Battery Energy Storage System Grid Forming Controls (PAC-2024-2)

Interconnection Process Working Group (IPWG)

March 12, 2024

Purpose & Key Takeaways

Purpose: Explore adoption of grid-forming (GFM) battery energy storage system (BESS) performance to support system stability

Key Takeaways:

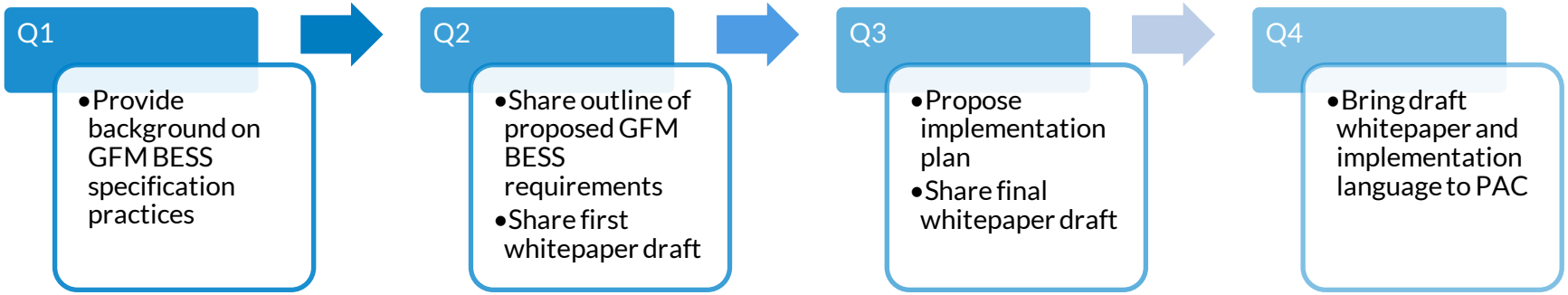
- MISO is working with stakeholders to develop GFM BESS performance requirements, which will include aspects of modeling and conformance.
- Today MISO is sharing a proposed schedule, principles, and initial framing for the effort.
- At the next IPWG, MISO will propose conceptual performance requirements and request stakeholder feedback.

MISO has developed several principles for the 2024 BESS GFM development effort

- Supporting system reliability is primary aim of requirements.
- Consider Original Equipment Manufacturer (OEM) equipment and plant design capabilities as a key input, in addition to the system reliability need.
- Keep requirements as simple as possible.
- Avoid conflicts with IEEE 2800-2022, which applies to all IBR (including BESS).
- Focus new process and data exchange requirements on crucial features.
- Choose flexibility over delay if needed, given the urgency and opportunity to act now.
- Avoid material impacts on storage operations (e.g., power dispatch and state of charge management) in developing “core capability” requirements.
- Position requirements for extensibility as future needs emerge.

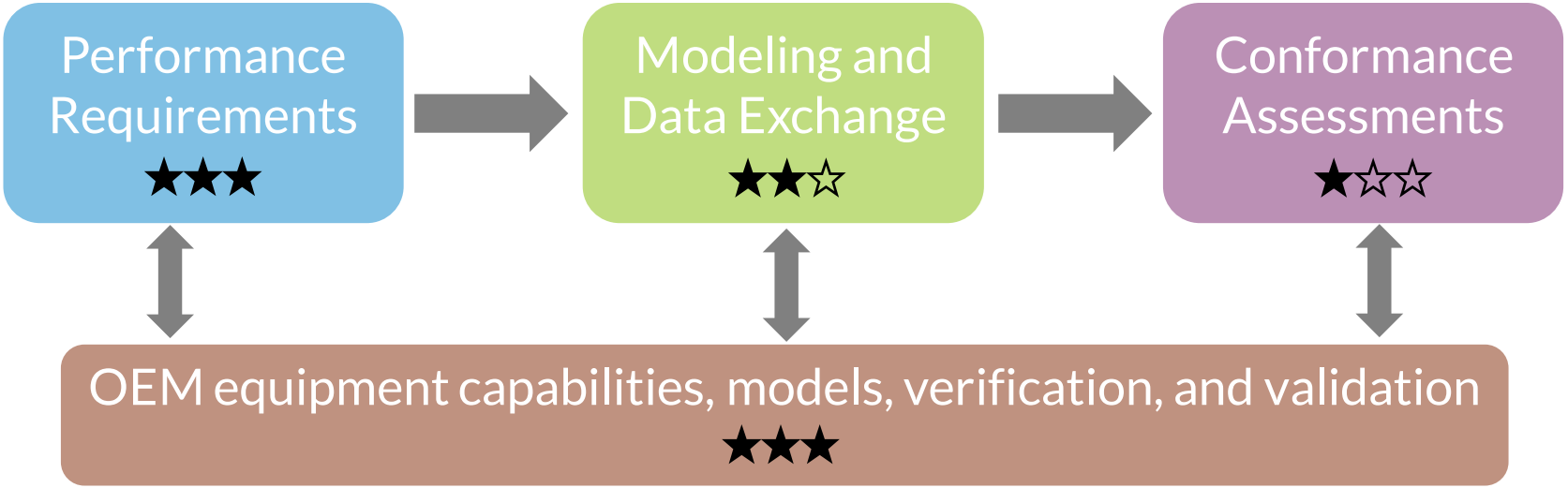
MISO is sharing this background to inform stakeholders of principles underlying MISO’s approach to developing GFM BESS performance requirements.

