A Unique Window of Opportunity: Capturing the Reliability Benefits of Grid-Forming Batteries

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Julia Matevosyan
Chief Engineer
ESIG

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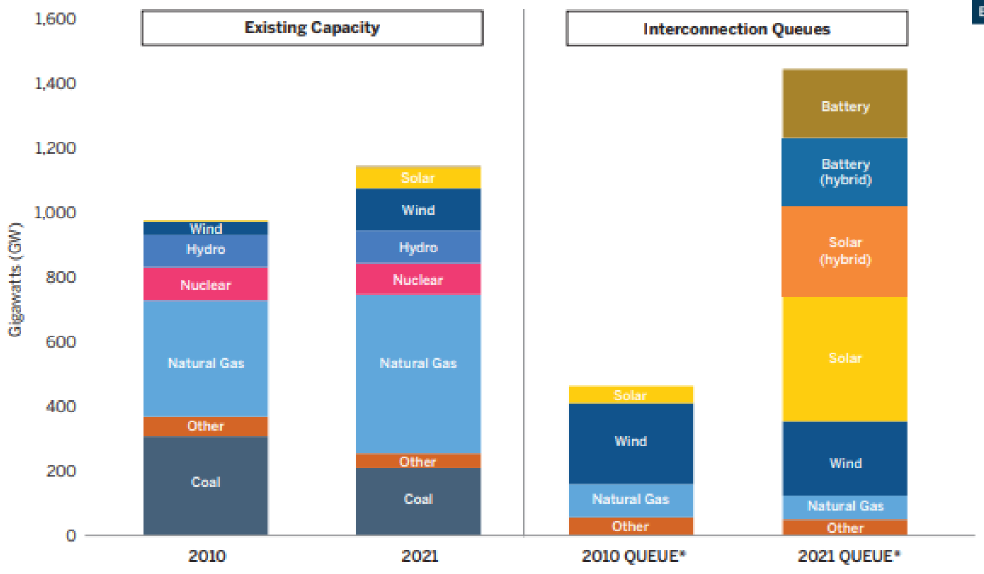
Motivation for the brief

"Hawaiian Islands, as they are nearing 90% IBR, are faced with the acute need for GFM batteries for maintaining grid stability and preventing blackouts. The rest of the U.S., where existing synchronous machines are still providing reliability services, has a unique window of opportunity to procure, test, and gain experience with GFM technology in a "safe environment," before the need for IBRs to contribute to grid stability becomes acute."

Existing Installed Capacity and Capacity in the U.S. Interconnection Queue, 2010 vs. 2021



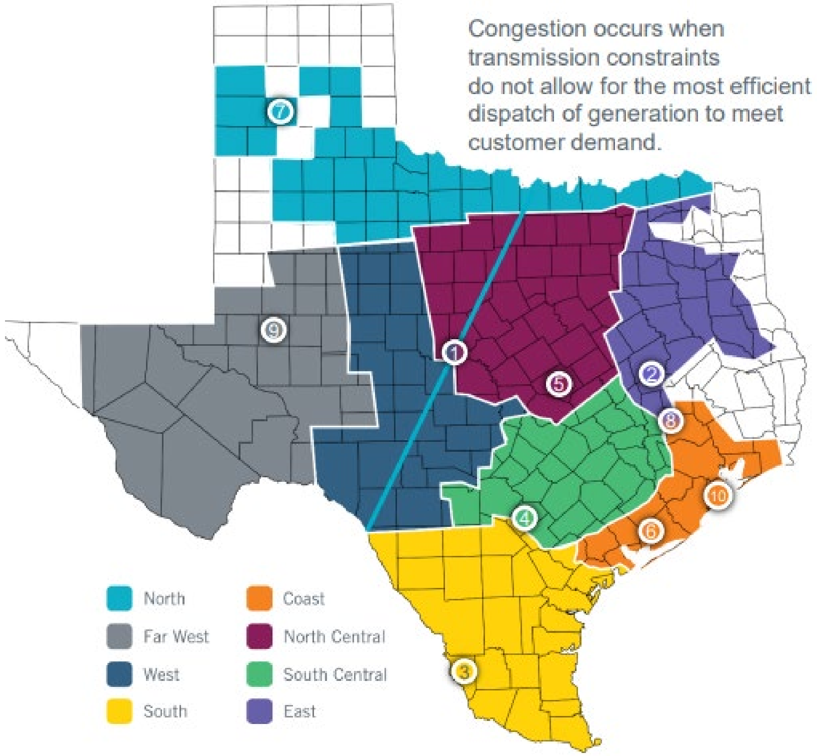
* Queue data represents about 85% of U.S. electric load; AK and HI and some non-RTO utilities not included.

