MISO Renewable Integration Impact Assessment Report – Summary

I. Purpose, Methodology, and Focus Areas

MISO published its Renewable Integration Impact Assessment (RIIA) report in February 2020. The RIIA is the culmination of 4 years of stakeholder collaboration and intense exploration into the impacts of increasing renewable integration, especially in the MISO region. The primary purpose of the RIIA study is to systematically identify MISO renewable integration inflection points where the underlying grid infrastructure, grid operations, or both need to be significantly modified to reliably achieve up to 50% of renewable deployment. The RIIA evaluates the impacts of increasing amounts of wind and solar resources for MISO to better understand the complexities of renewable integration issues and to examine potential mitigation solutions. The RIIA disclaims that "[it] is policy and pace agnostic: generation changes in the analysis are assumed to occur regardless of external drivers and timelines. As a technical impact assessment, RIIA does not directly recommend any changes to the existing electrical power system or construction of any new resources. That said, this body of work demonstrates that as renewable penetration increases, so does the variety and magnitude of system risk requiring transformational thinking and problem-solving." Therefore, the following five topics are not addressed in the RIIA study:

1. How to cost-effectively address grid reliability and resilience in the transition.
2. How to manage grid operational vulnerability and technology risk.
3. What are the integration and mitigation costs for achieving the 50% renewable penetration?
4. Timing of conventional generation retirements.
5. Recommendations for constructing specific new resource or transmission as normally included in the MISO transmission planning process.

The entire RIIA study focuses on the following three areas:

1. Resource Adequacy: to ensure the system has sufficient resources to reliably serve the load
2. Energy Adequacy: to ensure the system is capable of providing energy continuously in every single operating hour throughout the year
3. Operating Reliability: to ensure the system can be operated to withstand design contingencies defined by current reliability criteria.

II. Key Findings

The MISO RIIA study demonstrates that the challenges related to operating the MISO system beyond 30% system-wide renewable penetration are not insurmountable. It concludes that renewable penetration beyond 50% can be achieved in the MISO region, but MISO does not give a timetable or cost for achieving greater than 50% renewables. When the renewable penetration is lower than 30%, MISO would require transmission expansions and certain changes in current grid operation, market, and planning practices. The system integration complexity increases sharply as the renewable penetration goes beyond 30%. When the renewable penetration is higher than 30% but less than 50%, MISO's region-wide renewable generation availability could surpass 100% of load for a few hours of the year and substantial regional

pockets from where the average renewable generation output approaches 100% of the subregional load, indicating significant challenges in system frequency control and system stability. When the renewable penetration goes above 50%, MISO requires additional coordinated actions among participants regarding renewable resource deployment, related transmission expansion, and sub-regional or local renewable energy policies. This is, in part, due to the fact that renewable growth does not occur uniformly across the MISO footprint or because the development of renewable resources in neighboring interconnected systems occurs fastest in areas with high-quality wind and solar resources, available transmission capacity, and favorable regulatory environments.

The RIIA recognizes that, as more renewable resources are added to the system and more conventional generation resources retire, there are new risks and system needs, including new stability risks, grid stress period changes, energy shortage and flexibility risks, and insufficient transmission and resource capacity. Flexible generation resources, additional transmission capacity, and smart grid technologies are needed to help mitigate these new issues.

The following are the key findings of the RIIA in the three focus areas:

- **Resource Adequacy**
  Resource changes will significantly impact grid performance, especially when the renewable penetration goes above the 30% level. There could be not enough resources for winter and/or late in the evening peak load in the summer. The risk of losing load compresses into a small number of hours, shifts into the evening, and has shorter durations but higher magnitudes, depending on the technology, seasonal mix, and geographic mix.

- **Energy Adequacy**
  The MISO system needs greater magnitudes and variations of ramping capacity, especially when the renewable penetration level goes above 40%. The system could be simply unable to flexibly generate enough energy under stressed conditions. High renewable penetration requires a quite different operation for the conventional generators than they do currently. The generation's response to the changes in load and renewable output would be further limited by transmission and generation constraints. The energy adequacy issue then becomes very complex if measured by the effort to develop the transmission needed to maintain and deliver renewable energy every hour in a year.

  MISO's current transmission infrastructure is inadequate to support the full access by the diverse resources across the MISO footprint. Advanced grid technologies and integrated system planning methodologies are needed as renewable penetration increases. Energy storage, paired with renewables or used as non-wire transmission alternatives, can help optimize energy delivery.

- **Operating Reliability**
  Steady-state analysis, which examines the thermal overload of the transmission system, shows that the resource locations and system conditions cause transmission risk to shift to spring and fall more frequently. Moreover, sensitivity analysis shows transmission risks shift to summer shoulder load periods when solar output is high.

Also, regional energy transfer increases and becomes more variable, leading to a need for extra-high-voltage transfer capabilities, which results in transmission bottlenecks shifting to higher voltage lines.

Dynamic stability analysis, which examines the voltage stability, frequency stability, rotor angle stability, and non-oscillatory behavior of electrical quantities, shows remotely clustered renewable resources and unavailable stable conventional generation are the new challenges. The power delivery from "weak-grid" areas needs transmission technologies equipped with dynamic support capabilities. Small disturbance-caused stability issues increase in severity when renewable penetration reaches 30% and beyond; therefore, power system stabilizers are needed. Frequency response is stable when instantaneous renewable penetration reaches 60%, but maintaining online generation headroom is required. The average critical clearing time for electrical faults improves as large generating units are replaced by renewables; however, local issues emerge.

As for the voltage and converter-driven stability issue, the RIIA demonstrates that as inverter-based resources increase in the system, there is a decrease in the thermal generation capacity, which intensifies reliability challenges.

III. Conclusions

The RIIA demonstrates that the MISO region can reach renewable penetrations of 50% or higher with transformational changes and coordinated actions among participants. Additional work is still needed to transform the way MISO and the power system are planned and operated to maximize the reliability and value creation across the MISO region in a high-renewable system.

Based on the major RIIA insights, MISO recognizes additional work on the following items:

- To ensure the resource adequacy, MISO will develop and implement market solutions to identify issues prior to 30% renewable penetration. MISO will improve the fidelity of renewable forecasts and incentivize resource additions to enhance resource diversity.

- To enhance the energy adequacy, MISO will explore the landscape of system flexibility solutions, fuel delivery risks, market incentives, co-optimization of economic and reliability transmission needs, co-plan and process changes across various MISO planning functions, and application of new grid technologies (FACTS, VSC HVDC lines, and grid-forming inverters).

- To increase the operating reliability, MISO will explore new dispatch assumptions and develop tools and processes to capture the changing risks in transmission planning in order to develop long-range, cost-effective, and least-regret transmission expansion plans. MISO will also explore and determine options to monitor and commit power system stabilizers to address "weak-grid" issues; such options might include new inverter technology, increased operation visibility, integrated transmission planning, battery storage, and new protection techniques and tools.