MISO update on IEEE2800 adoption efforts

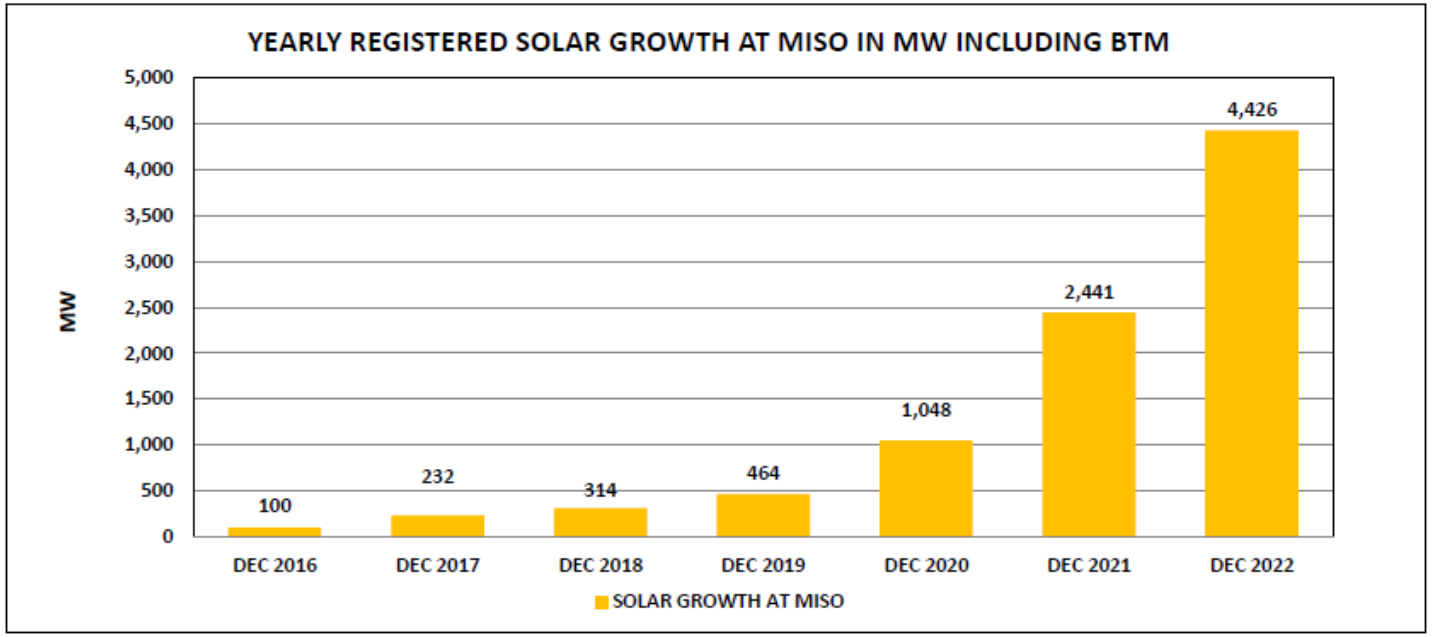
Presentation to ERCOT's IBRWG

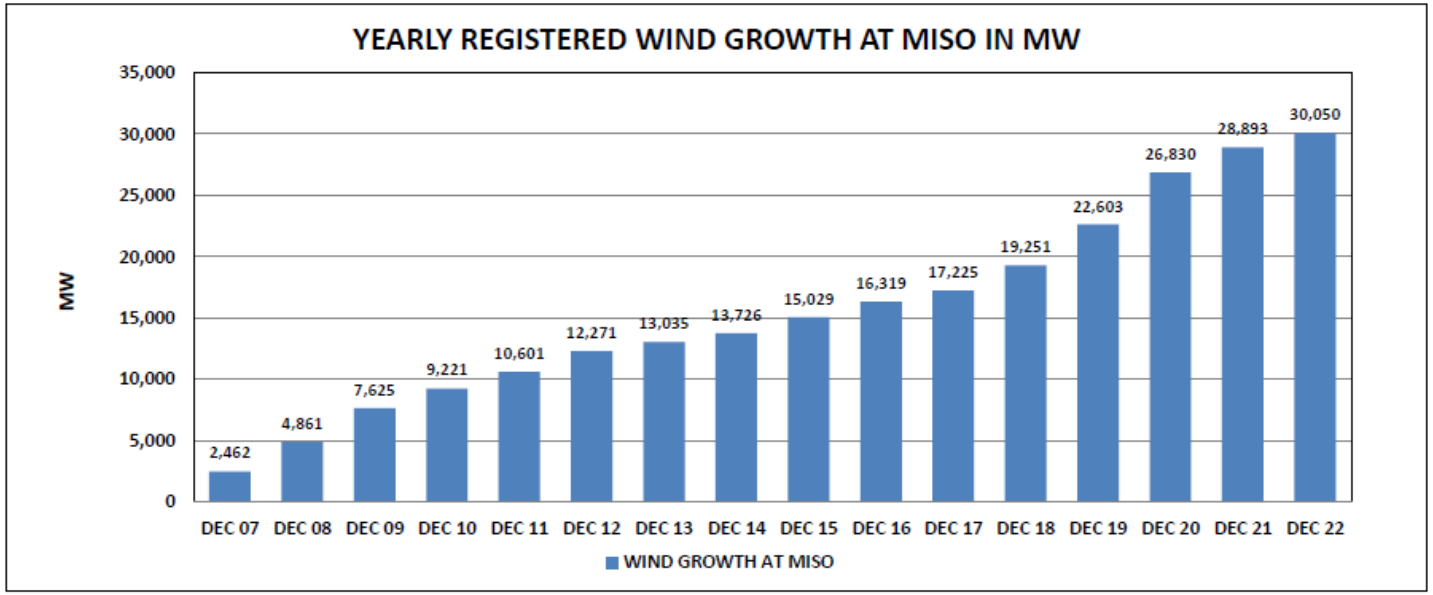
November 10, 2023

Current state: MISO's system has relatively low levels of solar and moderate levels of wind resource

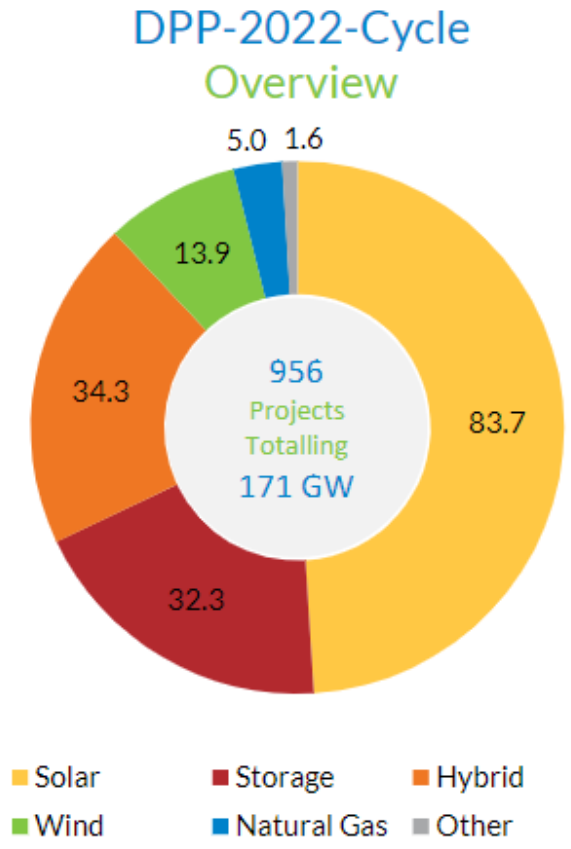
Taken together, wind and solar make up about 20% of the installed capacity.

- Approximately 35 GW of wind + solar resources within 190GW total installed capacity.





MISO's 2022 generator interconnection queue submissions set new records, with inverter-based resources (IBR) making up the vast majority of proposed resources



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**

Around 96% of capacity (~164 GW) is likely inverter-based.

While not all this will be built, it would mark almost a 5x increase in IBR over today.

