Manual No. 018

Business Practices Manual

Voltage and Reactive Power Management

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1. Introduction

This introduction to the Midcontinent Independent System Operator, Inc. (MISO) Business Practices Manual (BPM) for Voltage and Reactive Power Management includes basic information about this BPM and the other MISO BPMs. The first section (Section 1.1) of this introduction provides information about MISO BPMs. The second section (Section 1.2) is an introduction to this BPM. The third section (Section 1.3) identifies other documents in addition to the BPMs, which can be used by the reader as references when reading this BPM.

1.1 Purpose of the MISO Business Practices Manuals

The BPMs developed by MISO provide background information, guidelines, business rules, and processes established by MISO for the operation and administration of MISO markets, provisions of transmission reliability services, and compliance with MISO settlements, billing, and accounting requirements. A complete list of MISO BPMs is available for reference through MISO's website. All definitions in this document are as provided in the MISO Tariff, the NERC Glossary of Terms Used in Reliability Standards, or are as defined by this document.

1.2 Purpose of this Business Practices Manual

This document outlines the Voltage and Reactive Power Management Process undertaken by MISO and the companies within the MISO RC footprint in accordance with and beyond the NERC Standards for Transmission Operations (NERC Standard TOP) and Standards for Voltage and Reactive Control (NERC Standard VAR). It examines roles and responsibilities in analyzing, maintaining, monitoring, and controlling voltage levels, reactive resources, and reactive power flows within the MISO footprint.

This BPM applies to those facilities under the purview of the MISO RC. These facilities are specified through one of the following mechanisms:

- MISO Transmission Owner Facilities listed in Appendix H.
- MISO RC Services Customers facilities under Module F of the Tariff, whose facilities are specified in their executed Attachment KK-1.
- MISO RC Services Customers facilities under separate standalone agreements, JOAs, or contracts, etc.

1.3 References

Other reference information related to this BPM includes:

- Agreement of Transmission Facilities Owners to Organize the Midcontinent Independent System Operator, Inc., A Delaware Non-Stock Corporation

- BPM-002 Energy and Operating Reserve Markets
- BPM-008 Outage Operations
- NERC TOP-001 Transmission Operations
- NERC TOP-002 Operations Planning
- NERC TOP-003 Planned Outage Coordination
- NERC VAR-001 Voltage and Reactive Control
- NERC VAR-002 Generator Operation for Maintaining Network Voltage Schedules

1.4 List of Acronyms

- **AVR**: Automatic Voltage Regulator
- **EOP**: Emergency Operating Procedures
- **IROL**: Interconnection Reliability Operating Limit
- **JOA**: Joint Operating Agreement
- **LTC**: Load Tap Changer
- **MISO**: Midcontinent Independent System Operator
- **NERC**: North American Electric Reliability Corporation
- **RC**: Reliability Coordinator
- **RE**: Reliability Engineer
- **RTCA**: Real-Time Contingency Analysis
- **RTNET**: Real-Time Network Analysis – (MISO's State Estimator)
- **RTU**: Remote Terminal Unit
- **SCADA**: Supervisory Control and Data Acquisition
- **SE**: State Estimator
- **SOL**: System Operating Limit
- **SVC**: Statcom: Static VAR Compensators
- **TOP**: Transmission Operator

2. Roles and Responsibilities

2.1 MISO Reliability Coordinator

This section reviews MISO's responsibilities as the RC and Market Operator in order to manage and monitor voltage and reactive power.

The RC has the responsibility of:

- Monitoring and managing pre contingency voltage and reactive power
- Monitoring post contingency voltage and appropriately managing/planning for post contingency alarms
- Managing constraint by adjusting transfers across the system, generation redispatch and generation commitment as outlined BPM-002 Energy and Operating Reserve Markets, section 8.2.5.
- Mitigating system emergencies by directing actions required from the TOPs and executing, when necessary, MISO EOPs
- Performing forward operational planning processes that include, but not limited to:
    - Performing outage coordination function
    - Coordinating the voltage and reactive power operating guides with the adjacent RC/TOP in boundary areas

2.2 Transmission Operator

This section reviews the roles of the Transmission Operator within the MISO RC footprint. The TOP's primary responsibility is to monitor, analyze, and control voltage and reactive power flows as stated in NERC Standard VAR-001.

