Renewable Integration Impact Assessment

Finding integration inflection points of increasing renewable energy

Final Workshop
March 3rd, 2021

Discuss RIIA Summary Report and Executive Summary
The RIIA report is the culmination of nearly 4 years of technically rigorous exploration and stakeholder discussion concerning the challenges of increasing wind and solar energy in MISO

- Facilitated and participated in hundreds of RIIA related discussions including workshops, stakeholder meetings, member discussions, conferences, regulatory discussion and more
- Published several journal and conference papers
- Published report summarizing insights, describing all findings in detail and articulating assumptions

“MISO, our members, and the entire industry are poised on the precipice of great change as we are being asked to rapidly integrate far more renewable resources. Given our regional Reliability Imperative, MISO must act quickly, deliberately, and collaboratively to ensure that the planning, markets, operations, and systems keep pace with these changes. We can achieve this great change if we work together.”
— Clair Moeller, MISO President
Growing renewables are driving localized reliability risks now; RIIA finds these challenges will become footprint-wide beyond 30% system-wide renewable penetration

Risk patterns shifting, and new risks are emerging:

- **Stability risk** — The grid’s ability to maintain stable operation is adversely impacted, primarily when renewable resources are clustered in one region.

- **Shifting periods of grid stress** — Periods of highest stress on the transmission system shift from peak power demand to times renewables supply most of the energy and long-distance power transfers increase.

- **Shifting periods of energy shortage risk** — The risk of not having enough generation to meet demand shifts from the historic times of peak demand to hot summer evenings and cold winter mornings, when low availability of wind and solar resources is coincident with high power demand.

- **Shifting flexibility risk** — The ability of resources to provide system flexibility will be challenged.

- **Insufficient transmission** — The current transmission infrastructure becomes unable to deliver energy to load.

Adaptation within the existing planning, market, and operations constructs will suffice - but only to a point. New and changing risks require new practices to mitigate.

- **RIIA is:**
  - Technical analysis to evaluate the impact of increasing amounts of wind and solar
  - Examples of integration issues and potential mitigation solutions
  - Policy and pace agnostic

- **RIIA is not:**
  - A transmission planning study
  - A de-carbonization study
  - A list of recommendations for construction of any specific new resources or transmission in MTEP

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**MISO Futures Wind and Solar Generation**

MISO Futures include the following, which RIIA did not consider:
- Growing and changing load
- Carbon reduction targets
- New thermal generators
- IRPs and company/state goals, mandates, and announcements

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*LRTP – Long-range transmission plan*
Three major technical areas were analyzed to understand the challenges of increasing renewable energy:

**Operating Reliability**
Ability to withstand unanticipated component losses or disturbances

**Energy Adequacy**
Ability to provide energy in all operating hours continuously throughout the year

**Resource Adequacy**
Having sufficient resources to reliably serve demand

“RIIA is the most comprehensive engineering study of the power system renewable transformation.”
— Aaron Bloom, Chair, System Planning Working Group, Energy System Integration Group
Resource Adequacy: Risk of losing load compresses into a small number of hours and shifts to non-traditional hours

![Graph showing net load diurnal profile (GW) and loss of load probability over hours in EST. The graph highlights the risk of losing load in specific hours, with a risk arrow pointing to the affected period. The y-axis represents net load diurnal profile (GW) ranging from 0 to 90, and the x-axis represents hours in EST from 0 to 23. The graph includes lines for different loss of load probability scenarios: Base, 10%, 30%, 50%, and 100%. The legend identifies each line color by its percentage value.]
Resource Adequacy: Sensitivity analyses show risk shifting to winter and later in the evening, depending on technology and geographic mix.

### Maximum EUE - Wind Heavy Mix

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<th>Time (hr)</th>
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<th>Mar</th>
<th>Apr</th>
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### Maximum EUE - More Balanced Wind-Solar Mix

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### Risk Category:
- None
- Moderate
- High
Resource Adequacy: Diversity of technologies and geography improves the ability of renewables to serve load.
Resource Adequacy: Yearly weather variations drive Resource Adequacy outcomes

Wind ELCC variation by weather year and penetration

RIIA March 3rd, 2021 Webinar
RIIA Report Figure RA-22, page 41
Energy Adequacy: Increasing variability due to renewable generation will require generators to perform differently than they are today.

More hourly variability from renewables...

Renewable Output (GW)

Wind at 40%*
Solar at 40%
Wind at 10%
Solar at 10%

24 hours
1 day

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

Wind Curtailment (GW)

At 40%*
At 10%

24 hours
1 day

Coal and Gas Ramp (% of capacity)

At 40%*
At 10%

24 hours
1 day
Energy Adequacy: Existing infrastructure becomes inadequate to fully access the diverse resources across the MISO footprint.

- **“Start” models** represent the system with no solutions beyond those deployed in the previous milestone.
- **‘Final’**: models with solutions/mitigations added for the particular milestone.

MISO Total Energy Production and Curtailment: by RIIA Milestone

Penetration target only achieved after solutions deployed.

