MISO Planning Modeling Manual

Reliability Data Requirements & Reporting Procedures

Version 4.1

08-11-2022

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Contents

1 Introduction

1.1 Purpose

The purpose of this document is to outline data reporting procedures needed to support the development of base case models that realistically simulate steady state and dynamic behavior of the MISO transmission system. MISO develops a series of power flow and dynamics simulation models which MISO and its members utilize to perform reliability and economic planning studies needed to fulfill various NERC and Tariff compliance obligations.

Pursuant to requirement R1 of MOD-032-1, MISO as a NERC Planning Coordinator (PC), and its NERC Transmission Planners (TPs) have jointly established a set of common procedures for submitting data needed for developing planning models as described in this document.

Pursuant to requirement R1.3 of MOD-032-1, this Requirements and Reporting Procedures manual is posted on the MISO website at the following location: https://www.misoenergy.org/planning/planning-modeling/mod-032-1/

MISO TPs may elect to utilize the PC Reporting Procedures described herein to gather the required information from the MISO Model On Demand (MOD) application. Data owners should check with any TPs they are involved with to determine if a different reporting procedure exists for the TP.

The PC is also responsible for submitting models for its planning area to the Electric Reliability Organization (ERO) or its designee to support creation of the Interconnection-wide cases that include the Planning Coordinator's planning area per requirement R4 of MOD-032-1.

1.2 Process Overview

Figure 1-1 provides a high-level overview of the modeling process. Additional details on the modeling process are outlined in Sections 4 & 5.

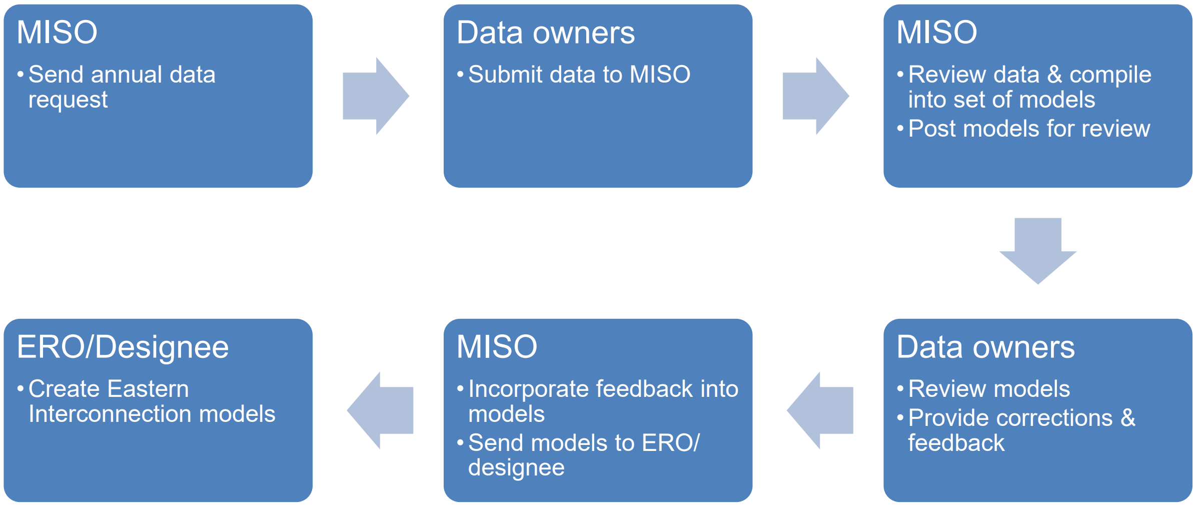


Figure 1-1: Modeling Process Overview

1.3 Responsible Entities

Pursuant to requirements R2 of MOD-032-1, identified data owners are responsible for providing the data necessary to model their assets to its Transmission Planner(s) and Planning Coordinator(s) as described in this document. Transmission Planners may notify data owners that they do not want the data and that it should only be sent to the Planning Coordinators. Applicable data owners and their respective data submission responsibilities include:

- Generator Owners (GO) are responsible for submitting modeling data for their existing and future generating facilities with a signed interconnection agreement and removing units that are retired per MISO's Attachment Y process.
- Load Serving Entities (LSE)[1] are responsible for providing their load forecasts corresponding to the scenarios developed.
- Transmission Owners (TO) are responsible for submitting data for modeling their existing and approved future transmission facilities.
- Transmission Service Providers (TSP) are responsible for providing long-term firm OASIS information to the Planning Coordinator used in preparation of the area interchange schedules.
- Balancing Authorities (BA) and Resource Planners (RP) currently do not have any data submittal requirements since they don't own facilities.

[1] MISO recognizes that LSE is no longer a functional entity under NERC. However, the MOD-032-1 standard has not yet been updated to reassign the LSE function. MISO will coordinate all updates to this document to meet the standard language.

1.4 Data Submittal Delegation Options

1.4.1 Generator Owners

GOs will coordinate with their interconnected TO in order to ensure that their data is consistent with the TO-submitted topology. The Generator Owner may request assistance from the Transmission Owner in ensuring the equipment is modeled in the format requested. The Transmission Owner will let the Generator Owner know if they are willing to assist. GOs may submit their data directly to MOD/MISO or work with their interconnected TO to submit the data to MOD/MISO on their behalf. GOs are expected to submit directly to MOD/MISO unless they have made arrangements with their interconnected Transmission Owner to submit data on their behalf. If arrangements have been made, the MOD-032 Letter of Notice of Data Submittal Duty form must be completed and submitted to MISO at PlanningModeling@misoenergy.org. Once submitted, this Notice remains in effect until notification is provided to MISO to suspend the Notice. The form can be found at https://www.misoenergy.org/planning/planning-modeling/mod-032-1/

1.4.2 Load Serving Entities

Load serving entities (LSE) will coordinate with their interconnected TO in order to ensure that their data is consistent with the TO submitted topology. In alignment with MISO BPM-011 Section 3.2, each LSE is responsible to work with applicable Electric Distribution Companies (EDC) to coordinate the submission of EDC demand and energy forecast data that are subject to retail choice. The LSE may request assistance from the Transmission Owner in ensuring the loads and equipment are modeled in the format requested. The Transmission Owner will let the LSE know if they are willing to assistLSEs are required to submit directly to MOD/MISO unless they have made arrangements with their interconnected Transmission Owner to submit data on their behalf. If arrangements have been made, the MOD-032 Letter of Notice of Data Submittal Duty must be submitted to MISO at PlanningModeling@misoenergy.org. Once submitted, this Notice remains in effect until notification is provided to MISO to suspend the Notice. The form can be found at https://www.misoenergy.org/planning/planning-modeling/mod-032-1/

1.4.3 Transmission Owner Submittal of Unregistered Entities

As a best modeling practice, MISO requests that TOs also submit modeling data at their disposal for unregistered entities in their footprint, as this will produce higher-quality models and ensure more accurate planning analyses.

2

Data Submission Requirements

Modeling data to be submitted is organized by responsible entity below. These data requirements are defined by MOD-032-1 Attachment 1 which is included in Section 10 of this document for reference. MISO as a PC will send a message confirming an entity's participation in fulfilling their modeling obligation/compliance with MOD-032-1 at the end of the model building cycle.

2.1 Load Serving Entity[2]

In coordination with their interconnected TO, the LSE shall provide the aggregate demand levels for each of the scenarios specified in Section 4.2. The LSE shall use the bus numbers assigned to them by the interconnecting Transmission Owner from their MMWG[3]-assigned bus ranges. Table 2-1 provides a summary of the data required to be submitted by the LSE.

Table 2-1: Data to be submitted by the LSE

Steady-State
Aggregate demand on a bus level
Location of new expected loads
Dynamics
Load Composition or Characteristics
Sequence Network[4]
Load
Grounding Designation[5]

2.2 Generator Owner

In coordination with their interconnected TO, the GO shall provide the necessary data to model their generating facilities. The Generator Owner shall use bus numbers assigned to them by the interconnecting Transmission Owner from their MMWG-assigned bus ranges. Table 2-2 provides a summary of the data required to be submitted by the GO.

Data for existing and planned generators with executed interconnection agreements should be submitted. Units that have been retired per MISO's Attachment Y process should be removed from Model On Demand accordingly. Actual dispatch will be determined based on study needs.

Table 2-2: Data to be submitted by the GO

Steady-State
Generator parameters
Generator step-up (GSU) transformer data
Seasonal output capabilities

[2] MISO recognizes that LSE is no longer a functional entity under NERC. However, the MOD-032-1 standard still lists this as an applicable function entity. MISO will coordinate all updates to this document to meet the standard language.
[3] Mulit-Regional Modeling Working Group
[4] If applicable and not supplied by the Transmission Owner
[5] Whether or not the load is grounded. Activate option in PSS®E

Station Service[6] Load
Reactive Power Compensation[7]
Inverter-based resource (IBR) Collector System

Dynamics
Generator
Excitation System
Turbine-Governor
Power System Stabilizer
Protection Relays Frequency Response

Geomagnetically induced current (GIC)
Substation data
GIC transformer data
GIC branch data
Fixed shunt data

Sequence Network
Generator
Branch
Generator Step-up Transformer
Station Service Load Induction Machine

2.3 Transmission Owner

The TO is responsible for providing the necessary data to model the items listed in Table 2-3.

Table 2-3: Data to be submitted by the TO

Steady-State
System Topology Buses AC transmission lines HVDC transmission facilities Transformers Reactive Power Compensation Static VAR Systems (SVS) Initial Generator Output in MOD (to be submitted by the TO whose model control area the unit is located within)[8]

[6] Refer to Section 4.4.6.1 for submittal requirements
[7] Additional reactive power support equipment (such as a switched shunt) used to maintain an acceptable power factor at the Point of Interconnection
[8] Applicable to generation which has a signed delegation agreement for data submittal by the Transmission Owner on file with MISO. In the circumstance where the model Control Area is not a Transmission Owner, then the LBA may submit the data instead of the control area Transmission Owner if MISO is notified via email by both parties to PlanningModeling@misoenergy.org

Steady-State
Aggregate demand on a bus level
Location of new expected loads

Dynamics
Static VAR Systems
HVDC Facilities
FACTS Devices
Protection Relays

Geomagnetically induced current (GIC)
Substation data
GIC transformer data
GIC branch data
Fixed shunt data

Sequence Network
Non-transformer Branch
Mutual Branch
Transformer
Switched Shunt
Fixed Shunt

3 Model On Demand (MOD) Training & Access

3.1 MOD Access Levels

A brief description of the different access levels in MOD is provided below:

- **Market Participant** – Ability to access the MOD Base case only
- **Ratings Only** – View and submit equipment ratings only
- **User** – Create and submit modeling data in MOD (applies to majority of MOD users)
- **Local Process Manager** – Review, approve and may submit information to MISO Process Manager
- **MISO Process Manager** – Reviews and accepts submittals (limited to MISO staff)

- **MOD Administrator** – Sets roles of MOD users (limited to MISO staff)

Data submitters will require "User" level access in order to submit the necessary data. The diagram below shows the sequence of data from their submission to MOD through their implementation in models.