The TOP must also abide by all the NERC TOP Standards, ensuring reliability, maintaining plans for reliable operations, outage coordination, as well as reporting and acting properly to SOL and IROL Violations.

For purposes of better managing Voltage and Reactive Power, all TOPs must be responsible for complying with the requirements in NERC Standard VAR-001 as well as NERC Standards TOP-001 through TOP-003 pertaining to Voltage and Reactive Power, in order to protect equipment and maintain a reliable system interconnection.

To permit MISO to perform its role as Reliability Coordinator, each TOP shall also be responsible for the following actions:

- Define acceptable voltage level and reactive power criteria within its operating boundary. The acceptable voltage level shall be maintained by MISO and applied in its systems used for monitoring voltage.
- Coordinate voltage and reactive power with other TOPs within the MISO footprint to ensure optimal and reliable operation in the region.
- Monitor voltage violations on transmission facilities, take corrective actions, , coordinate such mitigation with the neighboring TOP within the MISO Reliability footprint, and notify the MISO RC to request assistance when simple corrective actions are not sufficient.
- When assistance is needed across the RC border, the TOP shall coordinate with MISO for assistance from the neighboring RC.
- Follow the instructions of the RC to maintain reliable system conditions.
- As applicable, direct the GOPs within its TOP boundary when requesting generation of real or reactive power to control voltage and manage voltage violations. In addition, request assistance from the RC when simple corrective actions do not suffice.
- Communicate reactive device outages to MISO in accordance with the BPM for Outage Operations (BPM-008).

TOPs who have signed the Transmission Owners Agreement shall abide by the agreement as well as recognize and practice the directives in Article 4.

2.3 Generator Operator

This section reviews the roles of the Generator Operator (*i.e.*, those who operate generation connected to facilities under the purview of the MISO RC). The GOP has the primary responsibility of providing voltage and reactive power flow control as required by NERC Standard VAR-002. It is the GOPs responsibility to abide by NERC Standard VAR-002 and NERC Standards TOP-001 through TOP-003 pertaining to Voltage and Reactive Power as related to the GOP. The GOP shall also take the following measures to permit MISO to perform its role as RC:

- Provide reactive power supply and voltage control from generation sources or other ancillary services within plant capabilities and reply to TOP requested changes
- Submit AVR status in accordance with BPM-008 Section 4.1(including the unit and the anticipated duration of the AVR unavailability) if
    - the voltage regulation of an on-line generator is not available
      or

    - the voltage regulation becomes available following an outage
- Operate the AVR on automatic voltage control mode and report changes promptly for evaluation
- Communicate to MISO RC or RE reactive reporting for reduced unit reactive capability

3. Real-Time Operations

There are different types of assessments performed during Real-Time horizon to determine how to effectively manage voltage and reactive power. These assessments include:

- Real-Time Voltage Assessment
- Real-Time Voltage Contingency Analysis
- Real-Time P-V Analysis
- Real-Time Reactive Reserve Calculations
    - Static Reactive Reserves
    - Dynamic Reactive Reserves

MISO documents its System Operating Limit methodology for the operating horizon in its procedures, including how the above assessments may be used to establish SOLs

3.1 Real-Time Voltage Assessment

3.1.1 Assessment Method

MISO's primary method to assess Real-Time voltage in the reliability region is by utilizing the alarming function in MISO SCADA system as well as MISO RTNET voltage monitoring.

3.1.2 Real-Time Voltage Monitoring

During Real-Time Operations MISO RC will monitor:

- Voltages through SCADA voltage alarms and/or RTNET voltage results
- Critical circuit flows and bus voltage
- Pre-defined constraint boundary flows
- Load levels

MISO RC receives alarms when Real-Time SCADA voltages are beyond the limit as maintained by MISO or when the flowgate flows are 95% and 100% of their limits. For voltage monitoring, MISO utilizes four different alarming setpoints:

- Low Voltage Normal Alarm
- High Voltage Normal Alarm
- Low Voltage Emergency Alarm
- High Voltage Emergency Alarm

3.1.3 Actions Taken

3.1.3.1 Normal Alarm Action

To alert the RC that system parameters are moving outside designated limits, each monitored parameter has a normal alarm. If a normal alarm is received, the RC will assess the implications of the alarm especially with regard to the SOL methodology, reassess the system to determine if any security violation exists and decide if any action is required to maintain system security.

