Resource Availability and Need
Issues Statement Whitepaper
March 30, 2018
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1. Executive Summary

Changing market conditions at MISO have resulted in a resource portfolio with altered operational characteristics and less certain available and/or committed capacity each average operational day. In the past, a Maximum Generation Emergency (MaxGen) occurred every year or two when MISO needed access to emergency-only resources. Now, there have been 12 since the start of the 2016/17 Planning Year and they have occurred in all four seasons. This increase in MaxGen declarations is the result of five trends impacting the alignment of resource availability and need (RAN), which have caused increasingly notable challenges to MISO’s ability to serve load reliably throughout the year. This whitepaper is intended to set the stage for an issue and solution development effort that will help MISO and its stakeholders ensure the processes in use support the conversion of committed capacity resources into energy sufficient to enable reliable and efficient operation of the Bulk Electric System.

Key Trends

Trend 1: Aging and retirement of the portfolio’s generating units and the resulting impact on MISO’s operations. Retirements and increasing outage levels (both planned and forced) require MISO to operate with less available capacity than in the past. The effect is to reduce the redundancy provided by excess resource availability. For example, daily average energy offers were down 8 GW in Planning Year 2016/17 over Planning Year 2015/16. This reduction reflects a 4 GW net resource retirement and a 4 GW (23 percent) increase in the average MWs on outage.

Trend 2: Outage correlation. The MISO system has year-round load and supply needs, but is planned with a summer-focused capacity commitment. Lower overall capacity levels and higher outage rates have reduced available capacity in non-summer periods and, as a result, MISO has seen outages during non-summer periods imposing a growing challenge to ensuring sufficient available capacity in those periods. A dramatic increase in MaxGen declarations outside summer suggests this trend has impacted the sufficiency of energy availability.

Trend 3: Growth in demand side and other emergency-only capacity as a percent of the overall portfolio. LSEs committed nearly 12 GW of emergency-only Capacity Resources in 2017. This was 9 percent of the summer peak load forecast. These 12 GW of resources are not available to MISO’s operators without the declaration of a MaxGen event under the existing framework.
Trend 4: Growing reliance on intermittent or unscheduled resources. MISO has recently more heavily relied upon forecast yet uncertain or otherwise non-committed supply resources (Figure 1). The circles show MaxGen declarations when the margin for operational balance was such that reliability could have been at risk, but for these uncertain supply sources. While MISO has arrangements in place for purchase of emergency energy from neighboring systems during declared emergency conditions as occurred in January 2018, availability of such energy remains highly uncertain during such conditions. While the regions have successfully managed these issues to date, MISO must now assess its ability to ensure sufficient conversion of committed capacity into energy in all time periods in light of this trend.

![Figure 1: Resource Availability and Need since January 2014](image)

Trend 5: Growth of variable energy resources as a major element of the fleet. This increasingly important resource category, by its very nature, has different operational characteristics than legacy thermal resources. Renewable resources are accredited based on historic contribution during past system peaks, but there is no assurance that the accredited capacity will be available during a particular emergency event. If wind or solar happen to contribute less during a particular time of need than in past years the difference must be made up elsewhere. While it is also likely that, at times, these resources will help conditions by producing more than accredited, it is important to understand and plan for the operational implications of further renewable penetration. This will require further assessment to explore how best to manage operational reliability while depending on a larger fleet of capacity resources that must be forecast for operations rather than dispatched. MISO will continue to improve its ability to forecast resource availability and need so it can take timely action to meet net load and ensure operational adequacy, and further assessment is called for ahead of the anticipated continued growth of this segment of the fleet.
Action Plan

Through the stakeholder process, MISO seeks to initially validate the priority of concerns raised in this document and then work with stakeholders to identify options to address high priority issues ensuring reliable operations remain consistent with our planning standards. To do this, MISO proposes grouping RAN-related issues within three broad areas for improvement:

- Increase transparency of resource availability and need
- Refine resource availability requirements
- Improve price signals

MISO is working to improve its ability to understand, forecast and communicate uncertainties to enhance RAN transparency. There are two issues that MISO will bring to stakeholders for discussion in the near future. One, the nature of the challenges an increasing reliance on 12 GW of emergency-only resources pose and the possible changes that can address them. Two, MISO will review with stakeholders planned improvements to its outage coordination process in 2018 to review possible implications and determine the need for further enhancements. Items in the “refine resource availability requirements” and “improve price signals” areas will require further development with stakeholders and will be discussed with as the evaluation of transparency issues.

The RAN initiative provides an opportunity for MISO and its stakeholders to assess emerging challenges in the evolving industry landscape and to work collaboratively to assess solutions that will enable continued success at converting capacity into energy in line with planning outcomes.
2. Aging and Retirement of the Portfolio’s Generating Units

The aging and retirement of Planning Resources requires MISO to operate with less energy available for dispatch each day than has been true in the past. The effect is to reduce the redundancy provided by excess resource availability. Average energy offers were down 8 GW in Planning Year 2016/17 versus 2015/16 (Table 2.0-1). The difference is explained by retirements and a 4.2 GW (23 percent) increase in MWs on outage. An average loss of 8 GW of energy offers meant that the natural variabilities in load and resource availability are much more likely to result in MISO encountering issues in meeting real-time energy needs.

<table>
<thead>
<tr>
<th>Planning Year</th>
<th>Avg. Energy Offers (MWs)</th>
<th>Avg. Outages (MWs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014/15</td>
<td>126,400</td>
<td>16,800</td>
</tr>
<tr>
<td>2015/16</td>
<td>125,100</td>
<td>18,400</td>
</tr>
<tr>
<td>2016/17</td>
<td>117,100</td>
<td>22,600</td>
</tr>
</tbody>
</table>

Table 2.0-1: Average Energy Offers and Outages by Planning Year

Key issues:

- Retirements have reduced the excess capacity and energy available in the MISO region
- Aging can reduce the energy expected to be available from MISO’s resources
- MISO prepares for times when reliability is challenged by capacity insufficiency

2.1. Retirements reduce the capacity and energy available from MISO’s portfolio

When resources retire, or are otherwise no longer available to MISO’s operators, the result is less available capacity. This, in turn, leads to lower overall MW offers in the energy markets throughout the year. RAN varies over time in response to weather and system conditions. In the past, MISO had a larger buffer of dispatchable generation that provided flexibility to respond to higher than expected load (or lower energy offers) while still allowing energy market price signals to optimize unit commitment and dispatch. When capacity is tight, MISO’s operators make reliability commitments to address the uncertainty of resource availability and need in place of price signals in the market. This often leads to higher production costs, which are then uplifted, reducing the efficiency and equity of the MISO markets. Less resource availability also reduces the flexibility available to schedule outages for our aging portfolio of resources.
2.2. Aging can reduce the energy available from MISO’s resources

Aging can lead to higher forced, planned and maintenance outage rates (Figure 2.2-1).