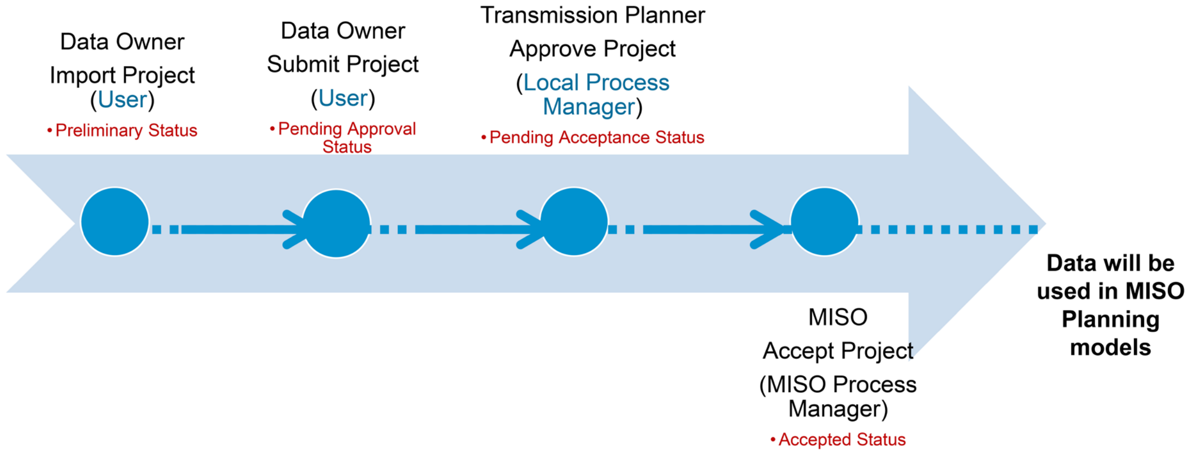


Figure 3-1: Sequence of MOD Data Submission

3.2 Obtaining Access to MOD

In order to gain access to MOD, each company must have a Universal NDA on file with MISO and each individual user is required to sign a Critical Energy Infrastructure Information (CEII) NDA. MISO Client Relations can assist in completing or verifying the NDAs. MISO Client Relations can be contacted via e-mail at clientrelations@misoenergy.org

Once the appropriate NDAs are in place, the company should complete one of the following MOD access request forms:

For access allowing submission of modeling data:

- https://cdn.misoenergy.org/Model-On-Demand Access Request102831.docx

For access allowing read-only of MOD base case (does not have ability to submit data to MOD):

- https://cdn.misoenergy.org/Market Participant Model-On-Demand Access Request102829.docx

3.3 MOD Training

MISO will generally conduct training on how to submit data through MOD annually in the Fall. Additional training sessions may be scheduled as needed. There are three general locations where MOD training materials are located.

1. Customer Learning Center on the MISO Learning Management System (LMS).
   - Current MOD training materials are found here.

- The process to access the Customer Learning Center is located on the MISO Public Website under Stakeholder Engagement/Training/Customer Training.
- The MOD Modules are located under Customer Training/Transmission Generation and Resource Planning/System Modeling.

2. MOD – Archived Cases section
    - Additional MOD Training
    - Recordings of previously MISO conducted training
3. MISO MTEP Sharefile
    - https://misoenergy.sharefile.com/home/shared >MTEP>MOD-032>Model On Demand file examples
    - MOD file examples found here are to aid in how to submit data

4

Power Flow Model Development

4.1 Data Format

Power Flow model data is to be submitted to MISO via MISO's Model on Demand (MOD) Tool in the MOD format as explained ahead. Models are developed using the Siemens PTI PSS®E software program. Data submitted should be compatible with the MOD and PSS®E versions currently specified by MISO. The formal data request submitted to members will provide the correct version information. Modeling data requests and notifications are sent to the Modeling User Group mailing list. Individuals can subscribe to the list at the following location: https://www.misoenergy.org/Pages/ListsSignup.aspx

4.2 Scenarios

For each annual planning cycle MISO will develop a set of power flow cases as shown in Table 4-1. The scenarios developed could change from year to year based on MISO and member needs. However, at a minimum those needed for TPL and MOD-032-1 compliance will be included. General descriptions of the scenarios are provided below:

- **Winter Peak Load (WIN)** – is defined as the winter peak demand expected to be served.
- **Spring Light Load (SLL)** - is defined as a typical early morning load level, modeling at or near minimum load conditions.
- **Spring Minimum Load (SML)** - is defined as a typical early morning load level, modeling at or near minimum load conditions.
- **Summer Peak Load (SUM)** - is defined as the summer peak demand expected to be served.
- **Summer Shoulder Load (SSH)** - is defined as 70% to 80% of summer peak load conditions. The Summer Shoulder shall represent a typical summer day peak value, not the shoulder values of a peak day.
- **Fall Peak Load (FAL)** - is defined as typical fall peak load conditions.

Table 4-1: Scenarios to be developed

Model Year	Spring Light Load	Spring Minimum Load	Spring	Summer Shoulder	Summer Peak	Fall	Winter Peak
0					X	X	X
1	X		X		X		X
2	X				X		X
5	X	X		X	X		X
10					X		X

As indicated in Table 4-1, modeling data is collected for years 0, 1, 2, 5 & 10. For example, for the 2020 model series the model years would be 2020, 2021, 2022, 2025, 2030.

4.3 Schedule

The annual schedule power flow model development schedule is shown in Table 4-2. Specific dates will be supplied with the annual data request.

Table 4-2: Power flow Development Schedule

Task	Estimated Completion
Steady State Data Request sent to TO, GO, LSE	August
Pass 1 models posted for review	August
Initial Data Request Information Due	September
Post Pass 2 models for review	October
Pass 2 data updates due for inclusion in Pass 3 including list of planned outages	November
Post Pass 3 models for review	December
Members submit final updates/corrections to MOD	January
Submit planned outages for inclusion in final pass	January
Post Final MISO models	March
Request Updates prior to MMWG submittal	April
Send final models to ERO (*Actual timeframe to be determined based on ERO schedule)	June*

4.4 Level of Detail

On at least an annual basis each data owner is required to submit the following model data to MISO's MOD database:

1. Transmission projects intended to be approved by MISO (moved to MTEP Appendix A) in the upcoming MTEP cycle; to be submitted by Transmission Owners
    a. This includes the projects that are submitted to MISO's MTEP Project Database by member companies by September 15 of each year.
    b. Section 10 contains NERC MOD-032-1 Attachment 1 detailing the minimum information that is required to effectively model the interconnected transmission system.
2. Generators with executed Generator Interconnection Agreements (GIA) & associated network upgrades. At a minimum, all generators with a nameplate capacity greater than 20 MVA or a facility with an aggregated nameplate capacity greater than 75 MVA must be modeled in detail including the gross generator values, station service loads[9], and generator step-up transformers (except for those meeting the exclusion criteria as specified in the NERC BES definition). Additionally, Blackstart Resources, as defined by NERC, identified in the Transmission Operator's restoration plan must be modeled in detail. Generation which meets the exclusion criteria as defined by NERC in the BES definition is not required to provide detailed model information but is recommended to do so. Units that have been retired are to be removed from MOD. Units that have not yet retired and have an approved Attachment Y should remain in MOD until the retirement

[9] Refer to section 4.4.6.1 for representation threshold

date, however, a MOD project may be submitted preemptively to remove the unit on its Attachment Y retirement date as long as the unit has a publicly announced retirement.

3. Bus/Load/Generation and Device Control Profiles, which include:
    a. Bus information (such as status, voltage magnitude, voltage angle) is not recommended to be included in Bus/Load/Generation profiles, as they are overwritten as part of the solution methodology.
    b. Load forecast for each scenario at the bus level representing a forecasted 50/50 coincident relative to the company peak; to be submitted by LSE or designated entity
    c. Corresponding generation limits and level for each scenario in the model list (Pmin, Pmax, Qmin, Qmax, Pgen); Generation limits/capabilities to be submitted by Generation Owner. Generator Owner shall submit generator capabilities (Pmax/Qmax) that correspond to a point in the reactive capability curve, Generation output to be coordinated between Transmission Owners and Generator Owners.
    d. Settings on regulating equipment such as transformers, switched shunts and HVDC data; to be submitted by data owner
4. Updates and/or corrections to approved future generation and transmission projects including planned maintenance equipment outages. Scheduled outages submitted to MISO via the CROW system with duration of greater than 6 months will be incorporated in the Pass 3 and final pass cases.
5. Any corrections that need to be made to existing system modeling in the MOD Base Case. Data owners shall provide facility retirement updates.
6. Non-Tier Order workbook information detailing the fuel type and capability within each modeled DER and other non-tier ordered resources, whether represented as a machine or as a negative load.

If the data has not changed since the last submission, a written confirmation that the data has not changed is sufficient. Such confirmation should be sent to MISO as the Planning Coordinator and the appropriate Transmission Planner. MISO correspondence should be sent by email to PlanningModeling@misoenergy.org.

The data submitted must be sufficient to perform reliability and economic studies on the bulk electric system (BES) as defined by NERC[10]. To that extent, relevant data associated with sub-100 kV facilities may also need to be provided.

4.4.1 MOD Naming Conventions

Files submitted to MOD (projects, profiles, etc.) must follow naming conventions specified in the following sub-sections.

4.4.1.1 *MOD MTEP Project Files*

MOD project files are used to make transmission system topology changes. MTEP project submissions are first created within MISO’s MTEP Project Database with a numerical Project

10 http://www.nerc.com/pa/RAPA/BES%20DL/bes_phase2_reference_document_20140325_final_clean.pdf

ID. Filenames should contain the company name acronym, the MTEP Project ID (MTEP_PRJID), and lastly the project name (PROJECT_NAME) as in the example below:

Example: ITC-MTEP_PRJID-PROJECT_NAME.prj

4.4.1.2 *Generator Project Files*

Generator project files are used to make generation additions, deletions, and modifications including any topology modification required for interconnection. Submissions to the Generation Interconnection Agreement (GIA) queue process are given a DPP Study Project ID. Filenames should contain the company name acronym, and the DPP Study Project ID (GXXX/JXXX/RXXX), and lastly the project name (PROJECT_NAME) as in the example below:

Example: ITC-JXXX-PROJECT_NAME.prj

4.4.1.3 *Bus/Load/Generation (BLG) Profiles*

BLG profiles contain load and generation information for each scenario. Each BLG profile name should contain the specific scenario, the MISO Series cycle, and lastly the company name acronym as in the example below:

Example for 2022 Summer Peak BLG profile: 2022SUM-MISO20-XEL-BLG.raw

4.4.1.4 *Device Control Profiles*

Device profiles contain information about settings on regulating equipment such as transformers, switched shunts and DC data. Each DEV profile name should contain the specific scenario, the MISO Series cycle, and lastly the company name acronym as in the example below:

Example for 2022 Summer Peak DEV profile: 2022SUM-MISO20-ATC-DEV.raw

4.4.2 Definitions

4.4.2.1 *Profile Types*

Commonly abbreviated in communication as BLG and DEV respectively, MOD Profiles contain load, generation and device control information for each model scenario within the MISO Series. During model building, Profiles are applied over the most recent Monthly Base Case models and over approved Projects thus overwriting data for seasonal changes. Profiles created for previous MISO Series cycles are not utilized again. They are re-created every cycle and cannot be used to modify transmission topology.

- **Bus Profiles**: Bus profiles update bus information. As such, this section of the BLG should not be populated as the information overwrites reviewed topology from Projects.
- **Load Profiles**: Load profiles reflect the expected load values associated with a specific year/case/sensitivity. All load identifiers within the Load Profile shall be capitalized to exactly match the load designation within the power flow case. Load data from these profiles are validated against the values submitted through the Module E process.
- **Generation Profiles**: Generation profiles reflect the expected output of generation associated with a specific year/case/sensitivity to meet the Load profile. Generation

shall not have a Pmax=Pmin=Pgen=0 as it effectively removes the generation from dispatch. Generation shall not have a Pmin=Pmax=Pgen; this restricts the unit from modifying its output based on sensitivity criteria. Exceptions must be documented and confirmed with MISO.

- **Device Profiles**: Device profiles reflect the transformer taps and control settings; generator scheduled voltage, regulating bus, and RMPCT; switched shunt control mode, status, and initial output; and the DC line schedules. All transformer winding voltages must be aligned with the correct tap positions. All transformer winding voltages must be aligned with the correct bus. Provide all DC dispatch profiles to realistically represent the season or sensitivity as specified. Device profiles should only be submitted for taps and settings that are changed on a seasonal basis as no profiles are re-used after their respective models have been built. Fixed settings should be submitted as a Non-MTEP MISO project as below.

4.4.2.2 *Project Types*

- **MTEP Appendix B**: Projects that are demonstrated to be a potential solution to an identified reliability, economic, or policy need.
- **MTEP Appendix A**: Projects that have been justified to be the preferred solution to an identified reliability, economic, or policy need, and have been reviewed and approved by the MISO Board of Directors.
- **Non-MTEP MISO**: Projects submitted by MISO members that represent facilities for which functional control has not been transferred to MISO and that don't fall under the jurisdiction of the MTEP process, as detailed in the Transmission Planning BPM under Section 4.2.3 (Project Reporting Guidelines).
- **Non-MISO Network**: Projects submitted by Non-MISO members/Non-MISO electric system
- **Base Case Change**: Projects submitted to make changes to the MOD Base Case
- **Generator**: Projects submitted to add generators with approved interconnection service, including all Network Upgrades identified in the Generator Interconnection Agreement.

