MISO's Review of Interconnection Requirements

Potential opportunities from reviewing standard IEEE 2800 capabilities and performance requirements

Starting at the larger reliability picture, Today MISO will share how IEEE 2800 implementation and generator requirements fit in

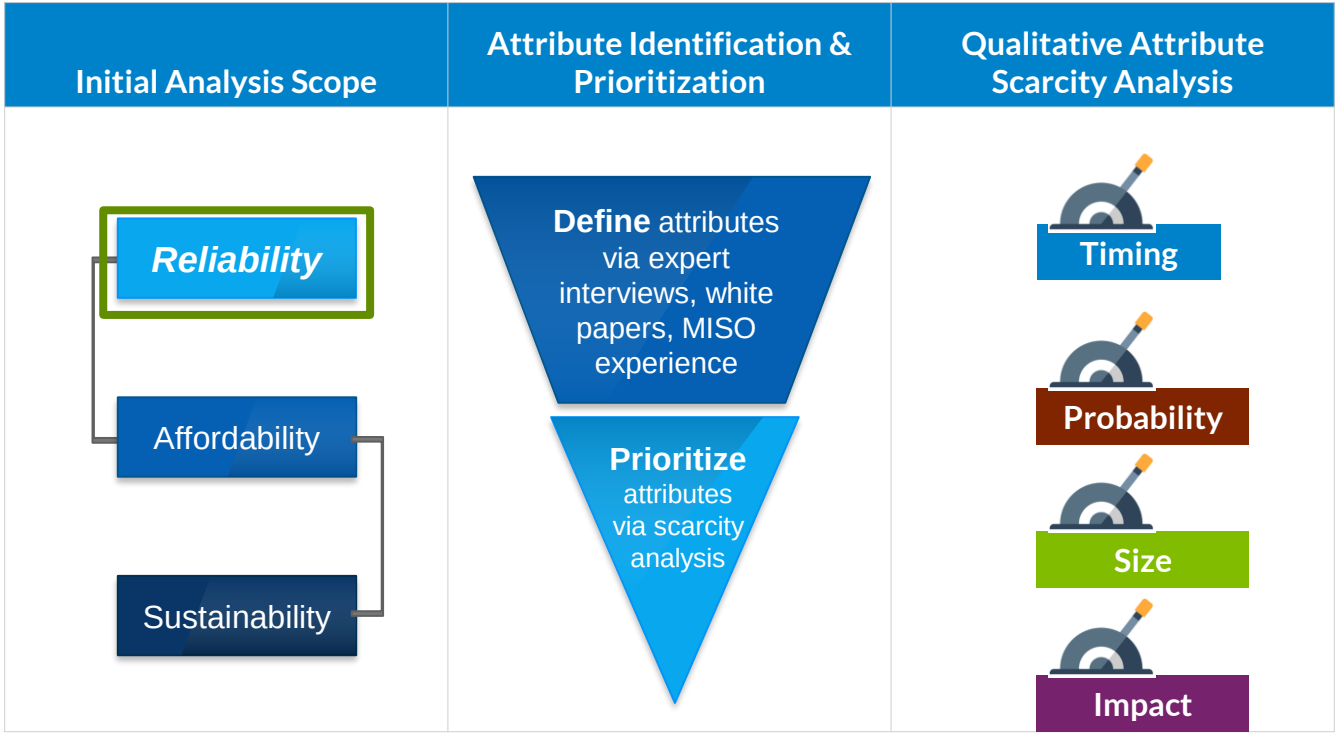
1. MISO's System Reliability **Attributes** effort in relation to Inverter-Based Resources (IBR)
2. Comparing **current generator interconnection requirements** against Standard IEEE 2800
3. **Opportunities to incorporate IEEE 2800** IBR capability and performance requirements

MISO recently initiated an investigation into needed System Attributes and how the continued resource transition could alter Attribute availability in the coming years

ISSUE	IMPLICATIONS	HYPOTHESIS
The resource transition continues to accelerate in the MISO region, creating new risks to reliability and market efficiency.	New resources do not have the same characteristics as those they are replacing, leading to the potential scarcity of attributes needed to operate the system.	We need to understand attributes necessary to provide ongoing system reliability and identify / implement methodologies (e.g., visibility, requirements, or market products) that will ensure those attributes are available.

