Price Signals Activating Power System Flexibility[1]

Demand-Side Flexibility Practices in the U.S. Midwest

Abstract: As countries build new-type power systems suited to high shares of renewable energy, they must integrate variable renewable generation while ensuring the secure and stable operation of the power system, which has become an increasingly prominent systemic challenge. As the share of renewable energy continues to rise, power systems need greater flexibility to maintain the balance between supply and demand. Electricity consumers with shiftable loads, behind-the-meter generation, or energy storage have the potential to provide part of this flexibility while lowering their own costs. The Midcontinent Independent System Operator (MISO) has improved the utilization of demand-side flexibility by allowing wholesale electricity prices to fluctuate over a wide range, promoting transparent and time-varying retail electricity prices, accrediting resources such as demand response, virtual power plants, energy storage, and renewable generation in its resource adequacy mechanism according to their reliability contributions, and establishing flexible interconnection rules for large loads. MISO's experience shows that accurate price signals, transparent and continuously evolving regulatory processes, and market rules that allow distributed resources to capture multiple value streams according to their capabilities offer useful reference for countries seeking to improve the utilization of power system flexibility and ensure the secure and stable operation of power systems with high shares of renewable energy.

Keywords: demand-side flexibility; wholesale electricity pricing; market power monitoring and mitigation; distributed energy resources; resource adequacy

I. Background

As the share of wind and solar power continues to increase, a key challenge for power systems is how to maintain the real-time balance between electricity generation and consumption in a cost-effective manner. Energy storage can absorb electricity during some periods and discharge it during others, but utilizing flexibility in the timing of electricity consumption and reshaping demand patterns to better match electricity supply is often a lower-cost option. Demand-side flexibility can take many forms. It may involve pumping water or charging industrial thermal batteries when renewable energy is abundant and releasing energy when supply is constrained. It can also involve shifting electricity use over short time periods or providing grid services that enable customer loads to respond to changes in system conditions within seconds or minutes.

The Midcontinent Independent System Operator (MISO) is a pioneer in integrating demand-side flexibility into power system operations in the United States. As a nonprofit independent system operator, MISO manages electricity supply for 45 million people across 15 U.S. states and the Canadian province of Manitoba. It performs both system dispatch and market operation functions and is regulated by the Federal Energy Regulatory Commission (FERC). With annual electricity sales of approximately 700 TWh and peak demand of about 120 GW, MISO is the second-largest power system operator in North America. MISO is also one of the power systems with a relatively high share of wind generation globally. In 2025, wind power accounted for 15% of its total electricity generation. Wind

[1] Case provided by CCICED Special Policy Study on *Building a New-Type Power System Aligned with the Next Round of Wind and Solar Growth Targets*

and solar power combined accounted for 19% of total generation, and during hours of peak renewable output, their share approached 47%[2].

MISO operates multiple markets, including annual and monthly auctions for generation and transmission capacity, as well as day-ahead and real-time markets for energy and ancillary services. It optimizes decision-making across the entire region in an integrated manner, ranging from long-term planning to minute-by-minute operations. Approximately 90% of customers in the MISO region are served by vertically integrated utilities. These utilities are regulated by state governments while coordinating system operations through MISO.

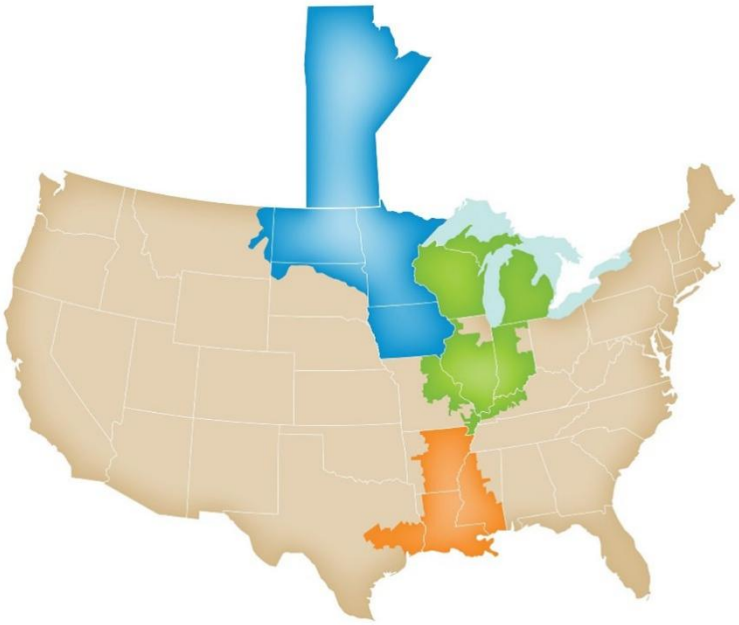


Figure 1. MISO service territory[3]

