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Preliminary assessment of Grid Forming Inverter-based Energy Storage Resources (GFM-IBR-ESR) in the ERCOT Grid

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Background and Objectives

- Increasing recent notable events (Odessa 1 in 2021 and Odessa 2 in 2022) have shown the need to strengthen the system and resilience necessary to mitigate the reliability risk.
- Continued focus on improving Resources' capability and performance **AND** improvements on the transmission system are **BOTH** needed to maintain the reliable operations of the ERCOT grid.
  - Adoption of NERC reliability guidelines, IEEE 2800, NOGRR245
  - Recommendation of synchronous condensers to strengthen West Texas grid
- Additional improvements will be needed to support the continued growth of IBRs in the ERCOT grid. Increasing discussion of grid forming inverters (GFM) to improve the IBR performance and system support have been noted especially in other regions with high penetration of IBRs. For example, AEMO, UK, Hawaii,…etc.
- ERCOT planning and operations evaluated the potential application of GFM Energy Storage Resource (ESR) in ERCOT grid, and the preliminary observations and findings are included in this presentation.

Outlines

- What is GFM
- Potential use cases of GFM
- Current GFM IBR/ESR Application
- ERCOT preliminary GFM evaluation on three scenarios
  - Scenario 1: a weak grid condition (a simple test case in PSSE to prove the concept)
  - Scenario 2: West Texas grid (tested in PSSE)
  - Scenario 3: an actual ERCOT local area with identified stability constraints (tested in both PSSE and PSCAD)
- Observations and Future Work

What is GFM

- NERC definition: GFM (Grid Forming) IBR controls **maintain an internal voltage phasor that is constant or nearly constant in the sub-transient to transient time frame**. This allows the IBR to immediately respond to changes in the external system and maintain IBR control stability during challenging network conditions. The voltage phasor must be controlled to maintain synchronism with other devices in the grid and must also regulate active and reactive power appropriately to support the grid

Reference: NERC, “Grid forming technology: Bulk power system reliability considerations” technical report, December 2021

GFL vs GFM

- Grid Support Functions

	Grid-Following Source	Grid-Forming Source	Synchronous Machine
System inertia	–	Synthetic – inherent	Physical – inherent
Provide fault current	–	1.2–1.5 pu	6–8 pu
Contribution to phase jump power	–	Yes	Yes
Fast frequency response contribution	Yes	Yes	–
Contribution to system strength	–	Yes	Yes
Provide synchronising torque	–	Yes	Yes
Provide damping power	Limited	Yes	Yes
Blackstart capability	–	Yes	Yes
Contribution to primary frequency response	Yes	Yes	Yes
Voltage/reactive power support	Yes	Yes	Yes

Reference: Dr. Mohammed, Dr. Alhelou and Dr. Bahrani, “Grid-Forming Power Inverters Control and Applications”, CRC Press, 2023

Potential uses cases of GFM

- Weak grid operations
- Damping of voltage and frequency oscillations
- Response to phase-jump
- Inertia response
- Fast fault current (balanced and unbalanced)
- Subsynchronous resonance
- Black start

Current GFM IBR Application Overview

- Not widely adopted in North America interconnection
- Primarily focus on GFM IBR ESR Projects due to the need of energy buffer

Project Name	Location	Size (MW)	Time
Project #1	KIUC	13	2018
Project #2	KIUC	14	2022
Kapolei Energy Storage	HECO	185	2023
Hornsdale	AEMO	150	2022
Torrens island	AEMO	250	2023
Wallgrove	AEMO	50	2022
Broken Hill BESS	AEMO	50	2023
Riverina and Darlington Point	AEMO	150	2023
New England BESS	AEMO	50	2023
Dalrymple	AEMO	30	2018
Blackhillock	Scotland	300	2026
Bordesholm	Germany	15	2019

