The Evolving MISO Grid and Multi-State Transmission

MN Legislative Energy Commission (LEC)

February 3, 2020
MISO & neighboring U.S. electric grid operators

MISO

- 15 states + Manitoba
- 42 million customers
- $30 billion market
- > 6,600 generation units with 175,000 MW capacity
- 72,000 miles of high voltage transmission lines
- ~ 190 member utilities
- > 460 market participants

MISO Control Centers:
Eagan, Indianapolis (HQ), Little Rock
MISO integrates dozens of ‘Balancing Authorities’ within MISO and coordinates with neighboring regions

Legend:
- MISO utility “Balancing Authorities”
- (Other colors are neighboring balancing authorities)

Illustrative of the complexity and the multi-state, interconnected nature of the grid
MISO Value Proposition: $3.5 billion in benefits annually, and over $23 billion since 2009

2018 Benefit by Value Driver

- Improved Reliability / Compliance: $391
- More Efficient Use of Existing Assets: $362
- Reduced Need for Additional Assets: $3,094
- Cost Structure: ($304)
- Total Net Benefits: $3,543

Cumulative Annual Benefits: $23,300 million

MISO provides approximately $3.5 billion in annual benefits to members.
MISO’s changing resource portfolio will remain a key influencer of the way value is created moving forward.

Portfolio Change (energy mix %)

- 2005: 76% Coal, 13% Nuclear, 4% Gas, 27% Wind/Solar, 4% Other
- 2018: 47% Coal, 16% Nuclear, 8% Gas, 27% Wind/Solar, 4% Other
- 2030: 22% Coal, 9% Nuclear, 29% Gas, 31% Wind/Solar, 4% Other
- 2030 + Policy*: 22% Coal, 9% Nuclear, 29% Gas, 36% Wind/Solar, 4% Other

*More aggressive utility de-carbonization goals and proposed policy changes in Illinois, Minnesota and Wisconsin may further accelerate renewables penetration.
The rapid increase in generator interconnection requests create system transmission capacity challenges

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

Recent experience in ‘Western’ MISO (last 3 completed queue cycles)

- Initial upgrade costs ID’d (Thousand $/MW)
  - Feb 2016: 460
  - Aug 2016: 610
  - Feb 2017: 1,000

- Capacity “In” (GW entering)
  - Feb 2016: 5.7
  - Aug 2016: 5.6
  - Feb 2017: 3.4

- Capacity “Out” (GW exiting)
  - Feb 2016: 4.7
  - Aug 2016: 2.3
  - Feb 2017: 0.2

- % Out (GW exiting/GW entering)
  - Feb 2016: 80%
  - Aug 2016: 40%
  - Feb 2017: 5%

➢ System capacity is fully committed; new requests are ‘hitting a wall’
MISO’s Renewable Integration Impact Assessment (RIIA) indicates integration complexity increasing sharply beyond 30% renewable penetration.
The regional transmission planning process provides a comprehensive, value-based approach

**Economic Planning**
Scenario-based planning to provide economic and market efficiency benefits

**Interconnection Planning**
Evaluate long-term interconnection queue requests; identify upgrades to integrate into base expansion model

**Policy Planning**
Long-term policy focused planning to analyze the impacts of changes in state or federal policy and industry trends; determine the transmission required to support those policies and industry trends

**Reliability Planning**
Validate needs for plans identified by the member Transmission Owners; seek efficiencies by combining plans, if possible; evaluate system against reliability standards

**Planning Horizons**
Reliability: 5 to 10 years
Economic: 15 to 20 years
MISO is expanding futures to ensure wide range of possible solutions

<table>
<thead>
<tr>
<th>Future #1</th>
<th>Announced Plans:</th>
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<tbody>
<tr>
<td></td>
<td>The footprint develops in line with utility announcements/plans, along with State mandates, goals, or preferences.</td>
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<table>
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<tr>
<th>Future #2</th>
<th>Advanced Fleet Change 2.0</th>
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<td>Changing federal &amp; state policies reduce emissions to 50%. EV adoption increase &amp; electrification begins and drives a 40% increase in energy demand.</td>
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<th>Future #3</th>
<th>Advanced Electrification</th>
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<td>Changing federal &amp; state policies will support carbon emissions reduction of 80% or more. Increased electrification occurs increasing energy demand by 70%.</td>
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- Futures “bookend” a range of economic, political and technological possibilities
- They help ensure that any new recommended transmission provides benefits and value, regardless of specific future developments
MISO plans transmission, not generation, but minimizing total costs requires balancing generation and transmission investment.
Since the MVP portfolio, investment trend has been focused on shorter term reliability needs.
MVPs continue to show value, over eight years after their approval, and are being highly utilized.

