# MISO Long-Range Transmission Planning

# Reliability Study for the Tranche 2 Effort

Note: MISO anticipates continued methodology and assumptions development and updates to this document. Date last updated: 08/23/2023.

## Contents

# 1 Introduction

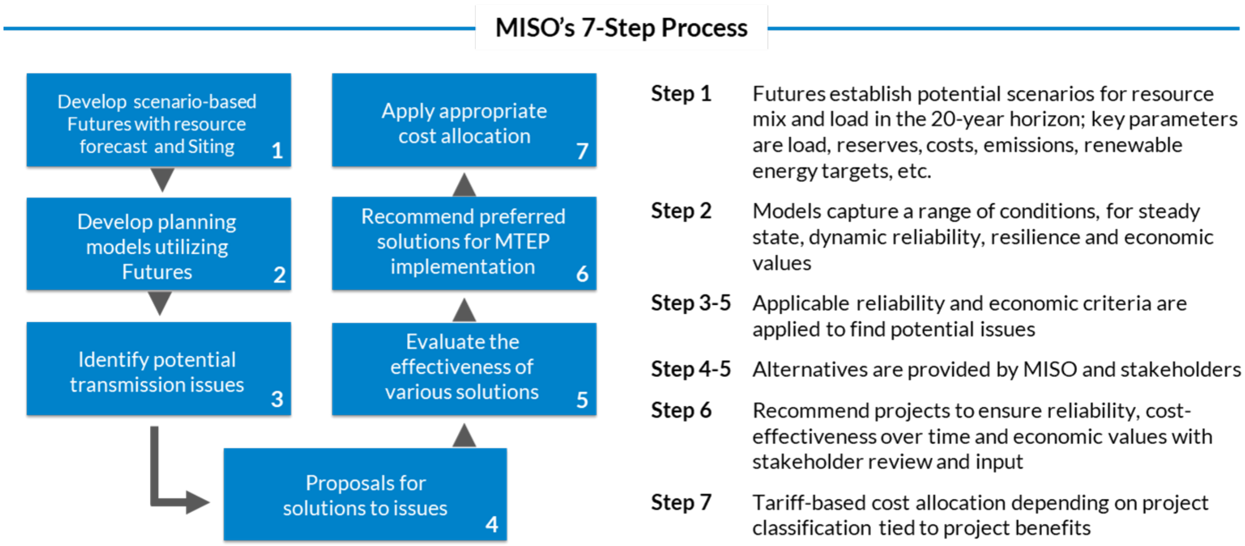
MISO developed this document to provide information regarding the proposed reliability modeling and study for Tranche 2 of the Long Range Transmission Planning (LRTP) initiative. This document provides an overview of the base modeling approach and assumption set to be used in Tranche 2 reliability analysis.

This document summarizes MISO's direction with the LRTP modeling effort; it is not an exhaustive and detailed description of all modeling needs for Tranche 2. It is written primarily for transmission planners familiar with modeling processes at MISO and NERC. This document discusses planned models for analysis and reasoning but does not delve into the actual analysis to be performed. Models required for economic analysis or other business case focused evaluations are not covered.

# 2 Overview

The evaluation of future requirements for subregional, regional and interregional transmission requires a broad approach compared to local planning and is conducted under MISO's value-based planning process (Figure 1). As part of MISO's Reliability Imperative, the LRTP initiative endeavors to:

- Facilitate the evolution of resource fleet and electrification-based load growth in the manner that balances value in the near-term and long-term.
- Develop a comprehensive plan using MISO's Future 2A assumption set to address transmission issues and needs.
- Incorporate reliability and economic planning processes and perspectives with future generation needs and expectations.



| | |
|---|---|
| **Step 1** | Futures establish potential scenarios for resource mix and load in the 20-year horizon; key parameters are load, reserves, costs, emissions, renewable energy targets, etc. |
| **Step 2** | Models capture a range of conditions, for steady state, dynamic reliability, resilience and economic values |
| **Step 3-5** | Applicable reliability and economic criteria are applied to find potential issues |
| **Step 4-5** | Alternatives are provided by MISO and stakeholders |
| **Step 6** | Recommend projects to ensure reliability, cost-effectiveness over time and economic values with stakeholder review and input |
| **Step 7** | Tariff-based cost allocation depending on project classification tied to project benefits |

*Figure 1: Value-Based transmission planning*

# 3 Models for Reliability Analysis

MISO annually builds reliability models based on specific process needs. These models usually cover 2-, 5- and 10-year horizons. LRTP, as a future-focused planning paradigm, necessitates a longer time horizon so 10-year and 20-year models will be developed for Tranche 2 reliability analysis.