Source: Based on visualizations from Lawrence Berkeley National Laboratory's analysis "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection" (https://emp.lbl.gov/queues). © The Regents of the University of California, Lawrence Berkeley National Laboratory.

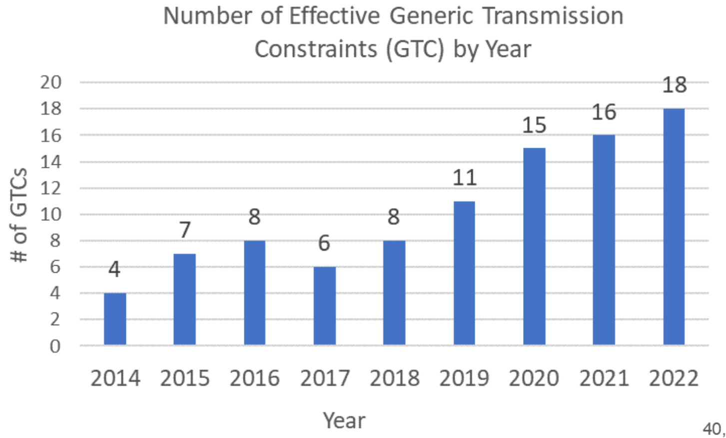
https://www.esig.energy/grid-forming-technology-in-energy-systems-integration/

Stability-Related Constraints & Renewable Curtailments, with Example of ERCOT

Top 10 Constraints on ERCOT System
(based on real time data)



Source: ERCOT, Report on Existing and Potential Electric System Constraints and Needs, December 2022

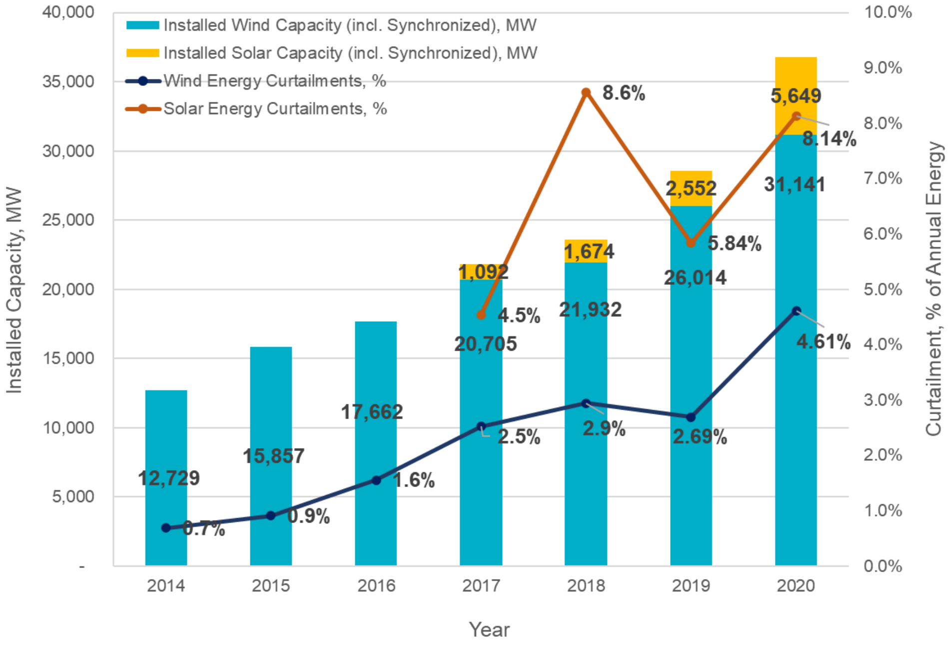


Peak Load – 80 GW

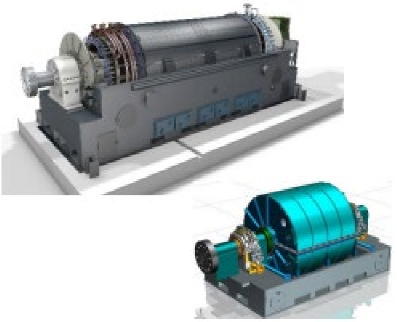
69.15% instantaneous IBR penetration in April 2022

Wind - 37.7 GW
Solar – 15 GW
Battery – 3 GW (1-2 h duration)