![Figure 2.2-1: Forced outage rates by region since 2011](image)

From the perspective of MISO’s operators the current accountability mechanisms for the must offer requirement do not provide transparency into what resources will be available in the day-ahead market. In principle, the must-offer requirement captures every ZRC as available but there are a number of provisions in MISO’s tariff that exempt ZRCs from an obligation to participate during a given Operating Day, limiting the energy offers and flexibility operators have to respond to challenging real-time conditions. These provisions include:

- The existence of a must-offer obligation is not a factor in MISO’s ability to reschedule outages, which are limited to specific transmission system reliability concerns or the expectation of an emergency
- Planned and maintenance outages do not impact a resource’s calculated Equivalent Forced Outage Rate Demand (EFORd) rate
- A wind resource receives credit based on historic capabilities during peak; on a given operating day, its must-offer requirement is limited to its projected capability
- Load Modifying Resources (LMR) do not have a must-offer obligation for any time periods outside summer. They can only be called on five times each summer and can have notification times up to 12 hours

2.3. MISO must continue to prepare for times when reliability is challenged by capacity insufficiency

MISO conducts summer and winter readiness workshops with stakeholders each year to assess its ability to meet the expected peak for these seasons (Figure 2.3-1). Recently these have also included deterministic scenario analysis accounting for outages and calculating a probability for the use of emergency-only resources such as Behind the Meter Generation (BTMG), Demand Response (DR) and the deployment of operating reserves.
Historically, MISO has not conducted readiness workshops in advance of the spring and fall because MISO and its stakeholders have not expected to be short in the shoulder seasons. However, in March 2018, MISO provided a spring outlook presentation at the Market Subcommittee¹.

MISO experienced an unexpected MaxGen Alert in its South region in October 2016. In response, MISO analyzed the event and made operational improvements to mitigate the risk of future occurrences. These short-term improvements focused on increasing situational awareness (Figure 2.3-2).

### Figure 2.3-2: Recent Improvements to Situational Awareness²

<table>
<thead>
<tr>
<th>Improvement Areas from Near to Long-Term Implementation</th>
<th>Issue Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conservative System Operations and Capacity Emergencies</td>
<td>Evaluate thresholds for entering into steps of the Maximum Generation Emergency Procedure</td>
</tr>
<tr>
<td>2. Process and Reporting</td>
<td>Increase visibility into regional capacity and include information as part of “handoff” reports, along with identification of additional training requirements</td>
</tr>
<tr>
<td>3. Determination of Stranded MW</td>
<td>Improve calculation and incorporation of stranded MW</td>
</tr>
<tr>
<td>4. Regional Directional Transfer (RDT) Limit</td>
<td>Ensure consistent application and enforcement of RDT limits</td>
</tr>
<tr>
<td>5. Reserve Zones</td>
<td>Work with MISO Stakeholders to discuss viability of establishing short-term reserves</td>
</tr>
<tr>
<td>6. Outage Analysis</td>
<td>Improve accuracy of maintenance margin processes, including forced outage assumptions, import capability, and outage analysis</td>
</tr>
</tbody>
</table>

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¹ [https://cdn.misoenergy.org/20180308%20MSC%20Item%202018%20Spring%20Readiness142806.pdf](https://cdn.misoenergy.org/20180308%20MSC%20Item%202018%20Spring%20Readiness142806.pdf)
In addition to the improvements shown in Figure 2.3-2, MISO has enhanced situational awareness for gas-electric coordination by conducting an annual gas generator survey to identify plant-specific service levels, expanded its operational communications with many pipelines, piloted the daily communication of gas usage to two pipelines, and is continuously monitoring gas pipeline alerts.

There was another capacity shortage MaxGen event in the South region on April 4, 2017. One especially challenging issue during this event was the stranding of MWs in the North/Central regions behind the Regional Dispatch Transfer Limit such that energy from the resources could not flow to where it was needed. This has led to further operational refinement in how and where MISO procures needed reserves with the Reserve Procurement Enhancement for sub-regional reserves slated for implementation in June 2018.

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3. Outage Correlation

The MISO system has year-round load and supply needs, but is planned with a summer-focused capacity commitment. Lower overall capacity levels and higher outage rates have reduced available capacity in non-summer periods and, as a result, MISO has seen correlated outages during non-summer periods imposing a growing challenge to ensuring sufficient available capacity in those periods.

Forced and planned outages have increased, reducing resource availability, especially in the shoulder seasons. Forced outages increased an average of 1.6 GW during Planning Year 2015/16 and another 4.2 GW in Planning Year 2016/17. The combination of planned and maintenance outages went from 5.56 percent in 2013 to 6.16 percent in 2016. As a result, higher uncertainty regarding whether sufficient energy will be available to meet forecast peak load has led operators to make MaxGen declarations so they can access needed emergency-only resources.

Key issues:

- Current Loss of Load Expectation (LOLE) calculations do not account for the correlation of outages experienced in non-summer seasons
- MISO is developing tools to facilitate outage coordination across different time horizons
- Fuel assurance impacts resource availability and the resilience of MISO’s footprint
- Price signals could inform the timing of outages but MISO is focused on the conversion of capacity into energy at this time

3.1. Current LOLE calculations do not account for the correlation of outages in non-summer seasons

MISO accredits resources based on historic outage rates on an annualized basis. This accreditation then becomes an input into several processes including the annual LOLE study, which determines the amount of capacity required, into the Planning Resource Auction, and in Outage Coordination processes such as the Maintenance Margin. MISO has been exploring whether seasonal forced outage rates might better represent resource availability (Figure 3.1-1).

![Figure 3.1-1: Five-year Seasonal/Annual EFORD for MISO Generator Availability Data System (GADS) class averages](image-url)
3.2. **MISO is developing tools to facilitate outage coordination across different time horizons**

Historically, MISO’s outage coordination process includes a review of the outage’s impact on reliability and if the reliability issue cannot be mitigated MISO will coordinate with the generation or transmission owner or operator to rescheduled the outage when feasible. MISO’s outage coordination process also utilizes a tool known as Maintenance Margin to predict the amount of MWs still available for planned outages that will maintain sufficient operational headroom capability. The results are posted on MISO’s OASIS website so generation and transmission owners and operators can use it to inform their outage scheduling (Figure 3.2-1).