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

MISO's IEEE 2800-2022 adoption effort began in 2022, tariff changes for selected priority requirements are expected to be filed by early 2024

*MISO is coordinating the timing of filing these tariff changes to align with other MISO FERC filings, timing of this filing is subject to change

The team first followed a gaps analysis approach to focus potential IBR recommendations before applying a prioritization framework

IEEE 2800 Requirement ("Shall")

Compared against

MISO Tariff Generator Interconnection Agreement (GIA) Requirement

Determination:

- Gap & nature of gap
- No Gap

From the gaps analysis, 21 requirements emerged as areas for further focus and prioritization

General

1. Measurement accuracy
2. Range of available settings
3. Prioritization of functions
4. Ramping for control parameter change

Monitoring, Control, and Scheduling

5. Responding to external control inputs
6. Remote configurability

Voltage Support

7. Capability at zero active power
8. Constant reactive power
9. Current injection during voltage ride through – balanced
10. Current injection during voltage ride-through - unbalanced

Dynamic Responses and Reliability Services

11. Frequency ride-through
12. ROCOF ride-through
13. Voltage ride-through
14. Transient overvoltage ride-through
15. Return-to-service (enter service) criteria and performance
16. Restore output after voltage ride-through
17. Voltage phase angle jump ride-through
18. Consecutive voltage deviation ride-through
19. Underfrequency fast frequency response
20. Overfrequency fast frequency response
21. Primary frequency response

MISO used a reliability lens to prioritize IBR performance requirements that were highlighted in the gaps analysis

Source	Purpose
NERC Disturbance Reports[1]	**Address known IBR performance issues observed in previous events**
FERC IBR Notice of Proposed Rulemaking (NOPR)[2] Led to Order 901	Highlight IBR performance issues FERC has directed NERC to address through future standards, which has full overlap with NERC Event Reports
UNIFI Grid Forming Specifications[3]	Consider advanced performance identified as necessary for the future grid in recent U.S.-based consortium looking at "grid forming" specifications
MISO Reliability Attributes[4]	Consider MISO's full, initial list of Attributes as an additional reliability view

[1] https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx. Cause codes are shown on slide 14.
[2] Federal Energy Regulatory Commission, Department of Energy. Reliability Standards To Address Inverter-Based Resources. Docket No. RM22-12-000. 12/6/2022. Available at: https://www.federalregister.gov/d/2022-25599.
[3] The universal interoperability for grid-forming inverters (UNIFI) Consortium is a DOE-funded, NREL-led effort to advance grid forming inverter technology. Specification for GFM IBR Version 1 document available at: https://drive.google.com/file/d/19YRpERnsssEJ62H_Tb0edtxHrZI37ZkK/view
[4] MISO, System Attributes Stakeholder Workshop. 12/21/2022. RASC-2022-1. Available at: https://cdn.misoenergy.org/20220921%20System%20Attributes%20Workshop%20Presentation626391.pdf

IEEE 2800 requirements were prioritized based on IBR tripping causes from eight recent NERC Disturbance Reports

Cause Code	2016 - Blue Cut Fire, CA	2017 - Canyon 2 Fire, CA	2018 - April May events, CA	2020 - San Fernando event, CA	2021 - Odessa 1, TX	2021 - June August events, CA	2022 - Panhandle event, TX	2022 - Odessa 2, TX
AC low voltage protection				x		x		
AC overcurrent protection				x		x		x
AC overvoltage protection					x	x	x	x
DC low voltage protection				x		x		x
DC overcurrent						x		
DC reverse current tripping		x	x					
Instant frequency tripping	x							
Instant overvoltage tripping		x	x					
Intra-plant interactions		x					x	x
Momentary cessation	x	x	x	x	x	x		x
Overfrequency protection						x		
PLL synchronization/phase jump		x			x			x
Slow active power recovery		x		x	x	x	x	
Underfrequency protection					x	x		x

This matrix is MISO's summary of information contained in the reports.