Growth of Wind and Solar Curtailments as More Capacity is Added to the ERCOT Grid, 2014-2020

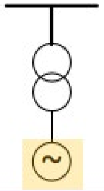


Current Strategies for Relief the Stability Constraints – Adding Transmission Assets



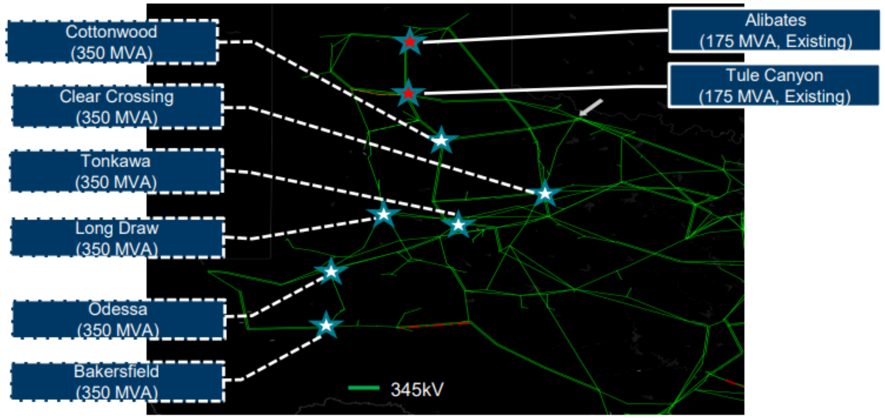
Synchronous Condenser – (w/wo Flywheel)

- Short circuit power and inertia support
- Rotating equipment



Source: Siemens Energy, Ian Ramsay, EIPC Workshop, June 2022

Additional six synchronous condensers with total of 2,100 MVA were identified that will provide effective improvement to WTX.



Source: ERCOT, *Strengthening the West Texas Grid to Mitigate Widespread Inverter-Based Events – Operation Assessment Results*, Regional Planning Group meeting, Feb 2023

New transmission lines to reduce electric distance between high IBR areas with low system strength and strong grid areas

Source: iStockphoto/Yelantsevv

Grid Forming Controls as an Alternative

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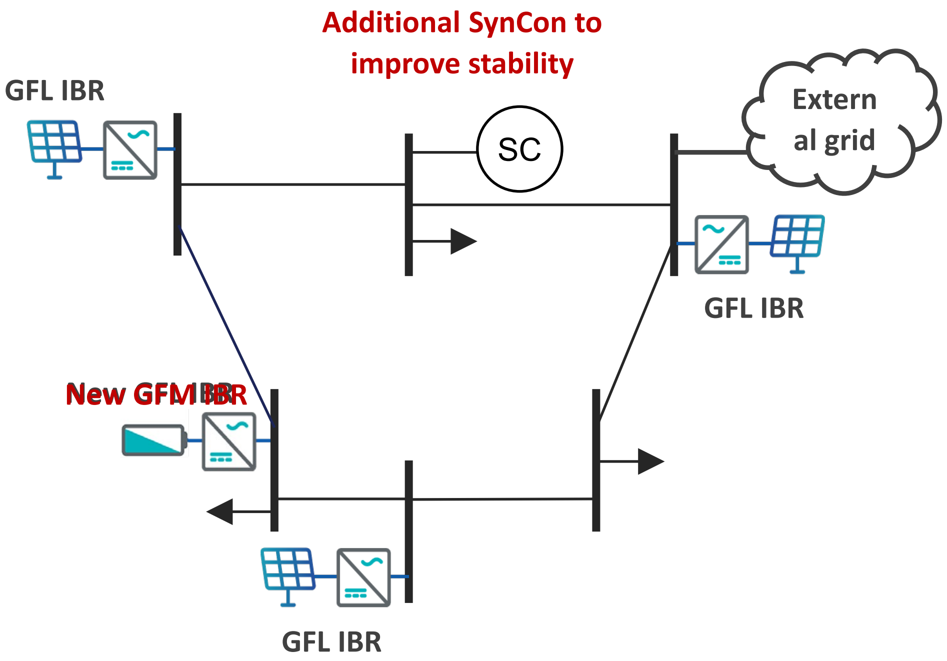
Advanced controls (broadly termed grid forming):

- can be designed to provide, within equipment limits, most of the services that are currently inherently provided by synchronous generators
- can have a stabilizing effect in areas with low system strength and improve stability for IBRs with traditional controls (broadly termed grid following).
- if implemented on planned IBRs, may provide more cost-effective alternative to improve stability, because the improvement is provided by the new resources themselves as they are added to the system and addition of supplemental transmission assets may not be needed.



