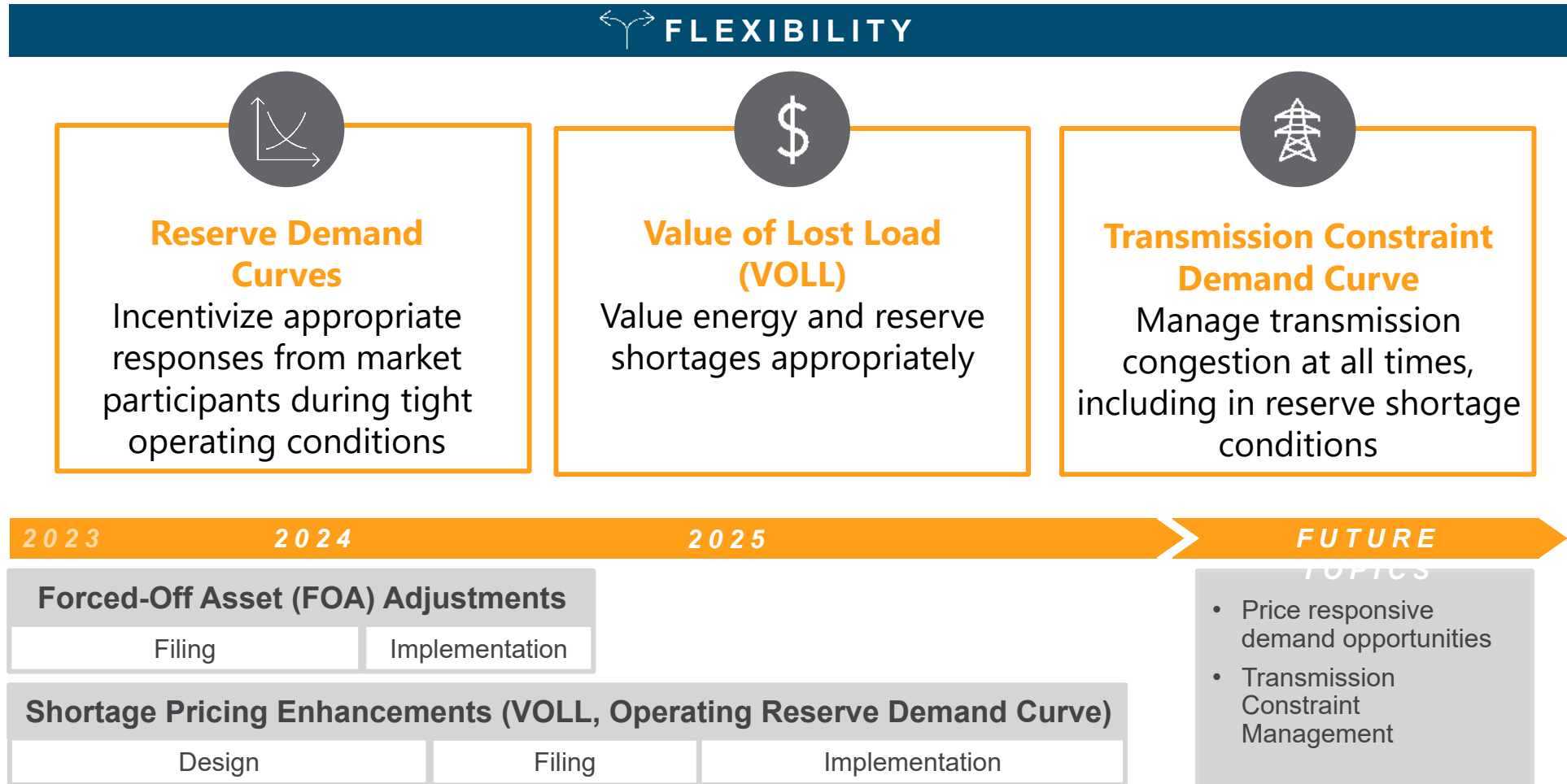
- Greater OR shortages increase the probability of load-shedding, which can be quantified with a Loss-of-Load-Probability calculation
- MISO developed an LOLP curve using measured uncertainties*:
 - Compare historical LAC and RT-SCED cases, to capture Net Load and Gen Outage/Derate uncertainties within a 10-30 min lead time
 - A Monte Carlo simulation generates the LOLP distribution, for varying contingency reserve (CR) levels
- To generate the ORDC, the LOLP curve is then scaled with an appropriate “System VOLL” of \$35,000/MWh, to reflect both the load-shedding costs, and the role of MISO Emergency Procedures
 - The System VOLL was selected based on the MISO composite value of \$36,888/MWh

MISO recommends removing \$2,000/MWh cap for DA Price-Sensitive Bids and Virtual Demand Bids