If MISO's RC determines that an action is required to restore system conditions to expected or anticipated levels, the RC in conjunction with the TOP may take the following actions:

- Check validity of alarm and make sure that alarm is not caused by bad measurement from the RTU (Remote Terminal Unit)
- Request/instruct TOP to switch reactors or capacitors as appropriate
- Implement guidance outlined in an operating guide (if available).
- Switch in / out of service circuits used for voltage control
- Request/direct nearby generators to return to voltage schedule, where applicable, or instruct to increase/decrease reactive output
- Manually adjust tap setting on LTC transformers
- Adjust reactive output from dynamic reactive resources such as SVC-Statcom, Synchronous Condensers, etc.

3.1.3.2 Emergency Alarm Action

Each monitored parameter has an Emergency alarm to alert the RC when system parameters have moved outside designated limits.

If an Emergency alarm is received, the RC reassesses the system to determine if any System Operating Limits are violated and decides if any action is required to re-secure the system.

In addition to the above actions available for "Normal Alarm Action," some options that may be available to the MISO RC and the TOP include (but are not limited to):

- Initiate congestion management if proxy flowgate is determined to be effective in managing voltages in the area.
- Commit on-line additional generation for voltage support in the affected area
- Curtail interruptible and/or firm load in the affected area
- Issue MISO alerts when necessary as stated in the MISO Emergency Operating Procedures.

3.2 Real-Time Voltage Contingency Analysis

3.2.1 Assessment Method

The primary method of assessing post contingency situation is by the usage of MISO RTCA. MISO RTCA utilizes data from the MISO SE (RTNET) and performs a full AC contingency analysis.

The RTNET results are used as the base case for the RTCA. The RTCA is then used to determine the secure feasibility of the existing power system if components are removed from operation. Both real and reactive power flow and bus voltage violations are determined.

Any voltage violations that do not have an associated operating guide will be investigated further and an emergency operating guide will be developed when necessary. The currently available operating guides are posted under a password-protected RA page(https://misoenergy.org/extranet/reliability-authority/reliability-coordination/operating-guides/).

The RTCA is used with the following assumptions and parameters*:

- Allow unit MVAR to adjust post contingency
- Not allow capacitor/reactor switching post contingency
- Not allow transformer tap change post contingency
- Not allow phase shifter tap change post contingency
- Respect unit reactive capability as modeled in MISO EMS model.

*MISO's RTCA is configured with the assumptions and parameters as outlined here, however in some cases MISO may define contingencies to simulate the effect of actions other than as listed here.

3.2.2 Real-Time Voltage Contingency Monitoring

MISO utilizes the RTCA tool to monitor potential post contingency emergency voltage violations beyond the limits maintained by MISO.

3.2.3 Actions Taken

If the RTCA indicates a potential post contingency emergency voltage violation, the Reliability Coordinator will evaluate the condition against the SOL methodology and may take any of the following actions as appropriate:

- Check validity of alarm and make sure that alarm is not caused by bad measurement from the RTU (Remote Terminal Unit)
- Request/instruct TOP to switch reactors or capacitors as appropriate
- Implement guidance outlined in an operating guide (if available).
- Switch in / out of service circuits used for voltage control
- Request/instruct nearby generators to adjust voltage schedule, where applicable, or instruct to increase/decrease reactive output
- Manually adjust tap setting on Load Tap Changer (LTC) transformers
- Adjust reactive output from dynamic reactive resources such as Static VAR Compensators (SVC-Statcom), Synchronous Condensers, etc.
- Initiate congestion management if proxy flowgate has been proven to be effective in managing voltages in the area.
- Develop, in conjunction with the TOP, a post-contingent action plan to remedy the potential violation within the TOPs criteria.

Note: The following actions are only taken if system condition warrants and proved to be effective to mitigate system emergency

- Commit and/or manually redispatch additional generation for voltage support in the affected area
- Issue MISO EOP alerts when necessary as stated in the MISO EOP
- Curtail interruptible and/or firm load in the affected area.