High penetrations of variable renewable energy generation and storage units introduce many different possible dispatch scenarios beyond what has been considered historically in MISO's MTEP reliability assessments. Combining all these different variable renewable energy and storage output possibilities with different load scenarios into reliability models is untenable.

As a regional planner, MISO is obligated to test transmission reliability under likely and possible dispatch patterns and develop transmission plans to ensure a transmission system that can respond to the operational needs of the MISO region. Thus, MISO will focus on the worst credible conditions from the system point of view, while recognizing that local conditions may vary.

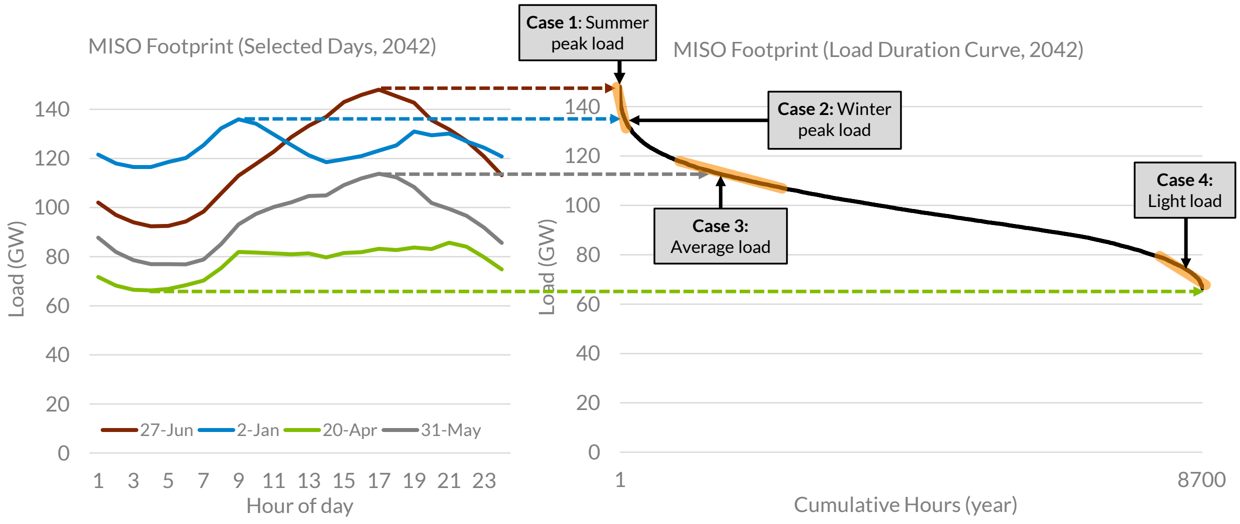
A set of base models will be used to assess the impact of variable renewable and hybrid generation and other system conditions. These broad base models will encompass multiple uncertainties around variable renewable energy output, load profiles, and seasons, thus providing the platform to perform a wide range of reliability studies. Core models are determined via load points on the MISO annual load duration curve (see Figure 2 and Table 1). These power flow models will provide the basis for steady state, dynamic, voltage stability and additional scenarios.

Reliability analysis will focus on four core cases listed above and additional scenarios described in later sections of this document to determine transmission needs and the impact of Tranche 2 potential solutions over a 10-year and 20-year timeframe.

