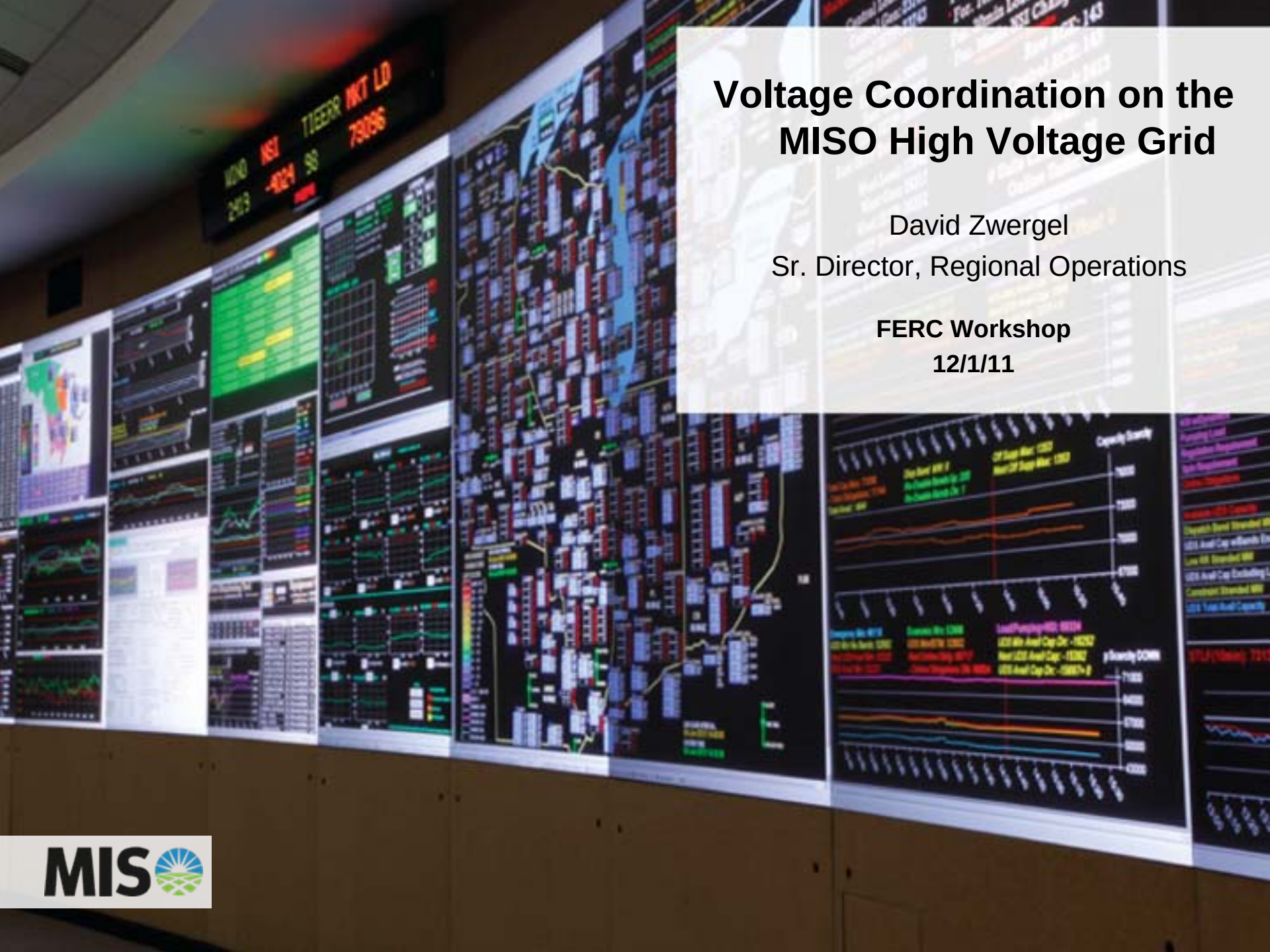

Voltage Coordination on the MISO High Voltage Grid

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Outline

- Voltage Coordination between MISO, TOPs and GOPs
- Reliability Coordinator (RC) Responsibilities
- Transmission Operator (TOP) Responsibilities
- Generation Operator (GOP) Responsibilities
- MISO Processes for Voltage Assessments
- MISO Processes for Voltage Control
- Economic Issues Related to Voltage Control

RC and TOP Coordination

- **MISO RC collaborates with the TOPs and GOPs to monitor voltages and manage voltage control devices and reactive resources to maintain proper voltage.**
  - RC's main responsibility is to monitor and manage pre and post-contingency voltage and reactive power; adjust transfers, generation re-dispatch and commitment; mitigate system emergencies; and perform forward operational planning processes.
  - TOPs' primary responsibility is to monitor, analyze, and control voltage and reactive power flows as stated in NERC Standard VAR-001. TOPs are also responsible for complying with NERC Standards TOP-001 through TOP-008 pertaining to Voltage and Reactive Power in order to protect equipment and maintain a reliable system interconnection.
  - GOPs' primary responsibility is to provide voltage and reactive power flow control as required by NERC Standard VAR-002, as well as VAR-002 and TOP-001 through TOP-008 as related to the GOP.