2024 IPWG and PAC proposed schedule: Grid Forming (GFM) specifications for Battery Energy Storage Systems (BESS)



	Date	GFM BESS topic objectives
IPWG	January 30	Inform stakeholders of IBR performance planned for development in 2024.
	March 12	Provide foundational information on GFM BESS specification practices.
	May 2	Share outline of initial proposed GFM BESS requirements. **Formal feedback request**.
	June 4	Share first revision of GFM BESS specifications whitepaper. **Formal feedback request**.
	July 23	Respond to stakeholder feedback and share second version of whitepaper. Introduce proposed GFM BESS implementation plan. **Formal feedback request**.
	September 3	Respond to stakeholder feedback and share near-final whitepaper, subject to PAC review.
PAC	October 16	GFM BESS performance requirements proposal. **Formal feedback request**.
	November 13	GFM BESS share feedback responses and modifications.

A system of performance, modeling, and conformance is needed for effective reliability support



MISO will prioritize the "front-end" elements in this initial effort.

Given the interrelated nature of these elements, and their different levels of maturity, adoption of emerging performance capabilities often requires tradeoffs.

★★★ Note: the number of filled in stars represents relative priority of element in initial MISO GFM BESS requirements. MISO views all areas as highest priority for eventual, full implementation.

MISO appreciates the Australian Energy Market Operator's framing of BESS GFM requirements as either "core" or "additional" capabilities

- MISO proposes to further evaluate this framing and focus only on the "core" requirements in 2024.
  - Core capabilities are anticipated to not require hardware oversizing; these are addressed through software.
- MISO's 2023 Attributes work focused on *system strength* capabilities of GFM controls, based on nearer-term needs.
- However, MISO will explore the full set of "core" capabilities considered in existing GFM BESS performance specifications.

Core capabilities:

- Voltage source behavior
- Frequency domain response
- Inertial response
- Surviving the last synchronous connection
- Weak grid operation and system strength support
- Oscillation damping

Additional capabilities:

- Headroom and energy buffer
- Current capacity above continuous rating
- Black start capability
- Power quality improvement

GFM controls will naturally provide both system strength and frequency strength, unless responses are control-limited

Given the natural GFM control response, and potential implications of current limiting, MISO suggests evaluating all "core" capabilities.

In suggesting an exploration of frequency strength, MISO is not proposing storage "overhead / energy buffer" requirements.