4.4.2.3 *Project Statuses*

- **Target MTEP A:** Projects that are proposed that are desired to be approved by the MISO Board of Directors in the current planning cycle
- **Conceptual**: Conceptual or vision plans
- **Alternative**: Alternatives to preferred projects in MTEP Appendix B
- **Proposed**: Projects that require additional review and are subject to change
- **Planned**: Projects that have completed the TO planning process and that the TO intends to permit and construct
- **In Service**: In Service Generator
- **Correction**: Base case change to be submitted for correction of MOD Base Case

4.4.3 Modeling Criteria

Criteria for inclusion of MOD projects into the base models are shown in Table 4-3.

Table 4-3: Project Inclusion Criteria

Project Type	Target MTEP A	Planned	Proposed	Alternative	Conceptual	In Service	Base Case Options *
MTEP Appendix A		IN MODELS					
MTEP Appendix B	IN TA MODELS	NOT IN MODELS	NOT IN MODELS	NOT IN MODELS			
Non-MTEP MISO		IN MODELS					
Non-MISO Network		IN MODELS					
Base case Change							IN MODELS
Generator		IN MODELS			NOT IN MODELS	IN MODELS	

*Base Case Options include Correction, Error Correction, Field Change, As Built, Emergency Upgrade, and Facility Addition.

4.4.4 Modeling of Generators

4.4.4.1 *Synchronous Generators*

Data must be submitted to model the synchronous machine components explicitly

- Point of Interconnection Transformer and Transmission Line (Medium to High voltage)
- Generator step-up transformer (Low to Medium voltage)
- Reactive Compensation
- Station Service Loads (if greater than 1 MW)
- Machine ID synchronized with unit ID
- MOD Project Name shall include the MISO interconnection queue study number for any generation improvements including installation or uprate
- Generator Bus name shall include MISO interconnection queue designation
    - For example, “JXXXX Gen” (bus name limited to 12 characters)

4.4.4.2 *Wind Farms*

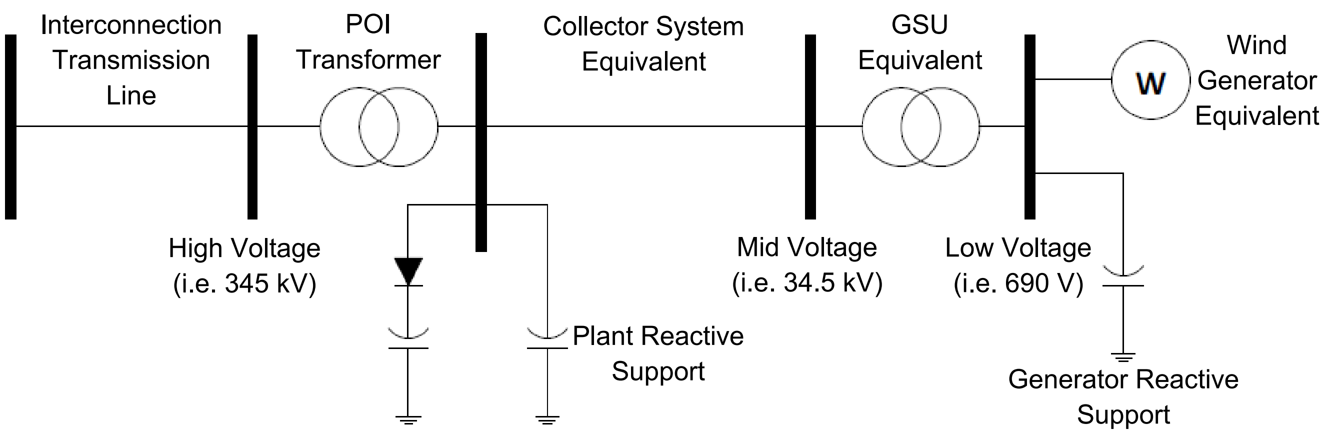
Data shall be submitted to allow wind farms to be modeled as a single equivalent machine with at least the following:

- Point of Interconnection Transformer and Transmission Line (Medium to High voltage)
- Equivalent generator step-up transformer (Low to Medium voltage)
- Collector System Equivalent (transmission lines representing the equivalent impedance of the collector system)
- Reactive Compensation
- Wind-free reactive status with new reactive limits
    - Unit Online

- PGEN=0
- Updated MVAR limits or updated Reactive assets nearby

- Wind Turbine Generator modeled at the appropriate low voltage (i.e. 690 V)
- WMOD[11] and WPF[12] populated with an appropriate non-zero value. If WMOD 2 or 3 is selected and units have differing leading and lagging power factors, please submit the more conservative value.
- Machine ID using a "W" character
- MOD Project Name shall include the MISO interconnection queue study number for any generation improvements including installation or uprate
- Generator Bus name shall include MISO interconnection queue designation
  - For example, "JXXXX Wind" (bus name is limited to 12 characters)

Figure 4-1: Single equivalent machine representation for wind farm



Modeling multiple equivalent machines for a single wind farm is acceptable when trying to model:

- Different turbine types/manufacturers
- Geographic diversity
- Explicit ownership
- Different development phases

Bus numbers for buses shown in Figure 4-1 should be coordinated with the interconnecting TO. Specific wind output levels are required to be specified for the various scenarios in the BLG profile, as shown in Table 4-4.

[11] Machine Control Mode
[12] Renewable Machine Power Factor

Table 4-4: Required Wind Output

Scenario	Wind Level	Wind Unit Output (%)*
Summer Peak	Capacity Credit Wind	Capacity Credit**
Fall, Spring	Off-Peak Average Wind	28.5%
Winter Peak, Light Load, Minimum Load	Average Wind	67%
Summer Shoulder	Average Wind	27%
Summer Shoulder	High Wind	83%
Light Load	High Wind	70%
Light Load	No Wind	0%

* Will be reviewed and updated periodically
** Wind Capacity Credit as assigned in the annual MISO Wind and Solar Capacity Credit Report

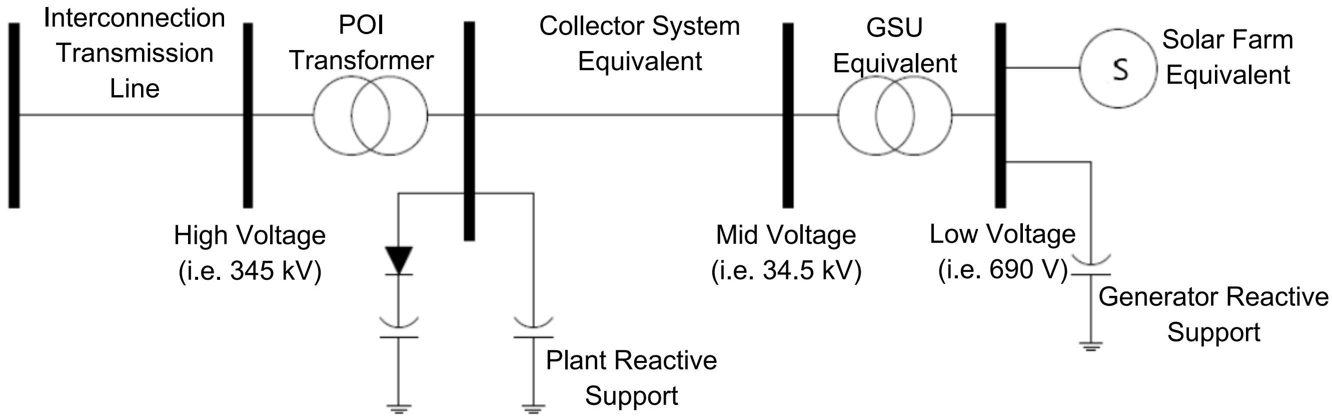
4.4.4.3 *Solar Farms*

Data shall be submitted to allow solar farms to be modeled as a single equivalent machine with at least the following:

- Point of Interconnection Transformer and Transmission Line (Medium to High voltage)
- Equivalent generator step-up transformer (Low to Medium voltage)
- Collector System Equivalent (transmission lines representing the equivalent impedance of the collector system)
- Reactive Compensation
- Sun-free reactive status with new reactive limits
  - Unit Online
  - PGEN=0
  - Updated MVAR limits or updated Reactive assets nearby
- Solar Modules modeled at the appropriate low voltage (i.e. 690 V)
- WMOD[13] and WPF[14] populated with an appropriate non-zero value. If WMOD 2 or 3 is selected and units have differing leading and lagging power factors, please submit the more conservative value.
- Machine ID using a “PV” or “S” characters
- MOD Project Name shall include the MISO interconnection queue study number for any generation improvements including installation or uprate
- Generator Bus name shall include MISO interconnection queue designation
  - For example “JXXXX Solar” (bus name is limited to 12 characters)

[13] Machine Control Mode
[14] Renewable Machine Power Factor

Figure 4-2: Single equivalent machine representation for solar farm



Specific solar output levels are required to be specified for the various scenarios in the BLG profile, as shown in Table 4-5.

Table 4-5: Required Solar Output

Scenario	Solar Unit Output (%)*
Summer Peak	Capacity Credit**
Light Load, Minimum Load, Winter Peak, Summer Shoulder (High Wind), Fall, Spring	0%
Summer Shoulder (Average Wind)	31%

* Will be reviewed and updated periodically
**Solar Capacity Credit as assigned in the annual MISO Wind and Solar Capacity Credit Report

4.4.4.4 *Energy Storage*

Data shall be submitted to allow Energy Storage devices to be modeled as a single equivalent machine with at least the following:

- Point of Interconnection Transformer and Transmission Line (Medium to High voltage)
- Equivalent generator step-up transformer (Low to Medium voltage)
- Collector System Equivalent (transmission lines representing the equivalent impedance of the collector system)
- Reactive Compensation

- WMOD[15] and WPF[16] populated with an appropriate value (WMOD =1 or WMOD = 2).
- Machine ID using an "ES" or "E" characters
- MOD Project Name shall include the MISO interconnection queue study number for any generation improvements including installation or uprate
- Generator Bus name shall include installation MISO interconnection queue designation
  - For example, "JXXX_ENSTOR1"

Table 4-6: Required Energy Storage Output

MODE	MW Output	WMOD	QT, QB Limits	Scenario
SATOA**	0%	1	Full Load MVAR Range	All Scenarios
Market Participant	Economic Tier Order	1	Full Load MVAR Range	All Scenarios

Storage Requires two Economic Tier Orders for Standby and Discharging
**Storage As Transmission Only Asset

4.4.4.5 *Hybrid Generation*

For modeling of plants with a shared interconnection, comprising of more than one fuel type, each fuel type shall be explicitly modeled as a machine whether AC or DC coupled.

4.4.4.6 *Generator Replacement Project*

A Generator Replacement project will interconnect a new generator at the same site as an existing generator.

Replacement generators shall be modeled on a new bus with, a new bus number, that has a common transmission interconnection as the unit(s) it is replacing. This bus shall be named with the replacement project number (RXXXX).

Both generators shall be represented in the model until the old unit is physically retired. Dispatch of the legacy and replacement generator will be dictated by the anticipated replacement date of the Generator Interconnection Agreement.

4.4.5 Distributed Energy Resources (DER)

A Distributed Energy Resource (DER) is an electricity supply resource that is either behind the meter on a customer premise or connected to a utility distribution system.

MISO recommends that existing inverter-based DER be explicitly represented within the power flow models. As an example, solar gardens or battery storage may have a significant aggregate impact on the transmission system at individual transmission-distribution interface buses.

Additional non-inverter-based DER are not expected to be explicitly represented at this time.