![Figure 3.2-1: Early December 2017 Maintenance Margin (MWs) from MISO’s OASIS](http://www.oatioasis.com/woa/docs/MISO/MISOdocs/Maintenance_Margin.html)

Operational adequacy may require a multi-tool process for different time periods due to the strengths and weaknesses of readily available analytical tools (Figure 3.2-2). For example, the existing Maintenance Margin tool relies on the probabilistic LOLE/Planning Reserve Margin (PRM) process and the potential RAN-informed process are most accurate for a time horizon several weeks to years out given their statistical approaches to dealing with uncertainty. Within several days of the operating day to a few weeks out, a more deterministic analytical process has potential to improve accuracy and when within a few days of the operating day MISO market based tools are expected to be most accurate.

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MISO will evaluate how it can enhance the LOLE inputs into its outage coordination Maintenance Margin processes. The existing process may lack accuracy as the inputs are average values and are not adjusted to the near-term conditions projected for the shoulder seasons when planned generation outage schedules occur. Relevant data would need to be fed into the existing automated processes to replace the LOLE inputs. MISO could have a RAN-informed forecast each month with daily granularity for a 3-year outlook. Daily granularity is necessary to review and accept short term and weekend generation planned outages.

One of the shortcomings of the current Maintenance Margin tool is that it does not account for stranded capacity trapped behind transmission constraints within Local Resource Zones. However, now that there are operational adequacy issues during the shoulder months when outages are elevated it will be important to incorporate stranded capacity estimates into the Outage Coordination processes. Operating history has shown that transmission constraints often strand roughly 2,000 MW when the system is congested and can strand as many as 4,000 MW of resource availability when it is needed the most.

MISO has a project in development with PowerGem to deliver a tool based on their TARA product (Transmission Adequacy and Reliability Assessment) to analyze Generation Outage Capacity, with a tentative delivery for spring of 2018. The focus of the tool is within a month of the operating day, this allows MISO to better take into account known and predicted outage and load conditions.

Within several days of the operating day, reliance on the MISO Day-Ahead and Forward Reliability Assessment Commitment processes is advised as the market tools have available a more accurate MISO Medium-Term Load Forecast and actual resource offers. This has been enhanced with resource sufficiency alerts that notify reliability coordination teams about potential issues up to seven days in advance giving operators more time and access to longer lead resources with which to address potential capacity insufficiency.

### 3.3. Fuel assurance impacts resource availability and the resilience of MISO’s footprint

A major fuel pipeline contingency impacting multiple Planning Resources could severely degrade operational adequacy during periods such as high load days or shoulder periods when many units take planned outages. It is appropriate for MISO and its stakeholders to assess risks from such low frequency, high impact events in terms of...
not only the probability of involuntary load shed but also in terms of how much load could be shed for how long and the potential for cascading failures and damage to critical infrastructure.

Additionally, MISO should assess how operating without the excess capacity it has had in the past impacts the resilience of its operations to typical uncertainties that may occur at the same time amplifying the stress on MISO’s system. Even in the absence of a major infrastructure event, fuel assurance issues can affect both gas and coal-fired generating units in the MISO footprint, causing them to fail to meet their commitments to deliver energy as expected. MISO has not proposed fuel-procurement directives for Market Participants with gas-fired resources or advised coal-fired plants on how to manage coal supplies or delivery arrangements. However, since these issues could potentially affect operational adequacy, MISO is taking steps to improve its situational awareness in this area, especially for gas-fired resources due to the just-in-time fuel delivery nature of gas. For example, MISO is now surveying asset owners in an effort to gauge how confident they are about natural gas deliveries during the winter season, what various services they subscribe to, and how reliably units can potentially switch to a secondary fuel type. While the survey is voluntary, MISO appreciates that participation levels have been nearly 90 percent in recent years. This information has been critical for MISO operations to establish greater situational awareness by matching units that may not have firm gas delivery service with individual gas pipeline notifications. This process results in MISO’s daily fuel impact report, which is utilized in the control room. As reliance on gas-fired resources continues to grow, MISO will expand its situational awareness as it pertains to fuel assurance and the potential risks to reliably operating the grid.

During periods of extreme winter weather MISO will have to be increasingly aware of challenges that these conditions bring and be prepared for potential contingencies. For instance, during the January 2014 Polar Vortex event, nearly 23 GW of coal and gas-fired generating capacity was unable to perform when called upon as the result of frozen components, mechanical issues, or the inability to secure the necessary fuel to operate as needed (Figure 3.3-1). Nearly 8 GW of gas-fired generation was unable to operate due to loss of fuel supply. As gas-fired resources are relied on more heavily it will be essential to identify the magnitude of this risk and mitigate it appropriately.

![Figure 3.3-1: Daily Forced Outages by Fuel Type - Jan 6-8, 2014](image)

Gas pipelines, by design, can impact multiple gas-fired generators. With limited reserve margins, a major fuel pipeline failure could severely degrade operational adequacy due to a fuel-supply loss to multiple gas-fired generators. The robust pipeline system in MISO makes it less vulnerable to gas-pipeline events than other areas of the U.S. – however, it is important to monitor changes in gas-pipeline infrastructure with increased gas-fired

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MISO

generation to ensure active mitigation of future vulnerabilities. There are ongoing federal policy discussions in this area. MISO has made a number of improvements over the last several years and is continuing its efforts in 2018.

3.4. **Price signals could inform the timing of outages but MISO is focused on the conversion of capacity into energy at this time**

Consistent with statements at the Resource Adequacy Subcommittee in the fall of 2017, MISO has not precluded further evaluation of seasonal capacity procurements within the Planning Resource Auction (PRA). Some stakeholders have continued to speak out in support of being able to utilize non-summer resources within the PRA process.

If MISO and its stakeholders continue to have operational adequacy issues after addressing the transparency-related issues recommended in this whitepaper, then MISO should evaluate mechanisms within the resource adequacy construct that can be adjusted to meet those needs. MISO could once again evaluate the granularity of the Planning Year. Is it still prudent to use a summer focused model to ensure a sufficient pool of assets for year-round operational adequacy? Reviewing resource adequacy on a seasonal or monthly basis may improve MISO’s ability to ensure operational adequacy at all times during the Planning Year. Changes to the PRA structure may impact prices, which should be considered in any such evaluation. Further exploration of these issues would be useful but our focus at this time is on assessing and optimizing the conversion of committed capacity into sufficient energy to carry out planning outcomes.
4. Growth in Demand Side and other Emergency-only Capacity

MISO has experienced growth in demand side and other emergency-only capacity as a percent of the overall portfolio. LSEs committed nearly 12 GW of emergency-only Capacity Resources in 2017. This was 9 percent of the summer peak load forecast. These 12 GW of resources are not available to MISO’s operators without the declaration of a MaxGen event under the existing framework and, in many cases, due state and local contractual or regulatory limitations including air permitting limits.

