Grid Forming (GFM) Technology Adoption in ERCOT – Status Update

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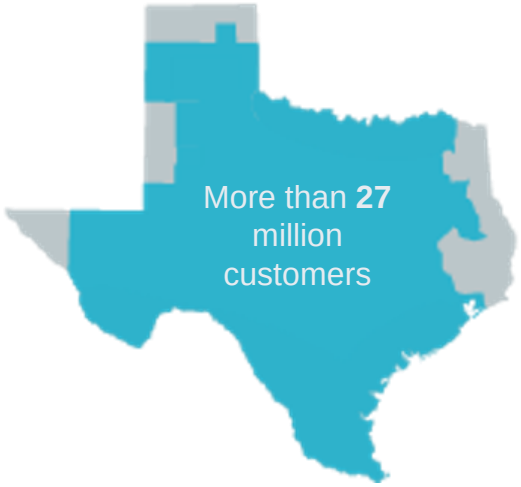
G-PST/ESIG Webinar Series
November 12, 2024

Agenda

- ERCOT Quick Facts
- ERCOT Inverter-Based Resource (IBR) Integration
- Consideration of GFM Technology
- Status update and next steps

ERCOT Facts



85,508 MW

Current all-time peak demand record (August 10, 2023)

39,450 MW

of installed wind capacity as of June 2024, the most of any state in the nation

27,881 MW

Wind Generation Record (June 17, 2024)

69.15 %

Wind Penetration Record (April 10, 2022)

25,333 MW

of utility-scale installed solar capacity as of June 2024

21,667 MW

Solar Generation Record (September 8, 2024)

42.98 %

Solar Penetration Record (March 28, 2024)

7,702 MW

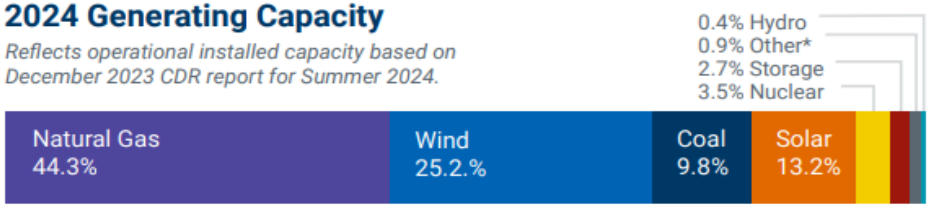
of installed battery storage as of June 2024

~75 % (~34,900 MW)

Preliminary Wind + Solar Penetration Record (March 29, 2024)

2024 Generating Capacity

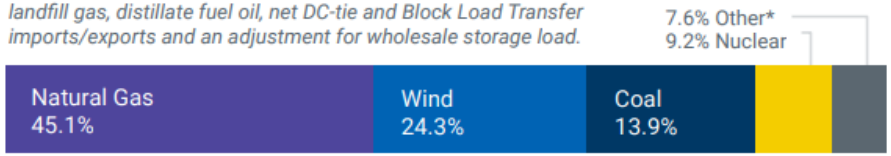
Reflects operational installed capacity based on December 2023 CDR report for Summer 2024.



The sum of the percentages may not equal 100% due to rounding.
**Other includes biomass and DC Tie capacity.*

2023 Energy Use

**Other includes solar, hydro, petroleum coke (pet coke), biomass, landfill gas, distillate fuel oil, net DC-tie and Block Load Transfer imports/exports and an adjustment for wholesale storage load.*