**Table 1**: Core models

| Core cases | Renewable and storage dispatch methodology | Reason for inclusion |
|---|---|---|
| **Case 1: Summer Peak Load**<br>• Represents summer peak demand which is the highest load on the annual load duration curve | • High coincident renewable output in the summer between 90% and 100% of the annual peak demand<br>• Storage off | • Test the ability to reliably serve load via variable renewable energy and conventional resources |
| **Case 2: Winter Peak Load**<br>• Represents winter peak demand | • High coincident renewable output in the winter between 90% and 100% of the annual winter peak demand<br>• Storage discharging | • Local/Regional/System load profile and peak is different from the summer case<br>• Test ability of renewables to reliably serve load considering load profile diversity<br>• Test system ability to export to Manitoba Hydro |

| Core cases | Renewable and storage dispatch methodology | Reason for inclusion |
|---|---|---|
| **Case 3: Average Load**<br>- Represents typical system conditions within 70-80% on the load duration curve | - High coincident renewable output between 70% and 80% of the annual peak demand<br>- Storage charging | - Assess system ability to move power and reliably serve load during the annual maximum coincident wind/solar, which is likely to occur during this timeframe<br>- Peak variable renewable energy case is essential to evaluate dynamic performance |
| Case 4: Light Load<br>- Represents lowest 10% on the load duration curve | - High coincident renewable output to test ability of the system to absorb reactive power<br>- Storage charging | - Review high voltages in steady-state models<br>- Low inertia in dynamics models is an operating point of interest for transient stability studies |



Indicative daily profiles and load duration curve developed from Future 2A load data, after accounting for energy efficiency

*Figure 2: Overview of load levels in Future 2A, informing the selection of reliability models. To the right, the load duration curve is shown, highlighting the four desired load levels for the core models. The left shows a series of indicative daily load shapes and how they map to the load duration curve.*

# 4 General System Model Criteria

Tranche 2 reliability analysis will focus on the refreshed Future 2A resource forecast. The Future 2A resource forecast defines type, timing, amount, and location of new resources in the footprint.

## 4.1 Topology Modeling

The MTEP22 reliability power flow models will be used as the transmission topology baseline and will generally align with the transmission topology used in the economic models. Voltage devices (including, but not necessarily limited to, synchronous condensers, shunt capacitor and reactor banks, static VAR compensators, and static synchronous compensators) will be present in the power flow models for reliability studies. All approved transmission projects from the MTEP22 planning cycle will be modeled including the LRTP Tranche 1 Portfolio.

## 4.2 Load Modeling

Load levels are selected from the Future 2A load duration curve after incorporating energy efficiency identified via the Future 2A process and align with what is modeled in economic analysis (see Figure 2). Because these load levels come directly from Future 2A load modeling, they include electric vehicles (EVs) and other technologies contributing to electrification load growth[1]. The load levels do not include the addition of storage charging, which will be captured separately as a part of dispatch assumptions. The bus-specific distribution of load developed for the economic models will be used to partition load across the power flow model buses.

## 4.3 Generator Modeling

All existing and future generator modeling align as much as possible with the assumptions of the economic models; however, the reliability models will additionally capture reactive power capability and transient stability parameters.

**Retired Generators:** The reliability models will remove any units that are retired as part of the Future 2A assumptions.

**New Generators:** The reliability models will add generation identified in Future 2A expansion and siting.

**Batteries:** New batteries will be sited in the reliability models based on the Future 2A expansion and siting. As, Future 2A modeled and added 4-hour lithium-ion batteries as the new storage technology, batteries in the reliability models will be represented consistent with these assumptions.

## 4.4 Transactions/Interchanges

Area Interchange between MISO and external areas is calculated by known long term commitments for firm transmission service (10- and 20-years out). Models will conform to Area Interchange limits with external areas for the base analysis and adjustments may take place as necessary to accommodate the 20-year out.

# 5 Dispatch Methodology for Reliability Analysis

A power flow case represents a snapshot of the specific system conditions – a "photograph" compared to the "movie" developed by economic models (e.g., PROMOD) of performance over a year. Based on load level MISO has identified four snapshots ("core models") and six additional scenarios by varying generation dispatch. "Models" represent credible system conditions and are studied to ensure the system operates

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[1] See *Futures Refresh Assumptions Book*, available at https://cdn.misoenergy.org/20230428%20LRTP%20Workshop%20Item%2003b%20Futures%20Refresh%20Assumptions%20Book628727.pdf

reliably. In other words, if the system is reliable for the core models and additional scenarios, it is believed the majority of the relevant bookends of possible system conditions will be captured. Thus, the system should perform reliably at a variety of other points within these ranges. To achieve this outcome when building reliability models and dispatching them, the goal is to pick conditions that are both stressed and reasonable.