---

[15] Machine Control Mode
[16] Renewable Machine Power Factor

4.4.5.1 *Responsible Entities for Data Submission*

The Transmission Owners (TO) shall coordinate with Load Serving Entities (LSE) in order to enable representation of these resources at the Transmission-Distribution (T-D) boundary. As LSEs are the owners of the information below the T-D boundary, their involvement in the process will be instrumental to success in implementation of DER representation.

To avoid misrepresentation of data, for each piece of information only one entity shall submit the DER information to MISO. MISO recommends the current method of load reporting be utilized.

4.4.5.2 *Required Information*

Information required to adequately represent DER in a Power Flow environment include:

- Interconnection location (PSS®E Bus Number)
    - TOs shall aid LSEs in identifying where DER is represented, in a manner similar to current Load Modeling practices
- Fuel Types and Nameplate Capacity at each interconnection location (Solar/Wind/Battery/Thermal/Other)
    - Single aggregate representation of the DER as a unit or load at each interconnection location
    - LSEs shall provide and designated entity shall report what fuel types are represented at each interconnection location
    - LSEs shall provide and designated entity shall collect and report the total capabilities (Real & Reactive) by fuel type for each interconnection location
- No additional T-D Transformers should be added to the models. Existing load locations shall be utilized.
    - TOs shall generalize the T-D transformer impact into the Machine or Load representation of the reported DER, if needed

MISO recommends leveraging existing processes, such as local interconnection agreements, to populate DER information.

4.4.5.3 *Representation in Power Flow Models*

DER representation with the power flow models shall be as a machine or as a distinct distributed resource within the load record.

- Machine Record
    - Recommended for non-aggregate units, such as non-zero marginal cost generation (ex. Thermal)
    - To be represented and treated similarly to Synchronous Generators (144.4.4.1)
- As a distributed resource on a distinct Load
    - Recommended for aggregate units, such as zero marginal cost generation (ex. Wind/Solar/Geothermal/etc)
    - This option allows for the best available information to be utilized in the Composite Load Model (CMLD)

- No more than one DER should exist at a single bus, aggregation from multiples to a single node is required
  - Load ID should be 'DR'
- Existing load modeling at interconnection location
  - Load values shall not net out the impact of the reported DER
    Reported Load = Forecasted Load + reported DER

4.4.5.4 *Non-Tier Order Workbook*

MISO shall distribute a workbook for data collection of the above information to facilitate DER representation and dispatch as part of the initial data request. This workbook will publish the current MISO Series dispatch for inverter-based units that are not part of economic tier order dispatch[17]. Additionally, DER machines, behind-the-meter generation (BTMG) and negative loads that are non-inverter based are labeled as "As Is" within the workbook where dispatch will remain as is submitted through BLG Profiles. Dispatch of DER will be handled with the same ruleset that governs BES generation[18].

MISO shall contact assets owners about mapping inquiries where further information is needed.

4.4.6 Load Modeling

MISO's general policy is that loads be created at all buses where step-down transformers take Energy from the Transmission System and supply the distribution system. Transmission Owners are responsible to populate the transmission/distribution boundaries with loads. Load Serving Entities/Designated Submitters are responsible for populating the loads with forecast MW/MVAR values through the BLG profiles. Additionally, the scalable load should also be easily identifiable. Therefore, the scalable load field should be populated as 1 if it is scalable (conforming) and 0 if it is not scalable (non-conforming).

The external area Load is modeled as represented in the NERC series models or the neighboring coordinated system used to develop the MOD base models.

4.4.6.1 *Station Service*

Bulk Electric System generators with station service load greater than 1 MW are required to model their station service load explicitly. In order to maintain a consistent naming convention associated with station service load, MISO recommends that all station service load have a load ID of SS. If there is more than 1 generator at a bus the station service load shall have a load ID of S1, S2, S3, etc. associated with the correct generator ID. If a legacy station service load ID is being used please communicate that to MISO via email to: PlanningModeling@misoenergy.org.

Nuclear generation station service loads are not required to adhere to the SS load identification recommendation above. Station service loads not directly connected to the generation bus are not required to adhere to the SS load identification recommendation above. The GO is

[17] Economic tier order dispatch is described in Section 4.4.14 (Dispatch)
[18] Inverter-based resource dispatch rules are defined in sections 4.4.4.2 (Wind), 4.4.4.3 (Solar) and 4.4.4.4 (Energy Storage)

responsible to inform MISO of the generator-station service association as part of their data submittal.

Station Service loads should be enabled or disabled based on the generator status within the year/case/sensitivity unless MISO is notified of special considerations. Station Service loads shall be positive values.

4.4.6.2 *Seasonal Load Forecast Expectations*

Load profiles provided must adhere to the prescribed year/season/sensitivity scenario. MISO will utilize the Module E submitted load data as a reasonability check assuming the following ratios:

1. Summer Peak 100% of Summer Peak
2. Summer Shoulder 70-80% of Summer Peak
3. Fall 50-70% of Summer Peak
4. Spring 50-70% of Summer Peak
5. Light Load 30-50% of Summer Peak
6. Minimum Load 30-50% of Summer Peak
7. Winter Peak 100% of Winter Peak

These comparisons will not include non-firm loads such as station service, Qualifying Facilities, etc.

4.4.7 Area Interchange

Area interchange will be set to model firm and expected inter- and intra-MISO transactions. An Area Interchange Transaction workbook will be utilized to determine Area Interchange. Data needed to model transactions will include the source and sink areas, transaction MW amount, applicable model scenarios, start/end dates and an OASIS reference (Transmission Service Reservation) number or a Grandfathered Agreement (GFA) number if applicable (Expected transfers may not have OASIS or GFA information). This data is required to be provided by TOs in collaboration with their Balancing Authority. The LBA may submit the data instead of the control area Transmission Owner if MISO is notified via email by both parties to PlanningModeling@misoenergy.org

Transactions need to be confirmed by both transacting parties. MISO will post a workbook to the MISO MTEP Sharefile for review, edits, additions and deletions. Final cases are solved by enabling the PSS®E “ties + loads” interchange function.

Method to collect transaction level data will be accomplished through a workbook.

4.4.8 Tie Lines

MISO will maintain a tie-line workbook for its members’ ties with external (non-MISO) entities. The workbook format will be determined by the ERO/designee. The Power Flow Coordinator maintains a Master Tie Line Database. A tie line will not be represented in a particular power flow base case model unless both parties have agreed to include it. Tie lines between MISO entities need to be coordinated between both parties. MISO can facilitate dialogue between its members if that is desired.

All existing and future planned tielines modeled in MOD must have matching representation for bus numbers and circuit ID in the ERAG MMWG and MISO MOD cases and must be linked to the ERAG Master Tie Line Database. For tie-lines not owned by a MISO member but connecting to a MISO member bus, the MISO member must submit a MOD project to connect the external and internal areas. All tie-lines must be represented within the MISO models regardless of normal operational status.

4.4.9 Ratings

Data owners are responsible for maintaining the ratings data for their facilities in MOD as per the FAC-008-3 standard. While creating cases, facility ratings are selected as indicated below:

- Rate 1=Normal
- Rate 2=STE (Emergency Rating, the rating used in contingency analysis)
- Rate 3=LTE (Long-Term Emergency Rating, not required)

4.4.10 Branch Modeling

AC line modeling must include the following characteristics:

- From Bus Number
- To Bus Number
- Ckt ID
- Line Resistance (R) in pu
- Line Reactance (X) in pu
- Charging (B) in pu
- Whether it is Metered on the From end
- Ratings (Refer to section 4.4.9 for rating guidance)
- Owner

If the line is a zero-impedance line the Ckt ID must start with a Z.

AC Line Name – this is an optional field that can be filled out. This field does require unique entries across the entire case. In order to assure unique entries, MISO recommends the following naming conventions:

1. For lines that are not inter-area ties (non-area ties), please have the corresponding area number or area name followed by a colon preceding the unique name (this keeps uniqueness within each area and under each area’s control).
2. It is recommended to avoid the use of underscore; if a duplicate entry occurs, an _# will be appended to the end (this will allow for easy parsing out for the data owner if a duplicate happens).
3. For area ties, include both areas separated by forward slash followed by a dash preceding the unique name. The order should be From bus area/To bus area.

    Example:

Non-area tie: 207-161kV line from XXX to XXX
Non-area tie: 217-ARPT DTWN
Area tie: 207/210-345kV tieline

4.4.11 Transformer Modeling

Transformer modeling must include the following characteristics:

- Owner
- Nominal voltages of each winding
- Winding ratings (Refer to section 4.4.9 for rating guidance)
- Regulated Bus
- Tap ratios
- Number of tap positions
- Tap position limits (Min. and Max.)
- Control Mode
- From/To/Last Bus Numbers and Circuit ID
- Proper Vector Group[19]
- Impedance data (R and X)

In addition, three-winding transformers shall be modeled in the following configuration:
Winding 1 – Highest KV – Highest MVA Rating
Winding 2 – 2nd Highest KV – 2nd Highest MVA Rating
Winding 3 – Lowest KV – Lowest MVA Rating

Data submitters may utilize a different winding configuration so long as the configuration is uniform throughout the submitter's area(s).

Transformer Name: This is an optional field that can be filled out. This field does require unique entries across the entire case. In order to assure unique entries, MISO recommends the following naming conventions.

1. For lines that are not inter-area ties (non-area tie), please have the corresponding area number or name followed by a colon preceding the unique name (this keeps uniqueness within each area and under each areas control).
2. It is recommended to avoid the use of underscore; if a duplicate entry occurs, an _# will be appended to the end (this will allow for easy parsing out for the data owner).
3. For area tie transformers, include both areas separated by forward slash followed by a dash preceding the unique name. The order should be From bus area/To bus area.

Example:
Non-area tie: 207-asdf GSU
Area tie: 207/210-asdf Phase Shifter

4.4.12 Voltage Limits

Data owners are responsible for maintaining the bus level voltage limits for their facilities in MOD. Data owners must provide:

[19] Only required for transformers to be included in GIC analysis. Please refer to Section 9.

- Normal maximum voltage (pu)
- Normal minimum voltage (pu)
- Emergency (N-1) maximum voltage (pu)
- Emergency (N-1) minimum voltage (pu)

4.4.13 Standard Case Effective Dates

Effective dates are cutoffs that are used to identify projects that are applied to the corresponding model scenario as noted in Table 4-7. Therefore, all projects that have their expected in-service date specified to be on or before the effective date are included in the corresponding model.

Table 4-7: Standard Effective Dates

Season	Standard Case Effective Date (MM-DD)
Spring Peak, Spring Light Load, and Spring Minimum Load	04-15
Summer Peak and Summer Shoulder	07-15
Fall Peak	10-15
Winter Peak	01-15

4.4.14 Dispatch

MISO uses a combination of generation dispatches for its NERC TPL analyses. Most models that are used for steady state analysis contain a control area level Network Resource dispatch. For implementing this dispatch, Network Resources in each control area are dispatched in economic tier order to meet the load, loss and interchange level. MISO maintains generation tiered merit order information in the Tier Order workbook. Interchange level is determined from the Area Interchange Transaction workbook which is gathered at the control area level. Light Load, High Wind models use the dispatch submitted to MOD from BLG Profiles.

5

Dynamics Model Development

5.1 Data Format

Dynamics modeling data needs to be submitted in the form of a Siemens PTI PSS®E Dyre (.dyr) file. Dyre file submittals can be of just changes to your system from the existing .dyr or of an entire representation of only your system in a .dyr. Models are developed using the PSS®E software program and DSA Tools TSAT program. Data submitted must be compatible with the PSS®E and DSA Tools TSAT versions currently specified by MISO.

Standard library models should be used to represent all active elements (generators, static VAR compensators, etc) whenever possible. If a user-written model (UDM) is being submitted, documentation and a .dll file must be submitted along with the .dyr file. The documentation must include the characteristics of the model including block diagrams, values and names for all model parameters, and a list of all state variables as stated in Section 6 of this document.

Modeling data requests and notifications are sent to the Modeling User Group mailing list. Individuals can subscribe to the list at the following location: https://www.misoenergy.org/Pages/ListsSignup.aspx.

5.2 Scenarios

For each annual planning cycle, MISO will develop a single dynamics data set to be used with the associated power flow models list in Table 5-1. The scenarios developed could change from year to year based on MISO and member needs. However, at a minimum those needed for TPL and MOD-032-1 compliance will be included.