ERCOT IBR Growth and Requirements Overview

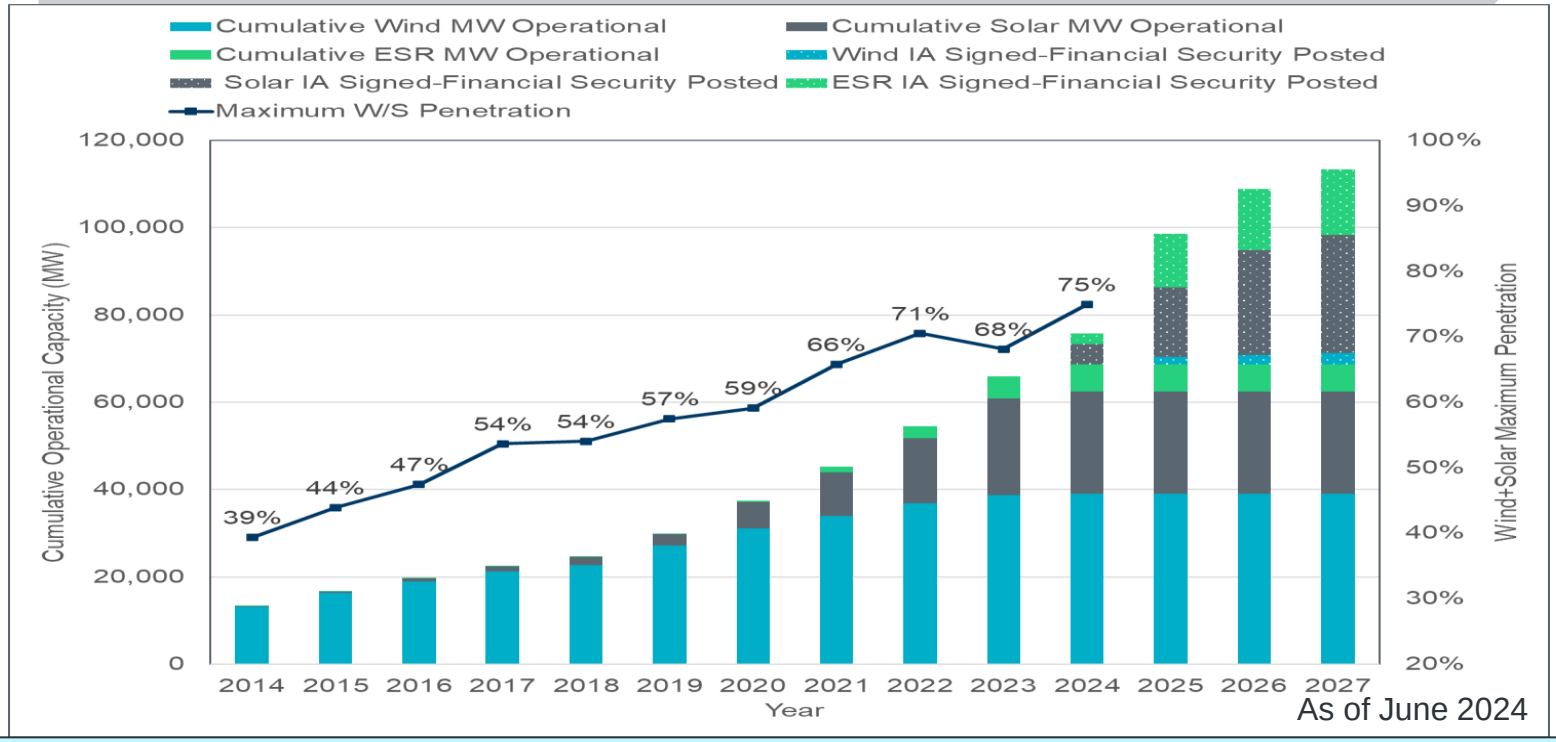
Minimum requirements

Voltage & Frequency Control (2008)

Ride Through Capability (2006,2014,2016 ,2024)

IEEE 2800-2022 (2023, ongoing)

Grid Forming (2024)



As of June 2024

- Both solar and energy storage have significant growth since 2020
- Solar could become the largest category of IBRs in ERCOT by 2025
- ERCOT could exceed 100 GW transmission connected IBRs by 2026