- FERC Order 831 specifies that resources should not be able to set prices above \$2,000/MWh
 - MISO and other ISOs/RTOs implemented resource (supply) offer caps
- At the same time, similar demand bid caps were established
 - Before Order 831, there were no DA bid caps in the MISO Tariff
 - Bid caps prevent DA Price Sensitive Demand to specify a value between \$2,000 and VOLL (Fixed Demand Bids will clear at any price, up to VOLL)
- With the recommended increase in VOLL, MISO also recommends removing the Energy Offer Hard Price Cap for Price Sensitive Demand Bids and Virtual Demand Bids
 - This would allow DA demand to specify a maximum bid price above \$2,000/MWh

Next Steps

Planned shortage pricing reforms provide greater transparency and incentivize market behavior for the changing fleet



Contact



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Appendix

Shortage Pricing Materials, including stakeholder feedback

- [Aug 24, 2023 MSC presentation](#)
 - Reserve Product Overview and Reserve Shortage Analysis
 - Price Formation Opportunities
- [Jan 18, 2024 MSC presentation \(feedback request\)](#)
 - Opportunities to Improve Shortage Pricing
 - Establishing the Value of Lost Load (VOLL)
 - EDR Offer Cap Implications
- [Feb 29, 2024 MSC presentation \(feedback request\)](#)
 - Ongoing VOLL/ORDC efforts by other ISOs/RTOs
 - MISO proposals for VOLL and ORDC
 - Introduction to a VOLL Circuit Breaker
- [Apr 18, 2024 MSC presentation \(feedback request\)](#)
 - Emergency Demand Response (EDR) Offer Cap Options
 - Considerations for a VOLL Circuit Breaker
- [May 23, 2024 MSC presentation](#)
 - Market design principles
 - Need for MISO shortage pricing reforms
 - MISO's current shortage pricing proposals
 - MISO's ongoing design effort for long-duration load-shedding events
- [Jul 9, 2024 MSC presentation \(feedback request\)](#)
 - Shortage pricing circuit breaker recommendations for extended-duration EEA3 events
 - Example of a long-duration EEA3 shortage pricing event
- [Aug 22, 2024 MSC presentation \(feedback request\)](#)
 - Review circuit breaker feedback from July MSC
 - Summarize MISO recommendations, including removal of caps for DA Price Sensitive Bids and Virtual Demand Bids
 - Request feedback on [draft Tariff changes](#)

Shortage Pricing Timeline

- **2007:** \$3,500/MWh Value of Lost Load (VOLL) was proposed for the ASM launch
- **2016:** Improvements to shortage pricing identified in IMM Recommendation (2016-1)
- **2019:** In response to FERC Order 831, MISO introduced a third \$2,100/MWh step to the ORDC
- **2020:** MISO released its [Emergency Pricing Evaluation paper](#)
- **2021:** MISO released the [Shortage Pricing Evaluation paper](#), which included: (1) the methodology to create the LOLP curve for different reserve levels; and (2) establishing a reasonable value for VOLL
- **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
- **2022:** Enhance demand curves for Short-Term Reserve and Ramp Up Capability Product
- **2023:** MISO focused on designing a solution for forced-off assets resulting from forced transmission outage situations, which was filed/approved in 2024. Stakeholder shortage pricing discussions began in the second half of 2023.
- **2024:** MISO continued shortage pricing discussions and released the “[Value of Lost Load and Operating Reserve Demand Curve](#)” white paper.

LMPs are impacted by reserve shortages (via the MEC) and transmission congestion (via the MCC)

$$\text{LMP}_i = \text{MEC} + \text{MCC}_i + \text{MLC}_i$$


MEC affected by:

- Marginal Resource Energy Offer
- [Reg] Shadow Price
- [Reg+Spin] Shadow Price
- [Reg+Spin+Supp] Shadow Price
- Up Ramp Capability Shadow Price
- Short Term Reserve Shadow Price

Sum the products for each binding constraint:

