EXHIBIT 1

MISO WINTERIZATION GUIDELINES

MISO WINTERIZATION GUIDELINES

UPDATED 10/23/2018

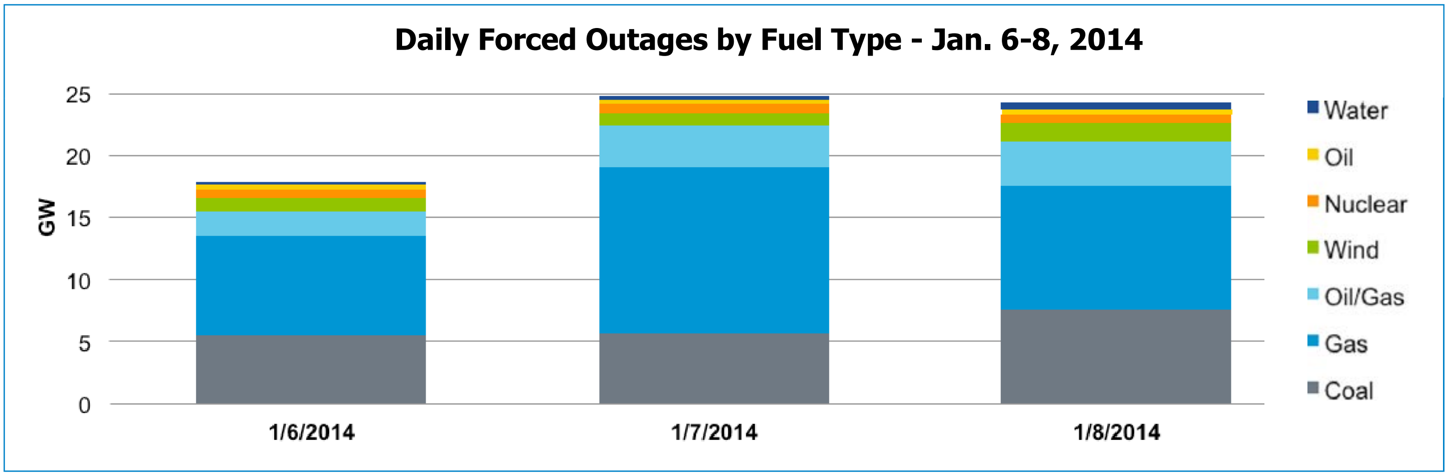
MISO

MISOENERGY.ORG

I. Introduction

Extreme winter conditions can contribute to significant losses of electric generation through a variety of factors. Cold temperatures can freeze equipment for various types of electric generators. Frozen transportation equipment and facilities can inhibit MISO generators from obtaining fuel.

The "Polar Vortex" event of 2014 culminated in an all-time MISO winter peak of over 109,000 MW. During this time, up to approximately 25,000 MW/day of capacity, not including derates, was forced offline due to weather related outages. These types of "forced outages," are not uncommon during extreme winter events where frigid temperatures can impact the operability of electric generators of all technology and fuel types. Coal generators took outages and capacity derates due to mechanical failures and fuel issues, such wet or frozen coal. Wind capacity also decreased with heavy snowfall and turbine icing. The facilities that were most impacted by the severe weather were natural gas units. Up to approximately 17,000 MW/day of gas-fired capacity (Gas and Oil/Gas classifications), was forced offline due to weather-related transportation restrictions, fuel line freezing, and other mechanical issues.



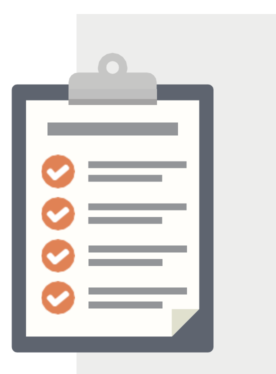
Source: 2013-2014 MISO Cold Weather Operations Report, MISO, November 2014

II. MISO Winterization General Guidelines

A. Evaluation of Potential Problem Areas

MISO believes that plant operations personnel should evaluate all equipment that has the potential to do the following:

1) Initiate an automatic unit trip
2) Impact unit start-up
3) Cause damage to the unit
4) Adversely affect environmental controls that could cause full or partial outages
5) Adversely affect the delivery of fuel or water to the units
6) Create a weather related safety hazard



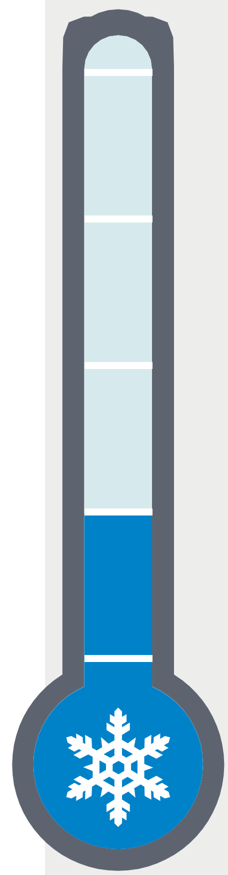
B. Detailed and Tested Winterization Plan

Power plant operators should create and have on hand a detailed winterization plan that covers preparations and procedures for freezing conditions. Weatherization arrangements should be developed by MISO generator operators for plant personnel to complete ahead of frigid weather conditions. In addition to pre-winter preparations, plant personnel training should be conducted well before winter begins. Lastly, weatherization equipment, such as heat trace systems, should be tested regularly ahead of winter.

C. Critical Instrument and Equipment Protection

Generator operators should evaluate and test secondary fuel capabilities (such as heating oil) ahead of winter operations. They should also ensure that all critical site specific problem areas have adequate protection to ensure operability during a severe winter weather event. Some examples of weatherization protection measures are as follows:

1) **Heat Trace**
    - i. Heat trace elements should be well insulated and correctly installed on power plant equipment in order to keep stations from freezing.
    - ii. Wiring on heat trace panels should be inspected and maintained to prevent deterioration and inoperability.
2) **Wind Break**
    - i. Temporary wind walls must be appropriately installed in order to disallow cold air to flow into plant.
    - ii. Additional protection on plant scaffolding floors can prevent a tunneling affect that could freeze equipment.
3) **Insulation**
    - i. Insulation must be inspected for holes and maintained in order to keep equipment from freezing.
    - ii. Properly installed and insulated weather barriers can prevent entry of cold air into plant.
4) **Instrument Cabinet Heaters and Insulation**
    - i. Heat instrument cabinets should be insulated and warmed with acceptable devices (e.g. 60 watt bulb).
5) **Freeze Protection Equipment**
    - i. Freeze protection equipment, such as temporary heaters, should be onsite and adequately tested ahead of extreme cold weather events.



D. Fuel Availability Considerations

MISO market participants are responsible to ensure fuel availability and deliverability to their generators. For coal units, plant operators should ensure that the onsite coal pile is kept from freezing during times of frigid temperatures. In addition, in advance of winter conditions, coal generators should confirm that the fuel supply is adequate and transportation is reliable.

For natural gas generators, market participants should review their individual transportation contracts to ensure that they have satisfactory means in which to deliver their fuel. These contractual characteristics include transportation firmness, storage rights, and gas services, such as no-notice and non-ratable agreements. In addition to primary fuel, natural gas units who hold dual fuel, most notably oil backup, should confirm that the plant has suitable backup fuel onsite and should ensure that the alternative fuel can successfully run the generator, through testing or other means.

E. NERC Reliability Guidelines and Procedures for Winterization

MISO advises generator operators to utilize NERC's winter generator reliability guidelines when preparing for and operating in severe cold weather conditions. These attached guidelines and procedures, titled *NERC Reliability Guideline – Generating Unit Winter Weather Readiness – Current Industry Practices and Elements of a Winter Weather Preparation Procedure Version 2* (Attachments 1 and 2), can be applied by plant operators to prepare units for winter operations. MISO understands that these NERC guidelines may be updated or revised from time to time and advises generator operators to follow the most up to date guidelines. These can be found in the below resources hyperlink under *NERC Reliability Guidelines*.

Resources

1. **NERC Winter Preparedness**

   https://www.nerc.com/pa/rrm/ea/Pages/Cold-Weather-Training-Materials.aspx

2. **NERC Reliability Guidelines**

   http://www.nerc.com/comm/OC/Pages/Reliability-Guidelines.aspx

3. **Reliability First Cold Weather Preparedness – Plant Winterization Visits ReliabilityFirst & Texas RE Lessons Learned, Best Practices & Recommendations**
   https://www.rfirst.org/KnowledgeCenter/Risk%20Analysis/ColdWeather/Pages/ColdWeather.aspx

4. **2013-2014 MISO Cold Weather Operations Report**

   https://cdn.misoenergy.org/2013-2014%20Cold%20Weather%20Operations%20Report103558.pdf

ATTACHMENT I

NERC RELIABILITY GUIDELINE

GENERATING UNIT WINTER WEATHER READINESS – CURRENT INDUSTRY PRACTICES
Version 2

I.	II.	III.	IV.	V.	VI.	VII.
Safety	Management Roles and Expectations	Processes and Procedures	Evaluation of Potential Problem Areas	Testing	Training	Winter Event Communications

Preamble:

The NERC Operating Committee (OC), Planning Committee (PC) and Critical Infrastructure Protection Committee (CIPC) develop Reliability (OC and PC) and Security (CIPC) Guidelines, which include the collective experience, expertise and judgment of the industry. The objective of the reliability guidelines is to distribute key practices and information on specific issues critical to promote and maintain a highly reliable and secure bulk power system (BPS). Reliability guidelines are not binding norms or parameters to the level that compliance to NERC's Reliability Standards are monitored or enforced. Rather, their incorporation into industry practices is strictly voluntary. Reviewing, revising, or developing a program using these practices is highly encouraged.

Purpose:

This reliability guideline is applicable to electricity sector organizations responsible for the operation of the BPS. Although this guideline was developed as a result of an unusual cold weather event in an area not normally exposed to freezing temperatures, it provides a general framework for developing an effective winter weather readiness program for generating units throughout North America. The focus is on maintaining individual unit reliability and preventing future cold weather related events. This document is a collection of industry practices compiled by the NERC OC. While the incorporation of these practices is strictly voluntary, developing a winter weather readiness program using these practices is highly encouraged to promote and achieve the highest levels of reliability for these high impact weather events.

Assumptions:

A. Each BPS Generator Owner (GO) and Generator Operator (GOP) is responsible and accountable for maintaining generating unit reliability.

B. Balancing Authorities (BAs) and Market Operators should consider strategies to start-up and dispatch to minimum load prior to anticipated severe cold weather units that are forecasted to be needed for the surge in demand, since keeping units running through exceptional cold snaps can be accomplished much more reliably than attempting start-up of offline generation during such events. Entities should develop and apply plant-specific winter weather readiness plans, as appropriate, based on factors such as geographical location, technology and plant configuration.

Guideline Details:

An effective winter weather readiness procedure, which includes severe winter weather event preparedness, should generally address the following components: (I) Safety; (II) Management Roles and Expectations; (III) Processes and Procedures; (IV) Evaluation of Potential Problem Areas with Critical Components; (V) Testing; (VI) Training; and (VII) Communications.

I. Safety

Safety remains the top priority during winter weather events. Job safety briefings should be conducted during preparation for and in response to these events. Robust safety programs to reduce risk to personnel include identifying hazards involving cold weather such as personnel exposure risk, travel conditions, and slip/fall issues due to icing. A Job Safety Analysis (JSA) should be completed to address the exposure risks, travel conditions and slips/falls related to icing conditions. Winter weather Alerts should be communicated to all impacted entities. A Business Continuity and Emergency Response Plan should also be available and communicated in the event of a severe winter weather event.

II. Management Roles and Expectations

Management plays an important role in maintaining effective winter weather programs. The management roles and expectations below provide a high-level overview of the core management responsibilities related to winter weather preparation. Each entity should tailor these roles and expectations to fit within their own corporate structure.

A. Senior Management

1) Set expectations for safety, reliability, and operational performance.
2) Ensure that a winter weather preparation procedure exists for each operating location.
3) Consider a fleet-wide annual winter preparation meeting, training exercise, or both to share best practices and lessons learned.
4) Share insights across the fleet and through industry associations (formal groups or other informal networking forums).

B. Plant Management

1) Develop a winter weather preparation procedure and consider appointing a designee responsible for keeping this procedure updated with industry identified best practices and lessons learned.
2) Ensure the site specific winter weather preparation procedure includes processes, staffing plans, and timelines that direct all key activities before, during and after severe winter weather events.
3) Ensure proper execution of the winter weather preparation procedure.
4) Conduct a plant readiness review prior to an anticipated severe winter weather event.
5) Encourage plant staff to look for areas at risk due to winter conditions and bring up opportunities to improve readiness and response.
6) Following each winter, conduct an evaluation of the effectiveness of the winter weather preparation procedure and incorporate lessons learned.

III. Processes and Procedures

A winter weather preparation procedure should be developed for seasonal winter preparedness. Components of an effective winter weather preparation procedure are included as Attachment 1.

After a severe winter weather event, entities should utilize a review process to formally recognize procedural strengths, evaluate improvement opportunities, and identify and incorporate lessons learned within applicable procedures. Changes to the procedure and lessons learned must be communicated to the appropriate personnel.

IV. Evaluation of Potential Problem Areas with Critical Components

Identify and prioritize critical components, systems, and other areas of vulnerability which may experience freezing problems or other cold weather operational issues.

A. This includes critical instrumentation or equipment that has the potential to:

1) Initiate an automatic unit trip,
2) Impact unit start-up,
3) Initiate automatic unit runback schemes or cause partial outages,
4) Cause damage to the unit,
5) Adversely affect environmental controls that could cause full or partial outages,
6) Adversely affect the delivery of fuel or water to the units,
7) Cause operational problems such as slowed or impaired field devices, or
8) Create a weather-related safety hazard

B. Based on previous cold weather events, a list of typical problem areas are identified below. This is not meant to be an all-inclusive list. Individual entities should review their plant design and configuration, identify areas with critical components' potential exposure to the elements, ambient temperatures, or both and tailor their plans to address them accordingly.

1) Critical Level Transmitters

i. Drum level transmitters and sensing lines
ii. Condensate tank level transmitters and sensing lines
iii. De-aerator tank level transmitters and sensing lines
iv. Hot well level transmitters and sensing lines
v. Fuel oil tank level transmitters / indicators

2) Critical Pressure Transmitters

i. Gas turbine combustor pressure transmitters and sensing lines
ii. Feed water pump pressure transmitters and sensing lines
iii. Condensate pump pressure transmitters and sensing lines
iv. Steam pressure transmitters and sensing lines

3) Critical Flow Transmitters

i. Steam flow transmitters and sensing lines
ii. Feed water pump flow transmitters and sensing lines
iii. High pressure steam attemperator flow transmitters and sensing lines

4) Instrument Air System

i. Automatic blow downs, traps, dew point monitoring, and instrument air dryers are functioning correctly.

ii. Low point drain lines are periodically drained by operators to remove moisture during extreme cold weather.

5) Motor-Operated Valves, Valve Positioners, and Solenoid Valves

6) Drain Lines, Steam Vents, and Intake Screens

7) Water Pipes and Fire Suppression Systems[1]

i. Low/no water flow piping systems

8) Fuel Supply and Ash Handling

i. Coal piles and coal handling equipment

ii. Transfer systems for backup fuel supply

iii. Gas supply regulators, other valves and instrumentation (may require coordination with gas pipeline operator)

iv. Ash disposal systems and associated equipment

9) Tank Heaters

i. Conduct initial tests

ii.Check availability of spare heaters

iii. Record current tanks indicators for SBS injection systems, flue gas desulfurization systems, dibasic acid additives, mercury control additives, etc.

C. Potential vulnerabilities associated with emergency generators, including Blackstart Resources, should be evaluated when developing the site specific winter weather preparation procedure as they may provide critical system(s) backup.

V. Testing[2]

In addition to the typical problem areas identified above, emphasis should be placed on the testing of low frequency tasks such as startup of emergency generators, where applicable.

VI. Training

Coordinate annual training in winter specific and plant specific awareness and maintenance training. This may include response to freeze protection panel alarms, troubleshooting and repair of freeze protection circuitry, identification of plant areas most affected by winter conditions, review of special inspections or rounds implemented during severe weather, fuel switching procedures, knowledge of the ambient temperature for which the freeze protection system is designed, and lessons learned from previous experiences or the NERC Lessons Learned program.

A. Consider holding a winter readiness meeting on an annual basis to highlight preparations and expectations for severe cold weather.

B. Operations personnel should review cold weather scenarios affecting instrumentation readings, alarms, and other indications on plant control systems.

C. Ensure appropriate NERC Generation Availability Data Systems (GADS) coding for unit derates or trips as a result of severe winter weather events to promote lessons learned, knowledge retention, and consistency. Examples may include NERC GADS code 9036 “Storms (ice, snow, etc.)” or code 9040 “Other Catastrophe.”

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[1] For safety reasons, fire protection systems should also be included in this identification process. These problem areas should be noted in the site specific winter weather preparation procedure.

[2] ~~See Attachment 2, Section H “Special Operations Instruction” for more information~~

VII. Winter Event Communications

Clear and timely communication is essential to an effective program. Key communication points should include the following:

A. Before a severe winter weather event, plant management should communicate with their appropriate senior management that the site specific winter weather preparation procedure, checklists, and readiness reviews have been completed.

B. Before and during a severe winter weather event, communicate with all personnel about changing conditions and potential areas of concern to heighten awareness around safe and reliable operations.

C. Before and during a severe winter weather event, the affected entity(ies) will keep the BA up to date on changes to plant availability, capacity, or other operating limitations. Depending on regional structure and market design, notification to the Reliability Coordinator (RC) and Transmission Operator (TOP) may also be necessary.

D. After a generating plant trip, derate, or failure to start due to severe winter weather, Plant Management, as appropriate, should conduct an analysis, develop lessons learned, and incorporate good industry practices.

