What is MISO?

- Midcontinent Independent System Operator
- MISO is a Regional Transmission Operator (RTO)
  - An RTO is a Federal Energy Regulatory Commission (FERC)-regulated control area operator of the electric transmission grid
- MISO does not own any transmission or generation assets and cannot have affiliation with any members
- MISO is a non-profit organization
- Membership in MISO is voluntary
Why have an RTO?

In establishing the framework for regional transmission system operators, FERC’s expressed a goal of removing impediments to competition in the wholesale bulk power marketplace and to bring more efficient, lower cost power to the Nation's electricity consumers.

As a Regional Transmission Organization, MISO assures consumers of unbiased regional grid management and open access to the transmission facilities under MISO’s functional supervision.

MISO’s Vision - Be the most reliable, value-creating RTO
MISO’s Evolution
MISO Scope of Operations

- ~42M End use consumers
- ~71,800 Transmission miles
- ~127,000 MW Peak Load (Market)
- ~177,000 MW Generation capacity
- ~460 Market Participants
- ~6600 generating units
- ~290,000 SCADA data points
- ~ 30 billion annual gross market (2018)
- 15 states
- One Canadian province
- Historic Wind Peak (December 30, 2019) ~16,800 MW
- Control Centers
  - Eagan, MN; Carmel, IN; Little Rock, AR

Reliability Coordination Area Map
North American Electric Grid Operators
Drive Value Creation - Reliable Delivery of Low Cost Energy

- Efficient Wholesale Market Management & Operations
- Comprehensive Transmission Planning
- Effective Regional Reliability Assessment

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What we do

Efficient Wholesale Market Management & Operations to Ensure Reliability

- Operate day-ahead and real-time energy and operating reserves markets
- Manage transmission system ‘congestion’ through economic dispatch of generation units
- Monitor energy transfers on the high voltage transmission system
- Schedule transmission service

Comprehensive Regional Transmission Planning

- Long-range transmission planning
- New generator interconnection and retirement
- Long-range studies, such as Renewable Integration Impact Assessment (RIIA)
MISO’s role in the process is here – managing flows on the transmissions system by directing generator usage.

MISO administers the “market” for electricity producers and users on a wholesale level.

MISO does not generate electricity for ourselves, nor does it buy electricity.
MISO markets play a critical role in reliability and cost-effectiveness

**Resource Adequacy**
- Prompt year capacity auction to ensure adequate capacity

**Financial Transmission Rights Market**
- Auction of transmission congestion hedges

**Day-Ahead Energy Market**
- Next day, hourly, financially binding commitment of energy and operating reserves (ancillary services)
- Commit resources to meet demand at least cost per resource offers and load bids from 410 participants at 2,440 price nodes

**Real-Time Energy Market**
- Dispatch 6,300 units to meet system demand, secure operating reserves and manage congestion
- Setpoints issued every 4 seconds; dispatch target every 5 minutes

**MISO Real-time Energy Markets**

**Additional MISO Market Activities:**
Counterparty credit administration, Invoicing of capacity, energy, ancillary services & transmission charges
How MISO Markets Work

Marginal resources set marginal prices: the last unit needed to meet demand on the “generation supply curve” sets price of energy for that time interval.

Operationally…

- “Day-ahead” market used to schedule units for next day
- Then, “real time” market balances actual demand and generation
- Generators can designate themselves as “must run”...
  - Typically coal/nuclear
  - Can be less than full load (i.e., opportunity to increase load in real time market)
  - Must run portion is a “price taker” – they get the clearing price
- Utilities can both “offer” generation (sell) and “bid” loads (buy) in the market
- RTO “settles” the transactions for both buyers and sellers and handles the billings
MISO conducts wholesale markets to ensure lowest costs and reliable operations

The requirement to balance demand (load) with supply (generation) instantaneously at all points on the grid... ...results in wholesale prices that can fluctuate rapidly to send timely signals to market participants.
MISO connects a large, diverse generation fleet...

Total MISO, 2018

Generating Capacity

175 Thousand MW

- Coal: 32%
- Gas: 42%
- Wind: 15%
- Nucl.: 8%
- Hydro/Other: 6%

Electricity Generated

640 Million MWh

- Coal: 47%
- Gas: 27%
- Nucl.: 16%
- Wind: 8%
- Hydro/Other: 2%

Source: Misoenergy.org website
The Evolving Future Grid:
Driving Reliability and Efficiency in the MISO Footprint
Guided by member and industry needs, MISO continues to advance reliability and deliver value to customers.