After integrating demand-side flexibility into power system operations, MISO achieved positive results. Following reforms to the capacity market, a reliability-based demand curve enabled price signals to more accurately reflect the value of resource adequacy, and summer capacity prices for the 2025/26 planning year increased from US$30/MW-day to US$666.50/MW-day. The scale of demand response resources also expanded. In 2025, available demand response capacity exceeded 14 GW, an increase of more than 1 GW compared with 2024. Through its integration of demand-side flexibility into power system operations, MISO has addressed several common barriers that power systems face in utilizing demand-side flexibility. These include insufficient price signals in wholesale markets, retail electricity prices that do not reward consumer behavior beneficial to the power system, unclear market participation rules for demand-side resources, and planning processes that do not fully account for flexibility needs.

II. Key Measures

(1) Allowing wholesale prices to reflect system conditions

[2] POTOMAC ECONOMICS. 2025 State of the Market Report for the MISO Electricity Markets[R/OL]. (2026-06)[2026-09-17]. https://www.potomaceconomics.com/wp-content/uploads/2026/07/2025-State-of-the-Market-Report.pdf.

[3] Blue indicates the MISO North Region, green indicates the MISO Central Region, and orange indicates the MISO South Region.

First, MISO sets a relatively high price cap to provide strong price signals for utilities. MISO sets a relatively high offer cap for generation units and other resources and establishes a market clearing price cap of US$10,000/MWh[4]. This provides strong price signals to utilities, encouraging them to use demand-side flexibility through electricity tariff design or program mechanisms to reduce costs. Utilities also stabilize their costs by entering into long-term contracts with generation and energy storage resources.

Second, MISO uses third-party monitoring and automated mitigation measures to control market power[5] risks. MISO does not rely on relatively low price caps to manage market power risks. Instead, it employs third-party monitoring and automated mitigation measures. If a generating unit is required to remain available but submits an offer that is not permitted, such as an offer price that exceeds its reasonable costs, the automated system replaces the offer with an appropriate reference value. If a generating unit fails to submit an offer at all, it is subject to ex-post investigation and may be fined one to three times the market value of the withheld energy[6].

Third, MISO allows electricity prices to become negative within a relatively wide range and is exploring ways to reduce the frequency of negative prices. Similar to many Regional Transmission Organizations (RTOs) in the United States and Europe, MISO allows electricity prices to become negative within a relatively wide range, with both the offer floor and market price floor set at –US$500/MWh. This floor serves as an emergency backstop under extreme conditions and is reached only during periods of severe oversupply; between 2025 and 2026, prices reached this level in only 7 out of 3.6 million hub-hours[7]. In addition, MISO plans to allow generating units, after being committed in the day-ahead market[8], to be released from their commitment on the operating day, helping to reduce both the frequency and magnitude of negative prices.

(2) Using transparent and time-varying retail tariffs

Utilities in the MISO region develop retail electricity rates through transparent processes and offer a variety of time-varying pricing options. Some of these pricing plans reflect not only electricity supply and demand conditions but also grid congestion. These rates enable consumers to shift electricity use from periods of scarcity to periods when electricity is more abundant, helping them reduce electricity costs while supporting grid operations.

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[4] Although limits on offers from individual resources are set at US$1,000–3,500/MWh, the market clearing price may reach higher levels if total system demand exceeds available generation capacity.

[5] Market power refers to the ability of market participants to influence or control market prices, causing them to deviate from competitive levels. In electricity markets, generators with market power can raise electricity prices above competitive levels and earn excess profits through strategic bidding (such as submitting high-priced offers) or physical withholding (such as failing to offer available capacity). Regional transmission organizations such as MISO therefore establish market power mitigation mechanisms to identify and correct such bidding behavior through conduct tests and impact tests, thereby preserving the integrity of market price signals.

[6] Midcontinent Independent System Operator. Market Monitoring and Mitigation (BPM-009-r24) [R/OL]. (2025-08-29) [2026-09-17]. Available at: https://www.misoenergy.org/legal/rules-manuals-and-agreements/business-practice-manuals/

[7] MISO. Historical Real-Time Locational Marginal Prices (ZIP): Historical Real-Time Locational Marginal Price (LMP) Data [DS/OL]. [2026-07-30]. Available at: https://www.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/

[8] The day-ahead market refers to an electricity market organized by a power exchange or market operator on the day before system operation to determine generation schedules and electricity prices for each period of the following day. In regional transmission organizations such as MISO, the day-ahead market uses security-constrained unit commitment and economic dispatch to determine market-clearing prices and generation schedules for each trading period of the following day. This provides predictable price signals and a basis for system operations in advance.