MISO, System Attributes Stakeholder Workshop, RASC-2022-01. September 21, 2022. Available at: https://cdn.misoenergy.org/20220921%20System%20Attributes%20Workshop%20Presentation626391.pdf

MISO's initial focus is on understanding the timing and scale of needed Reliability Attributes along with the risks posed, should certain Attributes become scarce



Next steps are underway to quantify Attribute needs

While energy and capacity are given significant attention, many critical attributes are required for reliable operations

Capacity

- Availability

Energy Adequacy

- Fuel assurance
- Long duration energy at high output

Essential Reliability Services

- **Voltage stability**
- **Small signal stability**
- **Voltage control**
- **Black start**
- **Detection of short circuit fault**
- Regulation
- Contingency reserve

Potential positive contributions from standard Inverter-Based Resource capabilities

Flexibility

- Ramp up capability
- Ramp down capability
- Short minimum down time
- Short minimum run time
- Rapid start-up

Illustrative list of potential System Reliability Attributes.

MISO kicked off an IEEE 2800 adoption effort in support of the Reliability Imperative and evolving system Attribute needs

Objective: Leverage recent industry developments surrounding inverter-based resource performance needs and capabilities, namely the publication of IEEE 2800-2022, with an aim to mitigate undesirable reliability events outlined in recent NERC disturbance reports and to position MISO for beneficial use of other IBR attributes (e.g., fast frequency response).

- By defining standard minimum performance requirements, MISO is benefiting from industry standardization and lessons-learned in other jurisdictions.
- Most performance issues identified by recent NERC disturbance reports could be remedied by IEEE 2800 compliance.

MISO performed outreach to peers and industry experts to capture a wide range of perspectives

Peer ISOs/RTOs

- Experienced significant IBR reliability events starting ~ 5 years ago with larger events serving as "wake up call".
- IEEE 2800 covers capabilities to address IBR reliability issues but is ineffective without enforceable compliance steps.
- IEEE 2800 can drive consistent plant performance and simplify some technical challenges
- Clause-by-clause adoption or recreation of standard concepts in requirements
- May go above and beyond IEEE 2800 requirements for some functions (e.g., phase angle jump)

Transmission Owners

- Adopting parts of IEEE 2800 through Local Planning Criteria update (e.g., dynamic active and reactive power responses).
- This TO's 2800 adoption is coupled with EMT modeling requirements with model verification being a major component of the effort.

Industry Standards Experts

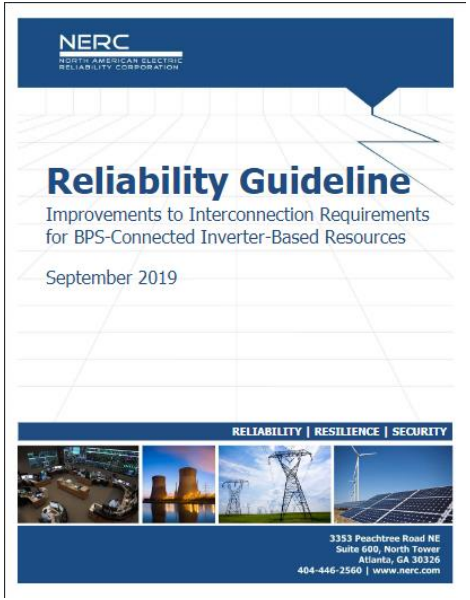
- While a wholesale NERC adoption of IEEE 2800 is not anticipated, ISO/RTO and TO adoption is highly encouraged based needs outlined in NERC Disturbance Reports and Reliability Guidelines[1].
- Echoing ISOs/RTOs with events, standard compliance along with model verification and validation are most pressing future issues.