As MaxGen declarations become more frequent, MISO has also progressed further into its Emergency Operating Procedures during the events. The data\(^5\) in Table 4.0-1 was pulled from the Day Ahead and Real Time system (DART) for the peak hour for each day when MISO made a MaxGen declaration.

<table>
<thead>
<tr>
<th>Day</th>
<th>Peak Load</th>
<th>CRREQ</th>
<th>GENMW</th>
<th>Wind</th>
<th>NSI</th>
<th>Non-Emergency Margin</th>
<th>Highest MaxGen Declaration</th>
<th>Outages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/18/2018</td>
<td>100,766</td>
<td>2,410</td>
<td>100,123</td>
<td>11,629</td>
<td>934</td>
<td>4,744</td>
<td>Step 2 c/d (South)</td>
<td>20,702</td>
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<tr>
<td>1/17/2018</td>
<td>105,526</td>
<td>2,410</td>
<td>103,055</td>
<td>12,252</td>
<td>2,658</td>
<td>2,330</td>
<td>Step 2 c/d (South)</td>
<td>18,394</td>
</tr>
<tr>
<td>9/25/2017</td>
<td>106,093</td>
<td>2,410</td>
<td>99,625</td>
<td>1,892</td>
<td>7,045</td>
<td>5,312</td>
<td>Alert</td>
<td>21,439</td>
</tr>
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<td>9/23/2017</td>
<td>106,250</td>
<td>2,410</td>
<td>97,277</td>
<td>4,750</td>
<td>9,327</td>
<td>5,900</td>
<td>Warning</td>
<td>22,133</td>
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<tr>
<td>9/22/2017</td>
<td>114,339</td>
<td>2,410</td>
<td>103,209</td>
<td>9,238</td>
<td>11,783</td>
<td>6,249</td>
<td>Event Step 1b/c</td>
<td>20,988</td>
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<tr>
<td>9/21/2017</td>
<td>108,274</td>
<td>2,410</td>
<td>98,166</td>
<td>8,748</td>
<td>10,682</td>
<td>10,956</td>
<td>Alert</td>
<td>21,092</td>
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<td>4/4/2017</td>
<td>74,638</td>
<td>2,410</td>
<td>68,295</td>
<td>5,002</td>
<td>6,419</td>
<td>20,607</td>
<td>South-only, Step 2a/b</td>
<td>37,648</td>
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<tr>
<td>10/5/2016</td>
<td>88,421</td>
<td>2,410</td>
<td>80,823</td>
<td>5,043</td>
<td>7,948</td>
<td>15,726</td>
<td>South warning</td>
<td>29,847</td>
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<td>10/4/2016</td>
<td>84,724</td>
<td>2,410</td>
<td>77,622</td>
<td>9,669</td>
<td>7,661</td>
<td>23,427</td>
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<td>30,301</td>
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<tr>
<td>8/29/2016</td>
<td>111,941</td>
<td>2,410</td>
<td>105,613</td>
<td>1,272</td>
<td>6,839</td>
<td>7,948</td>
<td>Central/North alert</td>
<td>13,012</td>
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<td>7/21/2016</td>
<td>120,367</td>
<td>2,410</td>
<td>113,149</td>
<td>3,563</td>
<td>7,531</td>
<td>6,119</td>
<td>Event Step 1</td>
<td>11,307</td>
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<tr>
<td>6/17/2016</td>
<td>107,062</td>
<td>2,410</td>
<td>97,832</td>
<td>2,715</td>
<td>9,552</td>
<td>1,777</td>
<td>South alert</td>
<td>18,853</td>
</tr>
</tbody>
</table>

**Peak Load:** Measured system load at the peak hour that day  
**CRREQ:** Contingency Reserve Requirement  
**GENMW:** Sum of Economic Maximum Dispatch (EcoMax) offers from non-wind units not on outage  
**Wind:** Actual wind generation at the peak hour that day  
**NSI:** Net Scheduled Interchange at the peak hour that day  
**Outages:** Sum of EcoMax offers from units on outage  
**Non-Emergency Margin:** EcoMax offers including wind and NSI minus peak load and CRREQ

**Table 4.0-1: Summary Statistics for 12 Days with MaxGen Declarations**

Key issues:

- It can be difficult for MISO’s operators to access emergency-only resources in time to respond to evolving system conditions
- The performance of individual LMRs often doesn’t match the MWs accredited for the resource in the PRA process
- The amount of committed LMRs recently passed 10 GW and more demand response is anticipated given technology trends

\(^5\) Information about the RAN data set and methodology can be found in the Analytical Appendix at the end of this document.
4.1. **It can be difficult for MISO’s operators to access emergency-only resources in time to respond to evolving system conditions**

MISO’s operators must first declare a MaxGen Event to get access to these resources. They do this when current or potential load and reserve obligations equal or exceed all available economic offers and net scheduled interchange (NSI). With the declaration of the MaxGen Event Step 1 (Figure 4.1-1) Operators get access to emergency resources and emergency ranges (above the EcoMax dispatch range). LMRs and Emergency Demand Response (accessible at MaxGen Event Step 2 b/c/d) are in the last set of resources that can be used to meet the energy balance prior to using operating reserves and moving to firm load shed.

![Figure 4.1-1: MISO Maximum Generation Emergency Procedures](https://cdn.misoenergy.org/20171106%20Winter%20Readiness%20Workshop%20Presentation128873.pdf)

These resources make up a significant share of MISO's Planning Reserve Margin. LMRs (DR and BTMG) provided 7.0 percent of the capacity committed to MISO during the last PRA process (approximately 9 percent of the forecast coincident peak load). These resources can have notification times up to 12 hours. LMRs were deployed on April 4 but it took two hours to get 120 MWs and five hours to get the 730 MWs available due to required notification periods (Figure 4.1-2).

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In recent MaxGen Events needed LMR quantities have had notification times of four hours or more. This has resulted in a dynamic where MISO’s Operators must consider whether to declare a MaxGen Event Step 2, four or more hours in advance of the expected need when there is still significant uncertainty in the forecast load. If MISO’s operators don’t make the required declaration ahead of time they risk not having the resources needed to meet obligations. If they do make the declaration and then commit and dispatch the resources they may create uplift and reduce the efficiency of market outcomes in pursuit of reliability.