   1) This process should include a feedback loop to enhance current winter weather readiness programs, processes, procedures, checklists and training (continuous improvement).

   2) Sharing of technical information and lessons learned through the NERC Event Analysis Program or some other method is encouraged.

Related Documents and Links:

1. Report on Outages and Curtailments during the Southwest Cold Weather Event of February 1-5, 2011, dated August 2011, Federal Energy Regulatory Commission and North American Electric Reliability Corporation
2. Winter Weather Readiness for Texas Generators, dated April 13, 2011, Calpine, CPS Energy, LCRA, Luminant, and NRG Energy
3. Electric Reliability Organization Event Analysis Process, dated January 2017, ERO Event Analysis Process and associated Lessons Learned
4. Previous Cold Weather Reports

Revision History:

Date	Version	Reason/Comments
12/03/2012	1.0	Initial Version – *Winter Weather Readiness* *(Approved by the Operating Committee March 5, 2013)*
06/05/2017	2.0	Three year document review per the OC Charter *(Approved by the Operating Committee August 23, 2017)*

ATTACHMENT 2

ELEMENTS OF A WINTER WEATHER PREPARATION PROCEDURE

A.	B.	C.	D.	E.	F.	G.	H.
Work Management System	Critical Instrumentation and Equipment Protection	Insulation, Heat Trace, and Other Protection Options	Supplemental Equipment	Operational Supplies	Staffing	Communications	Special Operations Instruction

This Attachment provides some key points to address in each of the winter weather preparation procedure elements, including severe winter weather event preparedness. These are not all inclusive lists. Individual entities should review their plant design and configuration, identify areas of potential exposure to the elements and ambient temperatures, and tailor their plans to address them accordingly.

A. Work Management System

1) Review Work Management System to ensure adequate annual preventative work orders exist for freeze protection, winter weather preparedness, or both.
2) Ensure all freeze protection, winter weather preparedness preventative work orders, or both are completed prior to the onset of the winter season.
3) Review Work Management System for open corrective maintenance items that could affect plant operation and reliability in winter weather and ensure that they are completed prior to the onset of the winter season.
4) As appropriate to your climate, suspend freeze protection measures and remove freeze protection equipment after the last probable freeze of the winter. This may be a plant specific date established by senior management.
5) Ensure all engineered modification and construction activities are performed such that the changes maintain winter readiness for the plant. Newly built plants or engineered modifications can be more susceptible to winter weather.

B. Critical Instrumentation and Equipment Protection

1) Ensure all critical site specific problem areas (as noted above in section III. Evaluation of Potential Problem Areas) have adequate protection to ensure operability during a severe winter weather event. Emphasize the points in the plant where equipment freezing would cause a generating plant trip, derate, or failure to start.
2) Develop a list of critical instruments and transmitters that require increased surveillance during severe winter weather events.

C. Insulation, Heat Trace, and Other Protection Options – Ensure processes and procedures verify adequate protection and necessary functionality (by primary or alternate means) before and during winter weather. Consider the effect of wind chill when applying freeze protection. Considerations include but are not limited to:

1) Insulation thickness, quality and proper installation

i. Verify the integrity of the insulation on critical equipment identified in the winter weather preparation procedure. Following any maintenance, insulation should be re-installed to original specifications.

2) Heat trace capability and electrical continuity/ground faults

i. Perform a complete evaluation of all heat trace lines, heat trace power supplies (including all breakers, fuses, and associated control systems) to ensure they maintain their accuracy. This inspection may include checking for loose connections, broken wires, corrosion, and other damage to the integrity of electrical insulation which could lead to the heat trace malfunctioning. Measure heat trace amperage and voltage, if possible, to determine whether the circuits are producing the design output. If there are areas where heat tracing is not functional, an alternate means of protection should be identified in the winter weather preparation procedure.

ii. Evaluation of heat trace and insulation on critical lines should be performed during new installation, during regular maintenance activities, or if damage or inappropriate installation is identified (i.e., wrapped around the valve and not just across the valve body).

iii. Re-install removed or disturbed heat tracing following any equipment maintenance to restore heat tracing integrity and equipment protection.

iv. Update and maintain all heat tracing circuit drawings and labeling inside cabinets.

3) Wind breaks

i. Install permanent or temporary wind barriers as deemed appropriate to protect critical instrument cabinets, heat tracing and sensing lines.

4) Heaters and Heat Lamps

i. Ensure operation of all permanently mounted and portable heaters.

ii. Evaluate plant electrical circuits to ensure they have enough capacity to handle the additional load. Circuits with Ground Fault Interrupters (GFIs) should be continuously monitored to make sure they have not tripped due to condensation.

iii. Fasten heaters and heat lamps in place to prevent unauthorized relocation.

5) Covers, Enclosures, and Buildings

i. Install a box or enclosure with inside heat for some transmitters.

ii. Install covers on valve actuators to keep the actuator from accumulating ice.

iii. Inspect building penetrations, windows, doors, fan louvers, and other openings for potential exposure of critical equipment to the elements.

D. Supplemental Equipment – Prior to the onset of the winter season, ensure adequate inventories of all commodities, equipment and other supplies that would aid in severe winter weather event preparation or response, and that they are readily available to plant staff. Supplemental equipment might include:

1) Tarps

2) Portable heaters, heat lamps, or both

3) Scaffolding

4) Blankets

5) Extension cords

6) Kerosene/propane

7) Temporary enclosures

8) Temporary insulation

9) Plastic rolls

10) Portable generators

11) Portable lighting

12) Instrumentation tubing

13) Handheld welding torches

14) Ice removal chemicals and equipment

15) Snow removal equipment

16) Cold weather Personal Protective Equipment (PPE) as appropriate to the respective regions

E. Operational Supplies – Prior to the onset of a severe winter weather event, conduct an inventory of critical supplies needed to keep the plant operational. Appropriate deliveries should be scheduled based on the severity of the event, lead times, etc. Operational supplies might include:

1) Aluminum Sulfate

2) Anhydrous Ammonia

3) Aqueous Ammonia

4) Carbon Dioxide

5) Caustic Soda

6) Chlorine

7) Diesel Fuel

8) Ferric Chloride

9) Gasoline (Unleaded)

10) Hydrazine

11) Hydrogen

12) Lighter Oil (#2 Diesel)

13) Sulfuric Acid

14) Calibration Gases

15) Lubricating Oils

16) Welding Supplies

17) Limestone

F. Staffing

1) Consider enhanced staffing (24x7) during severe winter weather events.

2) Arrange for lodging and meals as needed.

3) Arrange for transportation as needed.

4)Arrange for support and appropriate staffing from responsible entity for plant switchyard to ensure minimal line outages.

G. Communications

1) Ensure appropriate communication protocols are followed during a severe winter weather event.
2) identify a back-up communication option in case the primary system is not working (i.e. satellite phone).
3) Ensure communication is discussed as part of the job safety briefing during a severe winter weather event.

H. Special Operations Instruction (just prior to or during a severe winter weather event)

1) Consider employing the "buddy system" during severe winter weather events to promote personnel safety.
2) Institute operator rounds utilizing cold weather checklists to verify critical equipment is protected – i.e. pumps running, heaters operating, igniters tested, barriers in place, temperature gauges checked, etc.
    i. Monitor room temperatures, as required. Instrumentation and equipment in enclosed spaces (e.g. pump rooms) can freeze.
3) Test dual fuel capability and ensure adequate fuel supply (where applicable).
4) Consider pre-warming, early start-up, or both of scheduled units prior to a forecasted severe winter weather event.
5) Run emergency generators immediately prior to severe winter weather events to help ensure availability. Review fuel quality and quantity.
6) Place in service critical equipment such as intake screen wash systems, cooling towers, auxiliary boilers, and fuel handling equipment where freezing weather could adversely impact operations or forced outage recovery.

MISO
WINTERIZATION
GUIDELINES

EXHIBIT 2

MISO OPERATING PROCEDURES

MISO Operating Procedures

MISO's carefully designed operating procedures ensure reliability and predictable outcomes during emergency or abnormal operating situations.

Protecting Reliability

To maintain the reliability of the electric system, MISO operates under a set of carefully designed operating procedures that define system conditions and guide system operator actions in a variety of conditions.

These procedures empower MISO to quickly adjust to system conditions as they unfold. For example, extreme weather patterns or unexpected increases or decreases in available electric generation can affect the balance of supply and demand on the transmission system.

Did you know?

- MISO has never issued a call for rolling brownouts or blackouts, despite some of the hottest summers on record in 2006 and 2012, and record cold during the polar vortex of 2014.
- To maintain reliability, Conservative and Emergency operating conditions require a successive series of remedial actions.
- MISO must implement emergency procedures to use demand management (load modifying) resources. There are more than 9,000 MW of these resources.

Operating Conditions

- **Normal Operations**: MISO's Normal Operating Procedures (NOPs) guide our operation of the bulk electric system and are used during normal grid operations or, in some instances, to prevent an emergency. NOPs mitigate risk, facilitate the reliable and efficient operation of the electric system, and ensure compliance with federal and state regulatory requirements, reliability standards, and MISO's Tariff and contractual agreements.
- **Abnormal Operations**: MISO utilizes Abnormal Operating Procedures (AOPs) for events that deviate from normal but do not put the electric system at risk. Examples include malfunctioning software systems or other infrastructure problems affecting MISO or its members. The procedures help mitigate further risk and may include, but are not limited to, the back-up process used when a particular system fails.
- **Conservative Operations**: If conditions warrant, MISO will carefully transition from normal operating conditions to Conservative Operations to prepare local operating personnel for a potential event, and to prevent a situation or event from deteriorating. During conservative operations, non-critical maintenance of equipment is suspended or in some cases, returned to service. Operating personnel throughout the affected area are also in a higher state of alert. Conservative operation declarations may be initiated due to system conditions including severe weather, hot/cold weather, or geo-magnetic disturbance warning.
- **Emergency Operations**: Emergency Operating Procedures (EOPs) guide system operator actions when an event occurs on the electric system that has the potential to, or actually does, negatively impact system reliability. Emergency Operating Procedures are communicated in escalating order as advisories, alerts, warnings, and events. Advisories are provided for situational awareness of potential limited operating capacity. Alerts define the affected area and call to temporarily suspend generation unit maintenance in the defined area. During warnings, MISO may require external capacity resources to be available, or may curtail non-firm energy sales. MISO issues Max Gen Events due to a shortage of capacity resources. **During Emergency Events, MISO utilizes Emergency Pricing, which affects ex-post pricing, not system commitment or dispatch. Emergency Pricing will only be implemented during Max Gen Warnings, and Events, which may be caused by forced outages, higher than projected load, or other circumstances.**

Reference Documents

Find MISO's Reliability Operating Procedures on the MISO website:

https://www.misoenergy.org/markets-and-operations/reliability-operating-procedures/

General Guide to MISO's Emergency Operations Messaging

MISO's Emergency Operations messages define the area(s) involved, duration, and projections of system conditions. The table below is a summary, and does not replace or redefine MISO's Emergency Operations messages.

Message	Communication Intent	Potential Member/MISO Actions
Conservative Operations Declaration	**Alert for Situational Awareness:** Reliability issue possible for defined area.	• Potentially suspend transmission maintenance • Review outage plans for deferral, cancellation
Hot Weather, Cold Weather or Severe Weather Alert	**Alert for Situational Awareness:** MISO could be approaching tight supply conditions.	• Review outage plans for deferral, cancellation
Capacity Advisory	**Advisory for Situational Awareness**: Potential for limited operating capacity margins (<5%) in the next 2-3 days.	• Update facility and generation outages, including de-rates • Update generation offers • Update Load Forecast Values • Update LMR Availability and Self Scheduled MW values • Update EDR offers
Min Gen Alert	**Alert for Situational Awareness:** MISO is forecasting a potential supply surplus.	• Prepare for de-commitment (taking generation off line), reduction in purchases or other actions
Max Gen Alert	**Alert for Situational Awareness:** MISO is forecasting a potential capacity shortage.	• Declare Conservative System Operations • Prepare for possible Max Gen Event
Max Gen Warning	**Warning to Prepare for Possible Event**	• Curtail non-firm exports • Schedule all available external resources into the MISO Market • Implement Emergency Pricing Offer Tier 1. This is an ex-post pricing change, and does not affect system commitment or dispatch.
Max Gen Event (Step 1)	**Actions Taken to Preserve Operating Reserves:** NERC Emergency Alert 1	• All available resources in use • Generators instructed to start off-line resources. • Use of reserves not yet implemented. • Emergency Pricing Offer Tier 1 is still effective.
Max Gen Event (Steps 2, 3, 4)	**Actions Taken to Preserve Firm Load:** NERC Emergency Alert 2 (Step 3 declaration)	• Implement demand management programs • Utilize Contingency Reserves • Purchase Emergency Energy • Issue Public Appeals • Prepare for possible firm load shed • Implement Emergency Pricing Offer Tier 2. This is an ex-post pricing change, and does not affect system commitment or dispatch.
Max Gen Event (Step 5)	**Event Occurring:** NERC Energy Emergency Alert 3	• Shed firm load • Rolling brownouts or blackouts for defined area • Emergency Offer Tier 2 is still effective.

System Status Levels

MISO also issues color-coded System Status Levels (SSL) based on the severity of the impact to the bulk electric system. For more information, see MISO's Abnormal Operating System Status Levels Procedure, SO-P-AOP-00-203.

Operating Conditions			
SSL 0 **Low - Green**	**SSL Level 1** **Elevated - Yellow**	**SSL Level 2** **High - Orange**	**SSL Level 3** **Severe - Red**
Description: System status is normal. No adverse impacts.	**Description:** Short, minor impact to system, can be quickly remedied. **Examples**: Temporary infrastructure issue.	**Description**: Longer term, major impact to system, cause unknown. **Examples**: Loss of monitoring data or member infrastructure	**Description**: Major impact on MISO's ability to reliably operate system or market. **Examples**: Hardware failure, bomb threat, sabotage, control center evacuation

MISO Operating Procedures

MISO's carefully designed operating procedures ensure reliability and predictable outcomes during emergency or abnormal operating situations.

Protecting Reliability

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- **Abnormal Operations:** MISO utilizes Abnormal Operating Procedures (AOPs) for events that deviate from normal but do not put the electric system at risk. Examples include malfunctioning software systems or other infrastructure problems affecting MISO or its members. The procedures help mitigate further risk and may include, but are not limited to, the back-up process used when a particular system fails.
- **Conservative Operations:** If conditions warrant, MISO will carefully transition from normal operating conditions to Conservative Operations to prepare local operating personnel for a potential event, and to prevent a situation or event from deteriorating. During conservative operations, non-critical maintenance of equipment is suspended or in some cases, returned to service. Operating personnel throughout the affected area are also in a higher state of alert. Conservative operation declarations may be initiated due to system conditions including severe weather, hot/cold weather, or geo-magnetic disturbancewarning.
- **Emergency Operations:** Emergency Operating Procedures (EOPs) guide system operator actions when an event occurs on the electric system that has the potential to, or actually does, negatively impact system reliability. Emergency Operating Procedures are communicated in escalating order as advisories, alerts, warnings, and events. Advisories are provided for situational awareness of potential limited operating capacity. Alerts define the affected area and call to temporarily suspend generation unit maintenance in the defined area. During warnings, MISO may require external capacity resources to be available, or may curtail non-firm energy sales. MISO issues Max Gen Events due to a shortage of capacity resources. **During Emergency Events, MISO utilizes Emergency Pricing, which affects ex-post pricing, not system commitment or dispatch. Emergency Pricing will only be implemented during Max Gen Warnings, and Events, which may be caused by forced outages, higher than projected load, or other circumstances.**

Reference Documents

Find MISO's Reliability Operating Procedures on the MISO website:

https://www.misoenergy.org/markets-and-operations/reliability-operating-procedures/

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MISO Operating Procedures

General Guide to MISO's Emergency Operations Messaging

MISO's Emergency Operations messages define the area(s) involved, duration, and projections of system conditions. The table below is a summary, and does not replace or redefine MISO's Emergency Operations messages.

Message	Communication Intent	Potential Member/MISO Actions
Conservative Operations Declaration	**Alert for Situational Awareness:** Reliability issue possible for defined area.	• Potentially suspend transmission maintenance • Review outage plans for deferral, cancellation
Hot Weather, Cold Weather or Severe Weather Alert	**Alert for Situational Awareness:** MISO could be approaching tight supply conditions.	• Review outage plans for deferral, cancellation
Capacity Advisory	**Advisory for Situational Awareness:** Potential for limited operating capacity margins (<5%) in the next 2-3 days.	• Update facility and generation outages, including de-rates • Update generation offers • Update Load Forecast Values • Update LMR Availability and Self Scheduled MW values • Update EDR offers
Min Gen Alert	**Alert for Situational Awareness:** MISO is forecasting a potential supply surplus.	• Prepare for de-commitment (taking generation off line), reduction in purchases or other actions
Max Gen Alert	**Alert for Situational Awareness:** MISO is forecasting a potential capacity shortage.	• Declare Conservative System Operations • Prepare for possible Max Gen Event
Max Gen Warning	**Warning to Prepare for Possible Event**	• Curtail non-firm exports • Schedule all available external resources into the MISO Market • Implement Emergency Pricing Offer Tier 1. This is an ex-post pricing change, and does not affect system commitment or dispatch.
Max Gen Event (Step 1)	**Actions Taken to Preserve Operating Reserves:** NERC Emergency Alert 1	• All available resources in use • Generators instructed to start off-line resources. • Use of reserves not yet implemented. • Emergency Pricing Offer Tier 1 is still effective.
Max Gen Event (Steps 2, 3, 4)	**Actions Taken to Preserve Firm Load:** NERC Emergency Alert 2 (Step 3 declaration)	• Implement demand management programs • Utilize Contingency Reserves • Purchase Emergency Energy • Issue Public Appeals • Prepare for possible firm load shed • Implement Emergency Pricing Offer Tier 2. This is an ex-post pricing change, and does not affect system commitment or dispatch.
Max Gen Event (Step 5)	**Event Occurring:** NERC Energy Emergency Alert 3	• Shed firm load • Rolling brownouts or blackouts for defined area • Emergency Offer Tier 2 is still effective.