As the topology is the same for a particular year, the system stress is determined by variations in load and generation. High load conditions allow the analysis to identify low voltage and thermal issues (i.e., loadability). Average load conditions with high renewable penetrations allow the analysis to identify steady state and stability related issues related to high subregional transfer levels. Light load conditions allow the analysis to identify issues related to low MISO region system inertia, low system strength, and high voltage issues. These high and low load levels come, as noted above, from the Future 2A assumptions for LRTP.

Generation dispatch levels are established to reasonably represent the most stressful conditions of the system. The MISO system is dispatched as one balancing authority (BA), respecting transfer limits[2] between the North and South parts of the footprint, and it is prudent to look at the variable renewable energy output from the system point of view, correlated to the specific load range (seasons) while recognizing that local (zonal) conditions may vary (i.e., similar to the difference between zonal and system load peaks). Based on the generation siting (geographic location) coupled to the historical weather patterns for the year aligned with MISO Future 2A load shape, MISO can generate a reasonable dispatch for the core models.

When dispatching, the following equation must be satisfied: Generation = AI + Load + Losses.

Area Interchange (AI) with MISO external areas is calculated by known long term commitments for firm transmission service (10 and 20 years out). More specifically, power flow cases will be dispatched to ensure contract path limits are honored.

Load data is specific for each case.

Transmission losses are usually around 2-3% but change according to operating conditions. For reliability analysis, transmission load losses are calculated by the power flow algorithm.

Conventional units have more flexibility to be dispatched at any level and season. Variable renewable resources are time and weather dependent and, therefore, the goal when identifying generation dispatch for the four core models and additional scenarios is to get reasonable variable renewable energy outputs that would stress the system during those types of hours.

Future 2A data is used to inform the variable renewable dispatch assumptions. Reliability models utilize hourly load profiles in which energy efficiency is incorporated and renewable profiles are aggregated to the Local Resource Zone (LRZ)level. Existing and future renewable expansion is included in these profiles.

## 5.1 Variable resource dispatch

The following data-driven process is used to identify the variable renewable energy levels for each of the core models. This methodology was presented in LRTP Workshop on June 5, 2023, workshop materials are available at this link.

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[2] Information regarding Regional Transfer limits is located here: http://www.oasis.oati.com/MISO/MISOdocs/MISO_Subregional_Interface_Limit.pdf

a) To begin, MISO generates a scatter plot for each study year of load versus renewable output, with the latter based on data supplied by the VCE study (Figure 3 shows 2042). Then, a subset of points is selected for each core model (illustrated by the shaded boxes in the figure). For example, summer peak core models utilize summer hours with load in the top 10% of the peak.

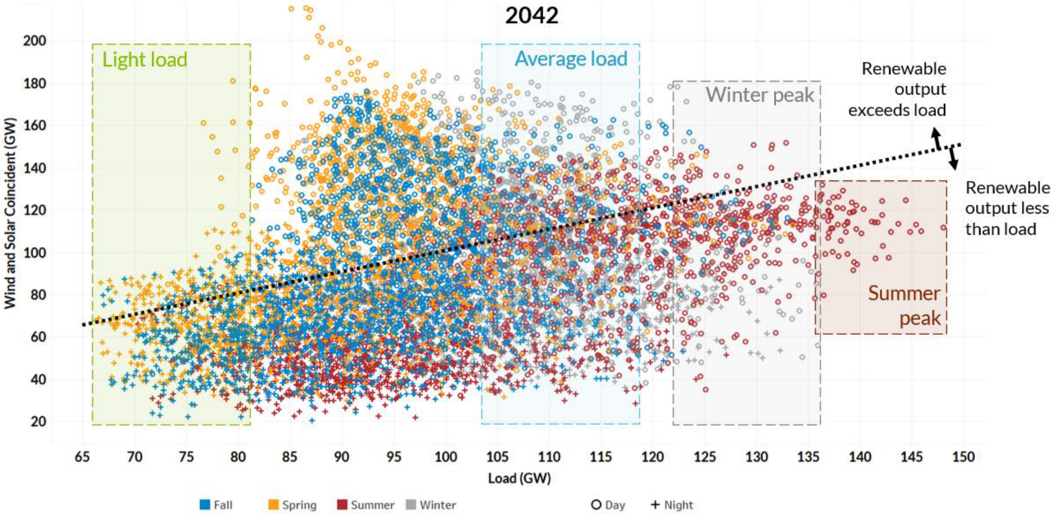

*Figure 3: Scatter plot depicts MISO load versus the sum of wind and solar coincidental output for all hours of the year 2042.*

b) For the points meeting the load criteria, the target instantaneous penetration of renewables is determined. The target instantaneous penetration of renewables is either the average of 95th percentile of coincidental renewables or capped at 80% of the highest load in that specific core model[3]. Figure 4 shows an example of these two options for the summer core model of 2042; for this example, the target renewable dispatch would be around 118 GW.