As investments in demand resources increase, MISO anticipates that the percentage of LMRs used to meet resource adequacy obligations will also increase. MISO has started discussions with stakeholders on the possibility of modifying the Emergency Operating Procedures, as suggested by the Independent Market Monitor (IMM), to consider modifying MISO’s Emergency Operating Procedures to deploy Emergency Demand Response (EDR) and LMRs more efficiently.

4.2. The performance of individual LMRs often doesn’t match the MWs accredited for the resource in the PRA process

MISO continues to evaluate LMR performance and the reasons for deviation. MISO is interested in hearing from stakeholders on this topic. Possible reasons include:

- LMR accreditation is based on summer performance expectations. Recent use of LMRs has occurred in the winter and spring.
- Some DR is weather-sensitive load. At times coincident with MISO peak a greater amount of MWs are expected from these DRs; during other times, a much smaller amount is expected. Without further

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investigation across all weather-sensitive DRs, a quantity associated with this variation cannot be made.

- More than 2,000 MWs of DR is the firm service level reduction type. If the end-use customer behind this firm service level DR is at a lower production level than is expected coincident at MISO’s system peak, the amount of demand reduction will be commensurately less.
- Another important issue is accurate and timely reporting of LMR availability in the MISO Communication System (MCS).

4.3. The amount of committed LMRs recently passed 10 GW and more demand response is anticipated given technology trends

Increased amounts of LMRs come with increased odds of using them. This could require MISO and its stakeholders to be comfortable with more frequent MaxGen declarations such as those experienced over the last two years.

Another issue to consider is whether LMR rules and accreditation, including desired notification timelines and seasonal availability, should be refined to support reliable and efficient operations now that LMRs constitute much of LSEs PRM. LMRs are not required to be available at all outside of the summer and can only be called on five times in a given Planning Year.

As the odds of calling demand reduction from LMRs increases, MISO must do a better job of providing information and market notices around LMR deployment. Workshops on the entire LMR process from bid-to-bill are encouraged. This should provide detailed information about the registration process, means for accreditation, how these assets are deployed, and how they are settled.
5. Growing Reliance on Intermittent or Unscheduled Resources

In recent years, MISO has seen an increased reliance on non-dispatchable or non-committed supply resources (Figure 5.0-1). The circled events show times when the margin for operational balance was nearly zero and reliability would have been at risk but for these uncertain supply sources. While MISO and its stakeholders have successfully managed these issues to date, MISO must now assess its ability to ensure sufficient conversion of capacity into energy in all time periods in light of this trend.

Increasing reliance on intermittent and unscheduled resources is expected to increase the uncertainty and volatility of resource availability further challenging operational adequacy. This may result in further need for out of market actions to manage constraints such as the RDT limit reducing the efficiency of unit commitment and dispatch.

Key issues:
- MISO has experienced variability in generation from wind during MaxGen declarations
- NSI has shown significant variability during MaxGen declarations

5.1. MISO has experienced variability in generation from wind during MaxGen declarations

Wind has provided between one and 12 GW at the peak load hour during MaxGens occurring in the last two years. The median wind value on a MaxGen day has been approximately 5 GW with a standard deviation of 3.5 GW. While there is significant day-to-day volatility, there tends to be less wind generation in the summer, average amounts in the spring and fall, and the most during winter.
5.2. NSI has shown significant variability during MaxGen declarations

Like wind, NSI has provided between one and 12 GW at the peak load hour during MaxGens occurring in the last two years. There is less day-to-day volatility in NSI but more variance has occurred during MaxGen conditions. The median NSI value on a MaxGen day has been approximately 3 GW with a standard deviation of 7.5 GW. Interchange with PJM is the primary contributor to NSI variability (Figure 5.2-1).
6. Growth of Variable Energy Resources

This increasingly important resource category is a growing part of the resource fleet. By its very nature, it has different operational characteristics than legacy thermal resources. Renewable resources are accredited based on historic contribution during past system peaks, but cannot be dispatched to meet needs during emergencies. If wind or solar happen to contribute less during a particular time of need than in past years the difference must be made up elsewhere. While it is also likely that, at times, these resources will help conditions by producing more than accredited, the significance of understanding and planning for the operational implications of renewable resources becoming an even more substantial part of the footprint’s portfolio is ripe. This will require further assessment to explore how best to manage operational reliability while depending on a larger fleet of capacity resources that must be forecast for operations rather than dispatched. MISO will continue to improve its ability to forecast resource availability and need so it can take timely action to meet net load and ensure operational adequacy. MISO will also initiate further assessments ahead of the anticipated continued growth of this segment of the fleet.

Key issues:

- MISO’s resource mix has changed significantly in the last 10 years
- MISO is working with its stakeholders to prepare for additional portfolio evolution in the future

6.1. MISO’s resource mix has changed significantly in the last 10 years

MISO’s resource mix has evolved over the last 10 years with the addition of significant amounts of wind and gas resources (Figure 6.1-1). Coal-fired resources have dropped from 76 percent of the capacity in MISO in 2005 to 48 percent in 2017. Over the same time period, gas-powered resources have increased from 7 percent to 24 percent and wind resources have increased from less than 1 percent to 8 percent. These changes in the resource mix have been integrated with enhanced system operations practices (e.g. Dispatchable Intermittent Resources and constraint management practices such as Transmission Constraint Demand Curves) to enable the resource mix to provide the aggregate operational characteristics required for reliable system operations.

The different operating characteristics of these new resources may lead to different challenges in real-time, which should be investigated and managed. Recent industry discussions have sought to identify essential reliability services that should be identified and valued according to supply and demand and their contribution to system reliability. Gas-powered resources typically ramp and cycle faster than coal-fired resources, providing operational flexibility, but rely on continuous fuel supply. Intermittent wind resources have variable production that requires other resources to ramp in response to changes in wind capability.
6.2. MISO is working with its stakeholders to prepare for additional portfolio evolution in the future

MISO’s portfolio will continue to change in response to economics, technology advancements and public policies. Recent trends are expected to continue and new trends such as increases in solar, distributed generation and increased demand response are being watched carefully for their potential impacts on the operational capabilities of the MISO resource fleet.