MISO Operating Procedures

System Status Levels

MISO also issues color-coded System Status Levels (SSL) based on the severity of the impact to the bulk electric system. For more information, see MISO's Abnormal Operating System Status Levels Procedure, SO-P-AOP-00-203.

Operating Conditions			
SSL 0 Low - Green	**SSL Level 1 Elevated - Yellow**	**SSL Level 2 High - Orange**	**SSL Level 3 Severe - Red**
Description: System status is normal. No adverse impacts.	**Description:** Short, minor impact to system, can be quickly remedied. **Examples:** Temporary infrastructure issue.	**Description:** Longer term, major impact to system, cause unknown. **Examples:** Loss of monitoring data or member infrastructure	**Description:** Major impact on MISO's ability to reliably operate system or market. **Examples:** Hardware failure, bomb threat, sabotage, control center evacuation

Table 4: Maximum Generation Emergency Overview

Level	MISO Major Actions	Stakeholder Major Actions
Event Step 1a	Commit AME resources	As directed by MISO, LBAs/GOPs/MPs start AME Resources
Event Step 1b/EEA1	Declare EEA1	MPs review Offers and ensure all available Emergency ranges and Resources are offered
	Activate Emergency Maximum Limits	
Event Step 2a/EEA2	Declare EEA2	
	Implement Emergency pricing - Tier 2	
	Instruct Load to be reduced via LMMs - Stage 1 and LMRs	As directed by MISO, LBAs reduce load via LMM - Stage 1
	Implement LMRs	MPs implement LMRs via MCS-LMR Tool
Event Step 2b	Commit EDR Resources	As directed by MISO, MPs commit EDRs
Event Step 2c	Implement Emergency energy purchases	LBAs issue public appeals to reduce demand per internal procedures and OE-417 filings
	Instruct LBAs to issue Public Appeals	
		LBAs in defined Event area shall prepare to shed Load
Event Step 3a	Notify affected GOPs with Generator de-rates to request waivers	Affected GOPs dispatch de-rated Generators with waivers from government regulations
	Implement spinning and supplemental reserves	
Event Step 3b	Elevate identified Priority 6-NN tags	
	Instruct Load to be reduced via LMMs - Stage 2	Affected LBAs reduce load via LMM - Stage 2
Event Step 4a	Implement Reserve Call from CRSG	MPs review Offers and ensure all available Emergency ranges and Resources are offered
Event Step 4b	Implement Emergency energy purchases from neighboring BAs (Operating Reserves)	
Event Step 5/EEA3	Declare EEA3	
	Issue Emergency Operating Instruction to shed load	LBAs shed load per MISO and confirm action via MCS Load Shed Tool
	Set LMPs and MCPs to the VOLL	LBAs review OE-417 filing requirements

THE FEBRUARY ARCTIC EVENT

FEBRUARY 14-18, 2021






EVENT DETAILS, LESSONS LEARNED AND
IMPLICATONS FOR MISO's RELIABILITY IMPERATIVE

misoenergy.org

THE FEBRUARY ARCTIC EVENT

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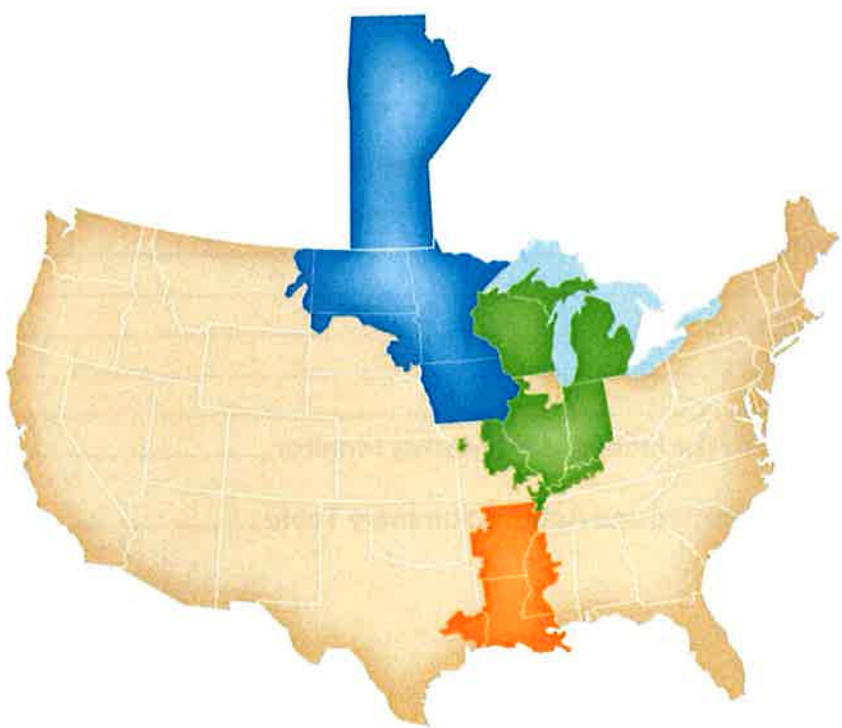
About MISO

MISO is a 501(c)(4) not-for-profit social welfare organization, approved by FERC in 2001, with responsibility for ensuring the reliability of the high-voltage electric transmission system and facilitating the delivery of lowest-cost energy to consumers. The system that MISO manages is the largest in North America in terms of geographical scope, with 471 market participants serving about 42 million people across all or parts of 15 states and one Canadian province, stretching from Canada to the Gulf of Mexico. Our energy markets are also among the largest in the world, with more than $22 billion in annual gross market charges.

Currently, the MISO region contains almost 66,000 miles of high-voltage transmission, as well as nearly 199,000 megawatts of electricity generating capacity. MISO does not own any of these assets. Instead, with the consent of our asset-owning members and in accordance with our FERC-approved tariff, MISO exercises functional control over the region's transmission and generation resources with the aim of managing them in the most reliable and cost-effective manner possible. The MISO region is predominantly comprised of traditionally structured and state-regulated utilities.



Executive Summary

Introduction

MISO strives to be the most reliable, value creating Regional Transmission Organization. As such, MISO is committed to using all of the planning, market, and operational tools at our disposal to keep the grid reliable today while creating transparency towards future needs and maintaining and enhancing reliability. The collaborative work with our stakeholders gives us confidence that we will collectively continue to ensure reliability of the Bulk Electric System.

Like much of the energy industry, MISO faces a rapidly evolving grid. At the same time the resource mix is rapidly shifting away from dispatchable thermal units and increasingly toward variable resources such as renewables and Distributed Energy Resources (DERs) and the growth of electric vehicles and other sources of load is putting extra demand on the system. MISO is actively working on preparing the region for this resource portfolio change. Weather events have also been and continue to be an important element of ensuring reliability.

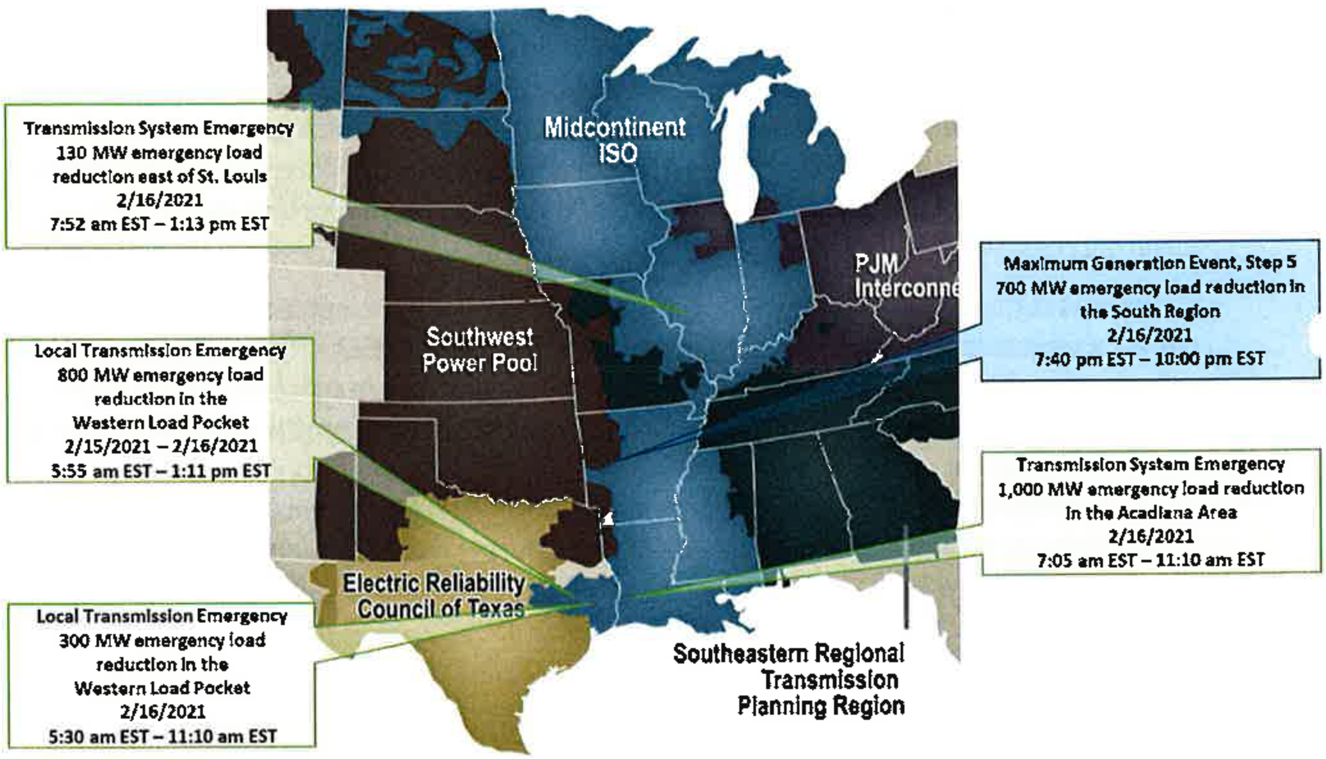
Extreme weather events like the February 2021 cold weather emphasize not only the necessary steps but the urgency with which we must move. MISO's Reliability Imperative – the actions that we are taking to ensure the current and future reliability of the grid – focuses on preparing the region for a future with a different risk profile stemming from a high penetration of renewables. The Reliability Imperative work is looking at enhancements to planning, markets, operations, and systems; changes that will also be needed to maintain reliability of the MISO region during more frequent extreme weather events in the future.

Arctic Event

During the week of February 15, 2021, cold weather impacted a large portion of the United States. MISO's region experienced unusually cold weather, especially in the southern states. High temperatures during the period were more than 30 degrees below average highs, while low temperatures were 20 to 30 degrees below average lows in much of the southern United States, making it one of the most extreme weather events in the last 30 years. These temperatures drove high demand for electricity while simultaneously reducing supply due to weather related generation performance issues and fuel availability. In addition, MISO's geographic location makes it a hub for large power flows across the system to serve electricity not just in its footprint but also in the neighboring systems such as the Southwest Power Pool (SPP). Supply shortage coupled with large power flows threatened reliability.

Throughout the extreme conditions MISO utilized numerous tools at its disposal – including operating policies and procedures covering a broad range of operating conditions, long-standing coordination with neighboring regions, like SPP and PJM – and leveraged the value of an expansive geography and diverse generation mix.

Ultimately, MISO and its members had to take emergency actions, including ordering emergency load reduction, which is a last resort tool needed in certain situations to prevent larger, uncontrolled outages. These actions ensured the reliability of the grid while limiting electricity interruptions to a handful of short duration events.



Note: time frames represent the duration from when emergency load reduction was ordered through release of the full amount of load

The challenges faced during this extreme weather event, including transmission emergencies and generator outages, are a stark reminder of the need to continue transforming to ensure the MISO Region is ready for the current and future challenges facing the industry. This is increasingly important as the region experiences more frequent challenging grid conditions, increasingly electrification, and an evolving resource mix that is becoming more dependent upon intermittent generation resources.

Summary of Arctic Event Activities

Preparations for the Arctic event began nearly a week before the worst of the weather hit the region. As MISO monitored the developing weather situation and gained increasing clarity about the timing and magnitude of cold temperatures, various operating procedures were implemented beginning on February 9 to ensure our members and others in the region were as prepared as possible. However, the most significant impacts to customers, including emergency load reductions, occurred February 15-16.

- **Eastern Texas:** In the early morning hours of February 15, snow and ice causing significant damage in eastern Texas. Two major transmission lines and two generators serving the area went offline. Power transfers to the area increased on remaining lines as MISO tried to deliver adequate energy to the impacted areas. However, due to the potential for overloading those transmission lines, which could cause instability and cascading outages, at 5:40 a.m. (EST) MISO declared a Local Transmission Emergency. Over the next two hours MISO instructed Entergy to reduce load by a total of 800 MW in part of Texas. Later in the day the two transmission lines were restored and MISO incrementally released the load reduction orders until all load was restored the afternoon of February 16.
- **Louisiana:** Early on February 16, with transmission and generation outages impacting parts of Texas, the east-to-west flows on the system were at risk of exceeding safe operating limits. As the morning load increased, between 7:00 a.m. and 7:31 a.m. MISO was forced to declare a Transmission System Emergency and instructed a total of 1,000 MW of emergency load reductions in North-Central Louisiana to keep flows under the transmission line limits. By 11:40 a.m. all load was restored and the emergency declaration was terminated.
- **Illinois:** On February 16, 2021, at 7:00 a.m., a Transmission System Emergency was declared in South-Central Illinois in response to concerns about transmission limit violations due to excessive east-to-west flows. This resulted in a "stranded capacity" scenario where adequate electricity was available, but it could not be moved to where it was needed. At 7:52 a.m., MISO directed Ameren to reduce load by 130 MW in South-Central Illinois to relieve electricity flows exceeding the system operating limits. The load was restored at 1:13 p.m.
- **System-Wide:** During the evening increase in electricity demand on February 16, 2021, multiple generators tripped offline in MISO's South Region. MISO declared a Maximum Generation Event at 6:35 p.m., committing Emergency Demand Response and coordinating with members to issue public appeals for energy conservation. A short time later, at 6:50 p.m.., MISO sought to temporarily increase the North-South

Regional Directional Transfer Limit in an effort to transfer more energy to MISO's South region. Unfortunately, the request could not be accommodated due to system overloads in neighboring systems. Realizing the grid's stability was in danger and being unable to move the needed energy to meet demand, at 7:40 p.m. MISO declared a Maximum Generation Event Step 5 and called for a 700 MW pro-rata emergency load reduction across MISO South Local Balancing Authorities. These emergency load reductions ended at 10:00 p.m. There were no further emergency load reductions and the Arctic Event officially ended when the last alert was terminated on February 20.

Key Takeaways

This event highlights the importance of challenges in delivering electricity, especially when it is needed most. Here are the 5 key takeaways.

1. Generation performance is critical, even when not experiencing extreme weather. MISO is counting on the generation to meet its commitment of delivering energy when it says it will be available. For the most efficient and reliable delivery of electricity we need sufficient generation to be available at the right times. While this is no easy task during normal operations, extreme weather events cause even greater negative impacts on generation performance because of issues like unexpected weather-related generator outages or fuel delivery challenges. Winterization to protect generation and fuel supplies from extreme weather can mitigate this risk but MISO and its members must assess and establish certain criteria. For instance, to what extreme temperature must generators be prepared to operate, how does MISO ensure consistency amongst similarly situated generation, and whose role it is to establish and verify such requirements? Finally, in cases where MISO does not have sufficient generation or when transmission lines are overloaded, emergency load reduction is the essential tool of last resort that can be used to prevent uncontrolled cascading outages. The industry needs to consider seasonal specific load reduction protocols, as the needs and constraints are different between winter and summer and any emergency load reduction events create significant hardship in affected areas.

2. Resource adequacy planning needs to be refined. Historically, tight supply and demand conditions typically only occurred on a few peak days in the summer, but today MISO experiences such conditions with increasing frequency across all seasons. Changing from an annual to a seasonal resource adequacy construct will help address this new reality. Further, fuel availability varies over time, and how and who should ensure fuel availability must be considered in reliability planning. Furthermore, if fuel assurance is

required, how do we do so in the most cost-effective manner (e.g., annual firm fuel when the generator may only be needed a few times a year)?

3. Transmission is vital to moving electricity from where it is generated to where it is needed most. The MISO region had adequate supply during the Arctic Event, but transmission constraints, including overloaded lines and the Regional Dispatch Transfer Limits, hindered the ability to move energy to the specific areas where it was needed. MISO's transmission system also supported our neighbors during the Arctic Event, in particular with substantial power flowing from the east through MISO to support reliable and efficient operations in the Southwest Power Pool (SPP). In addition to new transmission capacity, improved interregional coordination and interconnection will bring significant benefits to facilitate reliability and efficiency.

4. Operations of the future will require improved tools and information. Given the rapid shift in resource portfolios, and the increase in challenging weather events, system planners need more detailed and complete data to support event and post-event analyses, planning, and modeling; control room personnel will need more timely, granular, and high-fidelity data to support real-time operation decisions, and operational tools such as parallel flow visualization to improve real-time control room decisions. Automation and advanced analytics techniques will be key in providing insights into upcoming uncertainties and Grid status. Such improvements will help mitigate some of the types of challenges experienced during the Arctic Weather event, such as effectively modeling and managing of the Regional Dispatch Transfer Limits.