Table 5-1: Power flow Scenarios Used for Dynamics

Model Year	Light Load	Summer Peak	Summer Shoulder	Fall Peak	Winter Peak

1		X		
5	X	X	X	
10		X*		

*Will be built **if** proposed material generation additions or changes occur in between years 5&10. If year 10 Summer Peak is required to be submitted to ERO designee and MISO has no material generation additions/changes, MISO will submit +5 Summer Peak dynamics.

5.3 Schedule

The annual schedule for dynamics model development is shown in Table 5-2. Specific dates will be supplied with the annual data request.

Table 5-2: Dynamics Development Schedule

Task	Estimated Completion
MISO requests updated Dynamic data (.dyr updates)	April
Create Initialized Pass 1 Dynamics Package	April - May
Post Initialized Pass 1 Dynamics Package & provide output of sample set of disturbances	May
Data owners review and provide corrections	June
Incorporate updates and develop Final Dynamics Package	June
Post Final Dynamics Package	July
Dynamics Data submitted to ERO or its Designee	August (Actual timeframe to be determined based on ERO schedule)

5.4 Level of Detail

Dynamics simulations analyze the transient response of the power system following a disturbance. These simulations are in a timeframe of 0 to 20 seconds with a typical time step of ¼ cycle. As such it is necessary to develop a model that sufficiently represents the automatic response of all active elements to a disturbance on the power system.

On an annual basis each data owner is required to submit the following model data:

- Dynamic models to represent approved future active elements such as generators, FACTS devices, or fast switching shunts
- Updates to existing dynamic models

GOs and LSEs are expected to submit directly to MISO unless they have made arrangements with the interconnecting Transmission Owner to submit data on their behalf. If arrangements have been made, it must be communicated in writing to MISO at PlanningModeling@misoenergy.org

If the data has not changed since the last submission, a written confirmation that the data has not changed is sufficient. Such confirmation should be sent to MISO as the Planning Coordinator and the appropriate Transmission Planner. MISO correspondence should be sent by email to PlanningModeling@misoenergy.org.

5.4.1 Power Flow Representation

The dynamics model will use a power flow model consistent with the steady-state model outlined in Section 4. If changes are required to the power flow data for dynamics, they should be reflected in the steady-state power flow cases and the appropriate changes entered in MOD.

5.4.2 Dynamics Representation

5.4.2.1 *Generators*

At a minimum, all generators with a nameplate greater than 20 MVA or a facility with an aggregated nameplate greater than 75 MVA must be modeled in detail (except for those meeting the exclusion criteria as specified in the NERC BES definition) and additionally Blackstart Resources identified in the Transmission Operator's restoration plan. A detailed model of a generator must include:

- Generator Model
- Excitation System Model
  - May be omitted if unit is operated under manual excitation control
- Turbine-Governor Model
  - May be omitted if unit doesn't regulate frequency
- Power System Stabilizer Model
  - May be omitted if device is not installed or not active
- Reactive Line Drop Compensation Model
  - May be omitted if device is not installed or not active
- Frequency Response
  - Responsive *Generator is operated to be fully frequency responsive*
  - Squelched *Generator is frequency responsive but load controller will override after some time*
  - Non-Responsive *Generator does not regulate frequency*

Generators with detailed modeling must use a dynamic model from the Standard Generator Component Model List, specified in Section 6. If a suitable model is not on the standard list the data submitter may request a model be added to the standard list by providing MISO with a technical justification for doing so. Additions and subtractions to the standard list will be handled on a case by case basis.

Several legacy models have been omitted from the Standard Generator Component Model List since they can be directly converted to newer dynamic models with minimal effort and without changes to simulation results. The recommended conversions from a particular legacy model to a newer model are listed in Section 6.

In instances where detailed dynamic modeling is unavailable, generic data may be used. Generators without detailed modeling will be netted with the load (set as a negative load).

5.4.2.2 *Static VAR Systems & Synchronous Condensers*

Static VAR Systems (SVS) and synchronous condensers are reactive power devices that can vary the amount of reactive power supplied or absorbed within the simulated timeframe (0-20 seconds). These devices must be modeled in sufficient detail in order to simulate its expected behavior.

If the reactive power device is modeled as a generator (for example a synchronous condenser) it should follow the guidelines in Section 5.4.2.1.

5.4.2.3 *HVDC*

All HVDC transmission facilities must be represented with a sufficiently detailed model to simulate its expected behavior. For future HVDC transmission facilities where exact design specifications are not known generic HVDC models should be used (such as CDC6).

5.4.2.4 *Load*

The dynamic behavior of load must be modeled in sufficient detail to meet NERC TPL compliance obligations. The dynamic behavior of load can be specified on an aggregate (area/zone/owner) or individual bus level. Providing a specific dynamic load characteristic model or the motor load composition is acceptable.

Loads with detailed characteristic modeling must use a dynamic model from the Standard Component Model List, specified in Section 6. If a desired model is not on the standard list the data submitter may request a model be added to the standard list by providing MISO with a technical justification for doing so. Additions to the standard list will be handled on a case by case basis.

If a specific dynamic load characteristic model is not provided, the motor load composition of the load on a bus/area/zone or owner level is required in order to determine the appropriate dynamic representation. The composition of the load shall be defined as:

- Motor A – Small 3-Phase (i.e. compressor motors used in large air-conditioners and refrigerators)
- Motor B – Large 3-Phase (i.e. Fan Motor)
- Motor C – Medium 3-Phase (i.e. Pump Motor)
- Motor D – 1-Phase Air Conditioner Compressor Motor
- Electronic Load – Voltage Dependent Load
- Static Load – Frequency & Voltage Dependent Load

Based on the composition of the load an appropriate dynamic representation will be developed using the composite load model (CMLD). Additional details on how the composite load model parameters will be developed are specified in Section 7. A walkthrough of how to determine the motor load composition based on the Residential/Commercial/Industrial/Agricultural composition of the load is also detailed in Section 7.1.

5.4.2.5 *Protection Relays*

Generic protection relays are applied during the simulation that scan for bus voltages, out-of-step conditions, and against generic protection zones for transmission lines. These generic protection relays only monitor system conditions. Table 5-3 shows the generic relay settings.

Table 5-3: Generic Relay Settings

Generic Relay	Monitored Condition
Generic Transient Voltage Monitoring	$0.7 \le V_{bus} \le 1.2$ (12 cycles following the initiating event)
Generic Out-of-Step Monitoring	Apparent Impedance > Line Impedance
Generic Distance Relay	Circle A = 1.00 x Line Impedance Circle B = 1.25 x Line Impedance Circle C = 1.50 x Line Impedance

Equipment-specific detailed protection relay models shall be submitted for:

- Voltage and frequency ride through relay settings of BES resources
    - In support of PRC-006-5 and MISO's underfrequency load shedding analysis, frequency trip settings of resources that meet the gross nameplate criteria as stipulated in PRC-006-5, Requirements R4.1 through R4.6 as shown below.

      4.1. Underfrequency trip settings of individual generating units greater than 20 MVA (gross nameplate rating) directly connected to the BES that trip above the Generator Underfrequency Trip Modeling curve in PRC-006-5 - Attachment 1.
      4.2. Underfrequency trip settings of generating plants/facilities greater than 75 MVA (gross aggregate nameplate rating) directly connected to the BES that trip above the Generator Underfrequency Trip Modeling curve in PRC-006-5 - Attachment 1.
      4.3. Underfrequency trip settings of any facility consisting of one or more units connected to the BES at a common bus with total generation above 75 MVA (gross nameplate rating) that trip above the Generator Underfrequency Trip Modeling curve in PRC-006-5 - Attachment 1.
      4.4. Overfrequency trip settings of individual generating units greater than 20 MVA (gross nameplate rating) directly connected to the BES that trip below the Generator Overfrequency Trip Modeling curve in PRC-006-5 — Attachment 1.
      4.5. Overfrequency trip settings of generating plants/facilities greater than 75 MVA (gross aggregate nameplate rating) directly connected to the BES that trip below the Generator Overfrequency Trip Modeling curve in PRC-006-5 — Attachment 1.
      4.6. Overfrequency trip settings of any facility consisting of one or more units connected to the BES at a common bus with total generation above 75 MVA

- Automatic action of Special Protection Schemes (SPS)

5.5 Dynamics Data Checks

Once the dynamic models are created, a set of data checks to flag potential issues with the data submitted will be performed. Section 11.2 provides a list of the data quality checks performed. In addition to the data checks, a sample set of disturbances are run to assist in model review. Data owners are required to submit corrected model data in the time window specified in the model review request/notification.

6

Standard Generator & Load Component Model List

MISO recognizes the NERC Acceptable Model List posted at:
https://www.nerc.com/pa/RAPA/ModelAssessment/Documents/Acceptable Models List%E2%80%8B.xlsx.

Note that MISO does not accept models that are marked as not recommended or prohibited. MISO no longer accepts governor models that are unable to model deadband even though they are acceptable to NERC. For example, TGOV1 is currently an acceptable NERC model but since deadband is not modeled it is no longer acceptable to MISO. Also note that MISO does not accept user defined models (UDM) unless they meet the following conditions.

- The specific performance features of the user-defined modeling are necessary for proper representation and simulation of inter-Data Submitting Entity dynamics, and
- Standard PSS®E dynamic models cannot adequately approximate the specific performance features of the dynamic device being modeled.
- The User Written Model must be table driven, not CONET or CONEC based.
- When user-defined modeling is used in the MMWG cases, written documentation shall be supplied explaining the dynamic device performance characteristics, detailed block diagrams, model ICONs, CONS, and Variables. The documentation for all MMWG user-defined models shall be posted on the MMWG Internet site as a separate document. Any benign warning messages that are generated by the model code at compilation time should also be documented. This documentation must be continuous updated to demonstrate that new standard library models do not meet the necessary performance features.
- .dll files or source code and object file(s) shall be provided for all User Models. Source code shall be submitted in FORTRAN or the FLECS language of the PSS®E version currently specified by MISO.
- If a PSS®E UDM is not supplied, then a DSA Tools TSAT UDM must be created and maintained.

Please note that TSAT may not have a standard library model for all PSS®E or PSLF dynamic component models but still has the ability to automatically read and convert them into the appropriate TSAT format. Some models will be listed as “UDM” for TSAT, however; this should not be confused with the term “user-written model” or “UDM” used in the context of PSS®E or PSLF. Models must be provided which are usable within both the DSA Tools TSAT and PSS®E application.

7

Composite Load Model

The composite load model was developed through industry collaboration led by the efforts of the NERC Load Modeling Working Group (LMWG). The composite load model has since been implemented into the various commercially available software tools. Figure 7-1 provides a diagram of the composite load model. Please refer to the WECC Report "Composite Load Model for Dynamic Simulations"[20] for additional information about the composite load model.