In 2017, MISO began a Renewable Integration Impact Assessment (RIIA) to evaluate points at which renewable integration increases in complexity. Based on operational characteristics of different generator types and their incidence in the resource mix, there are points in penetration levels at which changes are needed to support additional renewable resources. The study demonstrates the variability of operational characteristics by resource type. Tables 6.2-1, 6.2-2 and 6.2-3 describe the general characteristics, ramp rates, and startup characteristics of controllable resource types.

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Gas</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>Pump Hydro</th>
<th>Oil</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Min Gen Level</strong> (% of Max Cap)</td>
<td>CC: 50.1</td>
<td>CT: 25.2</td>
<td>ST: 30.7</td>
<td>100</td>
<td>24.5</td>
<td>25.0</td>
<td>35.6</td>
</tr>
<tr>
<td><strong>Min Up Time</strong> (hours)</td>
<td>CC: 5.7</td>
<td>CT: 1.8</td>
<td>ST: 22.2</td>
<td>122.8</td>
<td>1</td>
<td>1.8</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Min Down Time</strong> (hours)</td>
<td>CC: 6.6</td>
<td>CT: 2.2</td>
<td>ST: 10.1</td>
<td>122.8</td>
<td>1.6</td>
<td>1.8</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Variable O&amp;M ($/MWh)</strong></td>
<td>CC: 1.48</td>
<td>CT: 0.80</td>
<td>ST: 1.40</td>
<td>2.52</td>
<td>0</td>
<td>0.74</td>
<td>1.71</td>
</tr>
<tr>
<td><strong>Forced Outage Rates</strong> (% of year)</td>
<td>CC: 5.8</td>
<td>CT: 5.8</td>
<td>ST: 9.1</td>
<td>4.8</td>
<td>5.2</td>
<td>NA</td>
<td>6.8</td>
</tr>
<tr>
<td><strong>Maintenance Rates</strong> (% of year)</td>
<td>CC: 7.4</td>
<td>CT: 3.4</td>
<td>ST: 8.2</td>
<td>Sched Maint.</td>
<td>6.1</td>
<td>7.7</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Table 6.2-1: General resource characteristics by resource type
The RIIA is exploring issues resulting from the integration of increasing amounts of variable renewable energy resources. Renewables like wind and solar have low incremental operating costs but variable output subject to the real-time availability of wind and sun. Zero fuel cost and incentives from state and federal entities incent these resources to generate as much as possible at low and sometimes even negative prices. These low costs can impact the energy market revenues paid to all resources by reducing LMPs. Operationally, other resources ramp to adjust to changes to variable renewable energy production to meet net load.

Distributed energy resources and demand response are limited but increasing portions of the MISO resource mix. There is potential for substantial increases in these types of resources in the portfolio. The equipment and technologies used in distributed energy resources and demand response are varied, which may provide a variety of operating characteristics. Requests for response from a distributed resource may have uncertainty in the effective location of the response leading to challenges in dispatching such resources to manage transmission system constraints. MISO will continue to explore the implications of the evolving resource portfolio on resource availability and net load requirements.
7. Action Plan

MISO will work with stakeholders to optimize the conversion of committed capacity into sufficient energy every hour of the Planning Year to ensure it is carrying out its planning outcomes. This Resource Availability and Need Issues Statement Whitepaper is intended to set the stage for conversations between MISO and its stakeholders about the emerging resource availability and need issues that challenge operational adequacy.

RAN-related issues fall within three broad areas for improvement in the processes MISO uses to convert committed Capacity Resources into sufficient energy in the operating day:

- Increase transparency of resource availability and need
- Refine resource availability requirements
- Improve price signals

MISO recommends starting with transparency-related enhancements that improve MISO’s ability to understand, forecast and communicate uncertainties regarding RAN. MISO is initiating discussions with stakeholders at the Reliability Subcommittee (RSC) to determine where changes are needed, given an increasing reliance on 12 GW of emergency-only resources. MISO will also discuss planned improvements to MISO’s outage coordination process at the RSC to assess the need for further enhancements. Other RAN-related issues introduced in this whitepaper will require further development and will be discussed with stakeholders in 2019 in the appropriate venue for each issue.
8. Appendix

8.1. Background

MISO’s Resource Adequacy mechanisms date to a time when the region had generation capacity well in excess of the PRM. To date, demonstration of capacity equal to the forecast coincident peak plus the PRM has enabled Load-Serving Entities (LSEs) to serve firm load throughout every planning year since the current processes were established.

However, changing market conditions and policies have resulted in a resource portfolio with altered operational characteristics and less available capacity overall. Under these evolving conditions, MISO has seen an increase in Maximum Generation (MaxGen) Emergencies including an emerging trend for emergency conditions outside the traditional summer peak period. Given these changes, MISO must now evaluate alignment of resource availability and need (RAN) to determine how today’s processes for conversion of committed capacity to energy enables reliable and efficient operation of the Bulk Electric System today and in the foreseeable future.

There are many reasons why Planning Resources may not be available to supply energy on a particular operating day. Typically, none of the individual uncertainties around RAN are large enough on their own to threaten reliability. It is when multiple uncertainties align that MISO faces challenges to serve load. There is little evidence that the individual uncertainties themselves are new; in combination, they have resulted in increasing challenges to operational adequacy.

Within this context it is increasingly difficult to maintain reliable and efficient operations when multiple challenges arise as occurred in late September 2017 and thus described in a market notification:

*The MISO Reliability Coordinator (RC) is declaring a Maximum Generation Alert effective from 09/25/2017 13:00 EST until 09/25/2017 19:00 EST for the following entities: MISO Balancing Authority Area. The reason for the alert is because of Forced Generation Outages, Above Normal Temps, Higher than Forecasted Load, import cuts due to TLR.*

[Figure 8.1-1: Temperatures above July averages drove load to closely resemble a summer peak, contributing to challenging circumstances](https://cdn.misoenergy.org/20171012%20MSC%20Item%202007%20September%2022%20Overview75133.pdf)
A significant contributor to the MaxGen declarations made outside of the summer has been high outages in the shoulder seasons when temperature - and thus load variability - is high (Figure 8.1-1). Future portfolio evolution could heighten these risks degrading the reliability and resiliency of MISO’s system.

8.2. Summary of previous stakeholder discussions

MISO’s Resource Adequacy Requirements were designed for summer-peaking system use and may not ensure transparency and reliability in the winter and shoulder-season months, especially as the resource landscape changes due to shifts in resource economics and regulations. One issue noted by stakeholders is that MISO’s PRA does not provide sufficient flexibility to allow for the efficient use of resources to meet seasonal and locational demand and risk profiles.