To address an evolving resource mix, MISO will need to transform the way it plans for and manages the operating day.

As we look to the future, member engagement remains essential to ensuring MISO continues to reliably create and deliver value.
MISO continues to advance reliability and market efficiency, consistent with the themes of the MISO Forward report.

- The ability of transmission and energy resources to meet requirements at all hours.
- The ability to see and coordinate relevant resource, demand, and power flow attributes in operating and planning horizons.
- The ability to anticipate and adapt to frequent and significant changes in resource output and demand, including the enabling of new sources of flexibility.

https://www.misoenergy.org/forward/
The changing resource portfolio will remain a key influencer in the way value is created moving forward.

* More aggressive utility de-carbonization goals and proposed policy changes in Illinois, Minnesota and Wisconsin may further accelerate renewables penetration.
Changing resource portfolio: coal and gas retirements

Generation Retirement Trend by Fuel Type
(Capacity in MW)

Total Approved Retirement since 2005
(24.3 GW)

- Coal: 73%
- Gas: 22%
- Nuclear: 2%
- Oil: 2%
- Diesel: 0%
- Other: 1%

Coal
Gas
Nuclear
Oil
Diesel
Other

2005: 13
2006: 7
2007: 242
2008: 98
2009: 234
2010: 786
2011: 1081
2012: 1024
2013: 880
2014: 931
2015: 1929
2016: 4410
2017: 4575
2018: 170
2019: 170
2020: 170

Total Approved Retirement since 2005: 7001 MW

MISO
Renewables account for **over 85%** of MISO’s current active generator interconnection request ‘queue’

**Projects entering MISO’s Generator Interconnection Queue over the past 4 yrs**

<table>
<thead>
<tr>
<th>Year</th>
<th>Wind (GW)</th>
<th>Hybrid (GW)</th>
<th>Solar (GW)</th>
<th>Gas (GW)</th>
<th>Storage (GW)</th>
<th>Other (GW)</th>
<th>Total (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>14.5</td>
<td>2.5</td>
<td>13.6</td>
<td>7.6</td>
<td>3.6</td>
<td>2.5</td>
<td>30.5</td>
</tr>
<tr>
<td>2017</td>
<td>40</td>
<td>17.6</td>
<td>22.1</td>
<td>7.6</td>
<td>2.9</td>
<td>3.5</td>
<td>47.2</td>
</tr>
<tr>
<td>2018</td>
<td>41</td>
<td>21</td>
<td>14.8</td>
<td>3.5</td>
<td>2.2</td>
<td>2.4</td>
<td>81.5</td>
</tr>
<tr>
<td>2019</td>
<td>44.5</td>
<td>28.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>72.7</td>
</tr>
</tbody>
</table>

**MISO’s Current Generator Interconnection Queue (currently active projects)**

- **Total:** 91 GW (583 projects)
  - Wind: 23 GW (128 projects)
  - Hybrid: 3 GW (52 projects)
  - Solar: 8 GW (22 projects)
  - Storage: 2 GW (7 projects)
  - Gas: 3 GW (18 projects)
  - Other: 52 GW (356 projects)

**Generation Capacity (GW)**

- 2016: 21 GW (120 projects)
- 2017: 40 GW (255 projects)
- 2018: 41 GW (239 projects)
- 2019: 44.5 GW (301 projects)
Reserve margins are adequate but have tightened since 2013; our neighbors tend to have excess capacity.

MISO Historical Reserve Margins

Actual Reserve Margin
- 2012: 27.4%
- 2013: 28.1%
- 2014: 18.6%
- 2015: 18.0%
- 2016: 18.2%
- 2017: 18.8%
- 2018: 19.1%
- 2019: 19.3%

Planning Reserve Margin (PRM) Req’mt
- 2012: 16.7%
- 2013: 14.2%
- 2014: 14.8%
- 2015: 14.3%
- 2016: 15.2%
- 2017: 15.8%
- 2018: 17.1%
- 2019: 16.8%

2019 Reserve Margin by RTO*
- MISO: 19.3%
- PJM: 29.0%
- SPP: 31.8%
- ISO-NE: 30.7%
- NYISO: 24.8%
- CAISO: 22.4%
- ERCOT: 8.5%

* Source: NERC Long-Term Reliability Assessment publications for anticipated reserve margins
Note: 2008 MISO is an estimate based on portions of MRO, RFC-MISO, and SERC data.
Note: 2008 PJM is RFC-PJM.
Recent significant operational challenges have occurred in non-summer months and resulted from trapped capacity.