- Penetration target only achieved after solutions deployed.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>10% Final</th>
<th>20% Final</th>
<th>30% Start</th>
<th>40% Start</th>
<th>50% Start</th>
<th>50% Final</th>
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<tbody>
<tr>
<td>Penetration%</td>
<td>9.39%</td>
<td>11.07%</td>
<td>20.76%</td>
<td>28.23%</td>
<td>39.38%</td>
<td>44.73%</td>
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RIIA Report Figures EA-4, page 53
Energy Adequacy: Grid technology needs to evolve as renewable penetration increases, leading to an increased need for integrated system planning.
Storage, without adequate transmission capacity in the system, may increase renewable energy delivery but may not sufficiently aid in meeting renewable penetration targets.

- Storage paired with renewables is more effective in increasing renewable energy delivery than when it is paired with load.
- Scenarios with higher solar and less flexible conventional generators, may result in higher LMPs.
Operating Reliability – Resource location and system conditions cause transmission risk to shift to spring and fall and increases in frequency

<table>
<thead>
<tr>
<th>10% Penetration</th>
<th>50% Penetration</th>
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<td><img src="image1.png" alt="Graph" /></td>
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**MISO Peak Load:**
High load with high renewables

**Shoulder/Light Load:**
For 10-20%: Shoulder load
For 30-50%: Lowest load with highest renewables

**MISO Peak Renewable**
High renewables with lowest load

Instantaneous % renewable at reference point

Significant change in dispatch mix and timing of system stress

RIIA Report Figure OR-SS-2, page 105

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Regional energy transfer increases in magnitude and becomes more variable, leading to a need for increased extra-high voltage transfer capabilities.
Operating Reliability – DS: Power delivery from weak areas may need transmission technologies equipped with dynamic support capabilities.

- Maps reflect cumulative solutions across milestones
- SCR – Short Circuit Ratio

RIIA Report Figure OR-DS-12, page 123
RIIA March 3rd, 2021 Webinar
Operating Reliability – DS: Small signal stability issues increase in severity after 30% renewable penetration

~0.3Hz inter-area oscillations observed for loss of 3300 MW generation in one of the 30% snapshots

Power system stabilizers may be needed to reliably operate the system

<table>
<thead>
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<th>Instantaneous Renewable Penetration (MW) at 30% milestone</th>
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<tr>
<td><strong>MISO</strong></td>
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<tr>
<td>30%</td>
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<tr>
<td>49%</td>
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<td>63%</td>
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RIIA Report Figure OR-DS-23; page 134

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Operating Reliability – DS: Frequency response is stable up to 60% instantaneous renewable penetration; the system may require additional planned headroom beyond 60%.
Finding: Shifting periods of grid stress and insufficient transmission require...

• Flexibility and innovation in transmission planning processes
  • Align planning dispatch assumptions with shifting system conditions and risk (LRTP)
  • Develop tools and processes to capture changing risks as they appear for transmission planning (LRTP)

• Proactive regional transmission planning
  • Proactively align to future needs, develop long-range, cost-effective, and least-regret transmission plans, and move construction forward (LRTP)
  • Educate stakeholders about complexities and opportunities of emerging technologies (LRTP)
Finding: Shifting periods of energy shortage risk and shifting flexibility risk require...

- New and revised market and resource adequacy mechanisms
  - Ensure resource availability outside of traditional risk periods, both during evening hours and winter periods (Market Redefinition).
  - Develop and implement market solutions to identify issues prior to the system reaching 30% wind and solar penetration (Market Redefinition).
  - Develop ways to increase the fidelity of renewable energy forecasts by using improved weather data.
  - Develop or adapt market products to incentivize flexible resources.
Finding: Stability Risk – New stability challenges require...

- Additional targeted research into multiple transmission technologies, operating tools, and market tools to incentivize availability of grid services
  - Explore and decide ways to address “weak-grid” issues, such as improved inverter technology, new technology pilots, operational visibility, proactive and integrated transmission planning
  - Update inverter control tuning approaches as penetration of inverter technologies increases
  - Explore new methods to stabilize the grid, such as battery storage
  - Explore operations tools to monitor and commit power system stabilizers when needed
  - Explore process to plan for new protection techniques or new transmission devices
Additional research is needed

- Evaluate opportunities to align and co-simulate power-flow and production cost models (to better capture hours of risk)
- Explore co-optimization between economic and reliability transmission needs, along with resource deployment (software, process, and data development needed)
- Explore additional opportunities to align and co-plan for system needs across the various MISO planning functions
- Explore the gaps, opportunities, costs, and benefits of new grid technology (such as FACTS, VSC HVDC lines, grid-forming inverters) and its ability to solve emerging grid needs
- Explore ways to incentivize new resource additions and capabilities (like power system stabilizers) to enhance technological and geographical diversity to serve MISO reliability

FACTS: Flexible AC Transmission System; VSC: Voltage Source Converter
We believe it will take transformational change, including redefined markets and planning processes, to enable efficient and reliable operations in the future. Coordinated action amongst all stakeholders will be necessary to facilitate participants’ decarbonization goals and plans for higher levels of renewable generation.”

– Richard Doying, MISO EVP Market & Grid Strategies
# Report Walk Through

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Questions?