In 2014, MISO began discussing changes to its annual Resource Adequacy Requirements with stakeholders to address winter resource availability concerns after the polar vortex. These concerns were primarily centered around natural gas availability during widespread cold snaps. There was no MISO and stakeholder consensus on moving to summer and winter procurements when MISO recommended this change in 2015. Since that time, MISO began experiencing resource availability issues outside of summer and winter and also started to anticipate more challenges in the future as more intermittent and seasonal resources, such as demand response, wind, and solar, replaced coal and nuclear generation. In February 2017, MISO noted that its near term concerns had evolved from consideration of a seasonal (summer and winter or four season) capacity construct to the availability of Planning Resources to supply energy throughout the year (referred to as “Address Resource Availability and Need”, or “RAN”).

At the September and October 2017 meetings of the Resource Adequacy Subcommittee (RASC), MISO delivered presentations on “Seasonal Resource Availability and Need” which focused on the conversion of capacity into energy in the operating time horizon. In general, stakeholder feedback during the meeting expressed a concern that RAN is an issue that affects other stakeholder forums and is beyond just the scope of the RASC Charter. Given this feedback, the leadership and MISO liaison of the RASC brought this issue to the Steering Committee in January 2018, which subsequently reassigned the issue from the RASC to the Reliability Subcommittee (RSC). Enhancements which modify MISO market or Resource Adequacy mechanisms will be coordinated with the Steering Committee and other appropriate stakeholder governance entities.

8.3. Resource Adequacy mechanisms

A number of areas provide inputs into resource adequacy mechanisms within MISO, but there are four key MISO and stakeholder processes. These four processes are the OMS⁹-MISO survey, the LOLE (Loss of Load Expectation) study, ZRC (Zonal Resource Credit) registration, and the PRA (Figure 8.3-1).

⁹ The Organization of MISO States, or OMS, represents the collective interests of 17 state and local utility regulators across 15 states and the Canadian province of Manitoba in the MISO region.
The OMS-MISO survey is a voluntary market participant survey, sponsored by the Organization of MISO States (OMS). It asks each Load-Serving Entity (LSE) to provide forward-looking demand forecasts over a 10-year period, and asks LSEs and resource owners to provide a level of confidence of going-forward participation for each resource in the footprint. Added to this are assumptions regarding potential resource retirements and expectations for new resources based on the interconnection queue.

The annual LOLE study, performed by MISO, conducts a probabilistic assessment of resource adequacy in the MISO footprint. The study uses Monte Carlo techniques to determine the probability of being unable to balance supply and demand, using the standardized expectation that the resource portfolio should be built so that supply can balance demand but for one day out of every 10 years of performance. The LOLE performed by MISO becomes an input into several processes, one of which is the PRA.

ZRC registration takes place during qualification for the PRA. During registration, the varying capabilities of each resource are translated into a common, tradable unit called the “Zonal Resource Credit.” The ZRC is a standardized unit of capacity accredited by MISO that considers the zonal location, historical outage characteristics (EFORd), and expected firm output to the system for each Planning Resource. These ZRCs facilitate the self-supply and bilateral arrangements that account for the majority of capacity committed through the PRA process.

The PRA clears supply against the demand associated with expectations set in the LOLE study for the upcoming Planning Year. It uses the assumption that demand is willing to pay up to the Cost of New Entry (CONE) for each unit of capacity until the PRM cap, and willing to pay nothing for any unit of capacity beyond it. The PRA is conducted two months prior to the start of each Planning Year.

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10 Equivalent Forced Outage Rate Demand (EFORd): The Equivalent Forced Outage Rate Demand, as defined by NERC.
8.4. **Operational adequacy**

MISO’s RAN forecasts will enhance its ability to serve load throughout the year (Figure 8.4-1). In the past, MISO observed that when it forecasted high load and/or resource availability challenges ahead of time it could take timely action to address them. Peak load in 2017 was set July 20 hour ending (HE) 17 at 121 GW. MISO declared a MaxGen event to meet a similar peak on July 21, 2016. The 2017 Summer Seasonal Assessment report explains, "Although the peak load was about the same as last year, there were no Maximum Generation Alerts or Events declarations. MISO avoided emergency conditions this summer with more accurate day-ahead forecasts and more complete commitments of resources this summer."\(^{11}\)

8.5. **Symptoms of RAN misalignment**

A dramatically changing landscape has made the conversion of committed capacity resources into sufficient energy every hour of the Planning Year more difficult, as demonstrated by recent operational trends. Increasing operational uncertainty is leading to more frequent MaxGen declarations, and to declarations extending farther into MISO’s emergency operating procedures.

MaxGen declarations are occurring more frequently. There have been 12 days of MaxGen declarations since the start of the 2016/17 Planning Year on June 1, 2016. By contrast, there were zero MaxGen declarations in the two years before June 1, 2016.

On April 4, 2017, MISO had its first deployment of LMRs since 2007. MaxGen declarations have occurred in the last three shoulder seasons as periods of higher-than-normal load have aligned with high levels of planned and

\(^{11}\)Page 5 of the Summer Seasonal Assessment. 
forced generation and transmission outages. MISO had just 4.2 GW of capacity margin on September 22, 2017, at the peak hour, of which 2.4 GW was emergency-only BTMG and emergency ranges (Figure 8.5-1). The use of LMRs, which don’t have an obligation to perform outside the summer, was likely averted due to 12 GW of net imports, and over 9 GW of wind. These levels of imports and wind are well above normal and even further above the amounts accredited through ZRC Registration.

![Figure 8.5-1: Demand and Capacity Analysis (MWs) for Peak Hour on September 22, 2017, HE 16](image)

Fortunately, MISO has not progressed to the point of required firm load reductions. However, MISO has run scarce of reserve products in the past as was the case during the Polar Vortex on January 7, 2014 (Figure 8.5-2).

![Figure 8.5-2: Reserve Scarcity](image)
9. Analytical Appendix

Analysis of historical data will help us better understand and forecast our availability and need for resources throughout the planning year informing our operational planning and outage coordination. The RAN data set goes back to January 2014. Figure 9.0-1 is similar to the one in the Executive Summary of this whitepaper but goes back an additional two years:

![Figure 9.0-1: Comparison of available capacity to peak load.](image)

9.1. RAN data set and methodology

The RAN data set consists of variables similar to those MISO has analyzed regarding the peak hour in its Seasonal Market Assessment Reports. The data set goes back to the beginning of 2014. It is from the Day-Ahead Real-Time (DART) system.