Table 1. Approximate tariff availability and adoption by customer class and tariff type or element

Customer class	Tariff Availability and Adoption				
	Flat price	Time-of-Use (TOU)	Real-time Pricing (RTP)	Demand charge	Coincident peak
Residential (most MISO states)	H/H	M/L	L/L	-	-
Residential (Michigan)	M/L	H/H	L/L	-	-
Small commercial & industrial (< 50 kW)	H/H	M/M	L/L	M/L	-
Medium commercial & industrial (50–500 kW)	M/M	H/H	L/M	H/H	L/L
Large commercial (>500 kW)	L/M	H/H	M/M	H/H	M/H
Large industrial (>500 kW)	L/M	H/H	M/M	H/H	H/H

Notes: Availability/Adoption (when offered):
L low (<35%), M medium (35–65%), H high (>65%)

Public utility commissions in the states within the MISO region are responsible for reviewing retail electricity rates and rate design. The review process is conducted through open regulatory proceedings. During these proceedings, utilities must submit proposed rate plans and supporting data and make them publicly available online. Stakeholders and consumers may provide comments, after which the commission issues a final decision, which may include modifications to the proposed retail electricity rates.

Approved retail pricing plans in the MISO region provide consumers with a range of options, including flat rates that remain constant throughout the day, time-of-use (TOU) rates that apply fixed peak and off-peak prices during specific periods of the day or year, and real-time pricing (RTP) linked to hourly wholesale electricity prices. For large customers, these pricing structures are often combined with demand charges[9]. Demand charges are based on a customer's highest level of electricity demand during the year and, in some cases, may also be based on the coincident peak[10] demand of the MISO system or the utility's own system peak.

(3) Enabling aggregated participation of demand-side resources through market rules

MISO, federal regulators and state regulators each play distinct roles in the development of rules governing virtual power plants (VPPs)[11]. MISO is responsible for implementing wholesale market participation rules approved by the Federal Energy Regulatory Commission (FERC), while state regulators oversee retail demand response programs and electricity rates.

Historically, demand response and VPP programs in the MISO region were primarily used to reduce peak capacity requirements and provide contingency reserves. In 2020, FERC issued Order No. 2222, requiring regional transmission organizations such as MISO to allow distributed energy resources to participate fairly in wholesale markets and receive the same market services as conventional resources. Since then, MISO has worked with stakeholders and FERC to design distributed energy

9 "Demand charges" are fees based on the highest power a customer actually draws during a billing period (usually one month). Under two-part tariffs, demand charges assessed on a customer's maximum demand compensate the utility for the fixed costs of the grid capacity built to meet that customer's peak power needs.
10 "Coincident peak" refers to the point at which the electricity demand of multiple customers, or of the power system as a whole, reaches its maximum at the same moment. It is the highest simultaneous power demand on the system.
11 A virtual power plant (VPP) broadly refers to the aggregation of flexible behind-the-meter loads, distributed energy storage, and distributed generation resources.

resource aggregation models, update market rules, revise its tariff provisions, and address issues related to metering, telemetry, and coordination with distribution utilities[12].

(4) Recognizing the reliability value of demand-side resources through capacity mechanisms

The MISO region uses a layered resource adequacy framework. Utilities develop and publicly disclose integrated resource plans covering 15 to 20 years and submit them for review by state regulators. These plans guide the long-term procurement of both generation resources and demand-side resources. Building on this foundation, MISO supplements long-term planning through annual resource adequacy assessments and seasonal capacity auctions, which provide price signals and help coordinate near-term regional capacity needs.

In recent years, MISO has made significant progress in improving its framework for assessing the capacity value of resources, including conventional generation, renewable energy, energy storage, and demand-side resources. First, capacity value is assessed on a seasonal basis, reflecting the availability of resources in different seasons rather than relying on a single annual value. Second, capacity value is based on actual performance. For conventional generators and demand response resources, capacity contributions are determined according to recent historical availability rather than installed capacity, with forced outage rates and verified operational performance explicitly incorporated into the assessment. Third, MISO applies a forward-looking approach to assessing the capacity value of wind and solar resources. These measures have shifted resource valuation from nameplate capacity (i.e., rated generating capacity) toward the actual contribution of resources to system reliability.