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[3] MISO will study impact of higher than 80% renewable output in the steady state via transfer techniques.

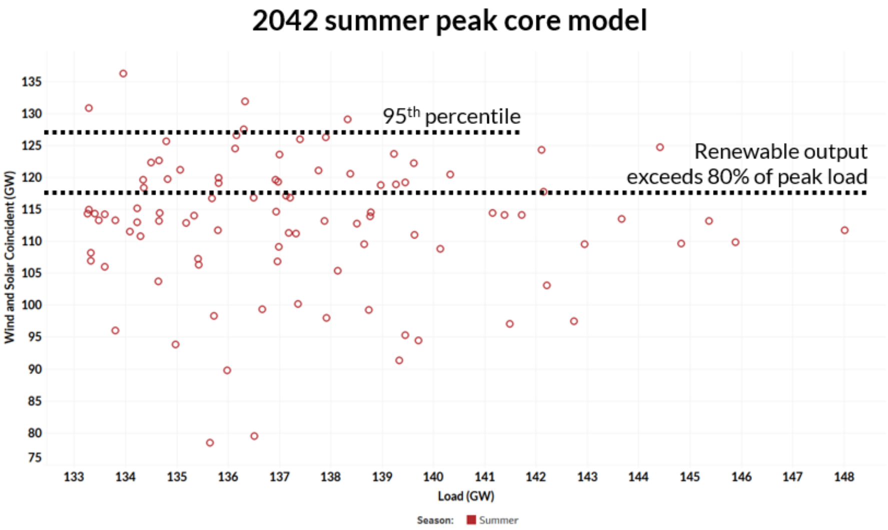

*Figure 4: Scatter plot depicts MISO load versus the sum of wind and solar coincident output during high-load summer hours (90-100% of peak)*

c) Once the overall variable renewable energy dispatch amount for a specific core model is determined, Future 2A data is used to determine the variable renewable energy dispatch to the granularity of LRZ. The box plot (Figure 5) below shows the percentage of nameplate capacity that is dispatched in each LRZ at each hour for the summer peak model as an example. These values are averaged for each LRZ and renewable type to develop a starting dispatch ("Average dispatch") percentage for units of that type in the model. Based on the example data shown, the wind dispatch for units in LRZ01 would be selected at 20% of nameplate in the 2042 peak summer core model.