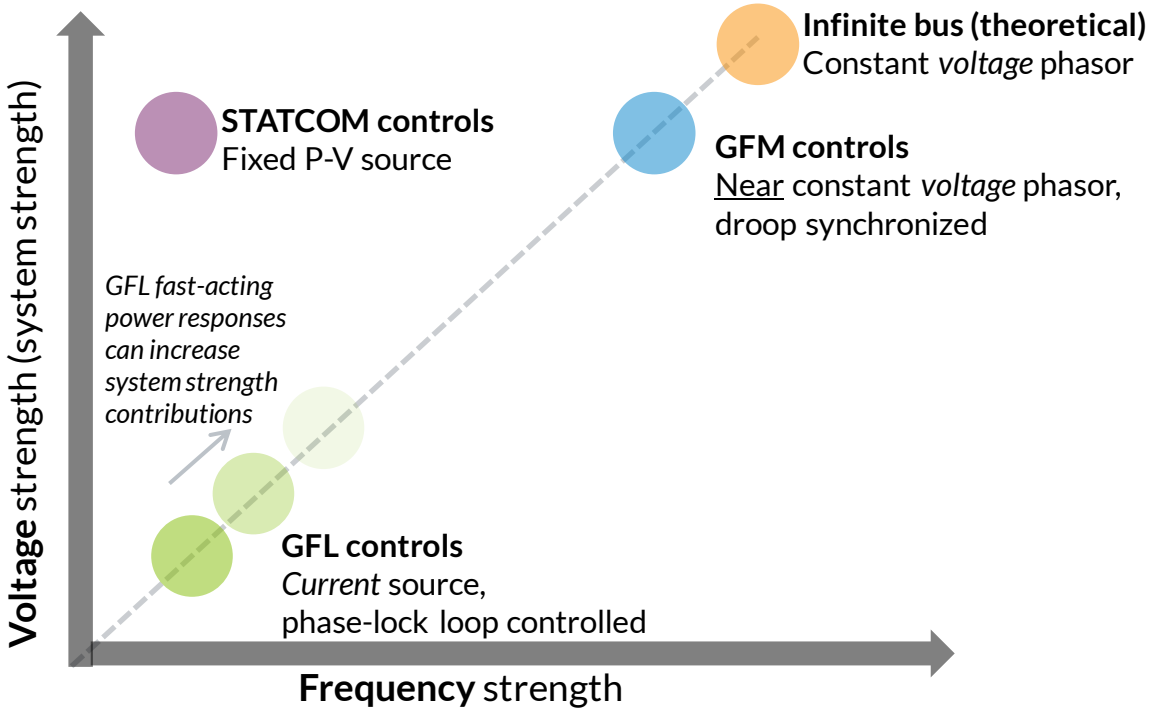


Image is adaptation from work at the Imperial College of London, presented to G-PST.

MISO is exploring a stepped approach to introducing GFM requirements with the 2024 focus on system strength and frequency support

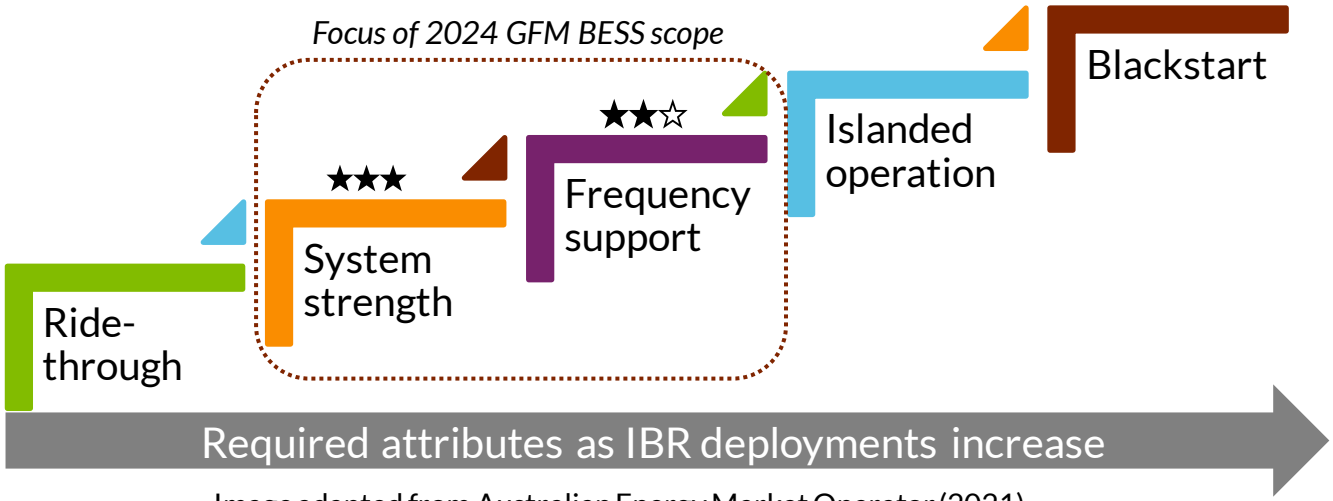


Image adapted from Australian Energy Market Operator (2021)

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Next steps

- MISO will continue to evaluate the GFM BESS landscape, internationally and domestically, in developing an initial conceptual proposal to be shared with stakeholders at the May IPWG.
- Stakeholders with GFM and/or BESS subject matter expertise are invited to reach out to MISO with comments at anytime, ahead of a planned feedback request at the May IPWG.
- MISO is beginning OEM outreach, collecting information about existing and future planned GFM BESS capabilities, to support MISO in crafting an initial proposal.