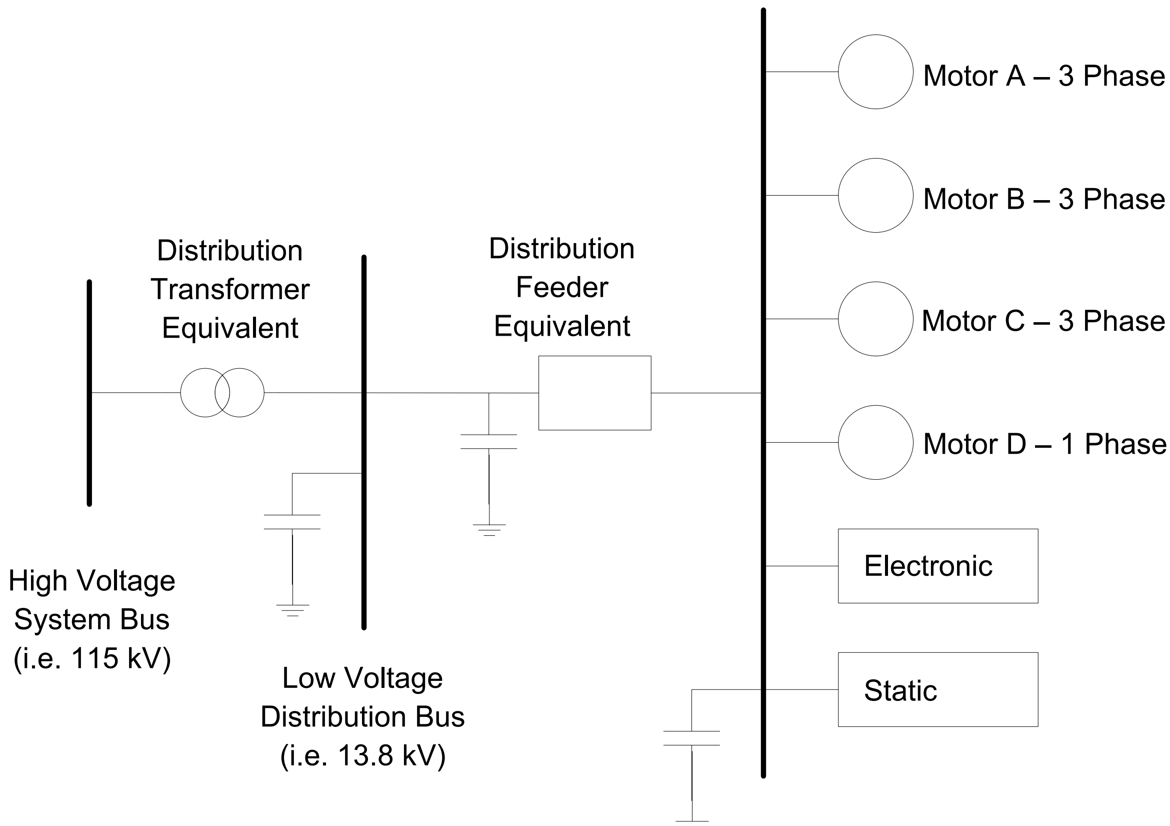


Figure 7-1: Composite Load Model

[20] https://www.wecc.org/_layouts/15/WopiFrame.aspx?sourcedoc=/Reliability/WECC%20MVWG%20Load%20Model%20Report%20ver%201%200.pdf&action=default&DefaultItemOpen=1

7.1 Parameter Derivation Based on Load Composition

The composite load model has 133 different parameters. The majority of these parameters are used to define the characteristics and behavior of the 6 main components of the model, which are listed below:

- Motor A – Small 3-Phase (i.e. compressor motors used in large air-conditioners and refrigerators)
- Motor B – Large 3-Phase (i.e. Fan Motor)
- Motor C – Medium 3-Phase (i.e. Pump Motor)
- Motor D – 1-Phase Air Conditioner Compressor Motor
- Electronic Load – Voltage Dependent Load
- Static Load – Frequency & Voltage Dependent Load

Table 7-1 provides example percentages of load composition for different components of load.

Table 7-1-1: Sample Summer Peak Load Composition Based on R/C/I/A

	Residential	Commercial	Industrial	Agricultural
Motor A	8%	12%	13%	10%
Motor B	7%	10%	22%	20%
Motor C	2%	4%	16%	22%
Motor D	34%	25%	0%	8%
Electronic	15%	18%	27%	10%
Static	34%	31%	22%	30%

Table 7-1-2: Sample Shoulder Load Composition Based on R/C/I/A

	Residential	Commercial	Industrial	Agricultural
Motor A	8%	12%	13%	10%
Motor B	7%	10%	22%	20%
Motor C	2%	4%	16%	22%
Motor D	25%	20%	0%	8%
Electronic	19%	23%	27%	10%
Static	39%	31%	22%	30%

Table 7-1-3: Sample Light Load Composition Based on R/C/I/A

	Residential	Commercial	Industrial	Agricultural
Motor A	10%	12%	13%	10%
Motor B	8%	10%	22%	20%
Motor C	2%	4%	16%	25%
Motor D	0%	5%	0%	5%
Electronic	40%	38%	27%	10%
Static	40%	31%	22%	30%

Table 7-1-4: Sample Minimum Load Composition Based on R/C/I/A

	Residential	Commercial	Industrial	Agricultural
Motor A	10%	12%	13%	10%
Motor B	8%	10%	22%	20%
Motor C	2%	4%	16%	25%
Motor D	0%	5%	0%	5%
Electronic	40%	38%	27%	10%
Static	40%	31%	22%	30%

Table 7-1-5: Sample Winter Peak Composition Based on R/C/I/A

	Residential	Commercial	Industrial	Agricultural
Motor A	10%	12%	13%	15%
Motor B	7%	10%	22%	20%
Motor C	2%	4%	16%	15%
Motor D	0%	0%	0%	0%
Electronic	35%	34%	27%	10%
Static	46%	40%	22%	40%

Since load components are defined as fractions of the total load, mixtures of Residential/Commercial/Industrial/Agricultural are handled by summing the weighted fraction as shown in Equation 7-2.

Equation 7-2: Derivation of Load Composition Based on R/C/I/A in Table 7-1-1

$$\begin{bmatrix} F_{ma}: \text{Motor A Fraction} \\ F_{mb}: \text{Motor B Fraction} \\ F_{mc}: \text{Motor C Fraction} \\ F_{md}: \text{Motor D Fraction} \\ F_{el}: \text{Motor A Fraction} \end{bmatrix} = \begin{bmatrix} \text{CON(J}+18) \\ \text{CON(J}+19) \\ \text{CON(J}+20) \\ \text{CON(J}+21) \\ \text{CON(J}+22) \end{bmatrix} = \begin{bmatrix} 0.08 & 0.12 & 0.13 & 0.10 \\ 0.07 & 0.10 & 0.22 & 0.18 \\ 0.02 & 0.04 & 0.16 & 0.22 \\ 0.34 & 0.25 & 0.00 & 0.10 \\ 0.15 & 0.18 & 0.27 & 0.10 \end{bmatrix} \times \begin{bmatrix} Residential \\ Commercial \\ Industrial \\ Agricultural \end{bmatrix}$$

7.2 Example Composite Load Model Based on Load Composition

The PSS®E dyre entry for composite load model has the following structure:

```
I, 'USRLOD', LID, 'CMLDxxU2', 12, IT, 2, 133, 27, 146, 48, 0, 0, CON(J) to CON(J+132) /
```

Where:

Model suffix "XX"	Corresponding "IT" Description	Corresponding "I" Description
BL	**1**	Bus number
OW	**2**	Owner number
ZN	**3**	Zone number
AR	**4**	Area number
AL	**5**	0 (All)

Below is an example of how the composite load fractions will be calculated based on a provided load composition.

Given the load composition for area 1 is:

- Residential – 40%
- Commercial – 30%
- Industrial – 20%
- Agricultural – 10%

Thus:

$$\begin{bmatrix} F_{ma} \\ F_{mb} \\ F_{mc} \\ F_{md} \\ F_{el} \end{bmatrix} = \begin{bmatrix} \mathrm{CON}(J+18) \\ \mathrm{CON}(J+19) \\ \mathrm{CON}(J+20) \\ \mathrm{CON}(J+21) \\ \mathrm{CON}(J+22) \end{bmatrix} = \begin{bmatrix} 0.08 & 0.12 & 0.13 & 0.10 \\ 0.07 & 0.10 & 0.22 & 0.18 \\ 0.02 & 0.04 & 0.16 & 0.22 \\ 0.34 & 0.25 & 0.00 & 0.10 \\ 0.15 & 0.18 & 0.27 & 0.10 \end{bmatrix} \times \begin{bmatrix} 0.40 \\ 0.30 \\ 0.20 \\ 0.10 \end{bmatrix} = \begin{bmatrix} \mathbf{0.104} \\ \mathbf{0.120} \\ \mathbf{0.074} \\ \mathbf{0.221} \\ \mathbf{0.178} \end{bmatrix}$$

The DYR entry would be:

```
1   'USRLOD'     *            'CMLDARU2'         12         4   2   133   27   146   48
                     0                 0
                    -1                 0         0.02        0.02           1
                     0                 1            1           1         0.9
                   1.1           0.00625            1        1.02         999
                     5                 0            0       0.104        0.12
                 0.074             0.221        0.178           1        0.72
                  0.52                 1            2         0.5           1
                   0.5                 0            2           1           1
                     0                -1            3         0.8        0.01
                   3.1            0.1384        0.121      0.1028      0.0028
                   0.1                 0          0.7        0.05         0.3
                     1              9999          0.6        0.02         0.7
                     1             99999            3         0.8       0.005
                     4             0.185         0.16         0.8      0.0044
                   0.5                 2          0.7        0.05         0.3
                     1              9999          0.6        0.02         0.5
                  0.75              0.25            3         0.8        0.01
                   3.1             0.185         0.16        0.35      0.0036
                  0.15                 2          0.7        0.05         0.3
                     1              9999          0.6        0.02         0.5
                  0.75              0.25        9999*         0.3       0.025
                  0.05                 1         0.98        0.45         0.1
                   0.1                 0            0           1           6
                     2                12          3.2          11         2.5
                  0.86               0.2         0.95           1        -3.3
                   0.5               0.4          0.6         0.5          15
                   0.7               1.9          0.1         0.6        0.02
                     0              9999          0.5           /
```

**The blue highlighted parameter is the Tstall value for motor D.*

- *To disable motor stalling, use the value 9999.*
- *If the motor is set to stall, a commonly used value is 0.03*

8

Short Circuit Model Development

In support of the TPL-007 harmonic analysis requirements, MISO Transmission Owners (TO) and Generator Owners (GO) are required to provide MISO the following positive, negative*, and zero sequence network information:

1. Generator
2. Load
3. Non-Transformer Branch
4. Mutual Branch
5. Transformer
6. Switched Shunt
7. Fixed Shunt
8. Induction Machine

Sequence network data shall be submitted to MISO using MOD project files. *Negative sequence data is automatically recognized by PSS®E as the negative of the positive sequence data. All formatting shall follow the currently applicable version of PSS®E within MOD. Topology must be consistent with MISO power flow model representation, i.e. designated 6-digit bus numbers and consistent transformer modeled windings.

MOD project filenames should contain the company name acronym followed by SEQNET and any other identifying information determined by the entity.

Example: ATC-SEQNET-345kV system

Data shall be submitted for all elements meeting any of the following criteria:

- NERC BES defined elements (excluding Blackstart resources with a point of interconnection less than 200 kV)
- 200 kV and higher MISO transferred transmission facilities
- Transformers interconnecting to the above facilities at 100 kV or higher via at least two terminals

Do not submit equivalized representation of neighboring networks represented within a TO/GO model.

MISO will be performing the harmonic analysis on the 5-year Summer Peak and 5-year Summer Shoulder, Average Wind models. For equipment not yet in service, provide short circuit information based on best engineering practices.

9

GIC Model Development

Additional data to supplement an AC power flow model is required to develop Geomagnetic Induced Current (GIC) system models in accordance with R2 of TPL-007. These models require system details related to the path of GIC through the system similar to DC modeling. MISO is requiring data on facilities that include power transformer(s) with a high side, wye-grounded winding with terminal voltage greater than 200 kV in accordance with the TPL-007 standard. Additional data beyond the required scope of TPL-007 will be accepted.

Details and examples of the data being requested are referenced in section 9.2. For brevity, only the data being requested is listed in sections 379.1. Data will be received by MISO through the submission of an Excel Spreadsheet attached to a GIC Model Data Request.

9.1 Required GIC Data:

9.1.1 Substation and Bus Data

A new data construct which supports the calculation of GIC is the Substation. This is a one-to-many relationship between a group of power system Buses within a Substation. Data required of the substation is:

- Substation number
  - The substation number should be the lowest Bus number of the highest voltage present within the substation. Substations numbers must be selected from the utilities' allocated bus numbers which can be found in the MMWG model building manual, located at:
    - https://rfirst.org/ProgramAreas/ESP/ERAG/MMWG/Pages/MMWG.aspx
- Substation summer ground resistance
- Latitude and Longitude of Substation
- Earth model to be applied
  - Either utilizing the acronym identifying the United States Geological Survey (USGS) Earth model or detailed parameters with additional Earth model input as part of section 9.1.5
- The bus data which correlates buses to the substation in which they are located

9.1.2 Transmission Line Data

MISO requires two categories of data be submitted for line data. Lines which are installed underground at greater than 200 kV or have implicit shunts with ground paths must be reported in data submissions. Underground lines require an indication of no induced current (Vp and Vq) be indicated with 0.0 entries. Line shunts are entered as a resistance correlated to the end of the branch which it is installed.