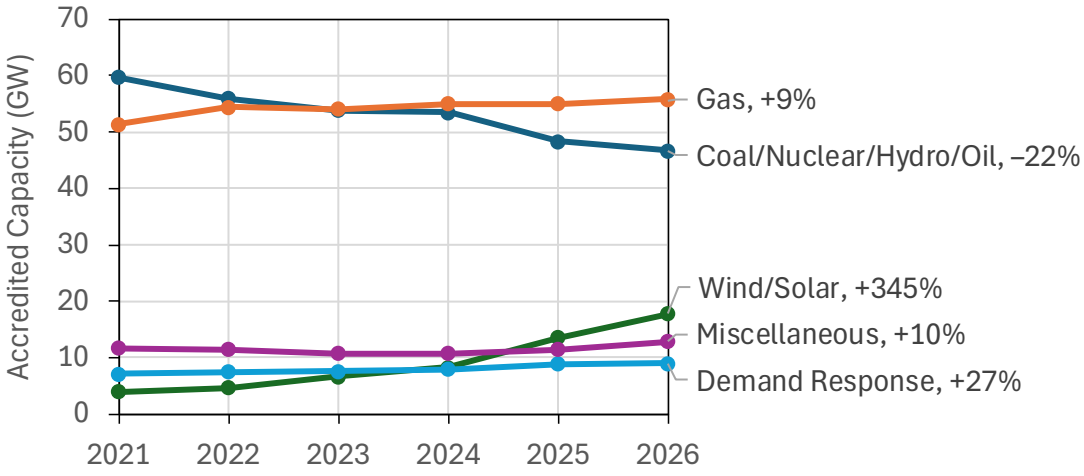


Figure 2. Summer capacity procured in MISO resource adequacy auctions, 2021–26

Source: MISO[13]

(5) Reducing barriers for large loads through flexible interconnection rules

MISO is currently developing new tariff and interconnection arrangements for large loads that are co-located with generation facilities, known as the Zero-Injection Generator Interconnection

[12] The reform process is expected to be completed by 2029, at which point VPPs will be able to compete with conventional generation and energy storage resources across a broader range of market services.

[13] MISO. Planning Resource Auction Results for Planning Year 2026/27 - Updated May 22[R/OL]. (2026-05-22)[2026-08-16].https://cdn.misoenergy.org/2026%20PRA%20Results%20Posting%2020260522%20-%20Corrections754715.pdf.

Agreement (ZGIA)[14]. This arrangement applies to situations in which generation facilities and loads are located at the same site and generation output never exceeds on-site electricity consumption. Except for momentary conditions, no electricity is exported back to the main grid.

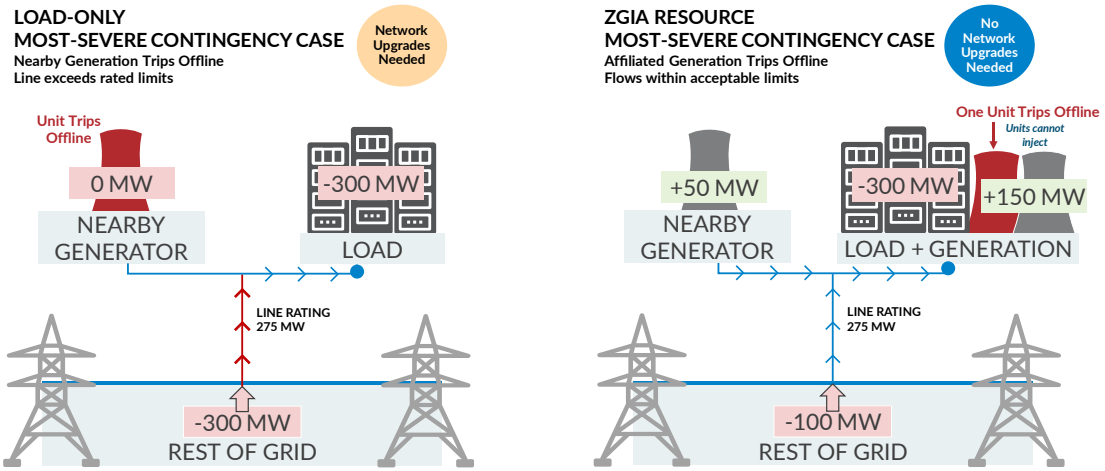


Figure 3. ZGIA allows loads with on-site generation to reduce the need for transmission and generation in the rest of the power system

Source: MISO Planning Advisory Committee [15]

Under the ZGIA framework, on-site generation facilities and loads are still subject to separate interconnection reviews and remain responsible for their respective shares of system costs. However, the review process for generation facilities would be streamlined, reducing the review period from 355 days for a stand-alone generation project to 90 days. In addition, the generating capability of the facility is taken into account when determining the electricity demand it places on the grid. Specifically, where multiple generating units are present and no single point of failure exists, all generating capacity except for two units held as safety backup may be credited to reduce the peak demand that the load presents to the grid. This can reduce the need for transmission upgrades or additional generation capacity, lower costs borne by customers, and shorten interconnection timelines[16]. Faster and lower-cost interconnection opportunities, in turn, create strong incentives for the development of flexible resources behind the point of interconnection, whether that flexibility comes from demand-side resources or from co-located generation and energy storage.