Reference: NERC, “Defining Grid Forming Capability in Interconnection Requirements for BPS-Connected Battery Energy Storage Systems Functional Specifications, Verification, and Modeling”, technical report, June 2023

Three scenarios were tested for GFM ESR impact

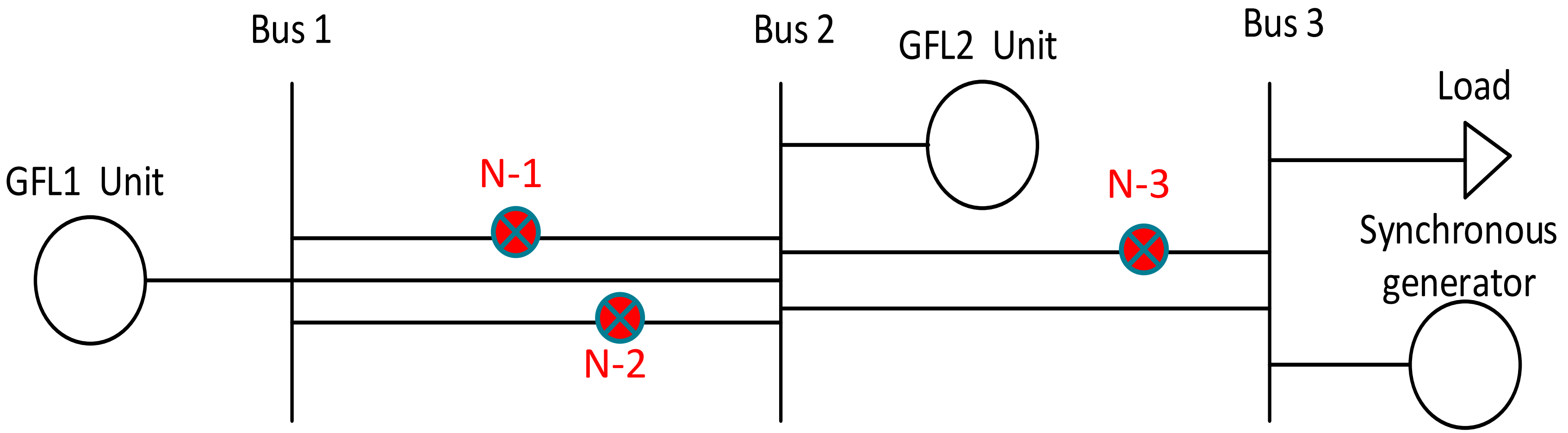
- ERCOT preliminary GFM ESR evaluation on three scenarios
  - Scenario 1: a weak grid condition (a simple test case in PSSE to prove the concept)
  - Scenario 2: West Texas grid (tested in PSSE)
  - Scenario 3: an actual ERCOT local area with identified stability constraints (tested in both PSSE and PSCAD)
- GFM ESR dynamic models used in these tests were supported by Pacific Northwest National Laboratory (PNNL) and Electric Power Research Institute (EPRI)

➢ Acknowledgment:
  - Dr. Wei Du from PNNL for providing GFM PSSE (REGFM_A1*) and PSCAD models
  - Dr. Deepak Ramasubramanian from EPRI for providing GFM PSSE and PSCAD models

*Beta version of REGFM_A1 has been developed in commercial tools PTI-PSS®E, GE-PSLF, PowerWorld Simulator and TSAT