MISO will not require utilities to include DC conductor resistance inputs for each line and will run calculations with program approximated DC value. Any submission of this data will be accepted and applied by MISO.

9.1.3 Transformer Data

Transformers require the most data of any transmission system element to be submitted. It is highly recommended to utilize the three-winding model within power flow tools instead of modeling the transformer as three two-winding transformers. The following information must be submitted:

- If present, the winding that a DC blocking device may be installed on
- Transformer DC winding resistances
- The transformer Vector Group
    - Alternatively, this may be submitted to Model on Demand within the AC power flow model data
- Transformer Core Construction, <u>or</u> K-factor if known
- If present, the size and location of grounding resistors
- Phase shifting transformers may require special consideration

9.1.4 Fixed Shunt Data (Reactors)

Reactors may offer a path to ground and are required within the GIC model where grounding exists. The below data fields are required for equipment at greater than 200 kV:

- Bus Number
- Shunt ID
- DC Ohms/phase of the reactors
- Grounding Resistor (if present)

9.1.5 Earth Model Data

If a model submitting entity has more comprehensive data on the Earth resistivity model, they may enter the data within the Earth Model Data.

9.1.6 Switched Shunt Data (Reactors)

Similar to Fixed and Line associated Shunts, Switched Shunts can offer a path(s) to ground. The below data fields are required for equipment at greater than 200 kV:

- Bus Number
- DC Ohms/phase of the reactors
- Grounding Resistor (if present)
- Block Number and Size
- Step Number

To date, simulation software allows for the entry of one DC resistance value for all represented paths. MISO will be collecting the "*blocks*" and "*steps*" to correlate this information to the switching status of the devices within the AC power flow model.

9.1.7 Load, DC Line Data, VSC and Facts Devices

Multiple devices may contain applicable transformers implicitly within the power flow model element. These devices are likely to be two winding wye-delta or delta-wye. For grounded wye transformers 200 kV and higher, data is required with the following information collected:

- Line name (only for DC devices)
- Bus Number
- ID
- DC Winding Resistance
- Grounding Resistor if present
- Transformer Core Construction, or K-factor if known

For loads which may represent lower voltage systems and have alternative transformer construction than grounded wye-delta, total winding resistance to ground should be used.

9.1.8 Use of Default or Estimated Data

The use of default or estimated data GIC models should be utilized as an exception. When parameters are estimated, a description of the estimate must be reflected in the comments along with plans to determine the required data.

9.1.9 Updating the AC Power Flow Model

Topology changes may be required to accurately represent GIC information. These topology changes are required to be submitted to MOD as Base Case Change, Facility Addition. The use of calculated equivalents in the GIC data will only be accepted with written permission from MISO and detailed documentation retained to describe the calculations utilized. For example: additional buses are required to be modeled when there are transformers that span two different substations and when substations have different ground grid resistances. Projects submitted to MOD for this purpose should include the syntax “GIC Update” in the project file name.

9.2 Reference Papers

- *Geomagnetic Disturbance Modeling Examples from the MISO system* – a confidential MISO reference document
- *Modeling and Evaluation of Geomagnetic Storms in the Electric Power System* (Krishat Patil, Siemens USA)
- MISO GIC Data Request Spreadsheet

9.3 Schedule

The annual request for GIC data will be communicated to members after the completion of the Dynamics Model series, usually during the June timeframe. Specific dates will be supplied with the annual data request.

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MOD-032-1 – Attachment 1

The table below indicates the information that is required to effectively model the interconnected transmission system for the Near-Term Transmission Planning Horizon and Long-Term Transmission Planning Horizon. Data must be shareable on an interconnection-wide basis to support use in the Interconnection-wide cases. A Planning Coordinator may specify additional information that includes specific information required for each item in the table below. Each functional entity1 responsible for reporting the respective data in the table is identified in the right column, adjacent to and following each data item. The data reported shall be as identified by the bus number, name, and/or identifier that is assigned in conjunction with the PC, TO, or TP.

Data	Functional Applicability
Steady-state *(Items marked with an asterisk indicate data that vary with system operating state or conditions. Those items may have different data provided for different modeling scenarios*	
1. Each bus a. nominal voltage b. area, zone and owner	TO
2. Aggregate Demand[21] a. real and reactive power* b. in-service status*	LSE
3. Generating Units[22] a. real power capabilities - gross maximum and minimum values b. reactive power capabilities - maximum and minimum values at real power capabilities in 3a above c. station service auxiliary load for normal plant configuration (provide data in the same manner as that required for aggregate Demand under item 2, above). d. regulated bus* and voltage set point* (as typically provided by the TOP) e. machine MVA base f. generator step up transformer data (provide same data as that required for transformer under item 6, below) g. generator type (hydro, wind, fossil, solar, nuclear, etc) h. in-service status*	GO, RP (for future planned resources only)
4. AC Transmission Line or Circuit a. impedance parameters (positive sequence) b. susceptance (line charging) c. ratings (normal and emergency)* d. in-service status*	TO
5. DC Transmission systems	TO

[21] For purposes of this item, aggregate Demand is the Demand aggregated at each bus under item 1 that is identified by a Transmission Owner as a load serving bus. A LSE is responsible for providing this information, generally through coordination with the Transmission Owner.

[22] Including synchronous condensers and pumped storage.

Data	Functional Applicability
6. Transformer (voltage and phase-shifting) a. nominal voltages of windings b. impedance(s) c. tap ratios (voltage or phase angle)* d. minimum and maximum tap position limits e. number of tap positions (for both the ULTC and NLTC) f. regulated bus (for voltage regulating transformers)* g. ratings (normal and emergency)* h. in-service status*	TO
7. Reactive compensation (shunt capacitors and reactors) a. admittances (Mvar) of each capacitor and reactor b. regulated voltage band limits* (if mode of operation not fixed) c. mode of operation (fixed, discrete, continuous, etc.) d. regulated bus* (if mode of operation not fixed) e. in-service status*	TO
8. Static Var Systems a. reactive limits b. voltage set point* c. fixed/switched shunt, if applicable d. in-service status*	TO
9. Other information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes.	BA, GO, LSE, TO, TSP
Dynamics *(If a user-written model(s) is submitted in place of a generic or library model, it must include the characteristics of the model, including block diagrams, values and names for all model parameters, and a list of all state variables)*	
10. Generator	GO, RP (for future planned resources only)
11. Excitation System	GO, RP (for future planned resources only)
12. Governor	GO, RP (for future planned resources only)
13. Power System Stabilizer	GO, RP (for future planned resources only)
14. Demand	LSE
15. Wind Turbine Data	GO
16. Photovoltaic systems	GO
17. Static Var Systems and FACTS	GO, TO, LSE
18. DC system models	TO
19. Other information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes.	BA, GO, LSE, TO, TSP
Short circuit	
20. Provide for all applicable elements in column “steady-state” a. Positive Sequence Data b. Negative Sequence Data c. Zero Sequence Data	GO, RP, TO
21. Mutual Line Impedance Data *	TO, GO*
22. Other information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes.	BA, GO, LSE, TO, TSP
Geomagnetically induced current (GIC)	
23. Substations a. associated bus(es) b. geophysical location (lat, long degrees) c. grounding resistance (ohms)	TO, GO
24. GIC branch data a. dc resistance (ohms/phase) b. if no GIC coupling: underground/water cable	TO, GO

Data	Functional Applicability
25. GIC transformer data a. dc resistances (ohms/phase) b. blocking device status c. vector group d. core design: phases, shell/core, legs e. K factor: a factor to calculate transformer reactive power loss from GIC flowing in its winding (Mvar/Amp) f. grounding resistances g. dc network model: T model for PARs	TO, GO
26. Fixed shunt a. dc resistance (ohms/phase) b. grounding dc resistance (ohms)	TO, GO
27. [Optional: alternative earth model]	TO, GO

11

Data Checks

Once the power flow models are created, a set of data checks to flag potential issues with the data submitted will be performed by MISO. In addition to the data checks shown below, a sample N-1 DC contingency screen is performed to assist with model review. Results of the data checks and sample contingency screens will be included along with each model posting. Data owners are required to submit corrected data in the time window specified in the model review request/notification.

11.1 Power Flow Data Checks

Name	Data Checked	Conditions Flagged
Bus Voltage	Buses	Existing TO planning criteria
Blank Voltage Fields	Buses	Blank BASKV field
Machines on Code 1 Buses	Buses; Generators	Generator at bus with IDE = 1
Online Machines on Code 4 Buses	Buses; Generators	Machine with STATUS = 1 at bus with IDE = 4
Code 2 Buses Without Machines	Buses; Generators	No generator at bus with IDE = 2
Unrealistic PMAX and PMIN	Generators Including off-line generators	PMAX < PMIN, PMAX > 2000, PMIN < -1000
Unrealistic QMAX and QMIN	Generators Including off-line generators	QMAX < QMIN, QMAX > 1000, QMAX < -1000
PGEN Outside Range	Generators with STAT = 1 & Bus IDE=2 or 3	PGEN > PMAX, PGEN < PMIN
Non-positive RMPCT	Generators	RMPCT ≤ 0
GTAP Out Of Range	Generators	GTAP > 1.1, GTAP < 0.9
CNTB Errors	Switched Shunts; Generators; Transformers with COD1 = 1	Conflicting voltage objectives
Small Voltage Band Shunts	Switched Shunts	VSWHI – VSWLO < 0.0005
Missing Block 1 Steps	Switched Shunts	Missing Block 1 steps
Transformer MAX below MIN	2-Winding Transformers with COD1 ≠ 0	VMA1 ≤ VMI1, RMA1 ≤ RMI1
Transformer Default R	2-Winding Transformers with COD1 ≠ 0	RMA1 = 1.5 and RMA2 = 0.51
Transformer Default V	2-Winding Transformers with COD1 ≠ 0	VMA1 = 1.5 and VMA2 = 0.51
Small Voltage Band Transformer	All Transformers with COD1 = 1	VMA – VMI < 2.0 × Step Size
Small Transformer Step Size	Transformers	0.015625 < Step Size < 0.00625

Name	Data Checked	Conditions Flagged
Max or Min at 0	2-Winding Transformers with COD1 ≠ 0	RMA1 = 0, RMI1 = 0, VMA1 = 0, VMI1 = 0
Branch Issues	Branches; 2-Winding Transformers	Branches: R > |X| Transformers: R1-2 > |X1-2| High/Low Reactance, Charging Issues
Rating Errors	Branches; Transformers	RATEB < RATEA, RATEA = 0, RATEB = 0
3 Winding Rating Errors	3-Winding Transformers[3]	RATEB < RATEA, RATEA = 0, RATEB = 0
Branch Overloads	Branches; Transformers	Branch loading above 100% of RATEA or RATEB
Islands	Buses	Buses with IDE 1 or 2 not connected to a bus with IDE = 3
Unrealistic MBASE	Generators	MBASE < PMAX, MBASE = 100
Unrealistic ZSOURCE	Generators	RSOURCE = 0 & XSOURCE = 1, RSOURCE = 1 & XSOURCE = 1, RSOURCE > XSOURCE
Machines Missing GSU	Machines at buses ≥ 50 kV	Implicit GSU not specified
Open ended branches	Branches, Transformers	Branch with STATUS = 1 connected to bus with IDE = 4
Branches to different bus voltages	Branches, Transformers	Branches between buses with different bus voltages
Wind units modeled at high voltage buses	Generators	Wind units that are modeled on buses 10kV or higher
Ensure WMOD is populated for wind units modeled with library models	WMOD	