RC Responsibilities

- **Monitoring and managing pre contingency voltage and reactive power.**
- **Monitoring post contingency voltage and appropriately managing/planning for post contingency issues.**
- **Managing constraints by adjusting transfers, generation re-dispatch and generation commitment.**
- **Mitigating system emergencies.**
- **Performing forward operational planning processes including but not limited to:**
  - Outage coordination.
  - Create operating guides with adjacent RC/TOP pertinent to boundary areas where additional focus and direction is needed.
  - Coordinate voltage and reactive power operating guides with adjacent RC/TOP boundary areas.

MISO

TOP Responsibilities

- **Define acceptable voltage levels, reactive power criteria, and generator voltage schedules within its boundaries.**
- **Coordinate voltage and reactive power with other TOPs to ensure optimum and reliable operation.**
- **Monitor voltage levels on transmission facilities and take corrective actions including the use of static devices (caps, reactors, transformer taps, SVCs etc.)**
- **Request assistance from RC when simple corrective actions are not sufficient, or when assistance across the RC border is needed.**
- **Follow reliability directives of the RC to maintain reliable system conditions, and notify RC of outages of reactive devices.**
- **Direct GOPs within its boundary when requesting generation of real or reactive power to manage voltage.**
- **Coordinates reactive power needs with the Distribution Providers connected to their system.**

GOP Responsibilities

- **Provide reactive power supply and voltage control from generation resources and respond to TOP requested changes.**
- **Operate and maintain within the TOP defined voltage schedule.**
- **Operate the Automatic Voltage Regulators (AVRs)**
- **Submit AVR status changes for online units to the RC and TOP.**
- **Communicate to RC and TOP changes in unit reactive capability.**

Processes for Voltage Assessments

Coordinated Seasonal Assessments

•MISO performs a summer and winter seasonal assessment based on projected loads, outages, and expected dispatch.

- Full AC analysis performed to identify any expected voltage issues or possible IROL conditions.
- Multiple predefined transfer scenarios performed to identify any voltage issues or new possible IROLs.
- P-V Analysis using VSAT (Voltage Stability Analysis Tool) performed on all identified voltage stability interfaces.
- Large Load Area Analysis performed on select metropolitan areas
  - VSAT produces P-V (Power vs. Voltage) and Q-V (Reactive vs. Voltage) curves for the large load areas.
  - Determines maximum import capability in area.
  - Indicates available actions to prevent system cascades or voltage instability for multiple contingency conditions.
  - Determines adequacy of operating and reactive power resources for area.

Voltage Assessments Processes

Week-Ahead Security Planning

•MISO performs outage coordination studies; process includes but not limited to:

- Pre and post contingency voltage assessment for predefined critical outages.
- P-V Analysis done using VSAT on predefined voltage stability interfaces.
- Reactive Reserve Calculation for predefined areas.

Day-Ahead Security Planning

•MISO completes a security assessment for the next-day using projected peak conditions. Additional forward looking analysis is performed using early morning off-peak load and morning-peak load conditions. Analysis includes:

- Offline P-V Analysis (VSAT)
- Offline Reactive Reserve Calculation

Voltage Assessment Processes (cont.)

Real Time Voltage Assessment

- **In Real Time MISO RC will monitor:**
  - Voltages through SCADA voltage alarms and/or RTNET voltage results. Voltages compared to TOP defined voltage limits.
  - Circuit flows and bus voltages
  - Predefined constraint boundary flows
  - Load levels
- **RC monitors Real Time Contingency Analysis (RTCA)**
  - RTCA utilizes data from state estimator (RTNET) and performs AC contingency analysis
  - RTCA determines both real and reactive power flow and bus voltages violations.
  - RC will monitor and take corrective action to prevent potential post-contingency voltage violations as determined by RTCA.

Voltage Assessment Processes (cont.)

Real Time Voltage Assessment

- **Real Time P-V Analysis (VSAT)**
  - MISO performs routine voltage assessments of specific areas using P-V analysis on a real time state estimator solution.
  - Analysis performed every 15 minutes on 5 different interfaces
  - Results posted on secure MISO reliability website for TOP review.
- **Real Time Reactive Reserve Analysis**
  - Reactive reserve levels are calculated for predefined areas.
  - Generator reactive power output is monitored based on generator capabilities, and RC is alarmed when specific generator reserves are depleted.

