MISO Reliability Attributes “Solution Space”

INITIAL ASSESSMENT OF PROMISING SOLUTIONS TO MEET IDENTIFIED PRIORITY ATTRIBUTE NEEDS

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PRESENTED TO

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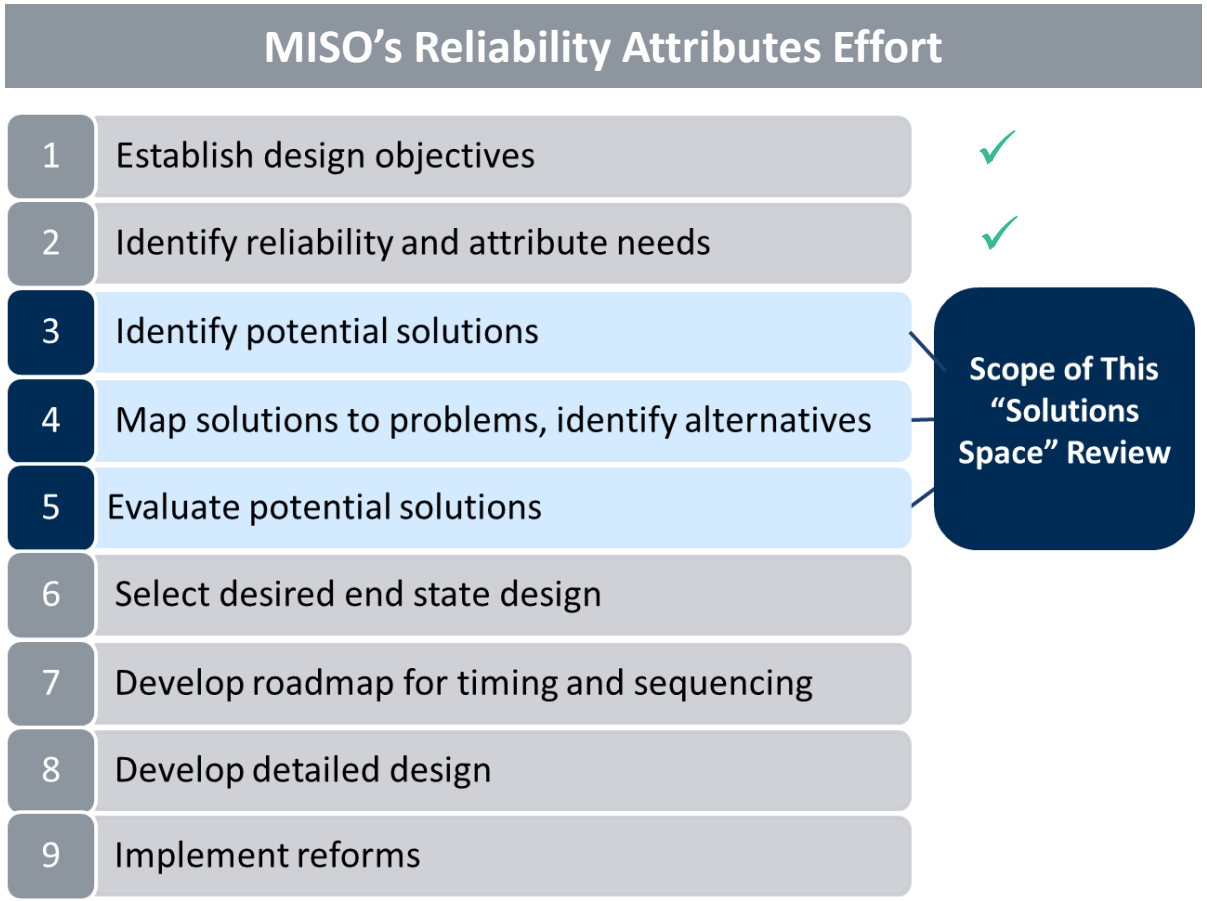
Transformation of the Grid Creates Challenges Requiring Proactive Solutions

The transforming fleet creates **challenges** that system operators will have to manage

MISO has identified priority reliability attributes that will be needed, aiming to proactively develop solutions for ensuring provision of those attributes, before problems become acute

Our review of **"Attributes Solution Space"** seeks to identify the most promising options for meeting identified needs. Recommendations will be considered as input to MISO's forthcoming Attributes Roadmap, where they can be further evaluated, developed, and implemented