Combining the sources revealed a need to address dynamic responses, starting with voltage and frequency ride-through

- NERC disturbance reports were given highest weight
  - Results in a bias towards historical events and tripping related issues
- Highest priority items are included in the first round of IEEE 2800 adoption
  - Remaining requirements will be explored soon afterwards

Category	IEEE 2800 Performance Capability	*NERC Disturbance Cause Code?*	*FERC IBR NOPR Topic?*	*UNIFI Performance Need?*	*Reliability Attributes Area?*	Resulting Priority
General	Measurement accuracy	X				Highest
	Range of Available Settings					Lower
	Prioritization of Functions					
	Ramping for control parameter change					
Monitoring, Control, and Scheduling	Responding to external control inputs					Lower
	Remote Configurability					
	Capability at Zero Active Power				X	
Voltage Support	Constant Reactive Power				X	Medium
	Current injection during voltage ridethrough - balanced	X		X	X	
	Current injection during voltage ridethrough - unbalanced	X		X	X	
Dynamic Responses and Reliability Services	Frequency Ride-Through	X	X	X	X	Highest
	ROCOF Ride-Through	X	X	X	X	
	Voltage Ride-Through	X	X	X	X	
	Transient Overvoltage Ride-Through	X	X	X	X	
	Return-to-Service (Enter Service)	X	X		X	
	Restore Output After Voltage Ride-Through	X	X		X	
	Voltage Phase Angle Jump Ride-Through	X	X	X	X	
	Consecutive Voltage Deviation Ride-Through			X	X	Medium
	Underfrequency Fast Frequency Response			X	X	
	Overfrequency Fast Frequency Response			X	X	
	Primary Frequency Response			X	X	

MISO moved forward with the top priority requirements, along with a few supporting items, as an initial step towards broader adoption of IEEE 2800-2022

	Capability or Performance Requirement	IEEE 2800 subclause
Supporting clauses, containing definitions	Reference Point of Applicability	4.2
	Applicable Voltages and Frequency	4.3
Priority requirements, reliability focus	Measurement Accuracy	4.4
	Return-to-Service (Enter Service)	4.10
	Voltage Ride-Through	7.2.2.1
	Current Injection During Voltage Ride-Through	7.2.2.3.4
	Transient Overvoltage Ride-Through	7.2.3
	Restore Output After Voltage Ride-Through	7.2.2.6
	Frequency Ride-Through	7.3.2.1
	ROCOF Ride-Through	7.3.2.3.5
	Voltage Phase Angle Jump Ride-Through	7.3.2.4

MISO contemplated several IEEE 2800-2022 adoption approaches, each with benefits and drawbacks, before recommending a Detailed Reference approach

Adoption approach	Benefits	Drawbacks	Entities using approach[1]
1. General Reference Cite IEEE 2800-2022 in full	- Simplest changes to Generator Interconnection Agreement (GIA)	- Does not account for the standard's decision points - Quickly creates large number of new requirements - Requires access rights to standard	- Florida Power and Light (FPL) - Salt River Project (SRP)
2. Detailed Reference Cite specific IEEE 2800-2022 clauses	- Allows for targeted, phased adoption	- Requires access rights to standard	- Duke Energy - ISO-NE - NYISO - Southern Company
3. Detailed Specification Recreate specifications from IEEE 2800-2022	- Allows for targeted, phased adoption - Avoids potential open access transmission tariff issues	- Presents copyright challenges - Requires altering of consensus language - Harmonization risks	- ERCOT - Ameren IL

[1] Inventory of IEEE 2800 adoption approaches provided by EPRI

MISO is proposing a Detailed Reference approach for adopting IEEE 2800-2022, citing adoption exceptions

MISO's proposed GIA redlines define requirements by exception, on the path to full standard adoption.

General (IEEE 2800-2022 Clause 4)