### MVP Benefits by Value Driver

<table>
<thead>
<tr>
<th>Value Driver</th>
<th>Total Benefits</th>
<th>Total Costs</th>
<th>Net Benefits</th>
</tr>
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<tbody>
<tr>
<td>Increased Market Efficiency</td>
<td>$13.9 – $53.8</td>
<td>$7.3 – $39</td>
<td>$7.3 – $39</td>
</tr>
<tr>
<td>Deferred Generation Investment</td>
<td>$0.25 – $1.1</td>
<td></td>
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<tr>
<td>Other Capital Benefits*</td>
<td>$1.6 – $2.7</td>
<td></td>
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<tr>
<td>Wind turbine investment</td>
<td>$16 – $57.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future transmission investment*</td>
<td>$8.7 – $18.4</td>
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* Benefit-to-cost ratios of 1.8 to 3.1

* Values were calculated in MTEP17 Triennial Review and converted to 2019$
The Evolving MISO Grid

Additional pages from MISO tour and overview presented to:

MN Legislative Energy Commission

November 20, 2019
MISO members participate across the electricity value chain

MISO focus

Generation

Transmission

Marketers

Distribution

Customers

Independent Power Producers (29)
- Allete Clean Energy
- Apex Clean Energy
- Geronimo
- NextEra

Competitive Transmission Developers (30)
- ITC-Midcontinent Development
- LS Power
- Xcel Energy Transmission Development

Transmission Owners (51)
- Dairyland Power
- Great River Energy
- Minnesota Power
- MN Municipal Power Agency
- Otter Tail Power
- SMMPA*
- Xcel Energy

Power Marketers/Brokers (36)
- EDF
- The Energy Authority (for SMMPA*)

Muni/Coop/Transmission Dependent (31)
- City of Rochester
- Wilmar Municipal Utilities

Eligible End-User Customers (9)
- ArcelorMittal USA
- Midwest Industrial Customers group

MISO Members by Sector (#); Minnesota examples

*Southern Minnesota Municipal Power Agency
What does MISO do?

Efficient Wholesale Market Management & Operations to Ensure Reliability

- Conduct day-ahead and real-time energy and operating reserves markets
- Manage least cost economic dispatch of generation units
- Monitor and schedule energy transfers on the high voltage transmission system

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 Vision: Be the most reliable, value-creating RTO
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 Hourly Load Profile - Average Summer Day
(Thousand MW)

24 hours
MISO connects a large, diverse generation fleet...

Total MISO, 2018

Generating Capacity

175 Thousand MW

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

Electricity Generated

640 Million MWh

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

Source: Misoenergy.org website
…a generation fleet which has shifted, with the pace accelerating toward more renewables and conventional unit retirement.

**Total MISO Generation Mix**

(% of MWh)

<table>
<thead>
<tr>
<th>Year</th>
<th>Nuclear</th>
<th>Gas</th>
<th>Solar</th>
<th>Wind</th>
<th>Coal</th>
<th>Other</th>
<th>Demand Side Mgmt</th>
</tr>
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<tbody>
<tr>
<td>2005</td>
<td>76%</td>
<td>13%</td>
<td>7%</td>
<td>4%</td>
<td>13%</td>
<td>7%</td>
<td></td>
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<tr>
<td>2018</td>
<td>47%</td>
<td>16%</td>
<td>8%</td>
<td>2%</td>
<td>27%</td>
<td>4%</td>
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**2033: Future Planning Scenarios**

- **Accelerated Fleet Change**
  - Nuclear: 30%
  - Gas: 29%
  - Solar: 13%
  - Wind: 9%
  - Other: 4%
  - Demand Side Mgmt: 4%

- **Distributed & Emerging Tech**
  - Nuclear: 32%
  - Gas: 30%
  - Solar: 16%
  - Wind: 11%
  - Other: 3%
  - Demand Side Mgmt: 4%
Within MISO, the state of Minnesota is a net importer of electricity, and a “crossroads”

As a state, MN consumes more electricity than it generates within state borders; it is a net importer in the MISO system

Source: US Energy Information Administration (EIA)
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

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

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

- **Wind**: 44 GW, 5.5 projects
- **Hybrid**: 2 GW, 7 projects
- **Solar**: 3 GW, 18 projects
- **Storage**: 23 GW, 128 projects
- **Wind**: 52 GW, 52 projects
- **Hybrid**: 3 GW, 22 projects
- **Solar**: 8 GW, 52 projects
- **Storage**: 3 GW, 18 projects
- **Other**: 2 GW, 7 projects