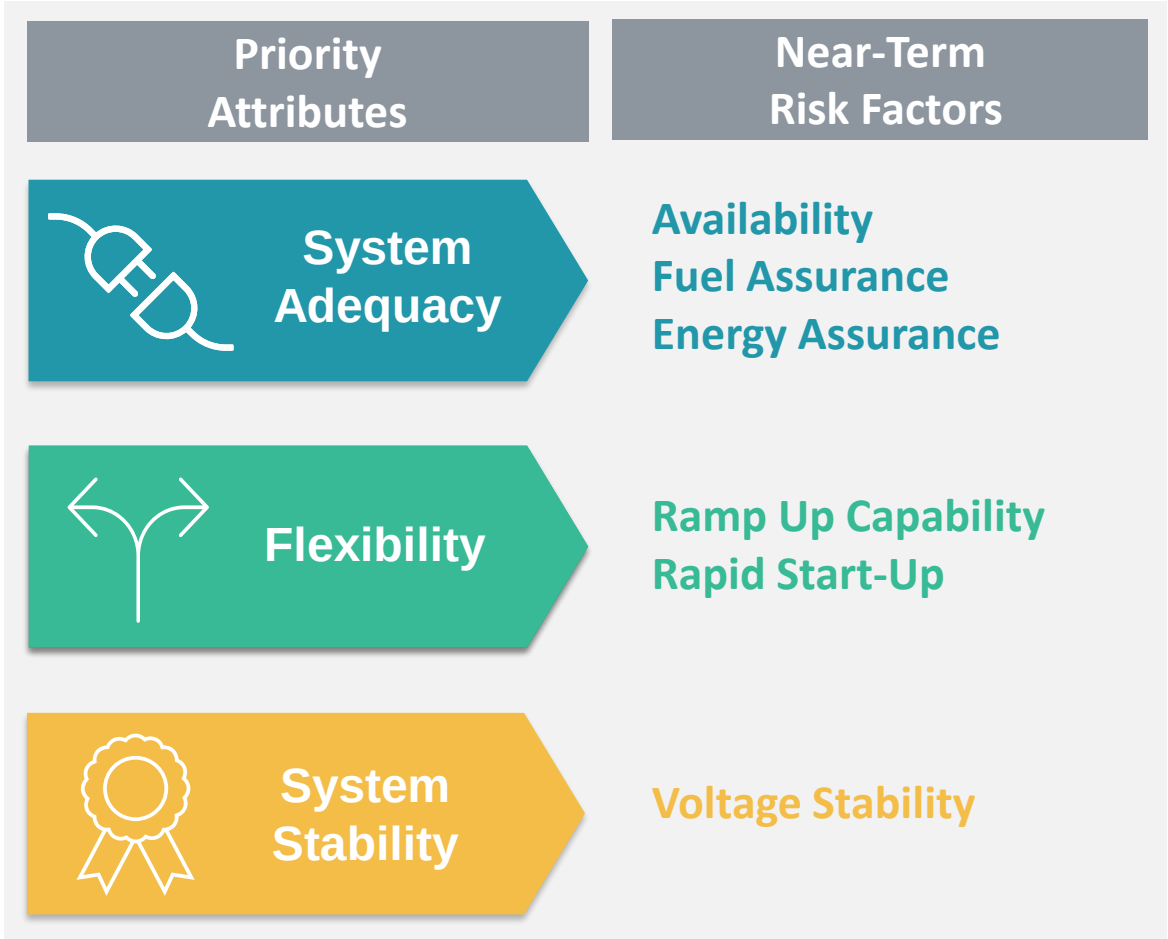


MISO Has Identified 3 Priority Attributes for Managing the Future Grid

Our task in this "solution space" review is to identify and recommend promising solutions for addressing attribute needs

Considering that MISO's forthcoming attributes roadmap will need to clarify:

- How to attract and retain resources with the needed capabilities, to ensure that sufficient resource capabilities will exist
- How to activate resources to provide the needed services when they are needed
- How to unlock emerging resources' potential to deliver the needed attributes, throughout fleet transition



Criteria for Evaluating Candidate Solutions

Technical criteria

- ✓ Helps **attract/retain** sufficient resources to provide the target reliability attribute
- ✓ **Operationally utilizes** the resources to provide the attribute

Economic criteria

- ✓ Promotes **economically efficient investment**
- ✓ Promotes **economically efficient operations and performance**