These are the variables associated with resource availability:

- **EcoMax (no wind):** EcoMax offer in RT not including wind
- **Wind:** Actual wind generation
- **NSI:** Actual Net Scheduled Interchange, MISO is typically a net importer
- **Emergency Range:** MWs available/offered in emergency ranges of online units
Resource Availability and Need

- **AME**: MWs available/offered by units designated as emergency only
- **LMRs**: MWs offered by LMRs, this data series begins January 2016
- **Outages**: EcoMax of units on outage status. Not counted in resource availability.
- **Stranded MWs**: Typically low, 1,000 – 3,000 MW proxy value used when RAN margin less than 15 percent. Stranded MWs reduce resource availability.

These are the variables associated with resource need:

- **Peak Load**: Load value for peak hour each operating day
- **Reserve Requirements**: Sum of operating and contingency reserve requirements

**Methodology**

\[
\text{Availability} = \text{EcoMax} + \text{Wind} + \text{NSI} + \text{Emergency Range} + \text{AME} + \text{LMRs} - \text{Stranded MWs}
\]

\[
\text{Need} = \text{Peak Load} + \text{Reserve Requirements}
\]

\[
\text{RAN Margin} = \text{Availability} - \text{Need}
\]

\[
\text{RAN Margin \%} = \frac{\text{RAN Margin}}{\text{Peak Load} + \text{Reserve Requirements}}
\]

### 9.2. Quantifying sources of uncertainty

Table 9.2-1 shows the individual variability of the variables in the RAN data set.

<table>
<thead>
<tr>
<th>Variability Statistics</th>
<th>EcoMax</th>
<th>Wind</th>
<th>NSI</th>
<th>Emerg. Range</th>
<th>AME</th>
<th>Peak Load</th>
<th>CRREQ</th>
<th>Margin</th>
<th>Outage MW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max</strong></td>
<td>116,949</td>
<td>13,591</td>
<td>11,783</td>
<td>6,148</td>
<td>5,321</td>
<td>120,367</td>
<td>2,997</td>
<td>71,924</td>
<td>37,900</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>57,473</td>
<td>50</td>
<td>(618)</td>
<td>1,451</td>
<td>540</td>
<td>65,257</td>
<td>1,681</td>
<td>9,605</td>
<td>6,811</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>79,852</td>
<td>4,475</td>
<td>4,522</td>
<td>3,053</td>
<td>1,719</td>
<td>84,000</td>
<td>2,410</td>
<td>38,352</td>
<td>18,033</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>82,073</td>
<td>4,966</td>
<td>4,709</td>
<td>3,158</td>
<td>1,895</td>
<td>86,507</td>
<td>2,446</td>
<td>38,402</td>
<td>19,071</td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td>11,903</td>
<td>3,007</td>
<td>2,128</td>
<td>745</td>
<td>808</td>
<td>11,938</td>
<td>119</td>
<td>10,373</td>
<td>7,196</td>
</tr>
<tr>
<td><strong>% of avg.</strong></td>
<td>0.15</td>
<td>0.67</td>
<td>0.47</td>
<td>0.24</td>
<td>0.47</td>
<td>0.14</td>
<td>0.05</td>
<td>0.27</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>% of avg. load</strong></td>
<td>0.14</td>
<td>0.04</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.14</td>
<td>0.00</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Correlation</strong></td>
<td>0.98</td>
<td>-0.26</td>
<td>0.11</td>
<td>-0.03</td>
<td>-0.38</td>
<td>-0.10</td>
<td>-0.60</td>
<td>-0.67</td>
<td></td>
</tr>
</tbody>
</table>

**Table 9.2-1: Variability statistics in the RAN data set**

Aggregate variability is described in Section 8.3 regarding historical modeling. Figure 9.2-2 shows the impact to resource availability if actual wind and NSI came in one standard deviation below the median from Table 9.2-1.
9.3. Historical modeling

To model average weekly margins for the MISO system one week in the future the following linear model was developed and refined to best fit the historical data:

\[ \text{margin}_t = \beta_0 + \beta_1 \text{margin}_{t-1} + \beta_2 \text{avemargin}_t + \beta_3 \text{outage}_{t-1} + \beta_4 \text{aveoutage}_t + \beta_5 \text{hd} + \beta_6 \text{cd} + \epsilon \]

Where:

- **t**: Week of the year number (1-52 or 1-53)
- **\epsilon**: Stochastic error
- **margin**: EcoMax + Wind + Emergency Range + AME + NSI – Peak Load – Required Reserves (MWh)
- **avemargin**: Average of Margin for the week t across the whole dataset (MWh)
- **outage**: Forced and planned outages (MWh)
- **aveoutage**: Average of outage for the week t across the whole dataset (MWh)
- **hd**: Maximum of 62 – current temperature or 0 (°F)
- **cd**: Maximum of current temp – 62 or 0 (°F)

| Coefficient | Estimate | St Error | t Value | Pr > |t| |
|-------------|----------|----------|---------|------|------|
| \( \beta_0 \) | 33733 | 4853.525 | 6.95 | <.0001 |
| \( \beta_1 \) | 0.31623 | 0.03951 | 8 | <.0001 |
| \( \beta_2 \) | 0.58551 | 0.08 | 7.32 | <.0001 |
| \( \beta_3 \) | -0.4042 | 0.08283 | -4.88 | <.0001 |
| \( \beta_4 \) | -0.50132 | 0.11465 | -4.37 | <.0001 |
| \( \beta_5 \) | -483.632 | 34.03514 | -14.21 | <.0001 |
| \( \beta_6 \) | -958.435 | 81.84421 | -11.71 | <.0001 |
Resource Availability and Need

This model was developed with the goal of prediction one week forward. The raw data is daily observations at the peak hour from January 1, 2014, to September 30, 2017. This data is averaged for each week to yield a dataset with 198 observations. The six independent variables were chosen from 233 variables all told. Inclusion and exclusion decisions were based on statistical significance, inspection of plots and several rationality checks.

This particular model is preferred because it’s relatively short and simple while relying on contemporaneous weather to achieve a good fit. This model is not meant to be interpreted as a causal model, only an indication of what one can expect next week for a set of conditions this week.

Revisiting the estimates; the estimate of $\beta_1$ can be interpreted as a 1 MWh increase in last week’s average margin we should expect to see a 0.3 MWh increase in the current week’s margin. The coefficients on all the megawatt hour valued variables can be read the same way. The weather variables have a different meaning. For example a 1 f° increase in Heating Degree Days (hd) would lead us to expect a 484 MWh reduction in that week’s margin.