- **Total**: 91 GW, 583 projects

- **2016**: 21 projects (2.5 Wind, 3.6 Hybrid, 14.5 Solar, 2.5 Other)
- **2017**: 40 projects (17.6 Wind, 7.6 Hybrid, 13.6 Solar, 2.5 Other)
- **2018**: 41 projects (14.8 Wind, 22.1 Hybrid, 14.8 Solar, 2.9 Other)
- **2019**: 55 projects (28.2 Wind, 2.7 Hybrid, 3.5 Solar, 2.4 Other)

- **Generation Capacity (GW)**

(M Nov/Oct 2019 Update)
Overview of MISO’s Renewable Integration Impact Assessment (RIIA)

Context:
RIIA is an ongoing study conducted collaboratively with MISO members to identify MISO-wide renewable penetration levels at which integration complexity significantly increases.

Emerging Themes:
• Up to 30% renewables, challenges appear manageable with regular, incremental transmission expansion
• By 40%, significant challenges begin
  o 40% MISO-wide equates to 70-100% local penetration in wind-rich Iowa, Minnesota, North Dakota, South Dakota
  o Tradeoffs required between renewable curtailment & transmission investment
  o Increased flexibility requirements (ramping from conventional generation)
  o Increased system stability concerns
• Challenges can be addressed; however, least cost solutions require careful study and regional coordination across the MISO footprint
• The value of MISO-wide diversity and ‘interconnectedness’ are key
Renewable Integration Impact Assessment (RIIA) seeks to find inflection points of renewable integration complexity.

**Focus Areas**
- **Resource Adequacy**
  - Having the sufficient capacity of resources to reliably serve peak demand.
- **Energy Adequacy**
  - Ability to provide energy in all operating hours throughout the year.
- **Operating Reliability**
  - Ability to withstand unanticipated component losses or disturbances.

**Illustrative example**
RIIA seeks to identify inflection points where integration complexity significantly increases.

RIIA begins by modeling the current system.

**Axes**
- **Renewable Integration Complexity**
- **Renewable Energy Penetration (steps of 10%)**
RIIA assumes a logical distribution for location and type of increasing levels of renewable generation across MISO.
As renewable penetration increases, so do the integration challenges…

Increasing curtailment of renewables is an integration challenge that calls for mitigation, such as transmission investment.
MISO’s Renewable Integration Impact Assessment (RIIA) indicates integration complexity increasing sharply beyond 30% renewable penetration

1. Risk of losing load compresses into a small number of hours and shifts into the evening
2. Existing infrastructure becomes inadequate for fully accessing the diverse resources across the MISO footprint
3. Regional energy transfer increases in magnitude and becomes more variable leading to a need for increased extra- high-voltage line thermal capabilities
4. Power delivery from low short circuit areas may need transmission technologies equipped with dynamic support capabilities
5. Frequency response is stable up to 60% instantaneous renewable penetration, but may require additional planned headroom beyond
6. Grid-technology-needs evolve as renewable penetration increases, leading to an increased need for integrated planning
7. Diversity of technologies and geography improves the ability of renewables to serve load

(Nov 2019 Update: from RIIA Phase 1&2 Wrap-up Workshop - 11/13/2019)
Increasing variability due to renewable generation will require generators to perform differently than today.

More hourly variability from renewables...

...requires increased flexibility (curtailments and ramp capability)

**Renewable Output (Thousands of MW)**
- Wind at 40%
- Solar at 40%
- Wind at 10%
- Solar at 10%

**Wind Curtailment (Thousands of MW)**
- At 40%
- At 10%

**Coal and Gas Ramp (% of capacity)**
- At 40%
- At 10%

*All %’s in labels refer to MISO-wide renewable penetrations levels*
Power system stability concerns significantly increase by 40% renewable penetration

- Stability concerns are driven by the reduction in conventional generation and the increase in inverter based (i.e., wind/solar/battery) generation
- Additional system reinforcement is needed (e.g., more transmission, keeping more conventional generation online)
Renewable integration complexity increases sharply by 40%, illustrating need for transmission expansion

- Integration complexity is measured as the approximate cost of the transmission fixes needed
- At the 40% penetration, transmission fixes could reduce curtailments from 18% to 9%
The generation fleet within MISO is evolving.

By 40% renewable penetration, significant integration challenges begin.

Challenges can be addressed; however, least cost solutions require careful study and regional coordination...diversity and interconnectedness are key.
Questions?

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*Renewable Integration Impact Assessment (RIIA)
All RIIA-related documents can be found on MISO’s web page (MISOenergy.org)

Home > Planning > Transmission Planning Studies and Reports > Renewable Integration Impact Assessment