3.3 Real-Time P-V Analysis

3.3.1 Assessment Method

MISO performs routine voltage assessment of specific areas using P-V analysis with a snapshot of the state estimator solution. These real-time studies are performed to determine the operating limit for the proxy voltage stability flowgate. The P-V analysis involves subjecting the real-time snapshot to a series of incremental transfers from a pre-defined source area to a pre-defined sink area. At each transfer level contingency analysis is performed for a subset of contingencies that are most limiting for the area. Voltages and line flows are monitored for various locations in the

study area. The limit is determined by the final operating point at which the powerflow case solves for base and contingency conditions.

A margin is applied to the calculated limit to establish an operating margin for use in real-time operations. By default this margin is 5% or 50MW (whichever is greater), unless otherwise agreed to by the impacted TOPs.

3.3.2 Monitoring

In Real-Time Operations the Real-Time voltage security analysis is automatically executed on an interval determined by MISO Operations and results are posted in the monitoring tools for use by the operators. These tools display the calculated limit and the actual line flows and provide visual indicators when the flows are above 90% of the limit and above 100% of the limit.

3.3.3 Actions Taken

If the flow is expected to exceed the calculated stability limit, the RC will assess the limit against the SOL methodology and implement steps necessary to mitigate the condition including, but not limited, to the following actions:

- Verify the limits and confirm with Real-Time powerflow studies
- Bind on the voltage stability flowgate at the confirmed stability limit
- Commit and/or manually redispatch additional generation for voltage support in the affected area

3.4 Real-Time Reactive Reserve Analysis

Real-Time Reactive Reserve Calculation

To ensure system voltages and reactive power remain within the guidelines, static and dynamic reactive reserves are used. These reactive reserve levels are calculated for predefined constraint boundaries by taking the sum of Reactive capability (QMAX) minus reactive output (QGEN) for each on-line unit and comparing to defined reserve margins.

Static Reactive Reserves

Static Reactive reserves are required to ensure voltages are maintained within the voltage limits maintained by MISO. These reserves can be held on most reactive equipment devices, but will be mainly held on static devices such as capacitor banks.

Dynamic Reactive Reserves

Dynamic Reactive reserves are required to ensure there is enough reactive power located in or near the affected area to keep the voltage profile within the required post contingent voltage standard. This will help avoid voltage collapse and minimize voltage step change. These reserves are usually held in dynamic devices such as generating units and other dynamic reactive resources such as Static VAR Compensators (SVC or statcoms), synchronous condensers, etc.

3.4.1 Monitoring

Attention must be given to reactive power shortages since these can lead to voltage instability or voltage collapse. Reactive power shortages in Real-Time operations must then be dealt with guidance from the RC. The RC will receive indications when the Real-Time dynamic reactive reserves are declining to unacceptable levels. The normal alarm will be set when the Real-Time dynamic reactive reserve is 10 percent above the required reactive reserve level and the emergency alarm will be set when the Real-Time dynamic reactive reserve has reached the required reactive reserve level. The RC will assess the effect of the degradation in reactive reserves and take the appropriate actions to secure the system.

3.4.2 Actions Taken

In areas where reactive reserve requirements are specified, operating guides provide detailed actions to restore the needed reactive reserves and restore system to a secure operating point. These actions may include the following:

- Placing capacitor banks in service
- Binding on the appropriate voltage stability interfaces
- Committing peaking units
- Curtailment of scheduled transactions
- Local Transmission Emergency
    - Utilizing emergency range of generation in the deficient area
- Curtailing interruptible load
- Shedding firm load

4. Day-Ahead Security Planning

MISO completes a security assessment for the next-day using projected peak loads with the scheduled transfers and expected generation pattern. MISO also performs an AC contingency analysis on the Next Day Security Analysis model.

5. Week-Ahead Security Planning

MISO performs outage coordination as stated in MISO BPM-008 Outage Operations. In regards to Voltage and Reactive power management, MISO outage coordination process includes, but is not limited to:

- Pre- and post-contingency voltage assessment for predefined critical outages
- P-V Analysis for predefined critical outages
- Reactive Reserve Calculation for predefined critical outages

6. Voltage Control Coordination

6.1 Coordination Objectives

Conflicting voltage levels and targets on neighboring systems can cause operational issues. The majority of these issues can be resolved by improving the coordination of the voltage schedules between the neighboring TOPs.