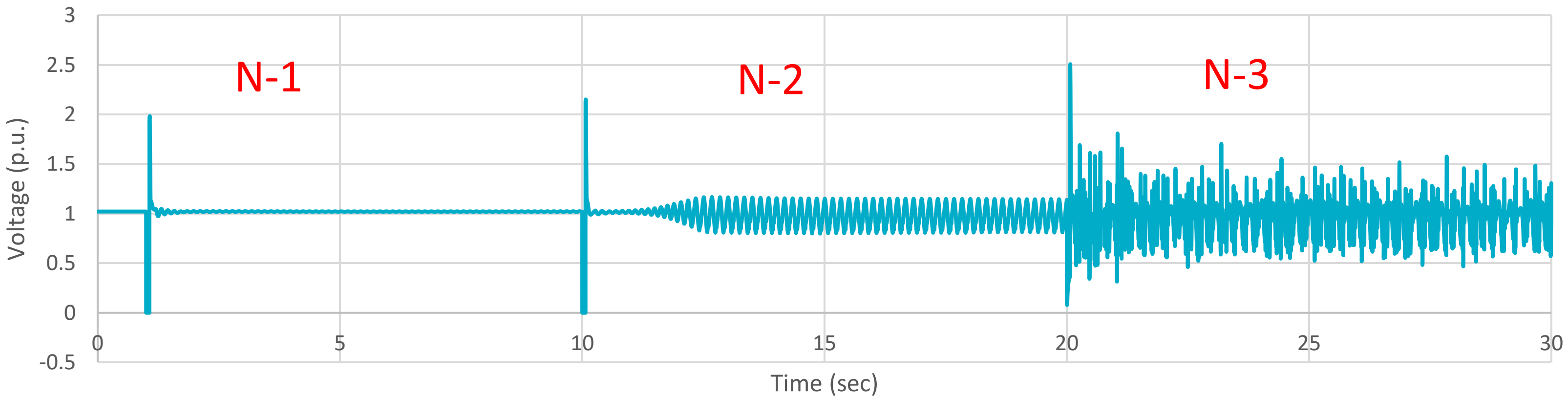
Scenario 1: Weak Grid Test Case Simulation (PSSE)