5. Reliability is the outcome of many years of forward-looking planning and decisions. Many entities, from regulatory bodies, members, market participants to end-use customers, have key roles in accomplishing this work. These roles need to be reviewed and adjusted to ensure that we collectively ensure continued reliability. As an example, Regional Transmission Organizations like MISO might not be in the best position to monitor or verify weatherization of the generation fleet. They could, however, help with analysis or provide input into the weatherization requirements needed to further reliability. MISO looks forward to the support and alignment of other entities to ensure the right roles and responsibilities for all involved.

MISO is committed to working collaboratively with its members, regulators, and other stakeholders to address these key takeaways. We invite all stakeholders to review and discuss these takeaways at the upcoming workshop and throughout the coming months.

Report Outline

This report begins with a description of the weather event and a detailed narrative of the impacts of that weather on the MISO system.

Next, the report covers topical areas with a more detailed description of MISO's response to the Arctic Event including lessons learned, and MISO's actions to address those lessons learned.

MISO has organized the topical discussions in rough chronological order where possible, followed by some cross-cutting areas:

- Planning, including both transmission and markets
- Preparation, including seasonal and event preparation and weather forecasting
- Operations, including Emergency Load Reduction and Regional Directional Transfer, Pricing, and Staffing and Tools
- Credit / Collateral
- Communication

The report identifies 20 lessons learned and over 35 actions, which are summarized in the Appendix.

The final section of this report includes MISO's responses to the findings from the Independent Market Monitor.

Event Narrative

Weather

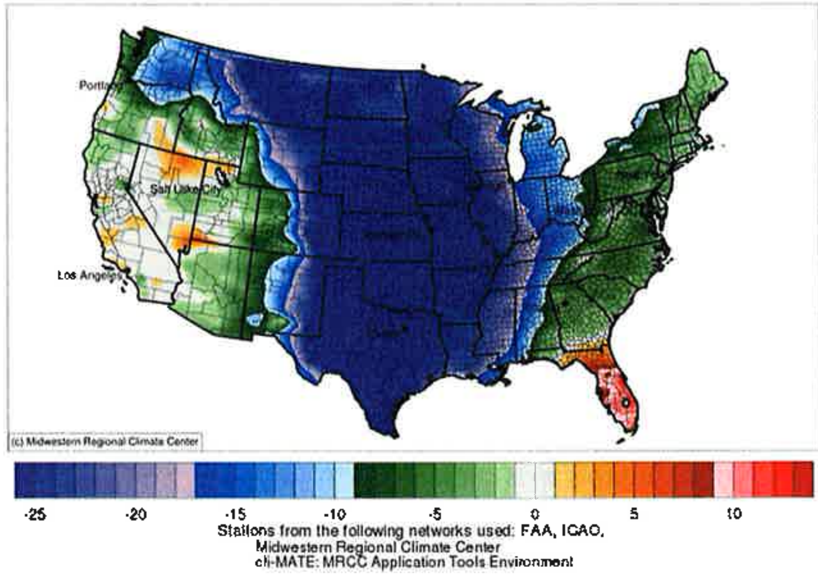
Beginning in early to mid-January 2021, the Polar Vortex[1] over the Arctic became destabilized, putting major population centers across the Northern Hemisphere at risk for cold air outbreaks. Ultimately, two concurrent weather events resulted in extreme weather conditions for much of the United States.

- On February 10, 2021, a winter storm formed north of the Gulf coast, dropping significant amounts of sleet and ice on many states in the Deep South and the Ohio Valley, including Texas, Georgia, Louisiana, Arkansas, Tennessee, as well as states on the East Coast. By mid-February, the weather pattern was oriented so that the core of the arctic air was directed towards central North America.
- Concurrently, the arctic air from the destabilized Polar Vortex also led to anomalous cold across the Plains and Midwest from February 12^{th}-18^{th}. This unusual weather pattern resulted in another winter storm that moved through the MISO South and Central Regions producing heavy snow and ice accumulation. The February 13^{th}–17^{th}, 2021 North American winter storm was a major winter and ice storm that started in the Pacific Northwest and quickly moved into the Southern United States, before moving on to the Midwestern and Northeastern United States a couple of days later. In the South, many cold temperature records were broken, driving winter peak loads close to the typically higher summer peak levels.

[1] The polar vortex is the large area of low pressure and cold air surrounding each of the Earth's poles. When conditions are right, the extreme cold air extend much farther from the poles than usual, significantly cooling large portions of the hemisphere for weeks or even months.

Average Temperature (°F): Departure from 1981-2010 Normals

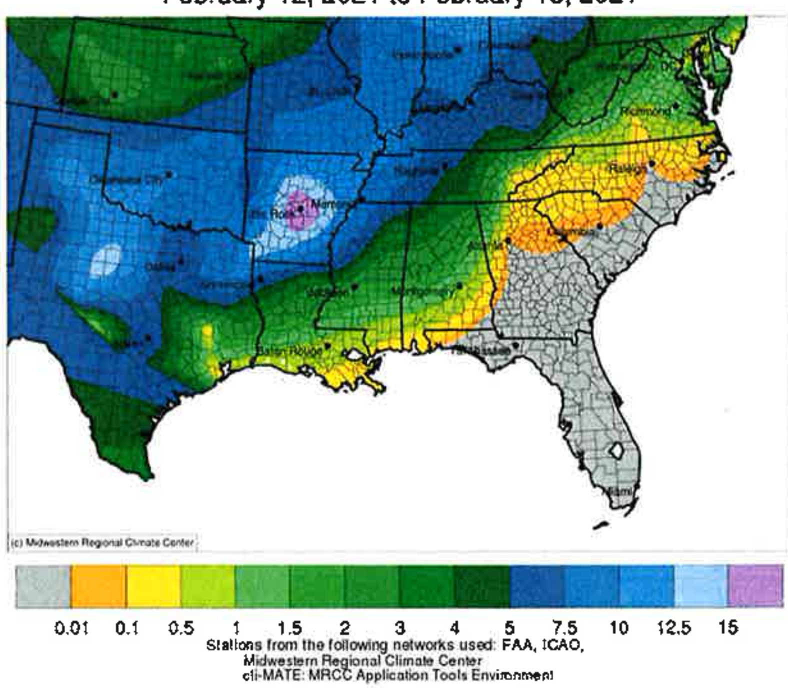
February 12, 2021 to February 18, 2021



This storm, along with various other storms from the previous two weeks, resulted in over 75% of the contiguous U.S. being covered in snow.

Accumulated Snowfall (in)

February 12, 2021 to February 18, 2021



MISO has observed an uptick in severe weather events that have impacted electric reliability, both within MISO and across the country.

Early 2010's

2011
Texas
Cold Weather
- 4 GW load shed
- 3.2M people effected

Southeast
Tornado Outbreak
- 300+ transmission towers destroyed

Southwest
Heat Wave
- 12-hour power failure
- 2.7M people effected

2012
Eastern US
Derecho Blackout
- 4.2M people effected

East Coast
Superstorm Sandy
- 8.6M people effected

Mid 2010's

2014
Midwest, East Coast
Polar Vortex
- Forced Outages: PJM 38 GW, MISO 29 GW

2017
Texas
Hurricane Harvey
- Forced Outages: 10 GW

Late 2010's

2018
Gulf Coast
Hurricane Michael
- 1.7M people effected

East Coast
Bomb Cyclone
- Record gas deployment

2019
Midwest
Polar Vortex
- Forced Outages: PJM 21 GW, MISO 30 GW

2020
California
Heat & Wildfires
- Rotating blackouts

MISO South
Hurricane Laura
- 500 MW load shed

2021
Texas
Arctic Event
- 4M people affected
- 20 GW load shed

A recent Electric Power Research Institute (EPRI) report has concluded that hurricanes are increasing in intensity and duration, extreme heat events are increasing in frequency and intensity, and cold events are increasing in frequency (though less cold on average).

Grid Impacts and Operation

Weather of this significance has wide-ranging implications for many aspects of society. One that can be adversely affected by severe weather conditions is the power industry. Because of the potential impacts to the grid, and subsequently to end-use customers, and the lead-times needed to ensure certain power plants are available, MISO begins preparations well in advance of severe weather events. This includes assessing weather forecasts and expected impacts to demand, generators and the transmission system, communicating with members and neighboring grid operators, and considering the need for actions to prepare the system.

In coordination with stakeholders, MISO has developed an extensive set of procedures – addressing a range of normal, abnormal, conservative, and emergency operating conditions – that direct certain actions based on established criteria to support grid reliability. Those that were utilized during this event are described here and the entire set of Reliability Operating Procedures can be found on the MISO website.

MISO generally utilizes Informational Advisories in advance of any declarations. These are used to communicate MISO's anticipation of a potentially challenging scenario in the near-future and any actions members should take to initiate preparedness and maximize our ability to collectively manage the situation.

Included in the Normal Operating Procedures is the Conservative Operations declaration. This step is used to provide an early indication to operating personnel that challenging system conditions are anticipated and that they should review outage plans with a goal of deferring, delaying or recalling any non-essential maintenance or testing. Similarly, Severe and Cold Weather Alerts are issued to notify members of potential challenges with energy generation or transmission resources associated with weather and to compel the review of outage plans and preparation for potential emergency conditions.

Emergency Operating Procedures address situations that have the potential to, or actually negatively impact system reliability. These various procedures have multiple steps, with the most extreme being coordinated emergency load reductions, sometimes called load shed, where energy is intentionally cut off to selected areas to prevent a more severe, uncontrolled power outage.

One such emergency procedure is a Transmission System Emergency, used when facing transmission system conditions that have the potential to exceed or have exceeded an Interconnection Reliability Operating Limit, and cannot be mitigated using normal procedures. Transmission System Emergency declarations are issued to mitigate the potential of violating a transmission line limit that could lead to instability, uncontrolled separation, or cascading outages impacting the Bulk Electric System.

Separate from MISO's procedures, NERC has three **Energy Emergency Alert (EEA)** levels to ensure consistent communication of energy emergencies across the Interconnection.

- EEA 1 – All available resources in use.
- EEA 2 – Load management procedures in effect.
- EEA 3 – Firm load interruption imminent or in progress.

Also in the emergency category are procedures focused on generating capacity challenges. The Market Capacity Emergency Procedure identifies roles and responsibilities and actions for parties to take during events. There are a number of steps within the procedure with implementation generally based on the projected amount of excess available capacity. The primary actions within the various steps are outlined in the chart and table below.

Another important component of MISO's efforts to maintain reliability are partnerships with neighboring systems. Throughout the Arctic Event, MISO was working hard to ensure reliability not only on its own system, but also to support the efforts of neighboring systems, especially in the Southwest Power Pool (SPP) area. At one point during the Arctic Event, PJM pushed as much as 13,000 MWs into MISO's system, which MISO and SPP used to maintain economic pricing and support grid operations. Notably, high flows strained MISO's transmission system on multiple occasions during the event, contributing to the need for emergency declarations and some of the emergency load reductions.

Normal Operating Procedures

Guide various situations that occur in the day-to-day operation of the bulk electric system.

Abnormal Operating Procedures

Utilized for events that deviate from normal but do not put the electric system at risk, such as malfunctioning software or telephone systems.

Conservative Operating Procedures

A subset of Normal Operating Procedures designed to prepare local operating personnel for a potential event and to prevent a situation or event from deteriorating. Examples include forecasts anticipating severe weather, hot/cold weather, or geo-magnetic disturbance warning.

Emergency Operating Procedures

Emergency Operating Procedures guide system operator actions when an event occurs on the electric system that has the potential to, or actually does, negatively impact system reliability. Examples include Market Capacity Emergencies and Transmission System Emergencies.

Summary of Market Capacity Emergency Operating Procedures

Event Status	Actions
CAPACITY ADVISORY: *Energy shortage is forecast*	Update stakeholder market data
ALERT: *Electricity supply is tight and may require emergency resources*	Maximum generation (Max Gen) declaration; defer maintenance; prepare for event
WARNING: *Conditions are tightening and may not meet requirements*	Schedule all resources; limit exports; implement emergency pricing
EVENT STEP 1: *Requirements cannot be met through normal operating limits*	Max Gen event; utilize emergency-only units and emergency pricing
EVENT STEP 2: *Requirements cannot be met through emergency resources*	Load Modifying Resources; external purchases; public appeals
EVENT STEP 3: *Operating reserves depleted*	Utilize supplemental reserves
EVENT STEP 4: *All available MISO resources utilized*	External emergency energy purchases
EVENT STEP 5: *Requirements cannot be met*	Coordinated load interruptions

Timeline of Key Arctic Weather Events

February 9-14, 2021

For this event, whose most significant impacts spanned February 14-17, preparations began much sooner. As MISO monitored the developing weather situation and gained increasing clarity about the timing and magnitude of cold temperatures, various operating procedures were implemented beginning on February 9, with the issuance of a Cold Weather Alert effective for February 13-15. MISO then issued Informational Advisories on February 10 and 11 to raise awareness of the importance for members to update MISO with accurate generation/resource offers reflecting projected fuel supply access or availability. These advisories also requested members implement any winterization processes or maintenance for generation resources in the footprint, as well as confirm fuel supply availability through the President's Day holiday[2]. Also, on February 11, as the expectation for the duration of extreme cold expanded, the Cold Weather Alert was extended through February 16.

On February 13 the impacts of the upcoming cold temperatures on the South Region pushed load forecasts higher, resulting in MISO committing all generators in the region that require long lead time and issued a Capacity Advisory for the South to raise awareness to the anticipated capacity challenges. With load forecasts still increasing on February 14, weather conditions becoming more severe, and generator fuel risks growing, MISO issued a Maximum Generation Emergency Alert for the South Region effective for February 15.

February 15, 2021 (all times Eastern Standard Time)

In the early morning hours of February 15, snow and ice moved through the South Region causing significant damage to transmission and some generation in the Western load pocket of the West of the Atchafalaya Basin (WOTAB) in eastern Texas.

At 02:34, the China–Stowell 230 kV transmission line, located in southwest Louisiana, tripped off-line. This is significant because it serves as a major corridor for power transfer into Western load pocket. At 03:20, the China–Height 230 kV line also tripped. The loss of these two lines impacted MISO's ability to move power into the area but did not yet necessitate emergency load reduction. The power transfers continued in the east-to-west direction as eastern areas were trying to support the delivery of power to the west.

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[2] Since natural gas markets do not operate on weekends or holidays, there was added complication because forward commitments were being made earlier for less certain forecasts farther in the future. Resources were lining up natural gas fuel based on Thursday forecasts of anticipated needs for Tuesday.

Between 04:25 and 04:50, two generating units tripped off-line, which increased the east-to-west flows observed on the system.

Summary of February 15 Arctic Weather Event Activities
Texas • 02:34 – China-Stonewell 230 kV transmission line tripped • 03:20 – China-Heights 230 kV transmission line tripped • 04:25-4:50 – Two generators tripped offline • 05:40 – Local Transmission Emergency declared • 05:55 – 500 MW emergency load reduction (Entergy) • 06:33 – 300 MW emergency load reduction (Entergy) • 11:48 – China-Height 230 kV line returned to service • 15:12 – 100 MW load reduction released • 16:19 – 200 MW load reduction released • 19:51 – China-Stonewell 230 kV line returned to service • 22:00 – 100 MW load reduction released • 22:46 – 100 MW load reduction released

Due to these unplanned generation and transmission outages, which impacted a main power transfer corridor into Southeast Texas, MISO declared a Local Transmission Emergency for the Western load pocket at 05:40. The transmission outages increased the electricity flows on other transmission lines in that area, creating the potential of overloading the lines and creating instability in the Western load pocket. Ultimately, this loss of generation and transmission led to a localized emergency load reduction event affecting Entergy Texas customers in the Western load pocket, when at 05:55, MISO instructed Entergy to shed 500 MW in the Western load pocket. With demand increasing during the morning load ramp and putting even more strain on the transmission system, at 06:33, MISO instructed Entergy to shed an additional 300 MW (for a total of 800 MW) in the Western load pocket to maintain transmission system security.

During and after the restoration of the transmission facilities, emergency load reduction orders were gradually released based on system conditions. At 11:48, the China–Height 230 kV line returned to service. At 19:51, the China – Stowell 230 kV line returned to service.

Between 15:12 on February 15 and 01:33 on February 16, MISO instructed 700 MW to be restored in the Western Load Pocket.[3]

February 16, 2021

As extreme weather conditions persisted into February 16, operational challenges during the morning's load peak resulted in Maximum Generation declarations for all regions, and emergency load reduction orders in both the South and Central Regions.

[3] The final 100 MW was restored at 13:11 on February 16, and the Local Transmission Emergency declaration was ended at 09:40 on February 17.

By 03:30, two generating units went on forced outage. At 05:30, with the previous day's Local Transmission Emergency still in effect, unexpected generator outages and transmission challenges drove grid stability concerns and the need to direct 300 MW of emergency load reduction in the Southeast Texas area. Additional generation outages occurring at 06:35 exacerbated the already high east to west flows on the system. At 07:00, a Transmission System Emergency was declared in North-Central Louisiana to attempt to keep flows under certain transmission line limits. However, the actions were not sufficient to stabilize the system and at 07:05 MISO instructed 500 MW pro-rata emergency load reduction in North-Central Louisiana from MISO's South Region Transmission Operators. At 07:31, an additional 500 MW of emergency load reduction was requested in that same area.