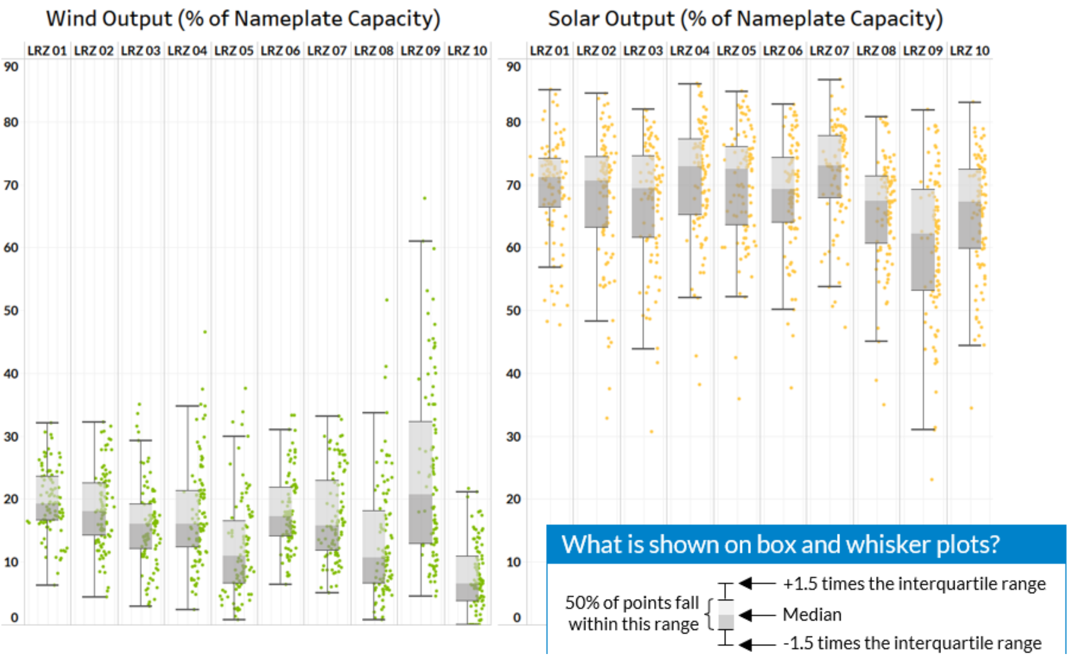

*Figure 5: Summer peak core model example to determine the renewable dispatch in each LRZ.*

d) The dispatch of all units is then scaled up to meet the system target instantaneous renewable output for the entire footprint, respecting the upper limits of the whiskers.

## 5.2 Battery dispatch

Because batteries can be operated over a wide range of conditions from discharging (providing power) to charging (adding load), the reliability models will use relatively straightforward assumptions for charging or discharging based on their nameplate value and expected system conditions.  After dispatching variable renewable resources as mentioned in above section, batteries will be dispatched next in the tier order.

a) The summer peak core model will have batteries dispatched to 0% of nameplate to capture both the impact of batteries depleted and to save discharge for twilight period. This core model represents the high coincidence of renewable energy resources with the peak load. It is reasonable to assume that batteries would wait until the sun sets on summer evenings to help serve the early evening load.

   i) The additional scenario (Twilight Summer Scenario) representing early summer evening (sunset) will assume 50% of the total nameplate of batteries are available to discharge to represent an 8-hour availability.

b) The winter peak core model will have batteries dispatched to discharge 50% of their nameplate, with assumptions on discharge length matching the summer evening (sunset) explanation above.

   i) The additional scenario representing low coincident renewables will consider battery exhaustion and will assume batteries are not available to discharge (i.e., 0% of fleet nameplate).

c) Batteries will be assumed to be charging at 60% of the fleet nameplate[4] in the light load and average load core models, due to the high instantaneous penetration of renewable energy combined with relatively lower load for these cases.

## 5.3 Remaining units

The remaining generation in each zone will be dispatched in the following order to satisfy the equation: Generation = Area Interchange + Load + Losses

a) The dispatch of the following units will be determined as follows: behind-the-meter based on load agreements, hydro based on historic seasonal performance, and nuclear units at full capacity.

b) Thermal units will be dispatched by a fuel tier order to satisfy each areas' generation requirement.

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[4] To illustrate how 60% was derived, assume a 4-hour battery is rated at 100 MW (400 MWh) has a round trip efficiency of 85%. The 85% loss is usually assumed as part of the charging cycle. Previous work has shown that 4-hour batteries will typically charge over an 8-hour period. Over an 8-hour period, the battery must consume 470 MWh (= 400 MWh/0.85) to account for losses. Dividing 470 MWh by 8 hours yields an average charging assumption of 59 MW over the 8-hour period. 59MW roughly translates to 60% battery capacity figure.

    i) To ensure that projects are identified which enable MISO member plans and goals, it is expected natural gas combustion turbine (CT) dispatch may only be used in summer and winter peak cases.

c) Flexible Attribute Units will be dispatched only as last resort.

d) The last committed units will be set as the Area Swing Units.

# 6 Model Solving and Needs Identification

Typically, power flow models with high instantaneous penetration of renewable energy are challenging to solve. Furthermore, the retirements and additions from Future 2A represent a step-change from the starting models of MTEP22. MISO has experience solving high renewable models through the Renewable Integration Impact Assessment (RIIA) and through building study models for the Definitive Planning Process (DPP) (i.e., interconnection queue). The goal of a power-flow model is to obtain a stable combination of voltages angle and magnitude information for each bus in a power system for specified load, generator, and topology conditions. Due to the nonlinear nature of this problem, to obtain a solution that is within an acceptable tolerance the following issues may be experienced:

- the maximum real or reactive mismatch at any bus in the system exceeded,
- overloaded lines,
- the voltage magnitude and angle difference between busses too big or unknown and
- the maximum number of iterations exceeded etc.