- A simple test case was developed to mimic known stability challenges in ERCOT



Unit	MVA
GFL1	300
GFL2	200
Syn Gen	488
Load	800

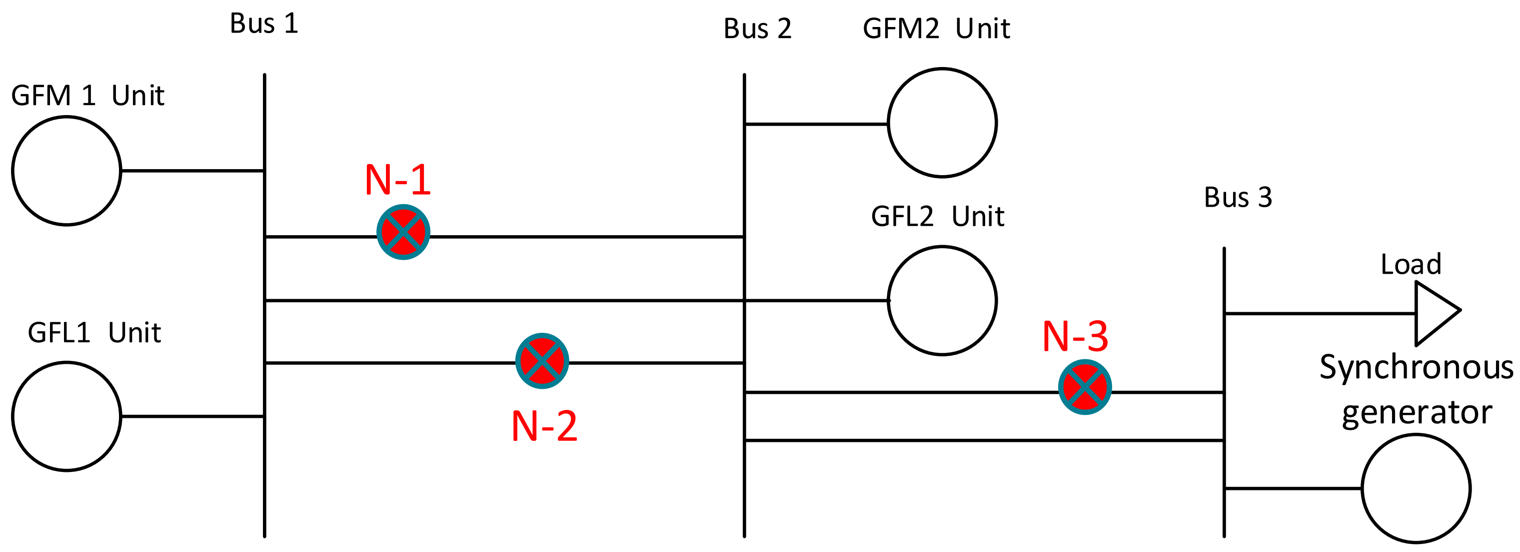
Bus 1 Voltage Plot



Grid Following (GFL) IBRs instability identified in a weak grid condition

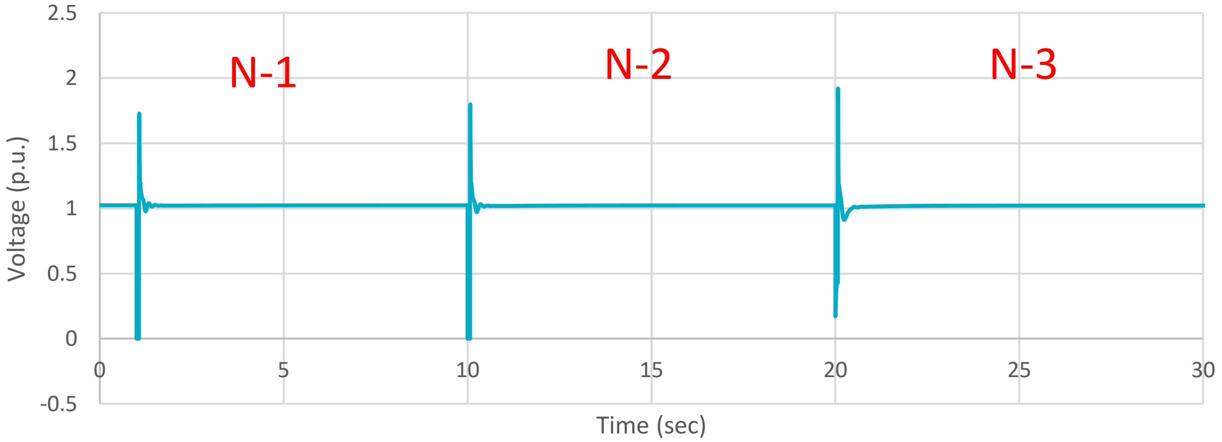
Note: The test cases will be published at: https://sites.google.com/view/weakgrid/home

Scenario 1: Weak Grid Test Case Simulation (PSSE)



Unit	MVA
GFL1	300
GFL 2	200
Syn Gen	488
Load	800
GFM 1	70
GFM 2	70

Bus 1 Voltage Plot



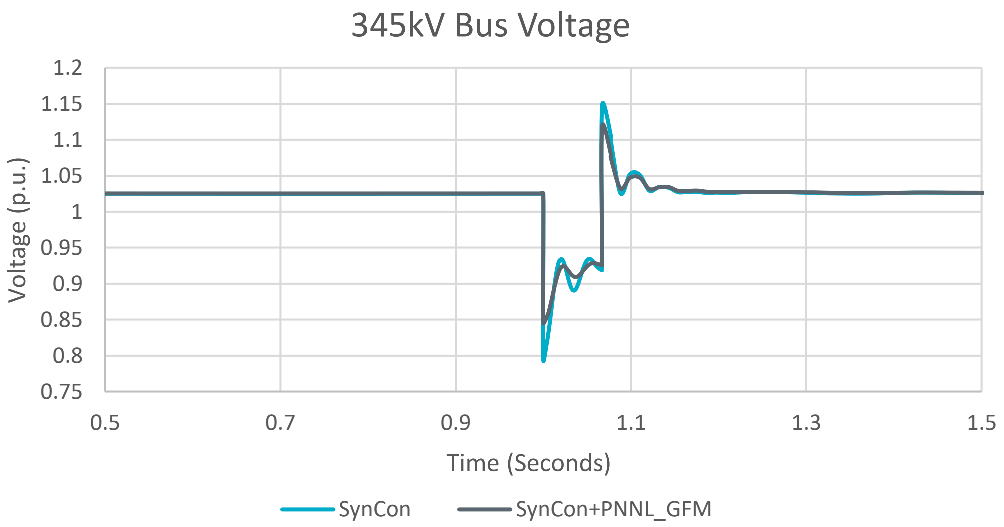
The addition of GFM ESR improves the overall system stability performance under weak grid conditions