Separately, at 07:00, a Transmission System Emergency was declared in South-Central Illinois in response to concerns about transmission limit violations due to excessive east to west flows (power flowing from east, through MISO's system to SPP and Texas). This resulted in a "stranded capacity" scenario

Summary of February 16
Arctic Weather Event Activities

Texas
- 01:11 – 100 MW load reduction released
- 01:33 – 100 MW load reduction released
- 03:30 – Two generating units forced offline
- 05:30 – Generator trips offline
- 05:30 – 300 MW emergency load reduction (Entergy)
- 06:35 – Generator outages
- 09:33-11:10 – 300 MW load reduction released
- 13:11 – The final 100 MW load reduction released; Entergy advised that not all load may be restored due to system damage

Louisiana
- 07:00 – Transmission System Emergency due to large transmission flows on Webre-Wells 500 kV transmission corridor, risk of cascading outages
- 07:05 – 500 MW emergency load reduction from Local Balancing Authorities to mitigate Webre-Wells 500 kV line issues
- 07:31 – Additional 500 MW emergency load reduction from Local Balancing Authorities
- 08:42-11:10 – All load reduction released (incrementally)
- 11:41 – Transmission System Emergency terminated

Illinois
- 07:00 – Transmission System Emergency due to overload of Coffeen-Roxford 345 kV line, risk of cascading outages
- 07:30 – Emergency Energy Alert, all resources committed, concerns about sustaining required contingency reserves
- 07:52 – 130 MW emergency load reduction (Ameren) to relieve system operating limits caused by excess east-west flows
- 13:13 – 130 MW load reduction released
- 14:00 – Transmission System Emergency terminated

System-Wide
- 18:35 – Due to generation losses and fuel unavailability, MISO declares Event Step 2c, commitment of Emergency Demand Response resources
- 18:50 – MISO requested to increase the North-South Regional Directional Transfer Limit from 3000MW to 3700 MW; the request was denied due to neighboring system conditions
- 19:40 – Maximum Generation Event Step 5 declared, 700 MW emergency load reduction across South regional Local Balancing Authorities
- 22:00 – Maximum Generation Event Step 5 terminated

where adequate electricity was available, but it could not be moved to where it was needed due to transmission line limitations. The Transmission System Emergency that was called for Coffeen-Roxford 345 kV contingency resulted in all generation in MISO market east of Illinois becoming unavailable. This large loss of capacity availability took MISO North and Central Regions into an EEA 1 and Max Gen Event. At 07:52, MISO directed Ameren to shed 130 MW in South-Central Illinois to relieve electricity flows exceeding the system operating limits.

At 07:30, MISO declared an Emergency Energy Alert (EEA) 1 and Maximum Generation Event 1b in MISO North and Central Regions, instructing generators to start off-line resources, as all available generation resources are committed and there is concern about sustaining the required contingency reserves.

Load in the South Region started to decrease after the morning peak, and the situation improved. MISO thus released the 1000 MW of the pro rata emergency load reduction in North-Central Louisiana and the 300 MW emergency load reduction in Southeast Texas:

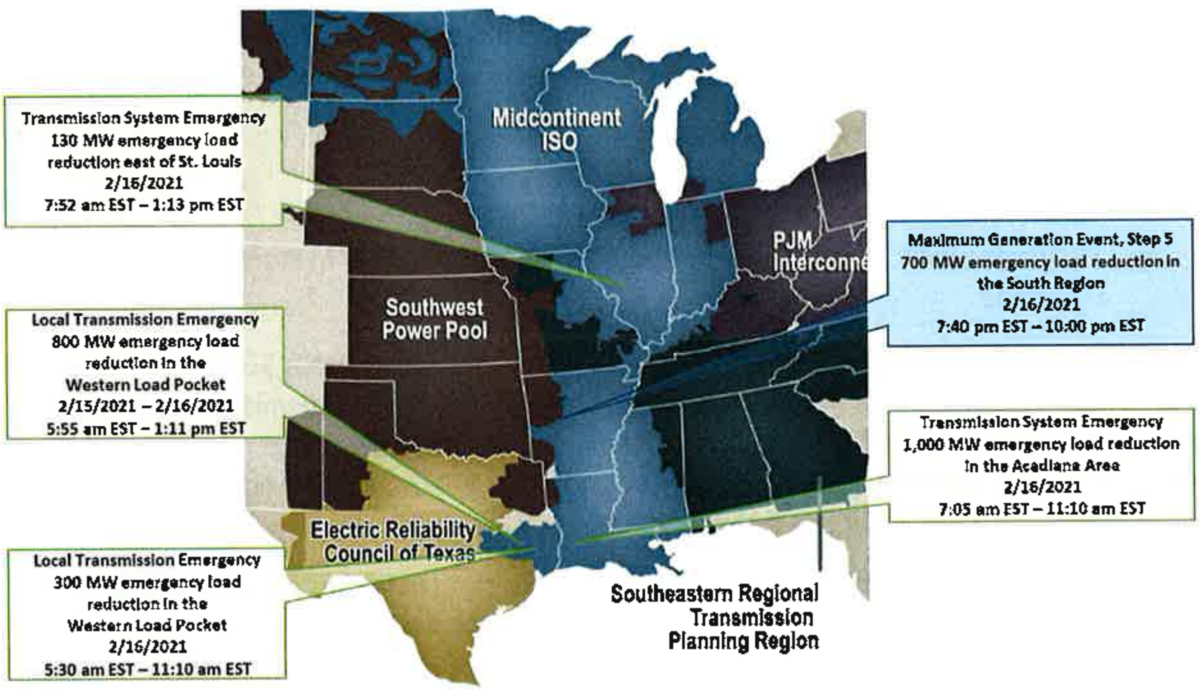
- 08:42: released 400 MW in North-Central Louisiana
- 09:33: released 150 MW in Southeast Texas
- 10:19: released 200 MW in North-Central Louisiana
- 11:10: released 150 MW in Southeast Texas and 400 MW in North-Central Louisiana

By 11:41, all emergency load reduction due to flows on Webre–Wells 500 kV line was restored in North-Central Louisiana, and MISO terminated the Transmission System Emergency. At 13:11, MISO released the remaining 100 MW of emergency load reduction requested from Entergy in Southeast Texas, and Entergy advised that not all load may be restored due to damage on the system.

At 13:13, Ameren restored 130 MW of load that was shed in Illinois because of the Transmission System Emergency, which MISO terminated at 14:00.

However, during the evening increase in electricity demand, multiple generators tripped offline in MISO's South Region, resulting in MISO declaring a Maximum Generation Event Step 2c (EEA-2) at 18:35, which allowed MISO to commit Emergency Demand Response resources when energy requirements cannot be met through normal and emergency-only generating resources. Public appeals for energy conservation were issued at the same time. A short time later, at 18:50, MISO sent a request to neighboring entities for the North-South Regional Directional Transfer Limit to be increased from 3,000 MW to 3,700 MW in an effort to transfer more energy to MISO's South region to compensation for the increased evening demand and offline generators. Unfortunately, the request could not be accommodated due to overloads in Joint Parties' neighboring systems, as TVA already had multiple constraints in excess of 100%.

Realizing the grid's stability was in danger and being unable to import the needed energy to meet demand, at 19:40, MISO declared a Maximum Generation Event Step 5 (EEA-3) for the MISO South Region with instructions for a 700 MW pro-rata emergency load reduction across MISO South Local Balancing Authorities. Utilities in Arkansas, Mississippi, Texas, and Louisiana were each given their pro-rata share of load to shed from their systems. The entities then determined which customers would be impacted. The entire emergency load reduction event lasted two hours and twenty minutes, terminating at 22:00 as load decreased and MISO released all emergency load reduction for restoration.

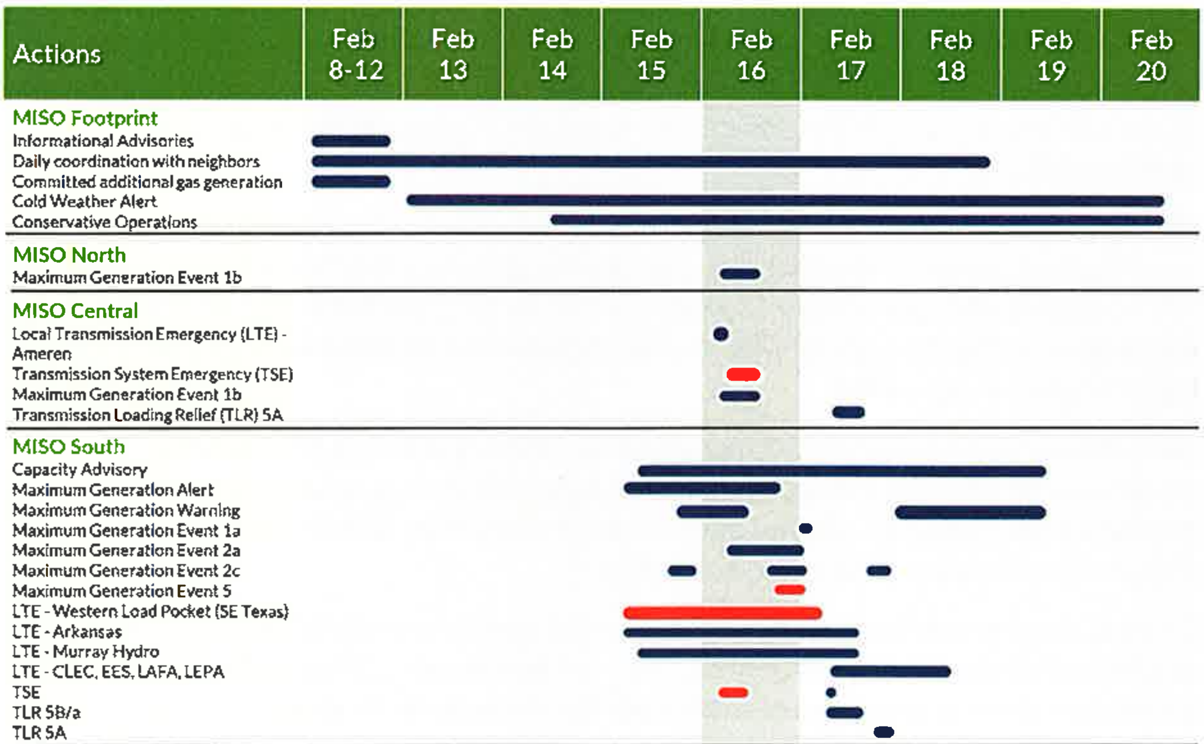


Note: time frames represent the duration from when emergency load reduction was ordered through release of the full amount of load

During an EEA-3 event, per the MISO Tariff, prices in the affected area increased to the established Value of Lost Load (VOLL), $3,500/MWh. This value is an estimate of the cost of service interruption to customers and is paid to both supply that increases output and to demand response load that is lowered.

Although there were no further emergency load reduction events in MISO's footprint after February 16, 2021, the Arctic Event officially ended when the last alert was terminated on February 20. The following graphic shows the major actions taken in MISO's footprint from February 8-20, 2021.

While control room operators were managing generation and transmission issues, other MISO staff worked with local authorities to help get fuel supply to the plants. Those activities included having conversations with local officials about the importance of power plants. These conversations helped facilitate the prioritization of plows to clear roadways for fuel delivery and ensure plants could operate.



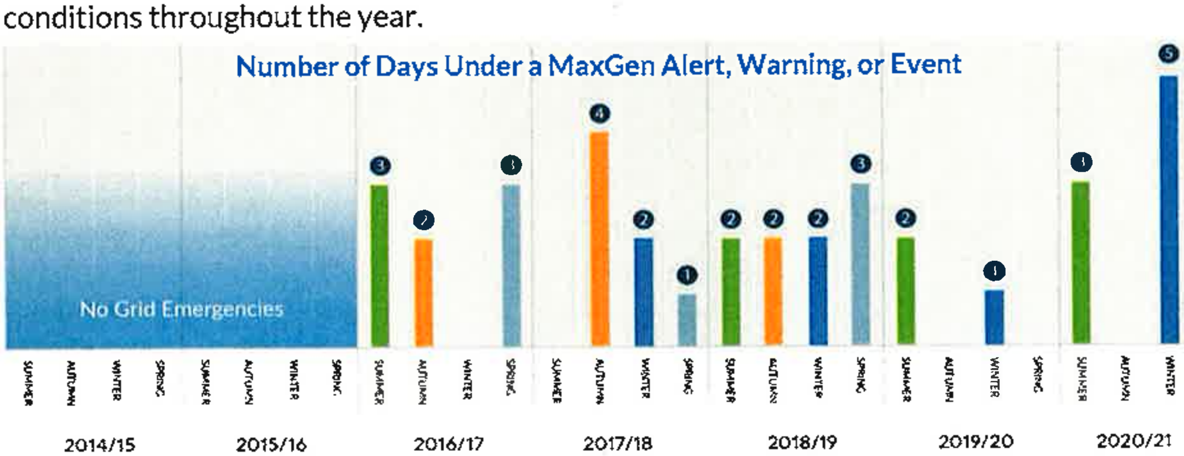
Review of MISO Processes Supporting Grid Reliability, with Lessons Learned and Action Items

The February 2021 Arctic Cold Weather event provides a real-life case study of the challenges MISO faces in ensuring electric reliability at the lowest feasible cost every hour of every day, even under the most demanding conditions. During this weather event MISO's control room had to manage high levels of generator and transmission line outages across the region, compounded by overloaded transmission lines, high demand for energy, and similar conditions in neighboring regions. Because of MISO's extensive transmission system, diverse resource mix, preparation, and procedures, we were able to limit the impact to a two-hour regional emergency load reduction and several local events. At the same time, the MISO region is likely to see more events in the future that strain system reliability.

Meeting the Reliability Imperative to ensure the future reliability of the grid, requires much more than merely effective operational management of the bulk electric system. It is the outcome of ongoing analysis, process improvement, planning, and preparation that has been occurring throughout MISO's existence and will continue as long as electricity is important to our way of life.

Over the last several years MISO has observed concurrent trends of increasing occurrences of extreme weather conditions that strain the system and an evolving generation portfolio with a higher percentage of renewables that increases the complexity of managing the bulk electric grid.

Emphasizing the coming challenges, after several years of no emergency declarations, beginning in the summer of 2016 MISO has seen an increase in the need for maximum generation alerts, warnings, or events to manage through challenging operating conditions throughout the year.



It is clear that the approaches that served the region very well for many years must be adapted to the changing landscape. As a result, in recent years MISO stepped-up efforts to better understand the potential impacts of the evolving resource portfolio, changing supply, demand, and risk profiles, and system changes required to mitigate the various risks and demands.

The Renewable Integration Impact Assessment (RIIA) was a 4-year analysis conducted by MISO to understand the complexities of integrating renewable resources, which are intermittent in their energy generation capabilities, at varying penetrations in the interconnected electric system in the eastern United States, with a focus on the MISO system. The analysis found that as renewable energy penetration continues growing, up to about 30% penetration, the region requires transmission expansion and significant changes with current operating, market, and planning practices. However, managing the system when load being served from renewable resources exceeds 30% will require transformational changes in planning, markets, and operations, and coordination action with MISO members.

The annual MISO Forward report looks ahead to anticipate and understand the trends and changes in the energy landscape that shape the future of our industry. The latest MISO Forward report examines the changing nature of energy demand, as our nation trends toward decarbonization and increasing electrification. Past reports have explored the future needs of electric utilities as the resource mix transforms and the evolution toward demarginalization, decentralization, and digitalization that is changing the energy paradigm.

The following sections of this report cover topical areas with a more detailed description of MISO's response to the Arctic Event including lessons learned, and MISO's actions to address those lessons learned.

MISO has organized the topical discussions into groupings – first to cover the time periods leading up to and during the event, followed by a discussion of financial impacts and communication before, during, and after the event:

- System Planning, including both transmission and markets
- Preparation, including seasonal and event preparation and weather forecasting in the days and weeks before the event
- Operations, including Emergency Load Reduction and Regional Directional Transfer, Pricing, and Staffing and Tools
- Credit / Collateral
- Communication

Note, this report describes MISO's lessons learned (which are also compiled in the Appendix) – some of the follow-on actions are under MISO's direct control, and those actions may be planned to occur in the very near term or they may be scheduled over the coming years as MISO seeks changes to the Tariff or wait for additional infrastructure. These actions may evolve over time as MISO continues to learn and to hear more from stakeholders. Moreover, this report also describes lessons learned that will require actions from our stakeholders and MISO stands ready to consult or help them complete those actions. There may also be additional lessons or actions that are entirely housed without stakeholder organizations and not covered in this report. MISO is committed to working collaboratively with its members, regulators, and other stakeholders to address key takeaways. We invite all stakeholders to review and discuss these takeaways at the upcoming workshop and throughout the coming months.

System Planning

MISO engages in a number of efforts to better position the grid for future challenges. The electricity system is in a constant state of change shaped by existing generation and emerging technologies like battery storage and solar power. Retirements, aging thermal units, and the addition of intermittent wind and solar resources dramatically change the characteristics of the MISO resource fleet. While grid operators have managed variability and uncertainty in the system for decades, MISO expects this variability and uncertainty to become more profound, making it more challenging to manage supply, load, and reserves.

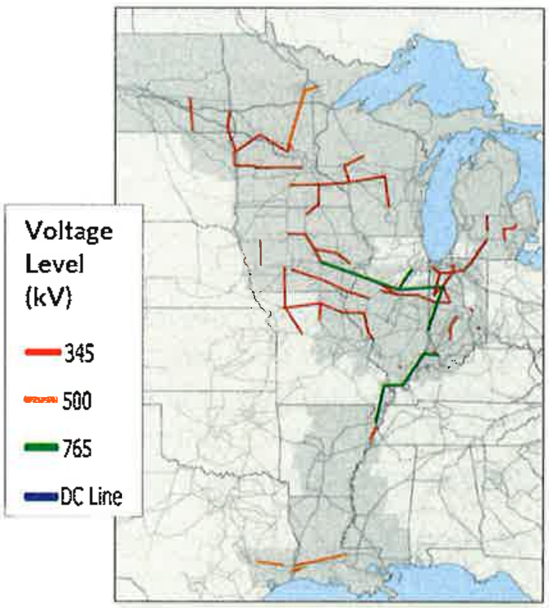
Transmission Planning

The goal of System Planning at MISO is to develop a comprehensive transmission system expansion plan that meets reliability needs, policy needs, and economic needs. Recent extreme weather events such as the Arctic Event have emphasized the importance of planning a robust, resilient transmission system, as the MISO system was able to move large amounts of power across the MISO grid from north to south, and to import power from the east for use by MISO and SPP.