11.2 Dynamics Data Checks

Models Checked	Data Checked	Conditions Flagged
All Gen Model with inertia defined as H	H	H = 0
All Gen Model with S(1.0)	S(1.0)	S(1.0) <0
All Gen Model with S(1.2)	S(1.2)	S(1.2) <0
All Gen Model with S(1.0) and S(1.2)	S(1.0)	S(1.0) > S(1.2)
All Gen/Exciter Model with S(E1)	S(E1)	S(E1) < 0
All Gen/Exciter Model with S(E2)	S(E2)	S(E2) < 0
All Gen/Exciter Model with S(E1) and S(E2)	S(E1)	S(E1) > S(E2) if E1 < E2
All Gen/Exciter Model with S(E1) and S(E2)	S(E1)	S(E1) < S(E2) if E1 > E2
All Gen Models with reactance/transient reactance defined as Xd and X'd in D axis	Xd	Xd <= X'd
All Gen Models with transient reactance/sub-transient reactance defined as X'd and X"d in D axis	X'd	X'd <= X"d
All Gen Models with sub-transient reactance/leakage reactance defined as X"d and XL in D axis	X"d	X"d <= XL
All Gen Models with reactance/transient reactance defined as Xq and X'q in Q axis	Xq	Xq <= X'q
All Gen Models with transient reactance/sub-transient reactance defined as X'q and X"q in Q axis	X'q	X'q <= X"d (X"d=X"q)
All Gen Models with reactance/transient reactance defined as X and X'	X	X <= X'
All Gen Models with transient reactance/sub-transient reactance defined as X' and X"	X'	X' <= X" if X"/=0 and T"/=0
All Gen Models with sub-transient reactance/leakage reactance defined as X" and XL	X"	X" <= XL if X"/=0 and T"/=0
All Gen Models with transient reactance/leakage reactance defined as X' and XL	X'	X' <= XL if X"=0 or T'=0

12

Entity Lists

Detailed list of NERC Compliance Registry is available at:

https://www.nerc.com/pa/comp/Pages/Registration.aspx

MISO membership listing is available at:

https://cdn.misoenergy.org/Current%20Members%20by%20Sector95902.pdf

Appendix 1

Transmission Planner Compliance

Pursuant to requirement R1 of MOD-032-1, MISO as a NERC Planning Coordinator (PC), and its NERC Transmission Planners (TPs) have jointly developed modeling data requirements and reporting procedures for MISO's planning area. Transmission Planners that have participated in the development of this document are as follows:

Transmission Planner	Transmission Planner Participant
ALLETE, Inc. (for its operating division Minnesota Power)	Ruth R. Pallapati
Ameren Services Company	Jason Genovese
American Transmission Company, LLC	Kerry Marinan Robert Krueger
Big Rivers Electric Corporation	Tim Curtis
Cedar Falls Utilities	Ken Kagy
Central Iowa Power Cooperative	Craig Timson
City Of Ames Electric Services	Lyndon Cook
City of Columbia, MO	Armin Karabegovic
City of Lansing by its Board of Water and Light	Jamal Ahmed Robert Tidd
City Water, Light & Power (Springfield, Illinois)	Chris Daniels Steve Rose
Cleco Power LLC	Terry Whitmore Chris Thibodeaux Ian Gray
Consumers Energy	Jeff Chilson Jeff Swan
Dairyland Power Cooperative	Steve Porter
Duke Energy Corporation	Phillip C. Briggs
East Texas Electric Cooperative, Inc.	Claudiu Cadar John Chiles Jason Shook (GDS Associates)
Entergy	William Hamilton Peng Yu
Great River Energy	Patrick Quinn
GridLiance Heartland	Rachael Ibuado
Henderson Municipal Power and Light	
Hoosier Energy Rural Electric Cooperative, Inc.	Sara Ostrander Mike Dicks
Indianapolis Power & Light Company	Mark Kemper Robert Grubb Brad Williams
International Transmission Company (d/b/a ITC Transmission)	Michael C. Hamlin Shalini Gupta

Transmission Planner	Transmission Planner Participant
ITC Midwest	Mike Hamlin Josh Grindeland (ITC Holdings Corp.)
Lafayette Utilities System	Hunter Boudreaux
Michigan Electric Transmission Company, LLC	Mike Hamlin Shalini Gupta (ITC Holdings Corp.)
MidAmerican Energy Company	Daniel Rathe
Minnkota Power Cooperative	Will Lovelace
Missouri River Energy Services	Wes Pfaff
Muscatine Power & Water (Board Of Water, Electric & Communications)	Lewis Ross Nick Lorenz Greg Slonka
Montana Dakota Utilities	Shawn Heilman
Northern Indiana Public Service Company	Lynn A. Schmidt
Otter Tail Power Company	Denise Keys
Prairie Power, Inc.	Karl Kohlrus
Rochester Public Utilities	Scott Nickels
Cooperative Energy	Jason Goar
Southern Illinois Power Cooperative	Jeff Jones
Southern Indiana Gas & Electric Company (Vectren)	Larry Rogers Mark Rose
Southern Minnesota Municipal Power Agency	Patrick Egan Rick Koch
Wabash Valley Power Association	Susan Sosbe Tom Imel
Wolverine Power Supply Cooperative, Inc.	Tyler Bruning
Xcel Energy	Craig Wrisley Dylan Kohl

Appendix 2 MISO 2023 Model List

MISO 2023 Series Model List

Type of Model	Planning Year	Scenario	Study Requiring Model	Profile	Year	Load Level	Topology	Gen dispatch	Wind dispatch	Solar Dispatch	MISO N/S Flow Limit
							2023 LBA 50/50 forecast				
2023 Series Base Powerflow Models											
Powerflow	0	Summer Peak	ECON, QOL	2023SUM-MISO23	2023	SUM	TA	LBA	CapCred	CapCred	1K
Powerflow	0	Fall Peak	Base Model (Maintenance Margin)	2023FAL-MISO23	2023	FAL	TA	LBA	29%	0%	1K
Powerflow	0	Winter Peak	Base Model (ERAG for CSA)	2023WIN-MISO23	2023/2024	WIN	TA	LBA	40%	0%	1K
Powerflow	1	Spring Peak	Base Model (Maintenance Margin)	2024SPR-MISO23	2024	SPR	TA	LBA	29%	0%	1K
Powerflow	1	Summer Peak	Base (ERAG,GI,LOLE and CIL/CEL,MM,CSA,Mock, UFLS)	2024SUM-MISO23	2024	SUM	TA	LBA	CapCred	CapCred	1K
Powerflow	1	Summer Shoulder (High Wind)	SSR	2024SHHW-MISO23	2024	SH	TA	LBA	83%	0%	1K
Powerflow	1	Spring Light Load	ERAG	2024SLL-MISO23	2024	SLL	TA	LBA	40%	0%	1K
Powerflow	1	Fall Peak	CIL/CEL	2024FAL-MISO23	2024	FAL	TA	LBA	28.5%	0%	1K
Powerflow	1	Winter Peak	ERAG	2024WIN-MISO23	2024/2025	WIN	TA	LBA	67%	0%	1K
Powerflow	2	Spring Peak	CIL/CEL	2025SPR-MISO23	2025	SPR	TA	LBA	40%	0%	1K
Powerflow	2	Winter Peak	ERAG	2025WIN-MISO23	2025/2026	WIN	TA	LBA	67%	0%	1K
Powerflow	2	Summer Shoulder (High Wind)	SSR	2025SHHW-MISO23	2025	SH	TA	LBA	83%	0%	1K
Powerflow	5	Spring Minimum Load (Average Wind)	ERAG	2028SMLAW-MISO23	2028	SML	TA	LBA	27%	0%	1K
Powerflow	10	Winter Peak	ERAG	2033WIN-MISO23	2033/2034	WIN	TA	LBA	67%	0%	1K
Powerflow	0	Summer Peak	PRA SFT	2023SUM-MISO23	2023	SUM	TA June 1	LBA, PRA	CapCred	CapCred	1K
Powerflow	1	Summer Shoulder (Average Wind)	SSR	2024SHAW-MISO23	2024	SH	TA	SCED	27%	31%	2.5/3K
Powerflow	2	Summer Shoulder (Average Wind)	SSR	2025SHAW-MISO23	2025	SH	TA	SCED	27%	31%	2.5/3K
Powerflow	10	Summer Shoulder (Average Wind)	SSR	2033SH-MISO23	2033	SH	TA	SCED	27%	31%	2.5/3K
Powerflow	2	Spring Light Load	TPL & Project Review	2025SLL-MISO23	2025	SLL	AA	LBA	0%	0%	1K
Powerflow	2	Summer Peak	TPL & Project Review	2025SUM-MISO23	2025	SUM	AA	LBA	CapCred	CapCred	1K
Powerflow	5	Spring Light Load (High Wind)	TPL & Project Review	2028SLLHW-MISO23	2028	SLL	AA	LBA	70%	0%	1K
Powerflow	5	Summer Peak	TPL & Project Review	2028SUM-MISO23	2028	SUM	AA	LBA	CapCred	CapCred	1K
Powerflow	5	Summer Shoulder (Average Wind)	TPL & Project Review	2028SHAW-MISO23	2028	SH	AA	LBA	27%	31%	1K
Powerflow	5	Summer Shoulder (High Wind)	TPL & Project Review	2028SHHW-MISO23	2028	SH	AA	LBA	83%	0%	1K
Powerflow	5	Winter Peak (North Flow for MH)	Project Review	2028WINNF-MISO23	2028/2029	WIN	AA	LBA	67%	0%	1K
Powerflow	10	Summer Peak	TPL & Project Review	2033SUM-MISO23	2033	SUM	AA	LBA	CapCred	CapCred	1K
Powerflow	2	Spring Light Load	TPL & Project Review	2025SLL-MISO23	2025	SLL	TA	LBA	0%	0%	1K
Powerflow	2	Summer Peak	TPL & Project Review	2025SUM-MISO23	2025	SUM	TA	LBA	CapCred	CapCred	1K
Powerflow	5	Spring Light Load (High Wind)	TPL & Project Review	2028SLLHW-MISO23	2028	SLL	TA	LBA	70%	0%	1K
Powerflow	5	Summer Peak	TPL & Project Review, LOLE, GI, SSR, CIL/CEL	2028SUM-MISO23	2028	SUM	TA	LBA	CapCred	CapCred	1K
Powerflow	5	Summer Shoulder	TPL & Project Review	2028SHAW-MISO23	2028	SH	TA	LBA	27%	31%	1K
Powerflow	5	Summer Shoulder	TPL & Project Review, GI, SSR	2028SHHW-MISO23	2028	SH	TA	LBA	83%	0%	1K
Powerflow	5	Winter Peak (North Flow for MH)	TPL & Project Review	2028WINNF-MISO23	2028/2029	WIN	TA	LBA	67%	0%	1K
Powerflow	5	Winter Peak (South Flow for MH)	TPL & Project Review, ERAG	2028WINSF-MISO23	2028/2029	WIN	TA	LBA	67%	0%	1K
Powerflow	10	Summer Peak	TPL & Project Review	2033SUM-MISO23	2033	SUM	TA	LBA	CapCred	CapCred	1K

Appendix 3

Document Version History

Version	Date	Comment
1.1	2016-07-16	
1.2 DRAFT	2016-10-16	Amended to include GIC modeling practices
2.0	2017-07-21	Finalized GIC sections
2.1	2017-09-29	Updated Standard Dynamics List
2.2	2018-08-07	Updated Introduction, Generator modeling
3.0	2019-12-05	Updated Load Section Added Profiles Section Updated Short Circuit Data Requirements for TPL-007 Harmonic Analysis Distributed Energy Resource representation requirements Updated hyperlinks
3.1	2020-08-21	Distributed Energy Resource Update Transformer Modeling added Branch Modeling added Dynamic Protection Relays New Appendix 2
	2020-10-28	Update tables to reflect new wind and solar dispatch levels as approved by PSC and PAC
4.0	2021-08-13	Changed Document Name Reordered multiple sections Added Voltage Limits section Updated language in multiple sections Updated hyperlinks Updated in-document cross-reference links
4.1	2022-08-11	Wind Farms – wind-free reactive status & description Solar Farms – sun-free reactive status & description Energy Storage – dispatch update Generator Replacement Project added Tie-line Modeling Update