To solve the models, many methods may be required, such as:

1) adding additional fictitious resource capacity,
2) adding additional transmission, including reactive support devices, and/or
3) modify load

7Any methods used to facilitate a solved case will be associated with the specific system issues that would not allow for the case to be solved, which may include voltage stability issues, angular stability issues, overloads and/or other related issues. For each case MISO will provide a summary of issues identified and methods (solutions) used to ensure modes are within acceptable tolerance. Once models are solved, addition of fictitious resources, transmission lines, reactive resources, or other model “tweaks” will be reexamined for necessity and removed from the case to the extent possible.

# 7 Analytics

## 7.1 Steady State Assessment

### 7.1.1 Planning Events (Contingencies)

MISO will study the impacts of P0, P1, P2, P4, P5, and P7 Planning Events expected to produce more severe system impacts on core models and additional scenarios. These events are developed in collaboration with MISO members for MTEP22 topology including Tranche 1 events. Once Tranche 2 projects are identified, contingency files will be expanded to include outages associated with Tranche 2 facilities. Multiple contingency events (P3 and P6 Planning Events derived from P1 Planning Events) on the power system where the outages occur electrically and geographically distant from each other have less impact when compared with those in close electric proximity. The LRTP study will consider those P3 and P6 events expected to produce more severe system impacts. In addition, MISO will simulate additional extreme contingencies which are reasonable and expected to have severe impacts on the system. These contingencies may include, but will not be limited to, loss of substantial renewable resource output in a local area (e.g., low wind output and zero solar output during summer night peak, etc.).

### 7.1.2 Monitored Elements

All Bulk Electric System (BES) elements within MISO Midwest for LRTP Tranche 2, including tie lines to neighboring systems will be monitored in the reliability analysis. In addition, first tier non-MISO member transmission systems are monitored. Under system intact conditions, branch loading will be monitored against normal ratings and safe loading limits[5], and bus voltage will be monitored against normal bus voltage limits. For contingencies, MISO will screen line loading against emergency, normal, and safe loading limits where applicable, and screen voltages against emergency and normal limits.

### 7.1.3 Dispatch Adjustment and Additional Scenarios

In addition to assessing performance of the system using the four proposed core models, MISO will perform six dispatch adjustment scenarios and traditional transfer studies to assess system performance related to subregional internal import and export capabilities and future needs. Under the Future 2A assumptions, the future resource fleet will represent a significant increase in the volatility and uncertainty of resource available and dispatch. Furthermore, generation patterns are expected to shift substantially between day and night as well as on a seasonal basis. The ability of load in one area to be supported by generation in a remote area will be far more important in the future to ensuring continued reliability of the power system. Dispatch adjustment additional scenarios are outlined in ***Table 2***.

**Table 2:** Proposed scenarios

| Scenario description | Reasoning | Core model (2042) | Dispatch up | Dispatch down |
|---|---|---|---|---|
| Twilight summer scenario | The evening transition period is expected to be a time of system stress and this scenario explores the ability of other resources to meet power needs, transitioning from the peak day to after the sun sets. | Summer peak | Battery, wind, conventional | Solar |
| Winter low renewable | Operating experience suggests multi-day periods of low renewable output will be stressful for the system. | Winter peak | All resources, except wind/solar | Wind and solar, battery |
| Subregional east-to-west transfer | Most of the core models are expected to show a west-to-east flow bias. However, it is possible east-to-west flow conditions could occur around 5% of the year, based on | Average load | Renewables and conventional | Renewables in LRZs 1-3 |

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[5] "Dunlop, R.D., Gutman, R., Marchenko, P.P., *Analytical Development of Loadability Characteristics for EHV and UHV Transmission Lines,* IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No. 2, March/April 1979."