MISO uses future scenarios, also called "Futures," in its planning processes. Rather than trying to pinpoint an exact mix of conditions into the future, these scenarios seek to span a broad range of potential resource and load scenarios and develop a grid that can meet a wide range of plausible conditions over twenty years into the future. Research and analysis into the evolution of the MISO system has identified six key components of system change that are reflected in the scenarios: Traditional Resource Retirements, Renewable Energy Growth, Increasing Energy Storage, Distributed Energy Resource Adoption, Electrification, and Decarbonization.

Long-Range Transmission Planning (LRTP), one of the four main components of the Reliability Imperative, is the process whereby MISO is leveraging the Futures to identify and inform short-term and long-term solutions to enable the resource portfolio shift. The conditions for successful planning include a consensus that transmission is required to address sub-regional and collective needs, a deeper analysis of those issues and solutions and ensuring allocation of cost that is roughly commensurate with benefits to each area.

The two maps below represent MISO's first pass at what the LRTP additions could be for Future 1 and Future 3. These are preliminary plans and will be refined through further analysis and discussion with stakeholders.



Future 1

Future 3

Planning can help to address the issue of having sufficient ability to move power within MISO and between different regions. MISO reciprocally provides and receives power from its neighbors. At one point during the Arctic Event, PJM, MISO's eastern neighbor, was exporting 13,000 MW into MISO. Transmission lines are just as critical across MISO's footprint boundaries as they are within MISO's service area. The future resource portfolio will require additional transmission to maintain the strength of connection in a world with increasing intermittent resources.

Lesson Learned: While MISO's robust grid, along with its ability to import power from outside of the region, resulted in relatively limited impacts during the Arctic Event, MISO needs to continue evolving its transmission system in response to the changing resource mix and evolving grid. The anticipated changes in resource mix and extreme weather puts increased urgency on transmission planning.

Actions to address:

- *MISO will leverage the Long Range Transmission Planning (LRTP) activities to identify intra- and inter-regional planning to ensure reliability as the resource mix continues to evolve and disruptive weather events become more frequent. In particular, LRTP will evaluate further north-south transfer capability which would have helped during the Arctic Event.*
- *Transfer capability - MISO will examine load pockets as part of transmission planning and resource accreditation.*
- *Along with LRTP, MISO will also continue to work with all of its seams partners to identify ways to increase coordination. For example, MISO and SPP are currently engaged in an effort focused on the SPP – MISO seam.*

Resource Adequacy

In the MISO Region, customer-facing utilities are responsible for making sure they can meet customers' electricity needs. MISO supports this responsibility by setting resource planning requirements such as planning reserve margins and resource accreditation standards, and by providing secure and reliable ways for utilities to buy or sell capacity. MISO aims to maintain confidence in the attainability of resource adequacy at all times.

Resources planning processes focus on mitigating resource adequacy risk during tight operating conditions. Historically, system risk has been concentrated in the summer season and typically associated with summer season system peak load. Accreditation of resources (or how much a unit counts towards capacity requirements) has also focused on resource availability during summer peak conditions. Increasingly, risk is spread throughout the year and a resource's winter capabilities may differ significantly from its summer capabilities. Additionally, outages during severe conditions like the Arctic Event currently have only modest impacts on accredited value and some outages have no impact (e.g., planned outages and outages outside of management control). The Resource Availability and Need (RAN) program, part of the Market Redefinition component of the Reliability Imperative, is evaluating seasonal risks to resource adequacy, informed in part by the 2015 Polar Vortex. Risks identified during that event have led to MISO to focus on creating a seasonal resource adequacy and accreditation construct.

Lesson Learned: MISO's resource adequacy construct provided transparency about adequacy of resources to meet projected summer loads. However, improvements can be made to more fully account for the non-summer risks and to ensure that resources will be available across all seasons. MISO has already seen and anticipates continued reliability challenges throughout the year – while reliability risk was once concentrated in the summer season, MISO now has to be increasingly concerned with every hour of the year.

Action to address:

- *MISO is moving to a sub-annual (4 season) resource adequacy construct and an accrediting methodology based in part on a resources' availability during the hours when the system is most in need (tight operating hours), thereby giving resource owners an incentive to ensure resources availability through investments in winterization, fuel assurance or other means. These changes are expected to be filed at the Federal Energy Regulatory Commission (FERC) in the second half of 2021.*

Lesson Learned: Current resource accreditation criteria do not specifically address generator readiness to operate during extreme weather events. With the rapid fleet transition toward natural gas and the increased frequency and severity of extreme weather, this issue is expected to worsen over time.

Actions to address:

- *MISO will work with states and others to identify changes that may be required in MISO processes or elsewhere, to better reflect resource availability during extreme weather events (e.g., winterization needs during extreme cold, fuel assurance).*
- *MISO will consider the impacts of the generation fleet change on the need for additional coordination with the natural gas sector on issues of fuel assurance.*

Market prices provide further incentives for resources to provide energy in the actual operating day. Price formation during shortage conditions is addressed further below and is also part of the Reliability Imperative component of Market Redefinition.

Preparation

Seasonal Preparation

Since 2014 MISO has conducted a Winter Readiness Workshop that brings together stakeholders to review winter lessons learned, winter operations guidelines, preparedness, resource assessments, and readiness.[4] Below we walk through the different components that are reviewed during the Workshop, including Winterization Guidelines, Seasonal Resource Assessments, Seasonal Transmission Assessments, and Generator Winterization Annual Gas Fuel Survey, and Drills.

Extreme winter conditions can contribute to significant losses of electric generation through a variety of factors. Cold temperatures can freeze equipment for various types of electric generators. Frozen transportation equipment and facilities can prevent generators from obtaining fuel. MISO provides Winterization Guidelines to help members mitigate the effects of winter weather risk. These guidelines, which benefitted MISO's region during the February 2021 Arctic Event, are the results of lessons MISO learned from the 2014 Polar Vortex event when approximately 25,000 MW/day of capacity (not including plants whose output was reduced due to weather), was forced offline due to weather-related outages.

MISO directs power plant operators to create a detailed winterization plan that covers preparations and procedures to complete ahead of frigid weather conditions.

In addition, MISO market participants are responsible for ensuring fuel availability and deliverability to their generators.

NERC also has reliability guidelines related to winter readiness. MISO advises generator operators to follow NERC's Winter Generator Reliability Guidelines when preparing for and operating in severe cold weather conditions. MISO advises generator operators to follow NERC's most recent guidelines. MISO is also actively engaged in the process to develop NERC Cold Weather standards along with other initiatives such as FERC's Climate Change, Extreme Weather & Electric System Reliability Technical Conference, to support the development of policies that will collectively address the increased risks seen during the Arctic Event.

[4] Note, that summer weather presents similar but distinct challenges such as severe weather patterns, forced outages, transmission congestion, seasonal maintenance, and higher than average load. MISO specifically prepares for hurricane season in a week-long training. MISO also conducts a Summer Readiness workshop at which MISO discusses its summer generation and transmission assessments, reviews applicable operating procedures, and communicates processes during abnormal and emergency conditions, as well as presents other topics related to seasonal operations. Additional information is available on MISO's website.

MISO also conducts two coordinated seasonal assessments. The **seasonal resource assessment** is done in all four seasons to evaluate MISO's available resources and perform risk assessments. Two scenarios are explored during the seasonal resource assessment – the first is a more general scenario with average levels of demand and resource outages. The second case is a more extreme scenario, with a high load level and a worst-case volume of resource outages (based on five-year historical outage information provided by resource owners and typically due to abnormal weather conditions). In this more extreme scenario, MISO explores the need to use emergency procedures and allows operators to practice monitoring load modifying resources and emergency load reduction.

Lesson Learned: In reporting results of Seasonal Assessments, MISO and stakeholders have not typically focused as much on the extreme cases (high load + high outages).

Actions to address:

- *MISO will focus more attention on extreme outcomes as well as expected outcomes during seasonal assessment workshops.*
- *MISO will evaluate how to incorporate existing extreme cases into Seasonal Assessments and drills.*

Lesson Learned: Current emergency load reduction plans are focused on summer needs. This new experience provides an opportunity for MISO and stakeholders to assess preparation for winter events.

Actions to address:

- *MISO will investigate the feasibility of a pre-winter feedback loop, which would allow members to express their readiness for the winter weather. This feedback would include information about generator weatherization and winter checklist completion.*
- *MISO will encourage Local Balancing Authorities (LBAs) to refine emergency load reduction plans to include winter event load shedding, when cutting power can have different consequences than in the summer. MISO will encourage the refined emergency load reduction plans to consider which elements are critical and what to do if the requested emergency load reduction exceeds their capacity to rotate outages.*
- *MISO will seek additional feedback from stakeholders on their learnings from past events during the Seasonal Assessment workshops.*

The **seasonal transmission assessment** analyzes and assesses the MISO transmission system under projected load conditions for the seasonal peak. The coordination of this study across the MISO footprint provides the benefit of reviewing the network over a much larger area than would normally be assessed by the individual participating Transmission Owner (TO). During the seasonal transmission assessment, four different analyses and simulations are conducted, including the Steady State AC Contingency Analysis, Thermal Analysis during Energy Transfer Simulations (or First Contingent Incremental Transfer Capability (FCITC)), Voltage Stability Analysis during Energy Transfer Simulations (or Power-Voltage Analysis (PVA)), and the Phase Angle Analysis during Energy Transfer Simulations. Contingency levels and sensitivity cases included in the seasonal transmission assessment are often beyond those typically considered in Real-Time Operations and regional planning criteria. These events have been evaluated to provide system operators with guidance as to possible but unlikely system conditions that would warrant close observation to ensure system security.

Lesson Learned: In extreme events, energy flows may be very different than those seen under normal operations. During the Arctic Event, MISO experienced very high flows across its system, and in an unusual direction as power was flowing from the (relatively warm) east coast to the more impacted central part of the country. With the increased severity of extreme events, it will become more important to plan for these scenarios.

Action to address:

- *MISO will include the impacts of high wheel through flows in the seasonal transmission assessment to better prepare for extreme weather events.*

In addition to the seasonal assessments, MISO also surveys its members using the **Generator Winterization Survey and the Annual Gas Fuel Survey**. The Generator Winterization Survey collects information on all generation while the Annual Gas Fuel Survey only collects information from generators with fuel types of gas, oil and gas, and coal and gas. In 2020, 71% of all generation (in MW) responded to the Generator Winterization Survey, improving from 60% in its first year (2019). In its seventh year, 83% of generation (in MW) responded to the Annual Gas Fuel Survey, up from 72% in 2019. MISO communicated the importance of these surveys through presentations at stakeholder meetings, emails, and phone calls. The information gathered includes statistics on generators with plans to prepare for the winter weather, generators with severe cold weather checklists, and generators that experienced freeze issues in the previous winter season. MISO also gathers information on gas fuel capacities. The survey information gathered for this past winter helped to inform operators during the Arctic Event as they dispatched generation.

Lesson Learned: Based on experience during the Arctic Event and the significant number of generator outages based on cold weather conditions, MISO believes that additional data, provided by additional survey participation, will help to inform decisions made during future extreme weather events.

Actions to address:

- *MISO is combining the Winterization and Annual Gas Fuel surveys and removing all backward-looking and redundant questions, with the goal of increasing participation in the survey. MISO will consider additional ways of accessing this information, including engaging in the process to develop NERC Cold Weather standards to be reflective of the increased risks seen during the Arctic Event.*
- *Incorporate fuel assurance into scenario planning and drills, with a particular focus on MISO visibility into fuel plans.*

To ensure readiness in all situations, MISO's operators partner with operators at member companies to run **drills** on the use of use emergency procedures and processes. Emergency Operating Procedures[5] guide operator actions when an event has the potential to negatively impact the Bulk Electric System. The procedures allow MISO and regional operators to defer or cancel transmission or generation outages to increase transfer capability and capacity. These procedures also provide instructions for returning planned outages/maintenance equipment to service in impacted areas, suspend all work on critical computer systems, and prepare for the implementation of Emergency Procedures.

Lesson Learned: Drills have been helpful in coordinating among operations staff. Given the wide scope of the Arctic Event, the drills were not sufficiently comprehensive. In recent years, MISO has shifted to more tabletop exercises with specific groups (e.g., outage coordination or cyber security). However, the Arctic Event and the expected growth in similar extreme weather events in the future points to the need for comprehensive drills that include more groups across MISO and member utilities.

[5] These procedures include Conservative System Operations, Severe Weather Alerts, Hot Weather Alerts, Cold Weather Alerts, and Geo-Magnetic Disturbance Warnings.

Action to address:

- *Increase comprehensive drills for extreme events – including operations, outage coordination, emergency load reduction planning, communications, and regulatory coordination. MISO plans to incorporate more fuel assurance scenarios and responses into planning and drilling.*

Event Preparation

Once a specific event is identified, there is additional preparation that MISO undertakes, often in coordination with its members, to prepare the system in the days directly leading up to the expected event.

MISO has many established processes and tasks to prepare for events, including some regular processes that are updated more frequently when the risk of extreme weather is changing rapidly.

- MISO conducts a Forward Reliability Assessment Commitment (FRAC) study on a regular basis, running cases based on submitted offers and delivering a six-day-ahead forecast. This normal process highlights upcoming risks, where extreme weather, including extreme temperatures, increase the chance of shortages. MISO addresses those risks with forecasting and risk assessment. During normal operations, MISO's forecasting team monitors and presents the current forecast data displayed on the Operational Forecast Dashboard. This data includes 168-hour weather and load forecasts at an hourly interval for MISO Systemwide and regionally. Graphical displays illustrate the high and low temperatures and hourly load forecasts over the next seven days. This dashboard and the accompanying data are presented every weekday to inform MISO Operations staff of the weather/load forecasts and to highlight any significant values and risks for situational awareness. The FRAC study process and Operational Forecast Dashboard have proven helpful in understanding the impacts of the weather conditions, including icing and extreme temperatures on renewable resources and operating gas resources in extreme cold.
- Additionally, MISO assesses the risk to the Net Schedule Interchange (NSI), or the flows between MISO and its neighbors. Particularly when a weather event is expected, MISO works closely with and monitors its neighbors (e.g., PJM, SPP, TVA.) to ensure that MISO is able to accurately forecast NSI leading up to the event. As a part of event preparation, MISO assesses which resources may trip offline or fail to start up in extreme weather. This risk assessment allows MISO to make decisions about starting resources with longer lead times or extending commitments for resources that may not be able to restart during an event.

- The week before the Arctic Event, MISO started discussing outage coordination with members, ensuring they had fuel and understanding what impacts a lack of fuel would have.[6] MISO's forecasting teams provided updates on the latest weather and load forecasts for the upcoming week to the Operations Department. MISO staff communicated the likely risks associated with the weather. Beginning February 9, 2021, and for the remainder of the Arctic Event MISO management received more detailed daily weather forecast briefings.
- In addition to frequent communication with MISO operators, MISO also sent many messages that reference the upcoming cold weather conditions that faced the MISO Balancing Authority. There were several informational messages sent in the MISO Communication System (MCS) which requested MISO members update their availability, keep their Day Ahead and Real Time offers updated, and prepare for the upcoming cold weather. Additionally, in accordance with the Conservative System Operations Procedure (SO-P-NOP-00-449), MISO declared a Cold Weather Alert and Conservative System Operations throughout the event.[7]

Lesson Learned: MISO's ability to accurately forecast weather conditions directly leading up to and during the Arctic Event, facilitated by having a meteorologist on staff, gave MISO the opportunity to prepare in advance, including issuing Informational Advisories early in the week prior to the event, reminding members to accurately reflect projected fuel supply access and availability to their generation and resource offers. These advisories also requested members implement any winterization processes and maintenance for generation resources in the footprint and confirm fuel supply availability through the President's Day holiday.

Action to address:

- ➢ *MISO will continue to leverage in-house and vendor meteorology expertise to inform MISO operational decisions and communication with members. MISO is continuing to assess how best to translate accurate weather forecasts into accurate forecasts of the effects of the weather (e.g., outages tied to weather).*

[6] The extreme cold caused icing on the wind turbines in MISO's footprint. However, output from wind generation was low throughout the duration of the event and the icing did not have a major impact to generation overall.
[7] These declarations were made at various times, and the entry conditions for each are specified within the public procedure.

> **Lesson Learned:** MISO's current process to identify available uncommitted resources is tedious, takes more time than necessary, and does not always leave sufficient time to start resources with a long lead time. The spreadsheet-based tool currently used to identify resources must be operated manually each time it is needed, taking upwards of five minutes to compile necessary information.

Action to address:

- *In order to provide more visibility into available units, MISO is preparing an Available Resource report as part of the Capacity Sufficiency Analysis Tool (CSAT) to communicate to MISO commitment teams the resources available for commitment. The report provides a list of resources available for capacity at any given point in time and helps operations make commitment decisions during tight operating conditions by producing a dynamic list of resources, meaning that a resource will automatically drop off the available commitment list if its window for start-up has passed for any given hour.*

In summary, MISO took the following steps leading up to the Arctic Event:

- Issued Informational Advisories reminding members to accurately reflect projected fuel supply access and availability in their generation/resource offers;
- Issued a Cold Weather Alert to prepare operating personnel and facilities for extremely cold weather conditions that may impact generation and/or transmission capacity;
- Committed additional generation with lead time enabling members to procure fuel;
- Extended the start/stop times for generation resources to avoid start failures due to cold weather thus ensuring availability during peak load times;
- Confirmed planned outage and return-to-service dates/times for generation and transmission outages;
- Continued communication and coordination with members requesting updated resource availability and offers;
- Proactively coordinated with members on maintenance outages which combined with limited maintenance work by members due to the holiday weekend did not require suspension of maintenance; and
- Coordinated with neighbors as they similarly prepared for this weather event.