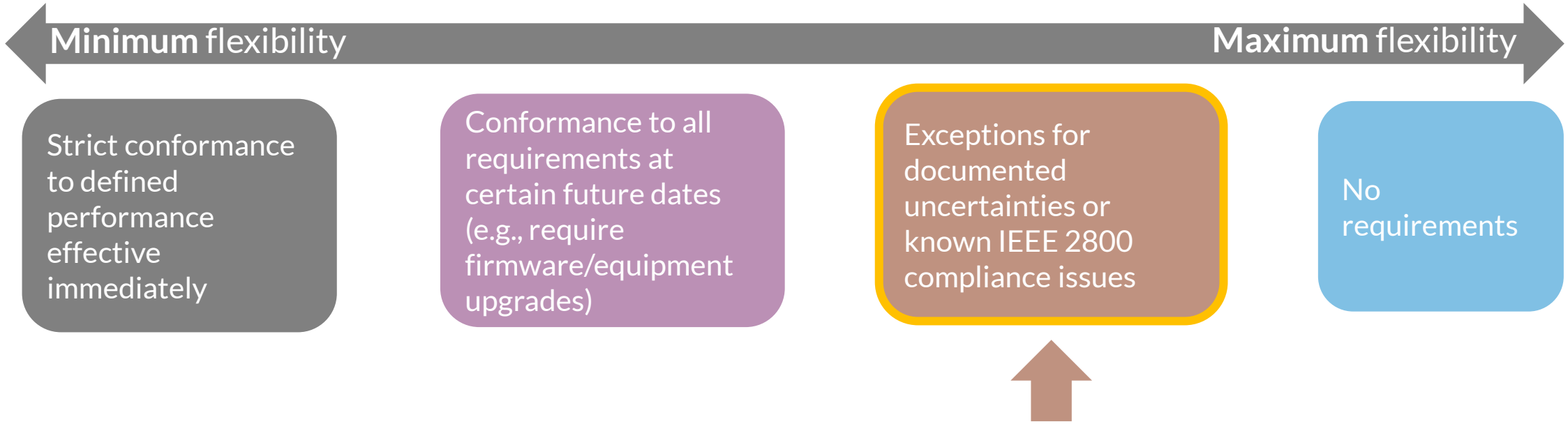
Inverter-based resources shall adhere to IEEE 2800-2022 Clause 4 requirements, with the exception of subclauses 4.5 (operational measurement and communication capability), 4.6 (control capability requirements), 4.8 (isolation devices), 4.9 (inadvertent energization of TS), 4.11 (interconnection integrity), and 4.12 (integration with TS grounding).

IEEE 2800-2022 Subclause	Required	Exception
4.2 Reference Point of Applicability	X	
4.3 Applicable Voltages and Frequencies	X	
4.4 Measurement Accuracy	X	
4.5 Operational Measurement and Communication Capability		X
4.6 Control Capability		X
4.7 Prioritization of IBR Responses	X	
4.8 Isolation Devices		X
4.9 Inadvertent Energization of TS		X
4.10 Enter Service	X	
4.11 Interconnection Integrity		X
4.12 Integration with TS grounding		X

Example for illustrative purposes only. Some IEEE 2800 requirements carry decisions on specifying parameters which would be included.

Clause 4.1 (Introduction) does not contain requirements, which is why it is not included in the table above.

MISO views a degree of flexibility for Definitive Planning Phase (DPP)-2022 performance requirements as striking a balance between facilitating needed reliability attributes while managing uncertainties



MISO proposes offering exceptions to specific IEEE 2800-2022 capabilities and performance requirements through documented evidence of conformance uncertainties or shortfalls for GIAs signed before January 1, 2025.

Next Steps

- MISO will respond to and incorporate stakeholder feedback for the tariff redlines proposed in October 2023
  - After finalizing tariff language, MISO will make a FERC filing in the coming months
- MISO will determine the appropriate conformance assessment method for each requirement
- MISO's ongoing Attributes project[1] is investigating future performance requirement needs and potential sequencing
  - Additional information will be shared in the Attributes roadmap publication later this year

[1] https://www.misoenergy.org/stakeholder-engagement/MISO-Dashboard/identification-of-sufficient-system-reliability-attributes/

Questions?