Process criteria

- ✓ Provides **transparency** and predictability, w/o excessive complexity
- ✓ Has acceptable **implementation cost and time**

Other considerations (in most cases part of the above and not additional differentiators)

- ✓ **Resource neutrality**
- ✓ Informs **long-term planning** for states and utilities
- ✓ **Adaptability** to changes in policies and market conditions
- ✓ **Compatibility** w/existing processes, markets & policies

System Adequacy: Challenges to Address

Investment Timeframe: Attracting & Retaining the Needed Resources

- Substantial recent & planned work to better incorporate emerging risks into Module E
- Likely an area of continuous improvement given pace of fleet transition
- Need to embrace reality that "emerging" resources will provide an increasing share of supply adequacy (up to 100% for some states/customers)

Operating Timeframe: Activating Resources to Provide Needed Services

- Capacity commitments not currently backed up by strong performance incentives when events arise
- Stronger energy and ancillary service market signals provide the most granular signals for resources to be available when & where they are most needed (this also sharpens signals to invest accordingly)

System Adequacy

Ensure fleet can serve load in all realistic modeled scenarios (up to relevant LOLE/EUE targets), including spiked/extended load or resource unavailability

Emerging Reliability Challenges	
Availability: traditional supply adequacy to meet 1-in-10 LOLE	• MISO fleet is rapidly transforming; renewables, storage, and gas replacing retiring coal and other thermal generation • Historical measures of need and resource contributions less relevant in the future
Energy Assurance	• Increasingly intermittent and fuel-limited fleet may struggle to serve load during multi-day weather events, "Dunkelflaute"
Fuel Assurance	• Reliance on natural gas may threaten reliability in extreme cold, even if adequate dispatchable capacity otherwise available

System Adequacy: Recommended Solutions

	Solution	Description
Investments	**Improved Reliability Modeling**	Continuous improvement to best characterize seasonal risks, fuel availability & energy adequacy (reflected in supply adequacy requirements)
	Enhance Capacity Accreditation	Continue to enhance accreditation to accurately measure value and accommodate all technologies. Energy & fuel limits reflected
	Evaluate: "Worst Winter" Risks	Scenario analysis of extreme winter to capture extremes not reflected in well-behaved reliability modeling. Results to inform: resource accreditation requirements & whether a deterministic adequacy standard might be desired
Operations	**Capacity Performance Incentives**	Introduce clear performance obligations for all capacity resources to deliver energy and ancillary services during scarcity events, with strong real-time performance incentives to reward resources over-performing relative to capacity obligations (paid for by penalties assessed to under-performers)
	Enhanced Operating Reserve Demand Curve (ORDC)	Expanded ORDC (higher price, higher volume) that reflects full reliability value of resource availability on a granular basis. Derived from probability of lost load × value of lost load
	Monitor: Long-Duration Energy Needs	Long duration energy needs will be partially (possibly entirely) mitigated by above solutions. Continue to monitor outlook for emerging risks (especially winter and dunkelflaute conditions), consider long-duration energy reserve product if identified

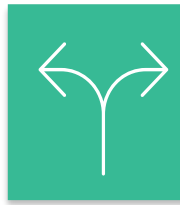
Flexibility: Challenges to Address

Investment Timeframe: Attracting & Retaining the Needed Resources

- Current hypothesis is that MISO will have *enough* flexible resources in the near term, but forecasted need vs. fleet capability can be proactively monitored

Operating Timeframe: Activating Resources to Provide Needed Services

- Current energy and ancillary service signals not yet reflecting all system variability & uncertainty, limits incentives to *activate all resources* to preposition and nimbly react to system needs
- Emerging & existing resources have vast potential to provide flexibility services, beyond what they are currently incentivized to do (limits MISO opportunity to gain visibility, control & operational experience)
- Absent enhanced market signals for flexibility, out-of-market commitment and dispatch instructions are likely to increase



Flexibility

Meet net load ramps with energy available on short notice to meet expected and unexpected net load ramps

Emerging Reliability Challenges

Rapid Start Up **Ramp Up Capability**	• Greater net load variability in high renewable system • System may lack adequate flexibility • Over-reliance on out-of-market actions