Processes for Voltage Control

Multi-Day Forward Reliability Assessment Commitment (FRAC)

•MISO performs multi-day FRAC studies to ensure generation needs are met for capacity as well as thermal and voltage constraints.

- FRAC study is a DC solution.
- Thermal proxies are used to represent voltage stability interfaces
- Constraints and voltage stability limits are based on Outage Coordination studies.

•Outage Coordination studies also identify voltage issues for local areas through their AC analysis and provide needed generation requirements to mitigate the issues in operating guides to FRAC.

- TOP is involved in identifying the voltage issue and the steps needed to correct the issue through the development of an operating guide.

•Generation commitments will be made in this process if the generation startup times are longer than 24 hours and therefore cannot be committed in later processes. Generation commitments will address:

- Capacity needs
- Voltage stability interface limits and thermal limits
- Local voltage support issues

Voltage Control Processes (cont.)

Day-Ahead (DA) Market

•MISO DA Market uses simultaneously co-optimized Security Constrained Unit Commitment (SCUC) and Security Constrained Economic Dispatch (SCED) algorithms to clear and dispatch energy and operating reserves based on predefined constraints. It may also detect additional thermal constraints through Simultaneous Feasibility Test (SFT).

- Algorithms use a DC solution.
- Voltage stability issues are represented in DA as predefined thermal proxies.
- Local voltage issues are controlled using a thermal proxy if one can be identified.
- Voltage stability and local voltage constraints are determined by Outage Coordination and Next-Day Security Analysis studies.

•DA commits necessary generation to meet the load bid into the market and identified constraints from an economic perspective.

- Generation re-dispatch and additional unit commitments will occur for a pre-defined thermal proxy for a local voltage issue.

Voltage Control Processes (cont.)

Forward Reliability Assessment Commitment (FRAC)

•Following the clearing of the DA Market, MISO performs another FRAC study using a DC solution. Based on forecasted load and scheduled interchange transactions, MISO commits additional generation to meet capacity needs and relieve transmission constraints.

•FRAC committed generation for voltage constraints is determined by:

- SCUC and SCED determining an economic need to mitigate voltage stability issues represented as thermal proxies.
- Manual commitment by operator to address a reliability need as specified in operating guides to mitigate local issues.

Intra-Day Reliability Assessment Commitment (IRAC)

•Periodically throughout the operating day, additional IRAC studies are performed to ensure enough generation is online to meet capacity, voltage stability constraints and thermal constraints needs.

•IRAC studies will address changes in the system since the FRAC study.

Voltage Control Processes (cont.)

Real Time Operations

•Reliability Coordinator will monitor the system for any voltage constraints or reactive power needs and take preventative and corrective control actions. General control options:

- Work with TOP to take zero cost actions by modifying static reactive devices (caps, reactors, LTCs, etc.) and generator reactive power output. Goal is to maximize the use of static devices to free up dynamic reserves on generators.
- Re-dispatch generation using a thermal proxy in Real Time SCED algorithm. Moving real power to reduce regional transfers and reduce real power imports in load pockets.
- Commit generation to provide dynamic reactive support, and real power support to reduce real power imports.
- Utilize emergency procedures up to and including the use of demand response resources and load reductions to correct voltage issues.

Economic Issues Related to Voltage Control

- MISO Market is designed to meet real power demand and control thermal constraints.
- MISO does not directly perform a security constrained economic dispatch of reactive power of resources. Reactive resources are committed and dispatched to reliably maintain security constrained economic dispatch of real power.
- Thermal proxies or flowgates are use to represent voltage stability issues caused by regional transfers. These voltage stability flowgates work well to maintain reliable and efficient operations in the market.
- Thermal proxies or flowgates do not work as well for local voltage issues.
- Local voltage constraints will typically be mitigated by commitment of additional resources with the result of voltage constraints being completely cleared.
- With the voltage constraint cleared, committed generation for voltage control purpose does not receive an economic signal (constraint is not bound in market).

Other Comments

- MISO continues to compensate Resources that provide Reactive Supply and Voltage Control under a cost-of-service construct under Schedule 2 of our Energy and Operating Reserves Markets Tariff
- MISO's Schedule 2 does not discriminate against compensating independent generators
- MISO has not developed and is not actively developing a market rules for procurement, scheduling, compensation, consumption and pricing of reactive power.
- MISO has developed proposals and is in the process of filing improvements to its markets to:
  - Establish tighter mitigation thresholds for Resources committed to address Voltage and Local Reliability issues
  - Allocate Revenue Sufficiency Guarantee Make-Whole Payment Uplift Costs associated with Voltage and Local Reliability Commitments to those who benefit from incurring those costs