The ultimate aim of a coordinated policy is to understand discrepancies between different policies/criteria between TOPs, discuss the relative issues, and develop a coordinated policy that fulfills the objectives outlined below.

These objectives are to:

- Improve overall system security
- Improve dynamic / static reactive reserves
- Improve utilization of reactive resources
- Reduce reactive flows between neighboring TOPs
- Reduce system costs
- Reduce reactive equipment switching
- Minimize potential for ‘hunting’

6.2 Identifying Coordination Issues

To pinpoint specific areas where there are coordination issues within and around the MISO footprint is a complex task. However, if problems are experienced by a TOP, they could be used as the starting point for any coordination investigations by MISO.

6.3 Resolving Issues

To resolve the voltage coordination issues, MISO must first understand the reasons behind them. To do this, MISO would need the following information from the adjoining TOPs:

- Target voltages for each generation bus
- Target voltages for each bus/sub-system
- Switching schedule for reactive equipment
- MVAR reserve policy (e.g. what equipment MVAR reserves are held on, how much, time of day changes, etc.)
- Any current coordination issues with adjoining TOPs

6.4 Determining Resolution

Initially MISO will need to analyze the following:

- Changes to the target voltage schedule (generators, capacitor) required to meet the objectives outlined above
- Effect of a change in policy on the TOP
- Effect on any investment requirements
- Effect of change on reactive losses

The information determined by this analysis will form part of the discussion into the change in voltage control policy between MISO and TOPs.

7. MISO Voltage Criteria and Alarming

MISO established standard operating voltage criteria for the MISO footprint. MISO voltage criteria will be utilized in the absence of regional voltage criteria supplied by the TOP. TOPs may request MISO to monitor different voltage criteria. This voltage criteria is used in outage coordination, operational planning, and real time operation studies. MISO will review the voltage criteria with the TOPs yearly, or as needed, to ensure voltage limits in this document are accurate.

The location of MISO Voltage Criteria and Alarming information is located on the MISO Extranet at Reliability Authority /Reliability Coordination/Reliability Operating Procedures /RTO Voltage Criteria and Alarming. Nuclear Plant Operating Agreements (NPOAs) and/or Nuclear Plant Interface Requirements (NPIRs) govern applicable nuclear plant voltage limits. MISO has NPOA and NPIRs on file and will not disclose nuclear plant voltage limits in this protected distribution. Members should reference the individual NPOAs and NPIRs as appropriate for specific nuclear plant voltage limits.

MISO configures its EMS Supervisory Control and Data Acquisition (SCADA) Alarming and Real Time Network Analysis (RTNET) applications with the limits for High Normal, Low Normal, High Emergency, and Low Emergency. The MISO Real Time Contingency Analysis (RTCA) application utilizes the limit for High Emergency and Low Emergency. In the event a TOP does not supply regional voltage criteria for their area, the MISO established voltage criteria, listed in the attached chart, will be used by default.

System	Facility	High Normal kV/p.u.	Low Normal kV/p.u.	High Emergency kV/p.u.	Low Emergency kV/p.u.
MISO	765 kV buses	818.55/1.07	765/1.00	841.5/1.10	688.5/0.90
MISO	500 kV buses	535/1.07	500/1.00	550/1.10	450/0.90
MISO	345 kV buses	362.25/1.05	327.75/0.95	379.5/1.10	310.5/0.90
MISO	230 kV buses	241.5/1.05	218.5/0.95	253/1.10	207/0.90
MISO	220 kV buses	231/1.05	209/0.95	242/1.10	198/0.90
MISO	161 kV buses	169.05/1.05	152.95/0.95	177.1/1.10	144.9/0.90
MISO	138 kV buses	144.9/1.05	131.1/0.95	151.8/1.10	124.2/0.90
MISO	120 kV buses	126/1.05	114/0.95	132/1.10	108/0.90
MISO	115 kV buses	120.75/1.05	109.25/0.95	126.5/1.10	103.5/0.90
MISO	110 kV buses	115.5/1.05	104.5/0.95	121/1.10	99/0.90