III. Lessons Learned

(1) Coordinating price signals and safeguards to encourage flexible responses

MISO's electricity market demonstrates that allowing prices to fluctuate within a relatively wide range, including negative prices during periods of oversupply, can provide accurate signals to generators, energy storage resources, and flexible loads, enabling them to adjust electricity production or consumption in response to changing system conditions. At the same time, price caps and floors serve

[14] PLANNING ADVISORY COMMITTEE. Consideration of Zero-Injection GIA[Z/OL]. (2026-01-21)[2026-08-03]. https://cdn.misoenergy.org/20260121%20PAC%20Item%2009%20Market%20Participation%20and%20Registration%20of%20Co-Located%20Load%20and%20Generation%20(PAC-2024-4)736238.pdf.

[15] Same as 14.

[16] MISO LARGE LOAD WORKING GROUP. Consideration of Zero-Injection GIA[Z/OL]. [2026-08-03]. https://cdn.misoenergy.org/20260420%20LLWG%20Item%2007%20Consideration%20of%20Zero-Injection%20GIA%20(PAC-2024-2B)751417.pdf.

as safeguards under extreme conditions, helping to prevent excessive wealth transfers between consumers and generators. Under normal market conditions, market power risks are managed through close monitoring of generator bidding behavior and targeted mitigation measures when necessary. Utilities also meet most of their resource needs through long-term planning and procurement under the oversight of state regulators, helping to manage risks prudently. Within this institutional framework, relatively large price fluctuations can provide clear signals for mobilizing demand-side flexibility without requiring all consumers to be directly exposed to such price volatility.

(2) Transparent processes and continuous refinement support institutional credibility

In the MISO region, long-term decisions are typically made through transparent processes that allow stakeholder participation, and the underlying analysis is disclosed both before and after decisions are made. This transparent and continuously evolving process can accelerate the exchange of experience across different jurisdictions, incorporate concerns that might otherwise be overlooked, facilitate consensus among stakeholders, and provide a basis for future policy improvements.

(3) Multiple value streams and appropriate market rules encourage resource participation

Distributed energy resources can respond to time-varying prices or participate through virtual power plants (VPPs), providing energy, capacity, and contingency reserve services, often at lower cost than conventional generation. Transparent regulatory processes improve the predictability of these projects, supporting sustainable business models and investment in these opportunities. However, existing programs generally do not compensate distributed resources for location-specific benefits, such as avoided transmission or distribution system upgrades. Fully unlocking the value of demand-side flexibility will require further development of programs that match the capabilities of distributed resources and provide compensation for the full range of services they can deliver.

(4) Consistent standards and actual contributions should guide reliability assessment

A key lesson from MISO's reforms to capacity value accreditation is that the reliability value of all resources should be assessed using consistent standards based on their actual contribution to system reliability, rather than differentiated according to resource type or nameplate capacity. The reforms are built on three principles. First, technology neutrality, ensuring that every resource, including demand-side resources, is accurately valued according to the services it actually provides. Second, a forward-looking assessment, whereby resource value reflects expected performance under future grid conditions, informed by historical performance data, rather than performance under past conditions alone. Third, probabilistic evaluation, which considers how resources are likely to perform under extreme conditions and incorporates factors such as forced outage rates, planned outages, and the generation characteristics of renewable energy resources. MISO's experience suggests that placing demand-side and supply-side resources within a common reliability assessment framework is an essential institutional foundation for unlocking demand-side flexibility.

(5) Flexible interconnection rules and incentives encourage loads to adapt to system needs

MISO's proposed ZGIA for customers with on-site generation demonstrates how well-designed interconnection rules can benefit both electricity users and the power system. The mechanism rewards customers for using on-site flexibility to reduce the need for grid-side generation and transmission investments, while maintaining appropriate review procedures and reliability safeguards. Similar approaches could also be applied to zero-carbon industrial parks and green manufacturing hubs in other countries, where large industrial loads may be combined with on-site renewable energy generation, energy storage, and flexible production processes. If planners are able to account for load flexibility

and on-site generation that can reliably reduce peak demand, upstream generation and transmission investment requirements may be reduced, helping to accelerate interconnection processes and lower costs.