Operational Details

Emergency Load Reduction and Regional Dispatch Transfer (RDT)

The challenges faced by MISO's operators during the Arctic Event were driven by a combination of complex factors, including generator outages, transmission outages, and excessive electricity flows on some undamaged transmission lines that exceeded safe operating limits. Throughout the event, MISO relied on its established procedures to operate the system safely and reliability, while mitigating the negative system impacts of the extreme conditions.

As discussed above (see "Grid Impacts and Operation"), MISO utilized its established Emergency Operating Procedures to manage energy flows and ensure system security. These procedures allowed MISO to adjust quickly to system conditions as they unfolded. For example, increased demand due to extreme cold weather coupled with unexpected changes in available electric generation and transmission flows can rapidly affect the balance of supply and demand on the transmission system. Procedures like Maximum Generation emergency procedures, coordination of generation and transmission, energy purchases from neighboring regions, and demand response and load-modifying resources are important tools that allow MISO greater flexibility to ensure system reliability. In the case of the Arctic Event, the extreme conditions required MISO to undertake the rare actions of directing member utilities to issue public appeals for electricity conservation and to shed load to protect the bulk electric system.

At one point during the Arctic Event, PJM pushed as much as 13,000 MWs into MISO's system, which MISO and SPP used to maintain economic pricing and support grid operations. Neighboring entities worked together to manage the issues caused by the Arctic Event, and several entities noted how effective the SPP and MISO coordination efforts were. The flows across MISO's system also contributed to the need for emergency declarations.

The MISO footprint is roughly shaped like an hourglass with the middle being the interconnection between MISO North/Central and MISO South Regions, which you can see in the graphic below. The black arrow in the picture represents the Regional Dispatch Transfer, or RDT. MISO's Transmission Owners have limited transmission facilities to move power through the RDT, so MISO has agreements with neighboring organizations to use their transmission capacity to move power back and forth between MISO North/Central and MISO South. The RDT Limit (RDTL) is a cap on MISO's contractual right to use the Joint Parties'[8] available system transmission capacity and is set at 3,000 MW North-to-South and 2,500 MW South-to-North.

Image represents average flows into, out of and through MISO over 3 days (February 15-17, 2021)

RDT = Regional Dispatch Transfer, which has a North-South limit of 3 GW

Due to extreme temperatures on February 15, 2021, load was increasing across the southern United States. Load in the South Region was approaching summer peak levels, which are typically higher than winter peak load. MISO had committed available resources to meet projected demand. See "Timeline of Key Arctic Weather Events" section, above, for a discussion of event timeline and key happenings. The following section provides details about operational aspects of the Arctic Event and Regional Dispatch Transfer (RDT) issues.

Regional Dispatch Transfer Limit (RDTL) (All times in EST)

The RDTL between MISO's North/Central and South Regions is an important tool for managing reliability and efficiency. However, in many instances, such as the Arctic Event, the 3,000 MW limit hinders operational effectiveness.

[8] Southwest Power Pool (SPP), Tennessee Valley Authority (TVA), and Southeastern Reliability Corporation (SERC).

During the period of February 8, 2021 through February 20, 2021, the MISO Reliability Coordinators[9] had several discussions and exchanged numerous phone calls with adjacent Reliability Coordinators about exceeding and adjusting the Regional Dispatch Transfer Limit (RDTL). Over the course of the Arctic Event RDTL flow was primarily in a North to South (N-S) flow direction close to the 3,000 MW limit. See Figure 1 below.

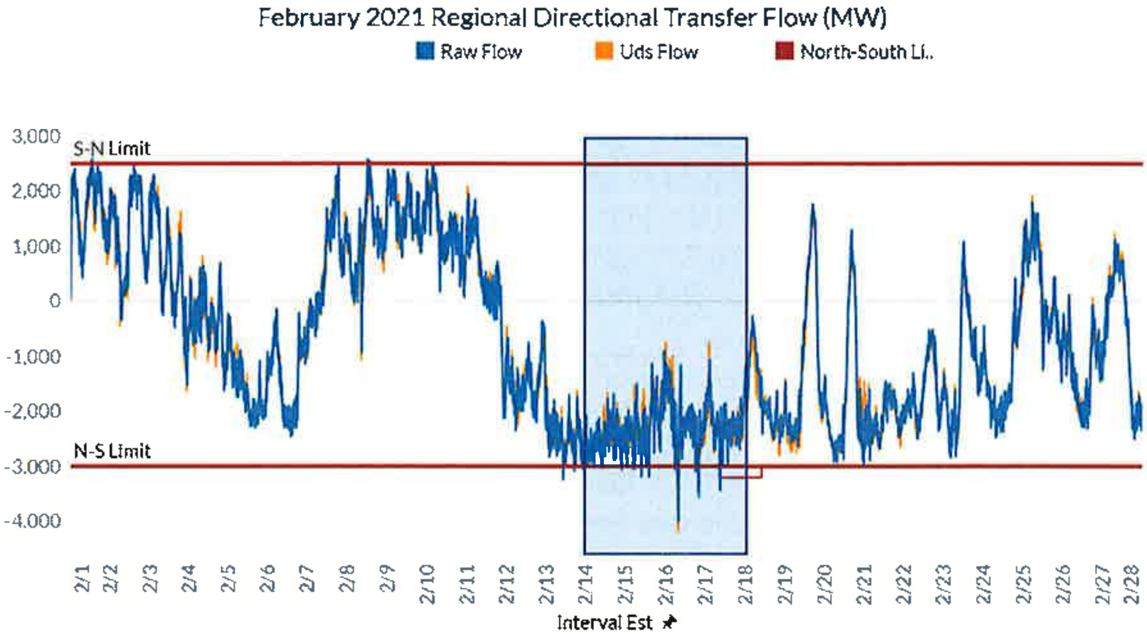


Figure 1: February 2021 Regional Directional Transfer Flow (Note: positive numbers represent South to North flows and negative numbers represent North to South flows)

The first interaction between MISO and the Joint Parties to discuss temporarily increasing the RDTL occurred on February 16 at 17:50, when MISO initiated a conference call in response to the loss of several generation units within a minute. These losses caused the RDTL to exceed the 3,000 MW N-S limit. During this call, SPP and SERC both saw no issues with increasing the limit. However, TVA reported their studies indicated a potential limit exceedance on other equipment if the RDTL was raised. No limit change was enacted and the RDTL flow was brought under the limit within 10 minutes.

The second discussion was on February 16 at 18:50, when MISO requested a limit increase to 3,700 MW. SERC identified they could facilitate an increase to 3,300 MW, but

[9] MISO has multiple roles, including as the region's Reliability Coordinator, a NERC designated role that is responsible for the reliable operation of the Bulk Electric System, has the Wide Area view of the Bulk Electric System, and has the operating tools, processes and procedures, including the authority to prevent or mitigate emergency operating situations.

any further increase would force them into a Transmission Loading Relief (TLR), which would cut schedules into MISO. TLR procedures are used in the Eastern Interconnection to prevent or manage potential or actual System Operating Limit (SOL) and Interconnection Reliability Operating Limit (IROL) exceedances to maintain reliability of the bulk electric system. TVA was unable to facilitate an increase due to multiple constraints including already being in a TLR procedure. SPP was studying options but stopped once TVA declared they could not accommodate. Shortly thereafter, TVA entered an EEA 2. No limit increase occurred.

The third interaction was on February 17 at 08:28 when MISO contacted TVA, SPP, and SERC regarding RDT exceeding the N-S limits and requested a limit increase to 3,200 MW. The Joint Parties agreed, and the limit was changed to 3,200 MW. At 08:43 MISO started individually calling the Joint Parties to request an additional RDTL increase to 3,400. SERC refused the increase. On February 18 at 10:00 the RDTL was reset to its normal 3,000 MW limit.

Unplanned Exceedance of the RDTL

From February 13 through February 18, the RDTL in the N-S direction was exceeded in 18 instances. Sixteen of the exceedances were less than 30 minutes, and 15 were 10 minutes or less in duration. There were no RDT exceedances in the S-N direction. Through most of this period, the RDTL in the N-S direction was near 3,000 MW. From February 17 at 08:28 until February 18 at 10:00, the RDT N-S limit was increased to 3,200 MW. This adjustment to the limit addressed one exceedance that occurred while the South Region was in a Transmission System Emergency.

The two remaining exceedances both took place on February 16, the first at 07:00, for 55-minutes, and the other at 19:18, for a 40-minute duration. Prior to the 07:00 exceedance, MISO was in a Maximum Generation Event 2C and the Central and South Regions both experienced transmission line exceedances which required immediate action. The Maximum Generation event, constraint loading, and the approach of the morning peak resulted in the RDT exceedance. Given the circumstances, MISO shed load both in the Central and South Regions to control constraints and RDT that morning. The exceedance in the evening of February 16 was a result of several generation units tripping offline during the afternoon and early evening. These unit trips put MISO in a position where it could not control the regional flow through methods used during normal operations. A combination of unavailable resources and high load resulted in RDT exceeding the limit as the South Region approached peak. The situation was remedied by ordering emergency load reduction. Load was restored shortly after peak conditions passed and RDT was maintained below the limit.

Under stressed system conditions, it is not uncommon for an RDT exceedance to occur due to a generation unit trip or other sudden system fluctuation. Generation reserves are typically available to bring the flow within limits promptly as demonstrated in the short-duration exceedances. Increasing the RDT constraint shadow price (or the indication of the marginal value of more RDT capacity) during emergency conditions would aid MISO in controlling exceedances because it provides a financial incentive to market participants.

One lesson learned from the earlier 2018 Cold Weather was that MISO had an opportunity for more effective communicating with the Joint Parties of RTDL exceedances. While MISO's communication did improve during the Arctic Event, room remains for further improvement.

Lesson Learned: The Regional Dispatch Transfer (RDT) can be more effectively managed during emergency operating conditions.

Actions to address:

- *Since identifying this action item following the 2018 Cold Weather Event, MISO has improved communication with Joint Parties on RTD exceedances. MISO will continue to look for ways to better coordinate with Joint Parties.*
- *When MISO requests a RDT limit increase and one or more of the Joint Parties deny MISO's request, MISO needs a better understanding of Joint Parties' system challenges such as congestion, flows, and outages, and reasons for MISO's request for a limit increase is being denied. MISO plans to address this issue in the current contract renegotiations.*
- *Review schedules at a more granular level and target cuts to those with greater impact to RDT. Develop a tool that MISO operations can use to visualize what is driving impacts to the RDT.*
- *Increase the shadow price for RDT prior to emergency events. Increasing the RDT shadow prices will limit flows and allow more efficient management of the RDT limit.*

Local Transmission Emergency and Maximum Generation Event Level 5 Pricing

Local Transmission Emergencies (LTE) are declared when MISO expects it will not be able to mitigate operating limit conditions using normal procedures in a timely fashion. During the Arctic Event, MISO declared several LTEs. Of note, MISO declared an LTE for the Western Load Pocket on Feb 15-16 because of large generation outages in the pocket and forced transmission outages causing potential overloads. This declaration included shedding firm load.

This section describes lessons learned and actions that combine both the Arctic Event and the 2020 Hurricane events (in particular, Hurricane Laura). While the events differ in season and root cause, they highlighted similar issues with localized emergency load reduction events that had both transmission and generation causes. Some of the actions listed here were identified after Hurricane Laura and are still in the process of being finalized and filed at FERC.

The IMM noted that during Hurricane Laura, MISO declared a capacity emergency for similar issues in the Western Load Pocket but opted for an LTE in the Arctic Event. Locational Marginal Prices (LMPs) and Market Clearing Prices (MCPs) would have required after the fact repricing and set to the Value of Lost Load (VOLL) ($3,500 per MWh) had MISO declared a capacity emergency (EEA 3)rather than the LTE in the Arctic Event. Instead average LMPs were $843 per MWh which did not reflect system conditions and operator's actions.

Outage studies showed that about 2,500 MW of generation would be unavailable by 16:00 on Feb 16. Public appeals for conservation were made. Realizing the grid's stability was in danger and unable to import the needed energy to meet demand, MISO declared a Maximum Generation Event Step 5 (EEA 3). Operators notified the Local Balancing Authorities in the South Region to collectively shed 700 MW of load to avoid widespread cascading outages: Entergy Arkansas - 146 MW, Entergy MS - 57 MW, SMEPA - 41 MW, CLECO - 73 MW, EES - 320 MW, LAFA - 9 MW, LAGN - 43 MW, and LEPA - 4 MW. The Local Balancing Authorities then determined which customers would be impacted. The entire emergency load reduction event lasted two hours and twenty minutes. Per the MISO Tariff, prices in the affected area are increased to the established Value of Lost Load (VOLL), which is $3,500/MWh. Because of a data processing issue some LMPs and MCPs had to be repriced after the fact for the Step 5 emergency load reduction event.

Lesson Learned: The current market design during transmission emergency events may not lead to efficient economic outcomes that support system reliability. Operating procedures and market capabilities need to be aligned, and in some cases enhanced, to result in real time prices that reflect system conditions, producing economic outcomes that support system reliability.

Actions to address:

- *Investigate and evaluate market price efficiency during Emergency Events requiring emergency load reduction below the Local Resource Zone levels in order to produce prices consistent with system conditions.*
- *Investigate and evaluate the allocation of Real-Time Excess Congestion, including Revenue Neutrality Uplift costs, due to scarcity pricing.*
- *Investigate ways to ensure that preliminary prices are representative of settlement prices during Step 5 emergency load reduction events. Implementation of such changes will have to be prioritized in light of MISO's Market System Enhancements acceleration effort.*

Tools and Training

As the independent system operator, MISO has responsibility to maintain electric reliability, which it does by addressing the holistic needs of the system – such as energy, capacity, resource adequacy, and flexibility. The electric system is increasingly fueled by wind and solar, and generation fleet change and extreme weather events such as hurricanes and the Arctic Event are increasing risk across the entire year (not just in the summer). To address these challenges, MISO is pursuing the "Operations of the Future" initiative as part of its Reliability Imperative. This effort is designed to ensure that MISO will have the kinds of skills, processes, and technologies it will need to effectively manage both wholesale and retail connected resources. For example, this initiative will leverage artificial intelligence, machine learning, and advanced analytics among other tools to help future MISO control-room operators effectively forecast, visualize, and manage grid uncertainty. It will also help MISO to better manage maintenance and "pre-position" the grid ahead of system changes such as weather. The Arctic Event and the increased extreme weather during the past year has strengthened MISO's focus on and sense of urgency to develop technological tools to support our operators in decision making.

Lesson Learned: Additional and improved technology tools to support operator decision making will be helpful in future events as the increase in extreme weather and fleet change will continue to present visualization and decision-making challenges.

Actions to Address:

- *Design tools to provide better visualization of the system and its pain points.*

> *Implement more efficient analysis programs to more easily and quickly inform operators of critical information needed to inform decision-making, such as a tool to help MISO understand the drivers of the RDT calculation.*

Lesson Learned: The Arctic Event and the extensive use of collaboration tools presented an opportunity to train newer Operators *without their being in the middle of the event response.*

Action to Address:

> *MISO will continue to leverage collaboration tools to allow newer Operations staff to observe during real-world emergency events.*

Credit and Collateral

The purpose of MISO's Credit Policy (Attachment L to the MISO Tariff) is to protect its members by preventing losses in the market that are passed onto its members. MISO's credit team typically calculates a participant's credit exposures based on the market participants' forecasted financial obligations from market activity, and then requires that amount be covered by financial security or secured credit as allowed under MISO's Tariff.

When a market participant can't satisfy financial obligations, also known as a default, MISO may suspend all services (subject to FERC approval for load serving entities). The defaulting entity's unpaid financial obligation is applied through short payments to the market. A short payment means MISO reduces the revenue distributions for the billing period by the amount of the financial default incurred in the market. Prior to 2021, MISO had no financial defaults of more than $1,000.

Leading into the Arctic Event, MISO's credit team anticipated a risk of significant increase in credit exposures resulting from the potential for emergency pricing being implemented. Because MISO was operating under emergency pricing conditions, there were lags in the settlement credit system for capturing the credit exposure risks from the Arctic Event. The credit team had regular contact with the market reliability and pricing teams to assess the duration and potential impact of the event on market prices.

The Arctic Event caused a significant increase in credit exposure for many market participants. The highest price impact of the event was primarily between February 15 to February 18. However, there was increased pricing and higher demand throughout the week of February 15. Due to the natural delay in forecasting financial obligation and the resulting credit exposure, margin activity didn't spike until the week beginning February

22, resulting in 140 margin calls totaling $325 million[10]. Margin call refers to when a market participant's credit exposure is greater than the financial security and unsecured credit they have in place with MISO, and MISO requests additional collateral or reduced activity in the market. All margin calls were cured by market participants, but some parties indicated a level of financial strain.

Several MISO market participants were concerned that credit calculations used to determine credit exposure would result in margin calls in excess of real financial obligations. There was a concern this could create un unnecessary additional financial strain from the Arctic Event. Market participants mentioned that Southwest Power Pool (SPP) was seeking a specific credit calculation waiver from FERC to suspend margin calls for several weeks post the Arctic Event. Given how the tariff defined credit exposure calculations, MISO did forecast an over collateral position for some market participants in the coming week. Hence, to prevent additional financial strain on some market participants, MISO sought a waiver from FERC on February 24 to allow adjustments to the credit exposure calculation, which FERC approved on February 25, 2021. In the waiver, MISO obtained approval from FERC to use the best available information for the credit exposure calculations. This allowed MISO's credit team to calculate credit exposure using the most current data to better estimate the forecasted financial obligation while not over-collateralizing the market. MISO implemented the changes immediately resulting in over $110 million of margin call relief for 40 market participants.

During this period MISO diligently investigated MISO market participants to identify any that may have been significantly exposed to other markets. The credit team established a target list and investigated each market participant. Fortunately, MISO identified only one market participant with an extreme level of exposure to other markets and that party had already filed bankruptcy.

Combining all high price volatility events including the most recent Arctic Event, MISO is investigating whether potential changes to the Tariff may be beneficial to protect the market.

