2019 Polar Vortex
Looking Back and Planning for the Future
MIPSYCON
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Julie Pierce – Minnesota Power

Derek Mosolf - MISO
MISO connects a large, diverse generation fleet...

### Generating Capacity

- **Coal**: 32%
- **Gas**: 42%
- **Wind**: 15%
- **Hydro/Other**: 6%
- **Nucl.**: 8%

**175 Thousand MW**

### Electricity Generated

- **Coal**: 47%
- **Gas**: 27%
- **Wind**: 8%
- **Hydro/Other**: 16%

**640 Million MWh**

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**Source:** Misoenergy.org website
The generation fleet has shifted, with the pace accelerating toward more renewable and conventional generation retirement.

Total MISO Generation Mix (% of MWh)

2005
- Nuclear: 13%
- Gas: 4%
- Solar: 7%
- Wind: 76%

2018
- Nuclear: 16%
- Gas: 8%
- Solar: 2%
- Wind: 47%

2033: Future Planning Scenarios

Accelerated Fleet Change
- Nuclear: 29%
- Gas: 30%
- Solar: 7%
- Wind: 11%
- Coal: 16%

Distributed & Emerging Tech
- Nuclear: 13%
- Gas: 30%
- Solar: 9%
- Wind: 13%
- Other: 4%
Minnesota Power

Significant Transformation

2005
5% Renewable

2019
30% Renewable Leader in Region

2021
50% Renewable
Within MISO, the State of Minnesota is a net importer of electricity, and a “crossroads”

As a state, MN consumes more electricity than it generates within state borders; it is a net importer in the MISO system

Source: US Energy Information Administration (EIA)
Weather Events & Changing Power System

• Extreme weather events increasing in frequency

• System transformation creating new operating dynamics

• Future system planning will need to consider new normal emerging
North/Central region experienced extreme cold weather this January, similar to the extreme cold weather in the South region last year.

**January 17, 2018**
South Region

- Minimum Temperature: 13°F
- System Peak Load: 106 GW
- Unplanned Outages: 13 GW
- Scheduled LMRs*: 0.9 GW
- Emergency Purchases: 1.2 GW
- RDT Max Flow & Direction: 3.9 GW N-S

**January 30-31, 2019**
North/Central Region

- Minimum Temperature: -26°F
- System Peak Load: 101 GW
- Unplanned Outages: 29 GW
- Scheduled LMRs*: 2.5 GW
- Emergency Purchases: Not Needed
- RDT Max UDS & Direction: 2.2 GW S-N

*LMRs = Load Modifying Resources
MISO and Members reliably managed operations during extreme cold, where temperatures fell below -30°F in some parts of the North and Central regions.

Resulting high load, unavailable generation, and uncertainty in both load and supply created challenges throughout the event.

Emergency procedures were implemented and maintained from early January 30 through the afternoon of January 31 to reliably manage the grid and maintain public safety.

Winter preparedness by MISO and its members ensured readiness for the extreme conditions, but, we note areas of needed improvement in load and wind forecasting, and voluntary load curtailment impacts.
A strong arctic high pressure system brought historic cold to the North and Central Regions on January 30-31, driving temperatures below Polar Vortex 2014 levels

- North Region low temperatures for the 2019 time periods were more than 6°F colder than 2014
- 2019 North region load was dampened by lingering voluntary load curtailments

*Average is for the two days listed
MISO’s operating procedures ensure reliability and gain access to additional resources during extreme situations.

Emergency Operating Procedures guide operator actions when an event has the potential to, or actually does, negatively impact system reliability.

- **Conservative System Operations**
- **Geomagnetic Disturbance Warning**
- **Severe Weather Alert**
- **Cold Weather Alert**
- **Hot Weather Alert**

**Maximum Generation Emergency Procedures**

- **Alert**
  - Define boundaries/suspend maintenance

- **Warning**
  - Schedule in External Resources, Curtail Non-firm exports, Reconfiguration

- **Event**
  - **Step 1 (NERC EEA 1)**
    - Emergency Resources/Dispatch Range
  - **Step 2 (NERC EEA 2)**
    - 2a. Load Management Procedures
    - 2b. Load Management Measures Stage 1/Load Management Resources
    - 2c. Emergency Demand Response
    - 2d. Emergency Energy Purchases/Public Appeals
  - **Step 3**
    - 3a. Utilize Operating Reserves
    - 3b. Load Management Measures Stage 2
  - **Step 4**
    - Reserve Call and Emergency Reserve Purchases
  - **Step 5 (EEA 3)**
    - Firm Load Shed
  - **Termination**

Data Source: SO-P-NOP-00-449 Rev 0 Conservative System Operations and SO-P-EOP-00-002 Rev 3 MISO Market Capacity Emergency procedures
An earlier than expected drop in wind output increased insufficiency risk early on the morning of January 30th.

