MISO January 30-31 Maximum Generation Event Overview

February 27, 2019
Key Takeaways:

- 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.
An earlier than expected drop in wind, primarily caused by cold weather cutoffs, increased risk of insufficiency for morning peak, triggering Max Gen Event Step 1a, effective for 0500 EST.
Subsequent forced conventional generation outages, as well as load forecast uncertainty and potential of additional outages, prompted a Max Gen Event Step 2a/b to access LMRs.

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.

LMRs = Load Modifying Resources
Total outages were higher than previous cold weather events with approximately 25% unavailable due to unplanned outages*

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.
Deployed and self-scheduled LMRs, school/business closings, and other voluntary load management across the North/Central Region aided in dampening demand below expectations.

![MISO North/Central Load Management Resources (LMRs) for Jan 30](chart1)

![MISO North/Central Hourly Load for Jan 30](chart2)

*LMR performance to be evaluated after receipt of meter data towards the end of March

* Does not include impact of closings not accounted for in forecast
Imports responded to emergency price signals, registering well above 5 GW through the evening peak and Jan 31 morning peak.
MISO effectively managed the Regional Directional Transfer flow below limits, while leveraging South Region available capacity.
MISO reliably met planned and actual obligations, given extreme temperatures, public safety concerns, forced outage risk, and import volume uncertainty.

**MISO North/Central Load and Capacity (MW)**

- Available Resources in Real-Time
- System NSI
- Planned Obligations
- Actual Obligations

**Available Resources in Real-Time** is the sum of Day-Ahead committed capacity, Forward RAC committed capacity, Intraday RAC committed capacity, and Regional Directional Transfer less “No-Shows” and capacity stranded behind constraints. Obligations include regulation and spinning reserve requirements.
Given extreme conditions, subsequent prudent operating steps resulted in Uplift Charges exceeding $18 million over two days, comparable to previous months with severe cold outbreaks.

Note: RSG is amortized over the commitment period, Price Volatility MWP is as occurred.
MISO evaluates extreme weather events to capture and incorporate lessons learned as part of its commitment to maintain the reliability of the Bulk Electric System.

- Gather additional operating parameters from all generation resources, such as temperature thresholds, to assist with accurate forecasting and reduce uncertainty in Real-Time.
- Establish load forecasting variables that address the impacts of known voluntary load curtailment, such as school and business closing, during extreme weather.
- Increase visibility into the availability and performance of Load Modifying Resources and Load Management Measures (LMR/LMM) during an event.
Appendix
MISO continued to monitor conditions and update communications accordingly during the event.
Extreme N/C cold drove high load, a sudden and unexpected drop in wind generation, forced outages, and uncertainty, which required the declaration of the Maximum Gen Event.

<table>
<thead>
<tr>
<th>MISO Classic (North/Central Regions)</th>
<th>2014 01/06-21°/-11°F</th>
<th>2018 01/07-13°/-10°F</th>
<th>2019 01/17-2°/-3°F</th>
<th>2018 01/28 2°/10°F</th>
<th>2019 01/29 -20°/4°F</th>
<th>2019 01/30 -26°/-10°F</th>
<th>2019 01/31 -21°/-8°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Peak Load (GW)</td>
<td>79.9</td>
<td>76.7</td>
<td>73.7</td>
<td>70.4</td>
<td>74.3</td>
<td>76.7</td>
<td>75.1</td>
</tr>
<tr>
<td>Average Daily MISO Wind</td>
<td>7.2 GW</td>
<td>2.0 GW</td>
<td>12.0 GW</td>
<td>12.9 GW</td>
<td>12.9 GW</td>
<td>4.3 GW</td>
<td>4.7 GW</td>
</tr>
<tr>
<td>Gas Price* ($/MMBtu)</td>
<td>$13.17</td>
<td>$7.39</td>
<td>$3.91</td>
<td>$3.13</td>
<td>$4.23</td>
<td>$7.42</td>
<td>$5.09</td>
</tr>
<tr>
<td>Average Daily RT LMP ($/MWh)</td>
<td>$97.74</td>
<td>$225.83</td>
<td>$40.90</td>
<td>$25.53</td>
<td>$26.92</td>
<td>$107.90</td>
<td>$49.29</td>
</tr>
<tr>
<td>Max Daily NSI (Import)</td>
<td>4.3 GW</td>
<td>-2.1 GW</td>
<td>3.4 GW</td>
<td>7.1 GW</td>
<td>9.0 GW</td>
<td>13.7 GW</td>
<td>7.8 GW</td>
</tr>
</tbody>
</table>

**Cold Weather Alert**

**Max Gen Event Step 1a**

**Conservative Operations**

**Max Gen Event Step 2a/b**

**Max Gen Event Step 1b/c**

**Max Gen Alert**

**Max Gen Warning**

Shading indicates declaration was active during that day.

- Temperatures are daily low values for North and Central Regions
- LMP is calculated as an average of Hubs in the North and Central regions
- *Chicago City Gate Gas Price

Data Source: Real-Time Operations, Market Analysis, and MISO Website

Called on Jan 25 for Operating Days Jan 29 – Feb 01
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**

- Geo-Magnetic Disturbance Warning
- Severe Weather Alert

**Maximum Generation Emergency Procedures**

1. **Alert**
   - Define boundaries/suspend maintenance
2. **Warning**
   - Schedule in External Resources, Curtail Non-firm exports, Reconfiguration
   - **Step 1 (NERC EEA 1)**
     - Emergency Resources/Dispatch Ranges
   - **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
3. **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*
MISO is prepared for emergency situations