Lesson Learned: (Bankruptcy and Default Provisions) The specific bankruptcy issue was the first of its kind in the MISO markets because the defaulting party is a load serving entity that did not name MISO as a critical vendor in the bankruptcy. The bankruptcy law puts an automatic stay in place in the action which prohibits MISO from sending certain notices, such as a notice of default, to the party. This creates misalignment with requirements and actions required in the Tariff, including Section 7 of Module A.

[10] For reference, MISO typically issues around 10 margin calls totaling an average of less than $10 million during a week of normal operations.

Action to address:

- *MISO is evaluating if Tariff amendments will help MISO address these types of situations in the future. A potential solution is amending the Tariff to modify the notice process required to parties to resolve the conflicts recently experienced.*

Lesson Learned: (Alternative Credit Exposure Calculations) During the Arctic Event, it became apparent that MISO would over collateralize several members under the Tariff, indicating that MISO needs a modification in the Tariff to account for impacts from extreme pricing events.

Action to address:

- *To better address potential future events, MISO may seek to revise the Tariff and allow for alternative calculations that may be used in extreme pricing volatility events with appropriate notifications to parties. This would be more efficient than requesting an emergency waiver from FERC in the middle of an event; and*
- *MISO is evaluating using the preliminary Locational Marginal Pricing and telemetry data in the credit exposure calculation to cover the expected future S7 settlements. If this approach works, MISO's Credit Policy would need to be revised.*

Lesson Learned: (Minimum Capitalization) The low minimum capitalization requirements in the Tariff may be insufficient in protecting the market in extreme pricing events.

Action to address:

- *Due to increased market price volatility, the minimum capitalization requirements are being evaluated to determine in what instances they provide inadequate protection for the market. Other RTO/ISOs have already made or are considering revisions in this area. MISO is working with the other RTO/ISOs for awareness and potential standardization within the industry.*

Lesson Learned: (Unsecured Credit) Unsecured credit provides a benefit to market participants; however, it also can create unexpected market exposure in extreme pricing events as some market participants may have no cash collateral posted with MISO to offset or cover market defaults.

Action to address:

- *MISO is evaluating approaches that might be used to determine prudent minimum cash equivalent collateral level for market participants, thereby, providing at least some protection to the market in the event of extreme market pricing volatility.*

Communications

MISO communicates to a diverse group, including its members, members' customers, stakeholder groups, seams partners, regulators, legislators, media, and natural gas industry partners. Reaching and informing our various stakeholders effectively and predictably is the driver behind the communication protocols established by MISO's crisis communication plan and operations procedures. Communication is critical during impactful operational events like the Arctic Event. This section of the Report discusses MISO's external communications and identifies areas of improvement.

Lesson Learned: Recent operational events such as the 2020 hurricane season and the Arctic Event offer an opportunity to further collaborate with members and other industry groups to understand and deliver more effective communications going forward. By collaborating, all parties may avoid or mitigate negative press, concern from legislators and regulators, and ultimately customer frustration.

Actions to Address:

- *MISO will increase coordination with utilities, regulators, and others to ensure consistent messaging and to determine how and when to make emergency public appeals for conservation in the near term. MISO will schedule a communication-focused event focused on crisis communications.*
- *Reinforce communications lessons learned with member companies during Hurricane Action Plan drills and Reliability Coordinator drills. Engage in identifying roles, responsibilities, dependencies, and processes for communications during winter and summer (including hurricane) readiness activities.*

Lesson Learned: Many entities, including members and reliability enforcement entities, requested data and meetings during and after the Arctic Event. Significant MISO time, including time from those in Operations, was required to respond to these inquiries or requests for information, and at times this support pulled people away from responding to the event.

Actions to address:

- *Proactively assess internal, regulator, and stakeholder data needs to identify sources for the data and standardize the format for delivering the data.*
- *Leverage this Arctic Event Report as well as other Reliability Imperative messaging to raise emerging issues and provide context for stakeholders, state regulators, and federal regulators.*
- *Promote use of the newly launched MISO Mobile app, which gives users access to MISO's real time data visualization tools (LMP Contour Map, Real-Time Total Load, and Real-Time Fuel Mix). MISO Mobile also provides important real-time notifications and alerts.*

MISO's Response to the Independent Market Monitor

At the Markets Committee of the MISO Board of Directors meeting on March 23, 2021, the MISO Independent Market Monitor (IMM) presented on the IMM Quarterly Report covering the Winter 2021 period. The IMM presentation found that:

- The MISO markets performed competitively this winter, despite frequent mitigation due to offer capping, and conduct was competitive overall.
- Extremely cold weather, tight conditions, and high gas prices in February contributed to a 75 percent increase in energy prices from last winter.
- Average energy prices rose 10 percent in the first two months of the quarter and 226 percent in February because of the Artic Event in February.
- In the first two months, gas prices increased by 24 percent over the prior year; however, in February gas prices were 12 times as high as in 2020.
- Average and peak load grew 3 and 8 percent, respectively, from last winter because of the colder conditions.
- Very high gas prices and transmission emergencies led to:

- Real-time congestion at a record quarterly level of $1.1 billion, which is more congestion than occurred in MISO during all of 2019; and
- Real-time and day-ahead Revenue Sufficiency Guarantee payments totaled $125 million and $45 million, respectively. This includes costs verified above the $1,000 and $2,000/MWh soft and hard offer caps.

The IMM stated that "MISO's operators performed well under extremely stressful conditions...[and] maintained the stability of the system and avoided the more severe reliability outcomes that occurred in neighboring markets." He cites the following key lessons learned and improvements based on this event:

1. Improve procedures to invoke transmission line-loading relief (TLRs) earlier in advance of a transmission emergency and associated actions.
2. Increase Transmission Constraint Demand Curves during emergencies to ensure pricing and dispatch reflects the emergency conditions.
3. Derate the Regional Dispatch Transfer (RDT) after shedding load in a MISO sub-region to create headroom for load to return sooner.
4. Modify sub-regional emergency procedures to utilize curtailments of non-firm exports that consume the Regional Dispatch Transfer (RDT) interface.
5. Define and/or activate market to market (M2M) constraints as quickly as possible to ensure partners provide available relief and pay for their share of the overloads.
6. Ensure that emergency pricing and shortage pricing is applied consistently in capacity and transmission emergencies.

MISO's ongoing Resource Availability and Need focus on Scarcity Pricing address several of these issues and our response to the IMM's State of the Market will respond to application of emergency and scarcity for capacity and transmission emergencies.

Appendix: Lessons Learned and Actions Summary Table

	Lessons Learned	Actions to Address
1	While MISO's robust grid, along with its ability to import power from outside of the region, resulted in relatively limited impacts during the Arctic Event, MISO needs to continue evolving its transmission system in response to the changing resource mix and evolving grid. The anticipated changes in resource mix and extreme weather puts increased urgency on transmission planning.	• MISO will leverage the Long Range Transmission Planning (LRTP) activities to identify intra- and inter-regional planning to ensure reliability as the resource mix continues to evolve and disruptive weather events become more frequent. In particular, LRTP will evaluate further north-south transfer capability which would have helped during the Arctic Event. • Transfer capability - MISO will examine load pockets as part of transmission planning and resource accreditation. • Along with LRTP, MISO will also continue to work with all of its seams partners to identify ways to increase coordination. For example, MISO and SPP are currently engaged in an effort focused on the SPP – MISO seam.
2	MISO's resource adequacy construct provided transparency about adequacy of resources to meet projected summer loads. However, improvements can be made to more fully account for the non-summer risks and to ensure that resources will be available across all seasons. MISO has already seen and anticipates continued reliability challenges throughout the year – while reliability risk was once concentrated in the summer season, MISO now has to be	• MISO is moving to a sub-annual (4 season) resource adequacy construct and an accrediting methodology based in part on a resources' availability during the hours when the system is most in need (tight operating hours), thereby giving resource owners an incentive to ensure resources availability through investments in winterization, fuel assurance or other means. These changes are expected to be filed at the Federal Energy Regulatory Commission (FERC) in the second half of 2021.

	increasingly concerned with every hour of the year.	
3	Current resource accreditation criteria do not specifically address generator readiness to operate during extreme weather events. With the rapid fleet transition toward natural gas and the increased frequency and severity of extreme weather, this issue is expected to worsen over time.	• MISO will work with states and others to identify changes that may be required in MISO processes or elsewhere, to better reflect resource availability during extreme weather events (e.g., winterization needs during extreme cold, fuel assurance). • MISO will consider the impacts of the generation fleet change on the need for additional coordination with the natural gas sector on issues of fuel assurance.
4	In reporting results of Seasonal Assessments, MISO and stakeholders have not typically focused as much on the extreme cases (high load + high outages).	• MISO will focus more attention on extreme outcomes as well as expected outcomes during seasonal assessment workshops. • MISO will evaluate how to incorporate existing extreme cases into Seasonal Assessments and drills.
5	Current emergency load reduction plans are focused on summer needs. This new experience provides an opportunity for MISO and stakeholders to assess preparation for winter events.	• MISO will investigate the feasibility of a pre-winter feedback loop, which would allow members to express their readiness for the winter weather. This feedback would include information about generator weatherization and winter checklist completion. • MISO will encourage Local Balancing Authorities (LBAs) to refine emergency load reduction plans to include winter event load shedding, when cutting power can have different consequences than in the summer. MISO will encourage the refined emergency load reduction plans to consider which elements are critical and what to do if the requested emergency load reduction exceeds their capacity to rotate outages.

		• *MISO will seek additional feedback from stakeholders on their learnings from past events during the Seasonal Assessment workshops.* •
6	In extreme events, energy flows may be very different than those seen under normal operations. During the Arctic Event, MISO experienced very high flows across its system, and in an unusual direction as power was flowing from the (relatively warm) east coast to the more impacted central part of the country. With the increased severity of extreme events, it will become more important to plan for these scenarios.	• MISO will include the impacts of high wheel through flows in the seasonal transmission assessment to better prepare for extreme weather events.
7	Based on experience during the Arctic Event and the significant number of generator outages based on cold weather conditions, MISO believes that additional data, provided by additional survey participation, will help to inform decisions made during future extreme weather events.	• MISO is combining the Winterization and Annual Gas Fuel surveys and removing all backward-looking and redundant questions, with the goal of increasing participation in the survey. MISO will consider additional ways of accessing this information, including engaging in the process to develop NERC Cold Weather standards to be reflective of the increased risks seen during the Arctic Event. • Incorporate fuel assurance into scenario planning and drills, with a particular focus on MISO visibility into fuel plans.
8	Drills have been helpful in coordinating among operations staff. Given the wide scope of the Arctic Event, the drills were not sufficiently	• Increase comprehensive drills for extreme events – including operations, outage coordination, emergency load reduction planning, communications, and regulatory coordination. MISO

	comprehensive. In recent years, MISO has shifted to more tabletop exercises with specific groups (e.g., outage coordination or cyber security). However, the Arctic Event and the expected growth in similar extreme weather events in the future points to the need for comprehensive drills that include more groups across MISO and member utilities.	plans to incorporate more fuel assurance scenarios and responses into planning and drilling.
9	MISO's ability to accurately forecast weather conditions directly leading up to and during the Arctic Event, facilitated by having a meteorologist on staff, gave MISO the opportunity to prepare in advance, including issuing Informational Advisories early in the week prior to the event, reminding members to accurately reflect projected fuel supply access and availability to their generation and resource offers. These advisories also requested members implement any winterization processes and maintenance for generation resources in the footprint and confirm fuel supply availability through the President's Day holiday.	• MISO will continue to leverage in-house and vendor meteorology expertise to inform MISO operational decisions and communication with members. MISO is continuing to assess how best to translate accurate weather forecasts into accurate forecasts of the effects of the weather (e.g., outages tied to weather).
10	MISO's current process to identify available uncommitted resources is	• In order to provide more visibility into available units, MISO is preparing an Available Resource report as part of the Capacity

	tedious, takes more time than necessary, and does not always leave sufficient time to start resources with a long lead time. The spreadsheet-based tool currently used to identify resources must be operated manually each time it is needed, taking upwards of five minutes to compile necessary information.	Sufficiency Analysis Tool (CSAT) to communicate to MISO commitment teams the resources available for commitment. The report provides a list of resources available for capacity at any given point in time and helps operations make commitment decisions during tight operating conditions by producing a dynamic list of resources, meaning that a resource will automatically drop off the available commitment list if its window for start-up has passed for any given hour.
11	The Regional Dispatch Transfer (RDT) can be more effectively managed during emergency operating conditions.	• Since identifying this action item following the 2018 Cold Weather Event, MISO has improved communication with Joint Parties on RTD exceedances. MISO will continue to look for ways to better coordinate with Joint Parties. • When MISO requests a RDT limit increase and one or more of the Joint Parties deny MISO's request, MISO needs a better understanding of Joint Parties' system challenges such as congestion, flows, and outages, and reasons for MISO's request for a limit increase is being denied. MISO plans to address this issue in the current contract renegotiations. • Review schedules at a more granular level and target cuts to those with greater impact to RDT. Develop a tool that MISO operations can use to visualize what is driving impacts to the RDT. • Increase the shadow price for RDT prior to emergency events. Increasing the RDT shadow prices will limit flows and allow more efficient management of the RDT limit.
12	The current market design during transmission emergency events may not lead to efficient economic outcomes that support system	• Investigate and evaluate market price efficiency during Emergency Events requiring emergency load reduction below the Local Resource Zone levels in order to produce prices consistent with system conditions.

	reliability. Operating procedures and market capabilities need to be aligned, and in some cases enhanced, to result in real time prices that reflect system conditions, producing economic outcomes that support system reliability.	• Investigate and evaluate the allocation of Real-Time Excess Congestion, including Revenue Neutrality Uplift costs, due to scarcity pricing. • Investigate ways to ensure that preliminary prices are representative of settlement prices during Step 5 emergency load reduction events. *Implementation of such changes will have to be prioritized in light of MISO's Market System Enhancements acceleration effort.*
13	Additional and improved technology tools to support operator decision making will be helpful in future events as the increase in extreme weather and fleet change will continue to present visualization and decision-making challenges.	• Design tools to provide better visualization of the system and its pain points. • Implement more efficient analysis programs to more easily and quickly inform operators of critical information needed to inform decision-making, such as a tool to help MISO understand the drivers of the RDT calculation.
14	The Arctic Event and the extensive use of collaboration tools presented an opportunity to train newer Operators without their being in the middle of the event response.	• MISO will continue to leverage collaboration tools to allow newer Operations staff to observe during real-world emergency events.
15	(Bankruptcy and Default Provisions) The specific bankruptcy issue was the first of its kind in the MISO markets because the defaulting party is a load serving entity that did not name MISO as a critical vendor in the bankruptcy. The bankruptcy law puts an automatic stay in place in the action which prohibits MISO from sending certain notices, such as a	• MISO is evaluating if Tariff amendments will help MISO address these types of situations in the future. A potential solution is amending the Tariff to modify the notice process required to parties to resolve the conflicts recently experienced.

	notice of default, to the party. This creates misalignment with requirements and actions required in the Tariff, including Section 7 of Module A.	
16	(Alternative Credit Exposure Calculations) During the Arctic Event, it became apparent that MISO would over collateralize several members under the Tariff, indicating that MISO needs a modification in the Tariff to account for impacts from extreme pricing events.	• To better address potential future events, MISO may seek to revise the Tariff and allow for alternative calculations that may be used in extreme pricing volatility events with appropriate notifications to parties. This would be more efficient than requesting an emergency waiver from FERC in the middle of an event; and • MISO is evaluating using the preliminary Locational Marginal Pricing and telemetry data in the credit exposure calculation to cover the expected future S7 settlements. If this approach works, MISO's Credit Policy would need to be revised.
17	(Minimum Capitalization) The low minimum capitalization requirements in the Tariff may be insufficient in protecting the market in extreme pricing events.	• Due to increased market price volatility, the minimum capitalization requirements are being evaluated to determine in what instances they provide inadequate protection for the market. Other RTO/ISOs have already made or are considering revisions in this area. MISO is working with the other RTO/ISOs for awareness and potential standardization within the industry.
18	(Unsecured Credit) Unsecured credit provides a benefit to market participants; however, it also can create unexpected market exposure in extreme pricing events as some market participants may have no cash collateral posted with MISO to offset or cover market defaults.	• MISO is evaluating approaches that might be used to determine prudent minimum cash equivalent collateral level for market participants, thereby, providing at least some protection to the market in the event of extreme market pricing volatility.

19	Recent operational events such as the 2020 hurricane season and the Arctic Event offer an opportunity to further collaborate with members and other industry groups to understand and deliver more effective communications going forward. By collaborating, all parties may avoid or mitigate negative press, concern from legislators and regulators, and ultimately customer frustration.	• MISO will increase coordination with utilities, regulators, and others to ensure consistent messaging and to determine how and when to make emergency public appeals for conservation in the near term. MISO will schedule a communication-focused event focused on crisis communications. • Reinforce communications lessons learned with member companies during Hurricane Action Plan drills and Reliability Coordinator drills. Engage in identifying roles, responsibilities, dependencies, and processes for communications during winter and summer (including hurricane) readiness activities.
20	Many entities, including members and reliability enforcement entities, requested data and meetings during and after the Arctic Event. Significant MISO time, including time from those in Operations, was required to respond to these inquiries or requests for information, and at times this support pulled people away from responding to the event.	• Proactively assess internal, regulator, and stakeholder data needs to identify sources for the data and standardize the format for delivering the data. • Leverage this Arctic Event Report as well as other Reliability Imperative messaging to raise emerging issues and provide context for stakeholders, state regulators, and federal regulators. • Promote use of the newly launched MISO Mobile app, which gives users access to MISO's real time data visualization tools (LMP Contour Map, Real-Time Total Load, and Real-Time Fuel Mix). MISO Mobile also provides important real-time notifications and alerts.