[1] NERC, Reliability Guideline, Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources, September 2019. Available at: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_IBR_Interconnection_Requirements_Improvements.pdf

In the past, MISO has updated interconnection requirements as industry best practices emerge

In 2020, prompted by new NERC Guidelines, MISO updated generator requirements:

- **Momentary cessation** prohibited
- **Phase jump** immunity introduced
- **Monitoring** and recording events to 1ms resolution
- **Rate-of-change-of frequency** protection prohibited except for equipment protection



Given MISO's current interconnection queue, with roughly 95% of new applications being IBR, and the release of IEE 2800, the timing is right to revisit interconnection requirements.[1]

[1] MISO, 2022 Generator Interconnection Queue Submissions. Available at: https://cdn.misoenergy.org/2022%20GIQ%20Submission%20Statistics626443.pdf

The team has followed a gaps analysis approach to focus potential recommendations

Step 1

IEEE 2800 Requirement ("Shall")

Compared against

MISO Tariff / GIA

Determination:
- Gap
- No Gap

MISO is currently here in the process

Step 2

Recommend implementation priority and timing for gaps, based on factors that may include:
- MISO reliability need
- Stakeholder perspectives
- OEM readiness
- Test and verification feasibility
- Tariff implications

MISO's approach was inspired by the work pioneered by EPRI and ERCOT.[1]

[1] ERCOT, IEEE 2800 vs Existing ERCOT Interconnection Requirements, Gaps Analysis Learnings. August 11, 2021. Available at: https://www.esig.energy/download/ieee-2800-vs-existing-ercot-interconnection-requirements-gap-analysis-learnings-stephen-solis

Preliminary potential opportunities to refine interconnection requirements were identified for further investigation and stakeholder discussion

- ● Range of available settings
- Measurement accuracy
- Prioritization of functions
- Ramping for control parameter change
- Responding to external control inputs
- Voltage control - specific control parameters and remote control
- ● Constant reactive power
- ● Reactive power capability at zero active power
- ● Current injection through voltage ride-through – balanced and unbalanced
- ● ROCOF ride-through
- ● Transient overvoltage ride-through
- ● Consecutive voltage deviation ride-through
- ● Restore output after voltage ride-through
- ● Fast frequency response – over frequency and under frequency
- Remote configurability

Note: MISO gaps/opportunities vary in nature from unspecified capabilities to refinements in already required capabilities or functional performance settings

● : Indicates a gap identified by peer ISO/RTO. MISO's view of peer gaps is non-exhaustive.

In early 2023, MISO plans to gather stakeholder input on IBR requirement prioritization, implications, and timing

- MISO intends to share the opportunities identified through the stakeholder Interconnection Process Working Group.
- Stakeholder feedback will help inform MISO's IEEE 2800 implementation plan.
- Implementation will likely require MISO Tariff changes to the pro forma Generator Interconnection Agreement

Questions?

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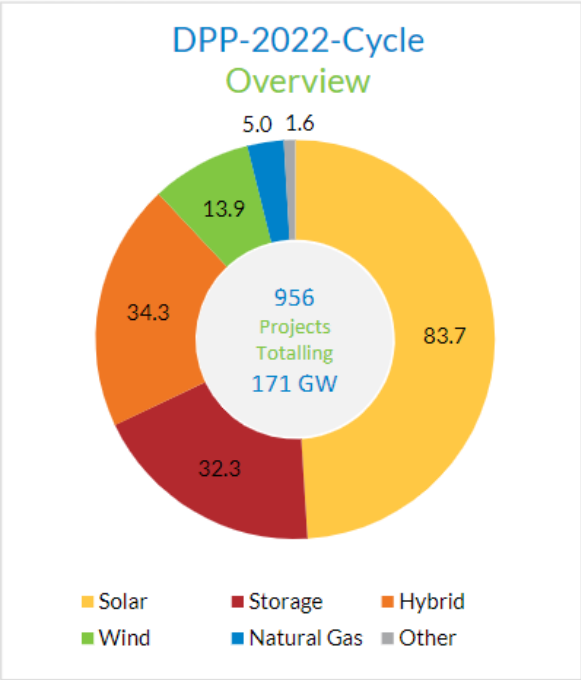
MISO's 2022 Generator Interconnection Queue Submissions Set New Records for MISO both by Volume and Makeup



Fuel	# of Requests	GW
Solar	469	83.7
Storage	231	32.3
Hybrid	163	34.3
Wind	66	13.9
Natural Gas	21	5.0
Other	6	1.6
Grand Total	**956**	**170.8**

MISO, 2022 Generator Interconnection Queue Submissions. Available at: https://cdn.misoenergy.org/2022%20GIQ%20Submission%20Statistics626443.pdf