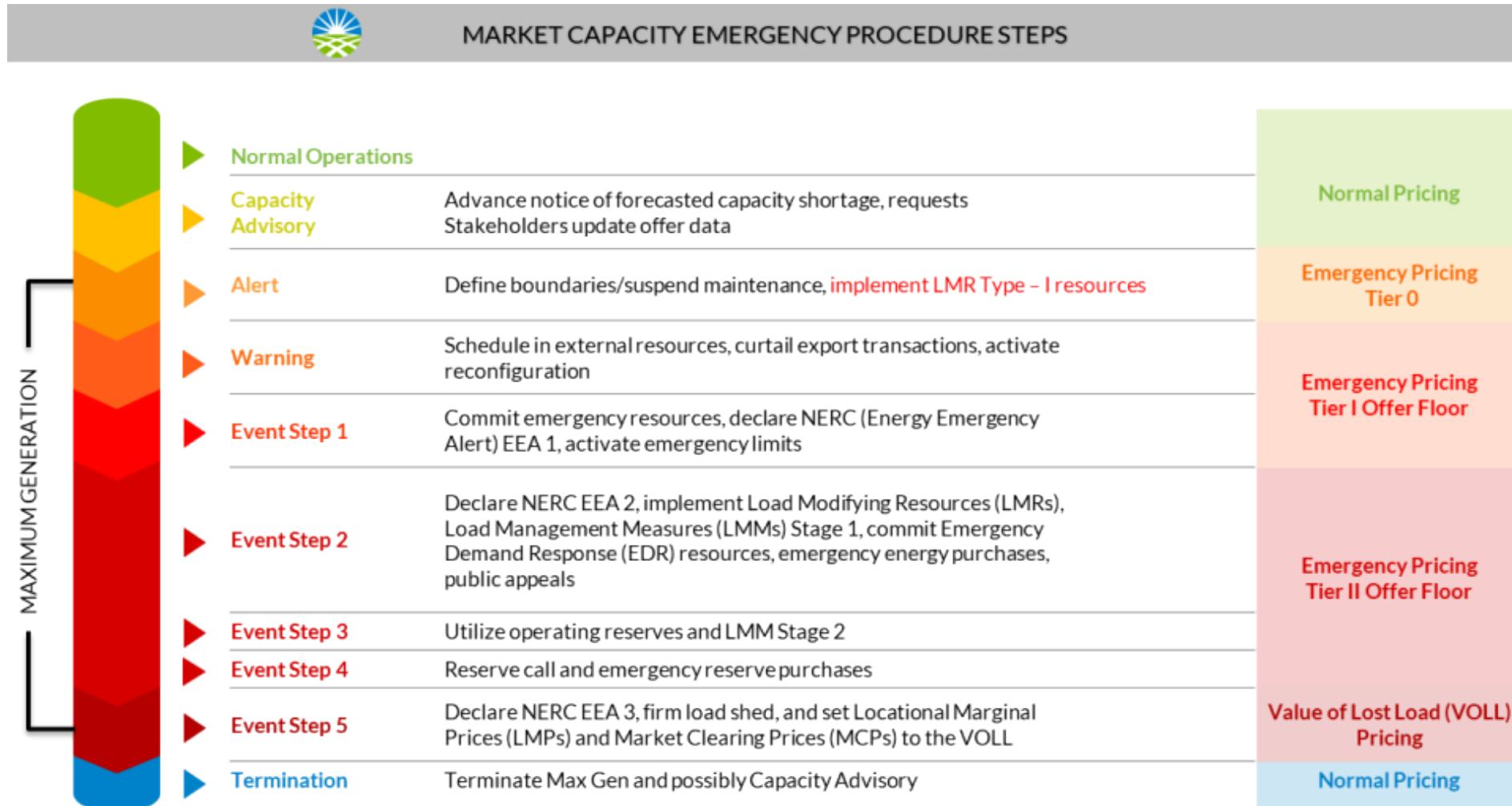
- Transmission Constraint Shadow Price *
Transmission Constraint Shift Factor

From BPM-002:

$$(5-9) \quad \text{MEC}_r = \left[\sum_{i=1}^I \{\text{Demand}_i * \text{LMP}_i\} \right] / \left[\sum_{i=1}^I \{\text{Demand}_i\} \right]$$

where Demand_i = Fixed Market Demand at EPNode i

Summary of Market Capacity Emergency Procedure Steps, including Max Gen steps leading up to firm load-shedding (EEA 3)



In the 2007 filing for the upcoming Ancillary Services Market, MISO described the approach to determine the VOLL of \$3,500/MWh *

- “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.”

MISO has updated the VOLL calculations using recent econometric results, delineating multiple load characteristics

- Utilized LBL meta-analyses with MISO-specific drivers (consistent with MISO's original approach in 2009 which was also the SOM approach, Rec 2016-1)
 - Used two-step regression models to estimate statistically significant outage cost functions

Hundreds of values for VOLL were updated, with breakdowns for:

Three customer load segments (Residential, Small Commercial & Industrial, Large Commercial & Industrial)

Multiple outage durations: **1 hour**, 2 hour, 4 hour, and 8 hour

Two seasons: **summer**, non-summer

Three time-of-day periods: afternoon, evening, **off-peak**

Commercial and Industrial sub-types: **manufacturing**, construction, or neither

State-level and MISO-wide aggregations

Highest VOLL factors are in bold

2023 MISO-wide VOLL (\$/MWh) components for key load classes and outage durations

Load Class	<u>1-hr outage</u>	<u>2-hr outage</u>	<u>4-hr outage</u>	<u>8-hr outage</u>	<u>12-hr outage</u>
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 *	\$36,889	\$23,545	\$18,342	\$18,309	\$18,342
System 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*