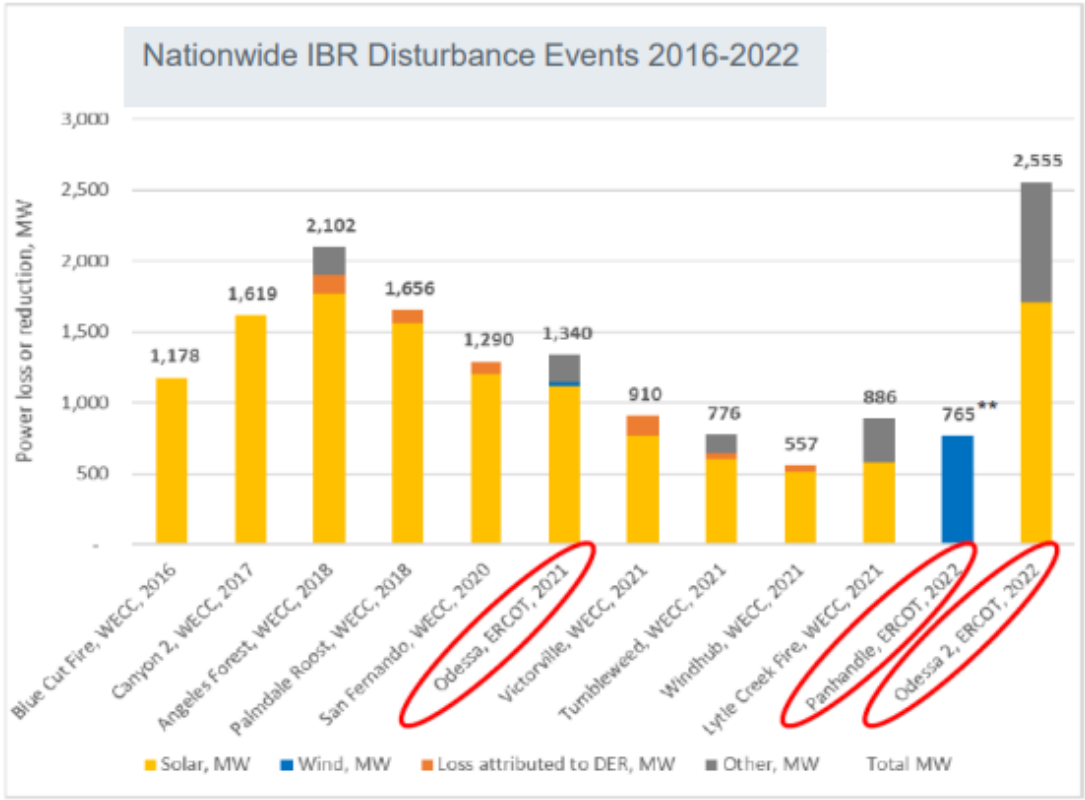
Grid Challenges

- All the existing IBRs connected to the ERCOT transmission grid are considered grid-following IBRs (GFL-IBRs) which generally do not provide system strength and inertia as inherently supported by synchronous generators.
- As a result, the transmission grid could become more volatile in voltage and frequency performance and impose the stability and reliability needs.

Grid Challenges (Sync Gen↓ + GFL IBR↑)	Increase stability constraints and reduce power transfer
	Increase risk of unit unstable operation or trip due to voltage/frequency volatility
	Reduce simulation confidence and situation awareness

System strength in West Texas

- Inverter-based resources (IBRs) in West Texas have experienced rapid and continued growth
- Because the West Texas area has a prevalence of IBRs and few synchronous generation resources, system strength is low in the area



- Faults in the area result in widespread low voltages, and the risk that a large number of IBRs do not ride-through these faults

System strength issues are an emerging ERCOT grid issue

Considered Mitigation Options -- Examples

- As IBRs become increasingly prevalent in ERCOT grid, the absence of online synchronous generation underscores the necessity for efforts to ensure stable grid operation
- ERCOT and the stakeholders have identified and implemented options to improve the grid stability

Synchronous condensers	• 2*150 MVA were installed in 2018 • 6*350 MVA are scheduled by 2027
IEEE 2800-2022 Adoption	• Adopt voltage/frequency ride through and section 5,7,9 • Plan to adopt other applicable requirements in the future
Dynamic Model Validation and Verification	• Establish requirements to ensure accurate dynamic models • Plan to adopt applicable IEEE 2800.2 requirements in the future
Generic Stability Constraints	• Establish and enforce operational stability constraints in real time operations • Implement online stability assessment