Batteries are a Low-Hanging Fruit

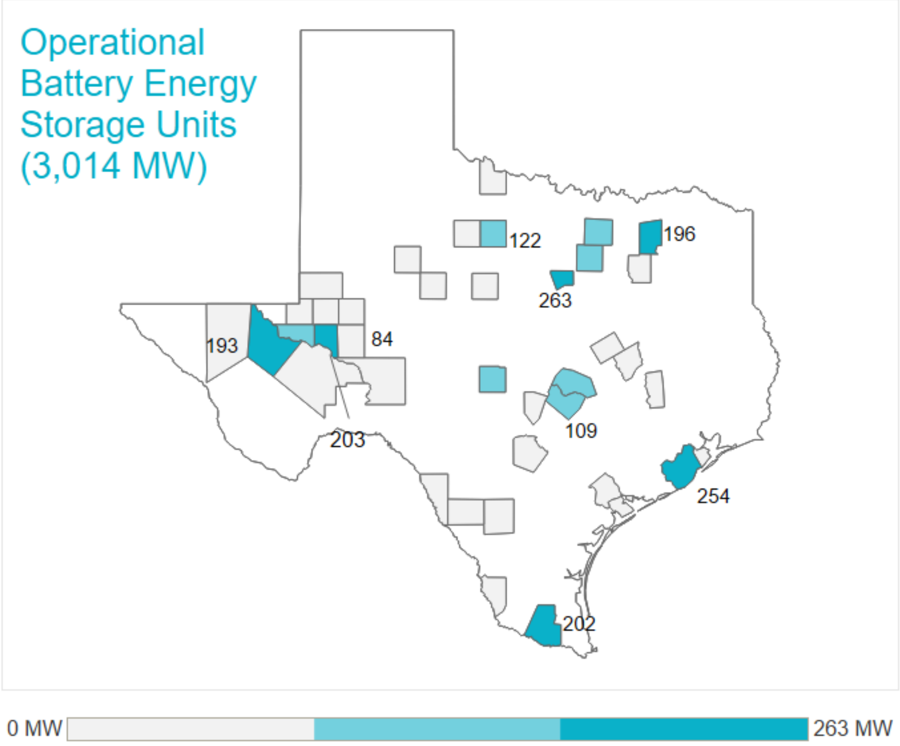
- GFM controls can potentially be implemented on any type of IBR including new solar and wind, but **batteries are the low-hanging fruit**.
- GFM behavior requires a certain amount of energy buffer, which for wind and solar resources means continuous operation below their maximum available power production.
- In addition, GFM control in wind turbines may result in greater and more frequent mechanical stress.
- The battery is the energy buffer, and only software modifications to a battery's controls are needed to make the battery a GFM resource.
- Why not deploy new batteries with traditional controls today and simply retrofit them at the later stage when needed? Retrofitting may potentially bring additional costs and delays (model updates, re-studies, changes to various contractual agreements)