Flexibility: Recommended Solutions

	Solution	Description
Investments	**Monitor: Flexibility Needs**	Statistically characterize system uncertainty and ramping needs at many timescales (e.g. 10 min, 30-min, multi-hour, day-ahead), today and projected into the future. Review current and projected resource mix capability to provide flexibility needs. (Projected shortfalls would signal timeframe and need to take further action, if below solutions are insufficient.)
Operations	**Expanded Ramping and Related Balancing Products**	Carefully analyze system ramping needs to translate into a suite of products on multiple timeframes consistent with needs (e.g. net load uncertainty at 10 min, 30-min, multi-hour, day-ahead). Particular focus on timeframes when out-of-market unit commitment actions might otherwise be taken. When combined with expanded ORDC, new and expanded flexibility products will greatly incentivize investments and activation of flexible resources
	Multi-Interval Dispatch	Pursue multi-interval look-ahead in energy and ancillary market dispatch, optimizing resource deployment plans based on current information
	Enable Storage Optimization	Pursue capability for energy & ancillary markets to optimize scheduling of batteries, controllable hydro, controllable demand (e.g. EV, thermal batteries), and other storage resources. Incorporate intra-temporal opportunity costs into price formation
	Enhance Capability to Rely on Emerging Resources	Build institutional capability to increasingly rely on emerging resources for flexibility needs, particularly to meet needs in locations where thermal dispatchable resources will become scarce. Enhance participation models, visibility, and control of resources – particularly in balancing service markets where untapped emerging resource potential aligns with system needs

System Stability: Challenges

- Increasing share of inverter-based DC resources introduces new sources voltage stability problems (and may the supply of synchronous AC resources that are able to absorb and dampen instabilities)
- Industry is making rapid advances in inverter-based resources' technical capabilities, standards to effectively utilize those capabilities to prevent and manage instabilities, and identify supplementary grid-strengthening technologies
- Best addressed by planning, standards and control solutions rather than market solutions, since problems and solutions are highly localized
- Continuous improvement needed (chasing a moving target)

System Stability

Support voltage stability, especially in areas with many inverter-based resources

Emerging Reliability Challenges	
Voltage Stability	• Without reforms to inverter-based resource capability and codes to use these inverter capabilities, localized pockets of high asynchronous generation risk voltage instability

System Stability: Recommended Solutions

Solution	Description
Technology Standards for Inverter-Based Resources	Continue to engage in proactive development of technology standards for inverter-based resources, to enhance capabilities of newly-interconnecting resources and improve use of control settings to manage and dampen instabilities. Care taken to ensure that standards advance grid needs, with balance and care to ensure that resources do not face excess barriers to entry
Transmission Planning Studies and Solutions (Addressed outside the attributes roadmap process)	Most other solutions to support system stability will be identified via enhanced transmission planning, associated studies, and identified technology solutions (pursued in other forums, out of scope for this exercise)

Summary: Recommended Solutions

	Modernize the System Adequacy Construct	Focus Market Signals on Emerging Flexibility Needs	Strengthen the Grid
Investments: **How to <u>Attract Resources</u> with the Needed Capabilities?**	• Improve **reliability modeling** • Enhance **capacity accreditation** • Evaluate **worst-case winter scenario** to inform accreditation and possible deterministic standard	• Monitor **outlook for flexibility needs** vs. fleet-wide capability to provide (identify potential shortfalls long before investments are needed)	• **Technology standards** for inverter-based resources • Continue to enhance monitoring, reporting & planning
Operations: **How to <u>Activate Resources</u> to Provide the Needed Services?** **(Sharpens investment signals for the most valuable resources)**	• Introduce capacity **performance incentives** • Enhance **operating reserve demand curve** based on reliability need and value • Monitor **outlook for long-duration energy needs**, consider energy duration reserves product if potential shortfalls not addressed by accreditation	• **Expand ramping and related balancing products**, to manage net load variability and uncertainty (e.g., 10-min, 30-min, multi-hour, day-ahead) • Pursue **multi-interval dispatch** in energy & ancillary market	*Most solutions likely to be standards and planning-based, rather than market-based*
How to Unlock Emerging Resources' Potential?	• Prepare for increasing reliance on "new" technologies for system adequacy • Ensure all resources' commitments deliver the same value, despite diverse technical characteristics	• Enable **storage optimization** • **Enhance E&AS participation model**, visibility, control & operational experience with emerging flexible resources and controllable demand	• Balance system needs/value vs. costs imposed (i.e. be careful to avoid introducing barriers to entry)

Q&A

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