Questions?

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Appendix

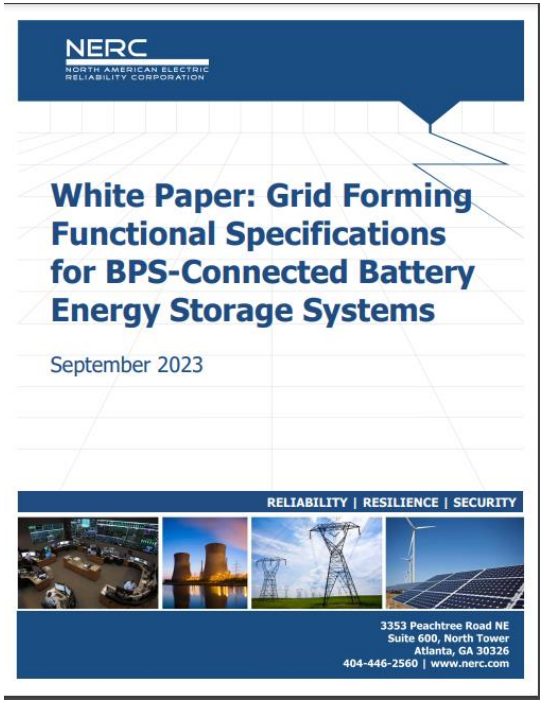
Resources on Grid Forming Specifications

Entity	Document	Link	Year
FINGRID	Grid Code Specifications for Grid Energy Storage Systems SJV2019	https://www.fingrid.fi/globalassets/dokumentit/en/customers/grid-connection/grid-energy-storage-systems-sjv2019.pdf	2021
FINGRID	Specific Study Requirements for Grid Energy Storage Systems	https://www.fingrid.fi/globalassets/dokumentit/fi/palvelut/kulutuksen-ja-tuotannon-liittaminen-kantaverkkoon/specific-study-requirements-for-grid-energy-storage-systems-en.pdf	2023
FINGRID	Modelling instruction for PSS/E and PSCAD models	https://www.fingrid.fi/globalassets/dokumentit/fi/palvelut/kulutuksen-ja-tuotannon-liittaminen-kantaverkkoon/fingrid-modelling-instruction-for-psse-and-pscad-models-2024_01_12-002.pdf	2024
NERC	White Paper: Grid Forming Functional Specifications for BPS-Connected Battery Energy Storage Systems	https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper_GFM_Functional_Specification.pdf	2023
AEMO	Voluntary Specification for Grid-forming Inverters	https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf	2023
AEMO	Application of Advanced Grid-scale Inverters in the NEM	https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/application-of-advanced-grid-scale-inverters-in-the-nem.pdf	2021
AEMO	Voluntary Specification for Grid-forming Inverters: Core Requirements Test Framework	https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en	2024
NGESO	Great Britain Grid Forming Best Practice Guide	https://www.nationalgrideso.com/document/278491/download	2023
NGESO	GC0137: Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability	https://www.nationalgrideso.com/document/159296/download	2021
UNIFI	Specifications for Grid-forming Inverter-based Resources Version 1	https://www.energy.gov/sites/default/files/2023-09/Specs%20for%20GFM%20IBRs%20Version%201.pdf	2022

Also see ESIG: Grid-Forming Technology in Energy System Integration, 2022
Comparison of Current GFM Equipment Specs, 2022

A recent NERC whitepaper also highlights the system stability benefits of commercial availability of grid-forming controls for battery energy storage systems

- The paper has several takeaways and recommendations relevant to Attributes:
  - GFM technology has been shown to operate reliably and provide stabilizing characteristics in transmission systems with high IBR.
  - GFM technology is commercially available and field-proven.
  - All newly interconnecting BPS-connected BESS should consider GFM controls.
  - Now is the time to begin the process of establishing GFM functional specifications for BESS in interconnection requirements, using NERC's functional specifications.
  - Careful testing and validation of GFM performance is still needed before broad deployment.



NERC, White paper: grid forming functional specifications for BPS-connected battery energy storage systems. September 2023. Available at: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper_GFM_Functional_Specification.pdf

Acronyms

IBR: inverter-based resources
BESS: battery energy storage system
GFM: grid forming
OEM: original equipment manufacturer