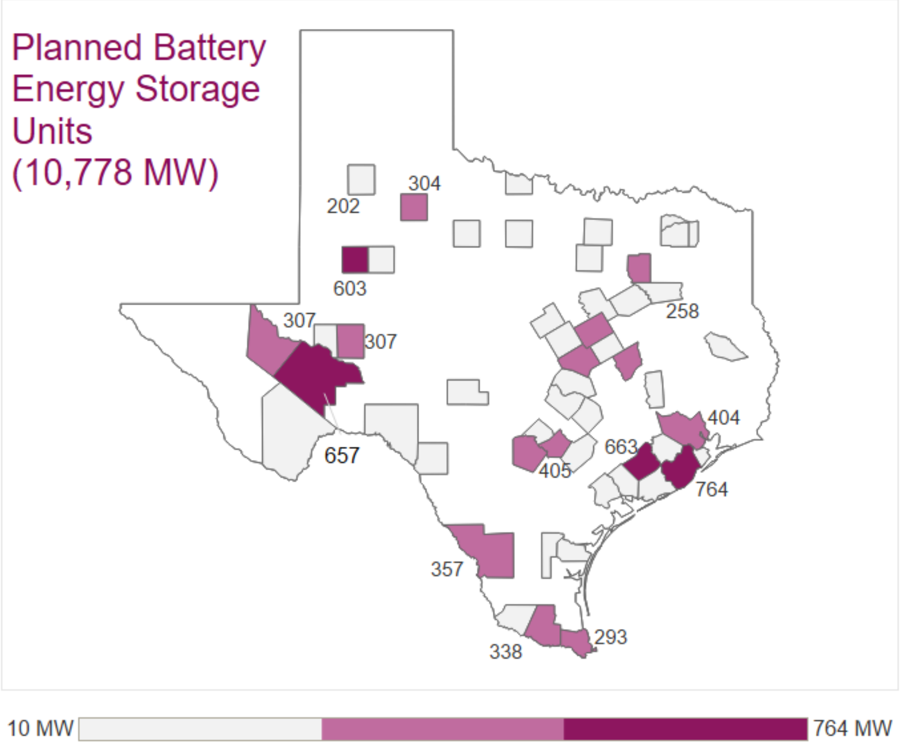
Source: Neoen Australia

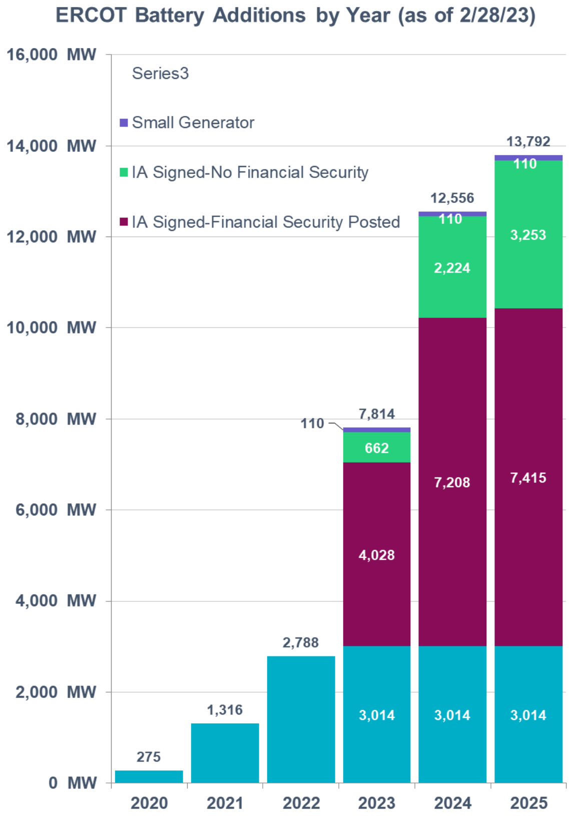
A number of batteries with advanced controls have already been deployed around the world, and further development is happening at unprecedented speed

Existing and New Batteries Behind Constraints

In the absence of clear requirements and market incentives for advanced control capabilities, all planned batteries will be built using traditional IBR controls. This may increase systems' needs for additional supplemental devices to improve stability, which will drive-up overall system costs.







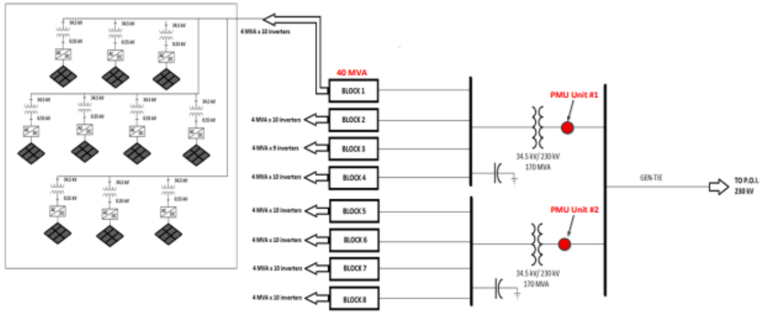
Footnotes: Operational category includes units approved to be Synchronized but not Approved for Commercial Operations. Planned category includes incudes DGRs and planned projects with signed interconnection agreements (IA Signed) thare have not been Synchronized to the ERCOT Grid.