Operating Margin – Peak Hour

<table>
<thead>
<tr>
<th>Date</th>
<th>January 17, 2018</th>
<th>September 15, 2018</th>
<th>January 31, 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.6%</td>
<td>2.1%</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

Maximum Flow (MW) and Direction

<table>
<thead>
<tr>
<th>Date</th>
<th>January 17, 2018</th>
<th>September 15, 2018</th>
<th>January 31, 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,936 MW in the N-S direction at 0725 EST.</td>
<td>3,249 MW in the N-S direction at 1450 EST.</td>
<td>2,453 MW in the S-N direction at 1220 EST.</td>
</tr>
</tbody>
</table>

Real Time LMP Price Spread (North to South)

<table>
<thead>
<tr>
<th>Date</th>
<th>January 17, 2018</th>
<th>September 15, 2018</th>
<th>January 31, 2019</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Average of -$133.89/MWh for the day</td>
<td>Average of -$59.99/MWh for the day</td>
<td>Average of $30.80/MWh for the day</td>
</tr>
</tbody>
</table>

 Longer-term Issues to Further Evaluate:

• Ensuring sufficient attributes to meet requirements every hour
• Aligning broad regional and local reliability requirements
• Sequencing and aligning enhancements to not only address near-term issues but also provide an effective progression of changes over time
The Resource Availability and Need (RAN) initiative includes efforts specifically focused on addressing operational and market concerns due to portfolio change.

<table>
<thead>
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<th>Progress, To Date</th>
<th>In Flight</th>
<th>Next Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve resource transparency and performance for spring 2019 and subsequent planning year</td>
<td>Continued refinements for 2020 Planning Resource Auction (PRA), progress on market-based solution</td>
<td>Continued improvement in availability and flexibility</td>
</tr>
</tbody>
</table>

**Load Modifying Resources (LMRs):**
- Create transparency and better align LMR obligations with other resources

**Outage Coordination:**
- Improve forward-looking transparency for stakeholders and MISO
- Increase early outage notification and flexibility during emergencies

**Visibility:**
- Multi-day Operating Margin forecast

**PRA Inputs:**
- Improve PRA inputs, focus on Load Modifying Resources
- Create rules outlining reasonable expectations for availability or replacement during the planning year

**Visibility:**
- Enhancements to the Multi-day Operating Margin forecast

**Resource Adequacy Construct:**
- Reflect risks throughout year
- PRA reliability value reflected in auction results

**Resource Accreditation:**
- Align with attributes based on all-hours reliability criteria
- Deliverability improvements

**Market Incentives:**
- Prices reflect operating conditions
- Incentivize needed system attributes (e.g., multi-day market mechanism)
MISO is assessing reliability risk in other major categories and scouting the broader horizon...

**Distributed Energy Resources and Transmission and Distribution Interface**
- Explore visibility and coordination needs and potential options to address challenges and opportunities

**Wind and Solar**
- Address increased variability and uncertainty in evolving fleet, more fully leveraging planning, markets and footprint diversity

**Insights, Studies, Innovation**
- Identify and explore other issues with potentially large impacts (e.g., electric vehicles, electrification, digitalization, computational improvements)

**Load (MW)**
- Gross load
- Net Load

**Renewable Integration Impact Assessment (RIIA)**
MISO plans transmission, not generation, but overall least cost solutions require balancing generation and transmission investment.
Transmission investment in MISO is trending up, but generally not for new ‘backbone’ transmission.

MISO Transmission Expansion Plan (MTEP)
Approved Investment by Year and Project Category (in billions)

Primary project types:
- Market Efficiency (Congestion)
- Transmission Delivery Service
- Generator Interconnection
- Multi-Value Projects (MVP)
- Baseline Reliability
- Other *

* Other = Projects based on local Transmission Owner identified needs including reliability, economics, equipment age and condition, environmental, etc.
MISO’s role continues to evolve as the industry’s requirements change
External engagement has been and will continue to be essential, as we define the needs of the future.
Questions

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