MISO Actual Wind Generation vs Day-Ahead Wind Forecast

Maximum Generation Event Declaration for 05:00 EST
Total outages were higher than previous cold weather events with approximately 25% unavailable due to unplanned outages*

MISO North/Central Daily Average Generation Outages and Derates

<table>
<thead>
<tr>
<th>Date</th>
<th>Polar Vortex 2014</th>
<th>Arctic Cold Snap 2018</th>
<th>Polar Vortex 2019</th>
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<td>29.0</td>
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The outage chart reflects the data as it resided in the CROW Outage system on Feb 11, 2019.

Wind often reported as derate over the time period.

^Percent based on PRA cleared generation plus uncleared internal MISO generation.

*Unplanned: Forced plus derates

Unplanned Outages (GW) | 20.1 | 29.6 | 28.9
% Unplanned^           | 18%  | 26%  | 26%
Deployed and self-scheduled LMRs, school/business closings, and other voluntary load management across the North/Central Region aided in dampening demand below expectations.
Imports responded to emergency price signals, registering well above 5 GW through the evening peak and Jan 31 morning peak.
Minnesota Power – Polar Vortex

- Diverse power supply supports system reliability
- Regional support and import of energy required to maintain balance
MP Customer Demand Response Programs Called Upon Full Suite

- **Residential Programs**
  - Heating Load Curtailment Program “Dual Fuel”
  - Time of Day Usage – price signal notification to pilot participants

- **Commercial and Industrial Programs**
  - Interruptible and Curtailment Programs
    - Economic
    - Emergency

Customer Demand Response Programs Available

- 265 MW
- Large Customer
- Residential/Commercial

*MISO called an Energy Emergency Alert 2B on January 30th, MP entered Emergency operations, 200 MW of emergency capacity curtailed*
More extreme weather events + intermittent renewables = grid reliability more important than ever
Experience provided lessons learned that will enable us to improve future operational performance

- Improve wind forecasting with additional resource parameters
- Incorporate facility closing impacts into load forecast
- Review emergency pricing rules
- Improve Load Modifying Resource availability & performance
- Improve generation availability & performance
LESSONS LEARNED

Advance Demand Response Programs for More Frequent Use

Update Demand Response Process Coordination with MISO

Review Energy Adequacy Needs for System with Higher Renewables

Review weather package options generation
System Transformation Study and Policy in Progress

- Renewable Integration Impact Assessment (RIIA)
- Resource Availability and Need
- Market Design Evolution
- Minnesota Public Utilities Commission Baseload Generation Plans
Renewable Integration Impact Assessment (RIIA) seeks to find inflection points of renewable integration complexity.

**Focus Areas**

**RESOURCE ADEQUACY**
Having the sufficient capacity of resources to reliably serve peak demand

**ENERGY ADEQUACY**
Ability to provide energy in all operating hours throughout the year

**OPERATING RELIABILITY**
Ability to withstand unanticipated component losses or disturbances

**Illustrative example**

Inflection points are milestones where complexity significantly increases.

RIIA begins by modeling the current system.
Results indicate integration complexity increasing sharply from 30%- 40% renewable penetration.
Overview Of MISO’s Renewable Integration Impact Assessment (RIIA)

**Context:**
RIIA is an ongoing study conducted collaboratively with MISO members to identify MISO-wide renewable penetration levels at which integration complexity significantly increases.

**Emerging Themes:**
- Up to 30% renewables, challenges appear manageable with regular, incremental transmission expansion
- By 40%, significant challenges begin
  - 40% MISO-wide equates to 70-100% local penetration in wind-rich Iowa, Minnesota, North Dakota, South Dakota
  - Tradeoffs required between renewable curtailment & transmission investment
  - Increased flexibility requirements (ramping from conventional generation)
  - Increased system stability concerns
- Challenges can be addressed; however, least cost solutions require careful study and regional coordination across the MISO footprint
- The value of MISO-wide diversity and ‘interconnectedness’ are key
Summary

• The generation fleet within MISO is evolving

• By 40% renewable penetration, significant integration challenges begin

• Utility system planning will need to integrate new scenarios, ensure energy adequacy in all hours

• Challenges can be addressed; however, solutions require careful study and regional coordination…diversity and interconnectedness are key