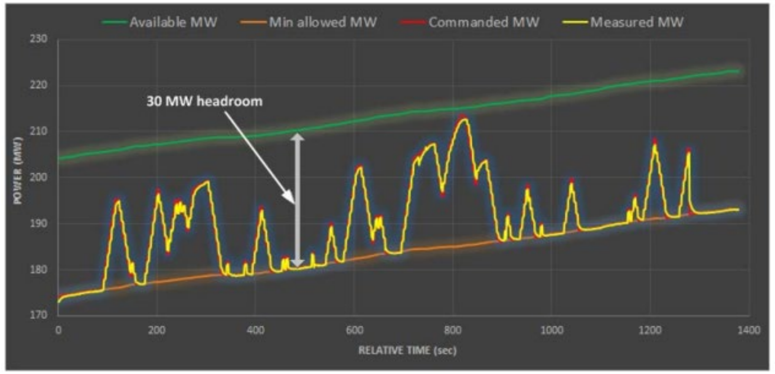
Data from ERCOT Resource Adequacy Department - February 2023 Resource Capacity Trend Charts

Testing and Demonstration of Services Ahead of Requirements Has Been Done Before

- In 2017-2018, First Solar and NREL tested several existing projects in to demonstrate that solar resources can provide reliability services (such as regulation, primary and fast frequency response, and voltage support) with similar or superior performance compared to conventional thermal generators.
- Similarly, **GFM capability can be deployed through a pilot project** operating several newly built batteries with GFM controls.
- A pilot involving a number of plants would allow testing of the interoperability of GFM IBRs from different inverter manufacturers with different GFM control strategies.
- In parallel with the pilot and in collaboration with involved manufacturers (to obtain manufacturer-specific models of GFM IBRs) **carry out simulation studies and explore broader benefits and grid impacts of deploying GFM capabilities** on all planned batteries in the interconnection queue.

Source: NREL and First Solar





Call for Action!

- Deploying advanced control capability in batteries is a low-hanging fruit solution to weak grid issues that increasingly are the cause of stability-related transmission constraints, and renewable curtailments.
- But the opportunity for ISOs/RTOs/utilities to utilize this resource-based solution may soon pass.
- While only a relatively small number of utility-scale batteries are installed in the U.S. today, a significant amount of battery capacity will likely be developed in the next few years.
- Without specifications and the appropriate incentives or requirements, this capacity will likely lack advanced control capability, which would result in continued stability challenges and the need for additional supplemental stabilizing equipment such as synchronous condensers or new transmission.
- With specifications and incentives or requirements, new batteries can be installed with GFM capability and help to improve grid stability, reduce curtailment, and reduce the need for additional stabilizing equipment.
- ISOs/RTOs/utilities can work with stakeholders to carry out studies of the benefits of deploying GFM technology and initiate pilot projects, similarly to how the provision of grid services from GFL IBRs was explored in the past.
- Experience from installations around the world, particularly in Hawaii, Australia, and Great Britain, can be used as a guide.

NERC IRPS Whitepaper – Coming Soon

Table of Contents

Relevant ESIG Project Teams

Three ongoing Project Teams under High Share of IBR TF (Reliability Working Group):

- **Stability Assessment Methods with High Share of IBRs** – focused on analysis of oscillation events, deliverable a practical guide for analyzing oscillations.
- **New Services with High Share of IBRs** – identify when system with high share of IBRs with GFL controls need new services? What services are needed, how to quantify, how to generalize across many systems, can IBRs with advanced control provide these new services?
- **Advanced Inverter Control Testing** – How to test IBRs for high level GFM requirements and specifications (e.g. UNIFI, OSMOSE, NGESO, HECO etc.)? How to demonstrate expected performance form inverters with advanced controls? The purpose is to provide more clarity to industry on the meaning of this requirements and behavior sought.

THANK YOU

Julia Matevosyan

julia@esig.energy

Grid Forming Definition

- **Grid-Forming:** The primary objective of grid-forming controls for IBRs is to maintain an internal voltage phasor. When grid-forming controls are applied in bulk power system (BPS) connected IBRs, the voltage phasor is held constant in the sub-transient to transient time frames. This allows the IBR to immediately respond to changes in the external system and provide stability in the controls during challenging network conditions. This phasor must be controlled to maintain synchronism with other devices and control active and reactive currents to support the grid. When grid-forming controls are applied in non-BPS connected IBRs (for example black-start or microgrids), this synchronization functionality is removed or limited, and the voltage phasor may be held relatively constant over time. This allows the plant to operate in an electrical island and define the grid frequency.
- There are many variations of both grid-forming and grid-following converter controls. Both are subject to physical equipment constraints including voltage, current and energy limits, mechanical equipment constraints (on WTGs) as well as external power system limits.
- Further, performance requirements for GFL plants, such as those laid out in standards (e.g. IEEE 2800 series and IEEE 1547 series) or ENTSO-E RfG, will also apply to GFM inverters unless explicitly identified as inapplicable.