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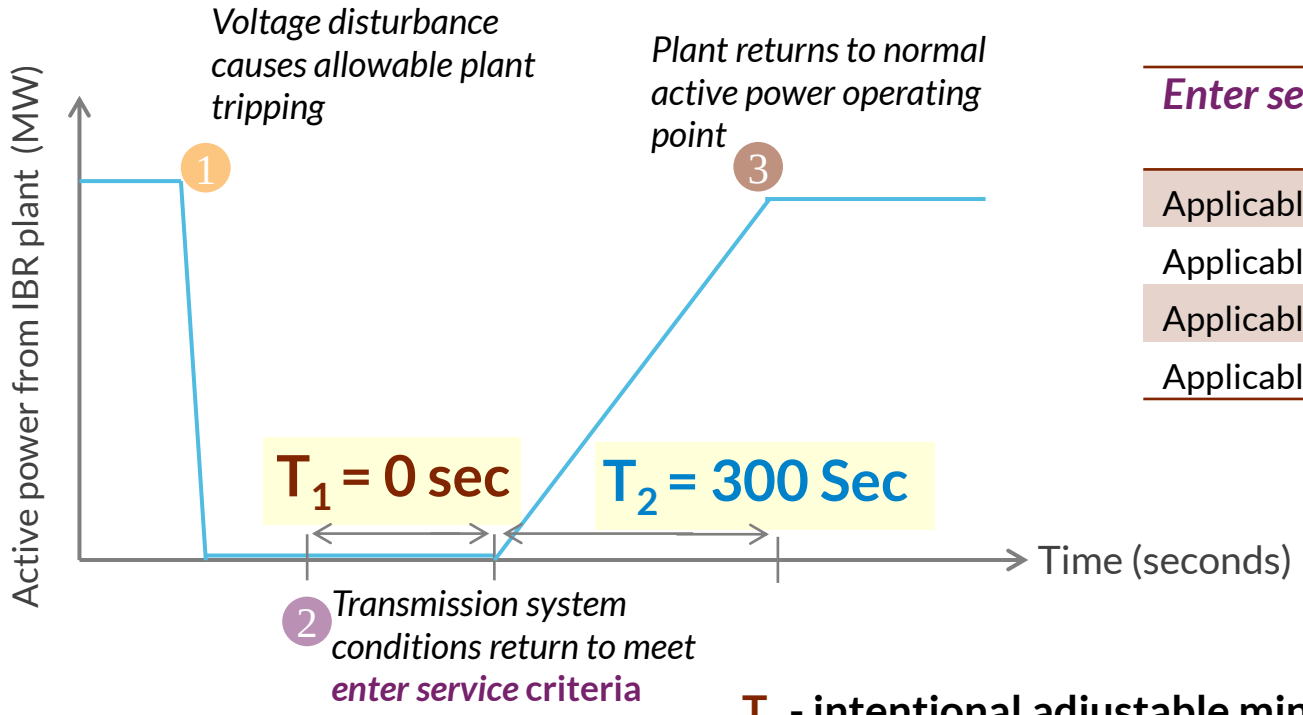
MISO adopted stakeholder feedback for *enter service* criteria and performance as defined by IEEE 2800

The Transmission Owner sector offered default values for Enter Service Performance (i.e., T_1, T_2) which, given no other stakeholder opposition, were adopted by MISO



Enter service criteria	Default Proposal	*Range of allowable settings*
Applicable voltage, minimum value	**0.90 p.u.**	0.90 p.u. to 0.95 p.u.[1]
Applicable voltage, maximum value	**1.05 p.u.**	1.05 p.u. to 1.10 p.u.[2]
Applicable frequency, minimum value	**58.8 Hz**	58.8 Hz to 59.4 Hz
Applicable frequency, maximum value	**60.12 Hz**	60.12 Hz to 61.2 Hz

T_1 - intentional adjustable minimum delay, with a ***range of allowable settings*** **from 0 s to 60 s.**
T_2 - duration of *enter service* period, with a ***range of allowable settings*** **from 1 s to 1000 s.**

[1] Transmission Operator or Transmission Owner and IBR Operator may agree on different minimum voltage value for weak grid interconnections.
[2] Voltages above 1.05 p.u. may be outside of the current interrupting capability of fault-interrupting devices rated based on ANSI C84.1.

MISO's proposal aligns with the general stakeholder preference, defining the reference point of applicability (RPA) to be the point of measurement (POM)

- RPA is the location where performance requirements apply
- IEEE 2800 default RPA is the point of measurement (POM), but allows for selection of a different RPA
  - Exception is voltage ride-through unit specifications, where the RPA is the point of connection (POC) for each IBR unit
- Stakeholders requested the POM as the RPA to align with current standard compliance practices