*Basis of \$5,000 VOLL
for EEA3 events >=4 hrs*

Value reduced by 18% if only considering “Services” sub-category of Small C&I

* Inter-class weights: 34% Large C&I, 31% Small C&I, 35% Residential

Resetting the DA and RT VOLLs following activation of a pricing circuit breaker

- When the DA and/or RT VOLLs have been reduced by a Market Price Circuit Breaker, they are not reset until after MISO has terminated the **Max Gen Emergency**, which can include various Alert/Warning/Event Step levels
 - In particular, the reduced VOLLs would continue to be used in additional EEA3 declarations during that specific Max Gen Emergency, and as a price cap for non-EEA3 emergency intervals
- Furthermore, the VOLL reset depends on the timing of the termination relative to the DA Market closing
 - If the Max Gen termination occurs **before** 1030 EPT, the VOLLs are reset to \$10,000/MWh at the end of the **current** Operating Day
 - If the Max Gen termination occurs **after** 1030 EPT, the VOLLs are reset to \$10,000/MWh at the end of the **next** Operating Day

MISO first recommends establishing a \$600 ORDC step to minimize “economic” OR shortages

- A \$600 step ensures that OR shortage prices do not fall below the sum of:
 - Tier I Emergency Offer Floor* of \$500/MWh (which is also the max STR Demand Curve); and
 - Contingency Reserve Offer Cap of \$100/MWh
- Reduces transient OR shortages resulting from an excessively low demand curve, and considers the combined pricing impact of OR and STR shortages
- Following an emergency declaration, market solution should not violate OR requirement to avoid resource offers at the Tier I EOF
- In addition, by reducing the first step from \$1100 (Current ORDC) to \$600, MISO can better manage congestion during small OR shortages

In addition to the \$600 step, MISO recommends establishing an \$1,100 ORDC step when reserves fall below the MSSC

- This second step increases the pricing when cleared OR falls below the Most Severe Single Contingency (EOP-002)
- The \$1,100 ORDC step is determined as the sum of:
 - Tier II Emergency Offer Floor* of \$1,000/MWh (also the Energy Offer Soft Cap), and
 - Contingency Reserve Offer Cap of \$100/MWh
- Following an emergency event declaration, market solution should not violate OR requirement to avoid resource offers at the Tier II EOF
- In addition, by reducing the second step from \$2100 (Current ORDC) to \$1100, MISO can better manage congestion during moderate OR shortages

MISO recommends an ORDC upper bound of \$6,000/MWh

- During extreme OR shortages, high energy prices encourage beneficial demand response, increased imports, and additional energy production
 - Higher prices are primarily established with the ORDC within the Marginal Energy Component (MEC)
 - Energy prices should approach VOLL
- A \$6,000/MWh upper bound allows up to \$4,000 for other MEC and LMP contributions to the energy prices, before the VOLL Price Cap is applied
 - Marginal energy offers can reach \$2,000/MWh
 - The STR Demand Curve has a \$500 upper limit
 - There are other smaller reserve product demand curves to also consider
 - This effectively caps the MEC at ~\$8,700 - \$9,000/MWh

Acronyms

ASM	Ancillary Services Market	LMR	Load Modifying Resource
AME	Available for Max Emergency (commit status = Emergency)	LOLP	Loss Of Load Probability
CB	Circuit Breaker (as in Market Pricing CB)	LSE	Load Serving Entity
C&I	Commercial and Industrial [loads]	MCC	Marginal Congestion Component (of LMP)
CR	Contingency Reserves (equals Spin + Supplemental Reserves)	MCP	Market Clearing Price
DA	Day-Ahead (market)	MEC	Marginal Energy Component (of LMP)
DAMAP	Day-Ahead Margin Assurance Payment	MLC	Marginal Loss Component (of LMP)
DER	Distributed Energy Resource	MP	Market Participant
DSRI	Demand Side Resource Interface	MRD	Manual Redispatch
DRR	Demand Response Resource	OD	Operating Day
EDR	Emergency Demand Response	OR	Operating Reserve (equals CR + Regulating Reserves)
EEA	Energy Emergency Alert (NERC)	ORDC	Operating Reserve Demand Curve
GSF	Generation Shift Factors	RDRR	Reliability Demand Response Resource (CAISO)
IMM	Independent Market Monitor	RT	Real-Time (market)
ISO	Independent System Operator	SMP	System Marginal Price
LBA	Load Balancing Authority	TCDC	Transmission Constraint Demand Curve
LBNL	Lawrence Berkeley National Labs	UDS	Unit Dispatch System
LMP	Locational Marginal Price	VOLL	Value of Lost Load