Consideration of GFMs

- Continued focus on improving IBRs' capability and performance **AND** transmission improvements are **BOTH** needed to effectively maintain the reliable operation of the ERCOT grid
  - Rely on one or limited improvement options could result in diminished reliability benefit

- ERCOT continues to explore additional improvement options which triggers ERCOT to look into the GFM IBRs

ERCOT GFM Requirement Development (~12 months)

Data Sources

- NERC
- GPST/ESIG
- PNNL
- EPRI
- UNIFI
- IEEE
- …
- Industry Reports
- Industry Trends and Hot Topics

Engagement

- Consultant
- Internal Core SMEs
- Vendors
- Utilities and System Operators
- Industrial and academia

Ways

- Meetings
- Projects
- Models

Identification

- Capability and limitation
- Grid needs and benefits using test cases and actual ERCOT cases with vendor provided models

Delivery

- Communication
- Develop performance requirements
- Propose requirements
- Implement the requirement (TBD)

ERCOT GFM Development (continue) – Key Observations

- Excellent industry collaboration and support
  - Four specific major energy storage resource (ESR) OEMs shared their detailed models to support ERCOT's GFM performance development
- The performance requirements generally are consistent among several system operators
- ESRs are available and ready to adopt GFM while other IBRs may still need further investigation and development
- GFM can be achieved with minimal impact to the hardware and commercial operations
- GFM can effectively improve the grid stability, mitigate the stability constraints, and event impacts
  - Both generic and OEM specific models were tested in the simplified test cases and actual ERCOT grid cases

ERCOT's GFM Proposal (undergoing stakeholder review and regulatory approval)

- Apply to ESR only, voluntary for the existing ESRs and mandatory for new ESRs
- Minimum impact to the project physical design and commercial operations
  - No requirements to provide blackstart capability
- Expect to meet the existing IBR performance requirements, like frequency support, voltage support, and ride through requirements
- Expect to examine the performance requirements through models and future actual performance
  - ERCOT contracted Electranix to help recommend the test frameworks of GFM-ESR models and the performance requirements
  - IBRs connect to ERCOT transmission grid are required to install Phasor Measurement Unit (PMUs) and digital fault recorders (DFRs)

An overview of ERCOT GFM Model Quality Performance Requirements

Test #	Description	Applicable Software Platform
1	Flat Start	PSCAD, PSS/E, TSAT
2	Phase angle jump	PSCAD
3	Small voltage disturbance	PSCAD, PSS/E, TSAT
4	Frequency change and inertia response	PSCAD, PSS/E, TSAT
5	System strength	PSCAD, PSS/E, TSAT
6	Large voltage disturbance	PSCAD, PSS/E, TSAT
7	Loss of synchronous sources	PSCAD, PSS/E, TSAT

- All four OEMs models were tested to examine the feasibility to meet the proposed tests and performance requirements.
- Two additional tests, series compensation and impedance scan, were recommended by Electranix but not included in the proposed requirements. These tests are relatively new concepts. ERCOT will continue assess these tests and may propose the needs in the future.
- ERCOT also develop tools to facilitate the automation of model testing and performance review for PSCAD and PSS/e models.

An overview of ERCOT GFM Unit Model Validation Requirements

Test #	Description	Applicable Platform
1	Step change in voltage	Hardware type test
2	Large voltage disturbance	Hardware type test
3	System strength	Hardware type test
4	Phase angle jump	Hardware type test
5	Subsynchronous test	Hardware type test

- To ensure accurate representation of IBR models against the actual hardware tests.
- It is technology specific, not site specific.

Current Status and Next Steps

- ERCOT has submitted the proposed GFM requirement for ESR through the revision request process.
  - NOGRR272 Issue, PGRR121 Issue
  - The final requirements will be subjected to the stakeholders' inputs and regulatory approval

- Next Steps and Future Plans
  - ERCOT will consider the GFM application in the transmission improvements
  - ERCOT will continue to collaborate with the industry and other system operators to identify best practices for grid stability improvements
  - ERCOT plans to continue investigate the feasibility of GFM support by other IBRs
  - ERCOT plans to continue investigate the GFM capability to support blackstart

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Thank You.

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