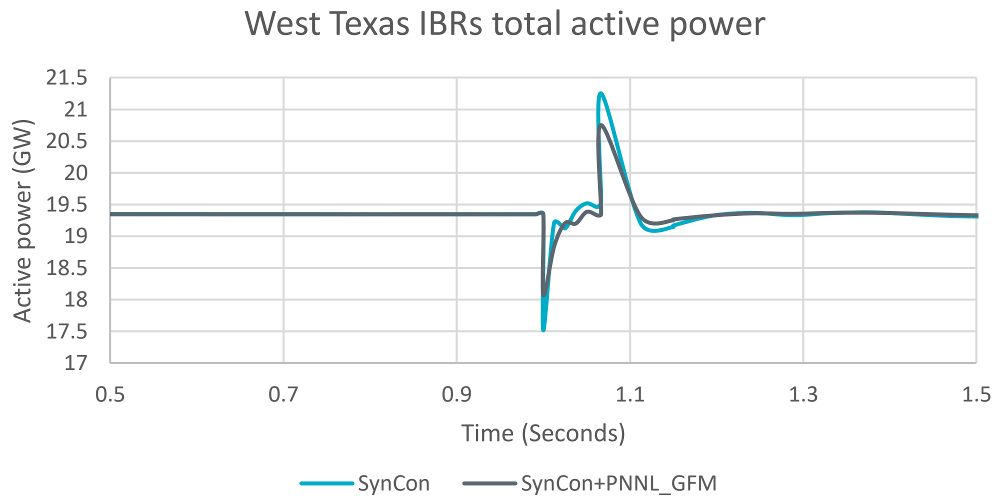
Scenario 2: West Texas Grid (PSSE)

- This study is based on Q4 QSA 2022 case in PSSE
  - West Texas IBRs were dispatched at 55%
  - Include 22 ESRs with ~2000 MVA capacity behind West Texas Export GTC
  - Include potential new condensers in six locations presented in the previous RPG meetings
- Generic GFM ESR models were used to evaluate the impact in this assessment
  - The ESR inverters maximum current capability were kept the same as the existing models
- Both GFM ESR models provided by PNNL and EPRI were tested and similar results were obtained

WTX System Strength with GFM (PSSE)

- The presence of the GFM did not reduce the dispatch stability limit
- GFM improved the system numerical performance
- Selected events were applied at West Texas in the simulation
- Notable Observations:
  - Reduce both voltage dip and overshoot
  - Reduce affected IBRs in WTX, less active power temporary reduction and swing
  - Reduce angle jump