| Scenario description | Reasoning | Core model (2042) | Dispatch up | Dispatch down |
|---|---|---|---|---|
|  | possible renewable outputs. |  | in LRZs 4-7 |  |
| Subregional west-to-east transfer | Periods of extremely high wind output in the west should be tested for deliverability across the Midwest footprint. This scenario evaluates flows from west to east. | Average load | Wind in LRZs 1 and 3 | Renewables in LRZs 2,4,5,6, and 7 |
| Transfer #2 (Subregional lower-to-upper transfer) | As the jet stream moves in the Lower region of the Midwest footprint, this scenario evaluates flows from lower-to-upper in the Midwest part of the footprint. | Average load | Wind in LRZs 4-6 | Renewables in LRZs 2 and 7 |
| Maximum renewable output | Periods of high renewable penetration that are above 80% renewable penetration dispatched in core models | Average load | Solar and wind | All resources except wind/solar |

## 7.2 Voltage Stability Analysis

PV analysis examines the relationship between power (P) delivered into a region and the voltage (V) of the load buses in the area to identify power flow limits between a defined source/sink and/or load(s) in a specific area. The purpose of this voltage stability analysis is to identify limiting any potential power transfer limits which could be considered a “bottleneck” or regions on the verge of voltage collapse, deprived of reactive resources under different scenarios across MISO’s footprint.

## 7.3 Dynamic Assessment

LRTP dynamic models will be constructed from the LRTP steady-state power flow models and, as a result, the topology and dispatch will match the steady-state power flow models. The only adjustments made to the power flow models are to the machine base and/or impedance to match electromechanical dynamics of the equipment in the power flow model to the dynamics model; this adjustment has no impact to the solution of the steady-state power flow models. In Tranche 2, for the transient stability analysis first pass, MISO will conduct regional studies using the Light Load and Average Load core models. If necessary, studies will be performed on additional models and scenarios.

To ensure events with a more severe impact are being simulated, MISO will perform a screening analysis on single and multiple element loss events. The screening analysis identifies additional potentially problematic bus faults based on the steady-state power flow case and calculates the critical clearing time (CCT) for single or multiple element loss events. A minimum Critical Clearing Time (CCT) is assumed as a cutoff to determine if an event must be simulated; these cutoffs are dependent on voltage level (Table 3). Utilizing these screening results and engineering judgement, MISO will run limited disturbances to ensure an adequate coverage of disturbances and update the screening methodology as needed.

MISO plans to monitor first swing transient stability, angular oscillation, damping characteristic, and voltage recovery for dynamic disturbances. In the event of an inability of the system to meet the necessary performance requirements, the performance will be reviewed in coordination with steady state issues and overall regional needs.

The rapid growth in Inverter Based Resources (IBRs) connected to the MISO system will require an assessment of potential widespread impacts of higher penetrations of variable renewable energy resources on reliable operation and potential mitigation of reliability issues related to IBR performance. MISO will perform the following studies on the light load case:

- Frequency response and
- Rotor angle stability.

**Table 3:** Minimum critical clearing time (CCT) criteria to determine transient contingency coverage.

| **Voltage Level (kV)** | **Minimum Critical Clearing Time (cycles)** | |
|---|---|---|
| | N-1 | N-2 |
| 300+ | 5 | 13 |
| 230 | 6 | 15 |
| 100+ | 7 | 20 |

# 8 Tools for Reliability Analysis

The following table describes the tools used for various types of reliability analysis.

**Table 4**: Tools for Reliability Analysis

| Type | Description | Timeframe | Tools |
|---|---|---|---|
| **Steady-state** | • Ensures that transmission facilities remain within safe design limits (line loading and voltage) following disturbances | • One operating point (instant)<br>• 5+ min after a system disturbance | • Powerflow<br>• (PSS/E, TARA) |
| **Transfer analysis** | • Assesses impact of various system conditions, dispatch patterns and intra- and interregional power transfer limits; focus on line loading and voltages | • Evaluate a sequence of operating points<br>• 5+ min after each change | • Transfer analysis<br>• (PSS/E MUST, TARA, DSA) |
| **Transient stability** | • Ensures that the system will not experience uncontrolled loss of load or generation following disturbances; focus on voltage and frequency performance | • 0-30 seconds following a system disturbance | • Dynamics<br>• (PSS/E, DSA) |

# 9 Version History

| Date Revised | Comments |
|---|---|
| 4/24/2023 | Original version |
| 8/23/2023 | Added clarifications, detail on renewable dispatch methodology, and sections on additional scenarios and reliability tools |