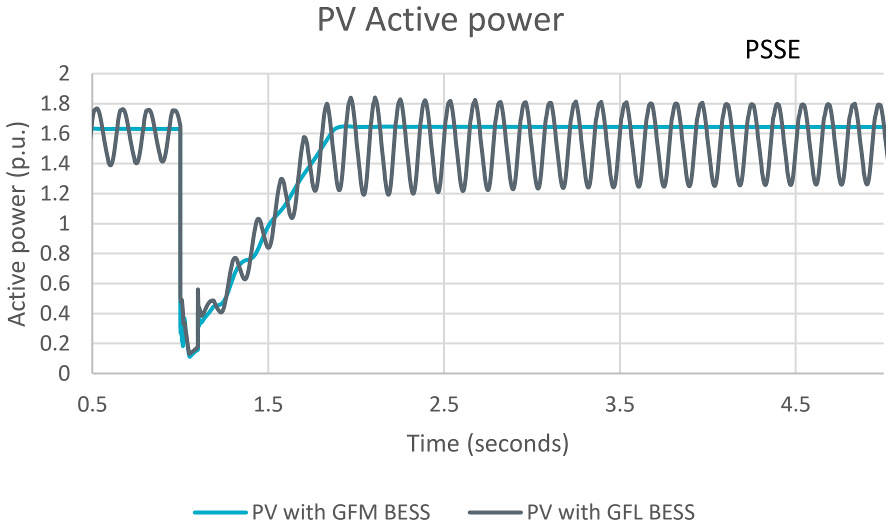


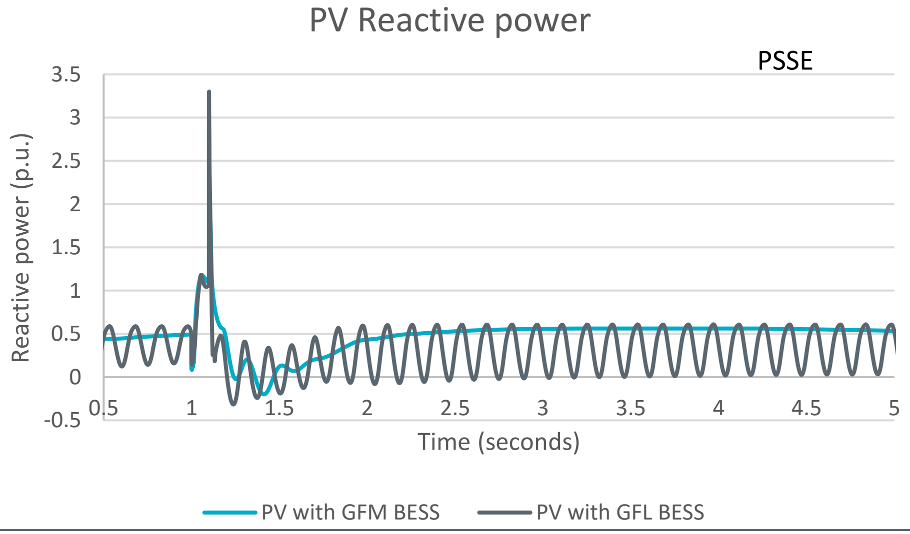


Scenario 3: Local area with identified instability (PSSE and PSCAD)

- A local area (138kV) in the ERCOT grid has been identified with stability issue due to weak grid challenges
  - Generation resources in this area include wind, solar, and ESR (all are GFL inverters)
  - Stability study indicated stability constraints under N-1 and N-1-1 based on original models provided by the developers and resource entities.
- A GFM ESR model was used to replace the original GFL model. The results in both PSSE and PSCAD tests show stable response for both N-1 and N-1-1 and no stability constraint is needed if the ESR is equipped with proper GFM capability

100% dispatch, N-1-1





Preliminary Findings and Next Steps

- ERCOT's preliminary assessment results indicate the GFM ESRs could be a viable option to improve system dynamic responses, but
  - cannot solve all the issues with GFM only
  - require headroom or energy buffer to provide adequate GFM support
  - still require proper control settings and coordination
- ERCOT will work on the GFM ESR requirements including but not limited to performance, models, studies, and verification.
  - Expect GFM ESR will be capable of meeting IEEE 2800 and existing ERCOT requirements
  - Expect GFM ESR will be required to meet additional performance requirements
- ERCOT will continue provide regular updates to the stakeholders and comments are welcome to provide to
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