ERCOT Advanced Grid Support Inverter-based Energy Storage System Assessment and Adoption Discussion

Shun Hsien (Fred) Huang
Operations Support

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ERCOT Team Support

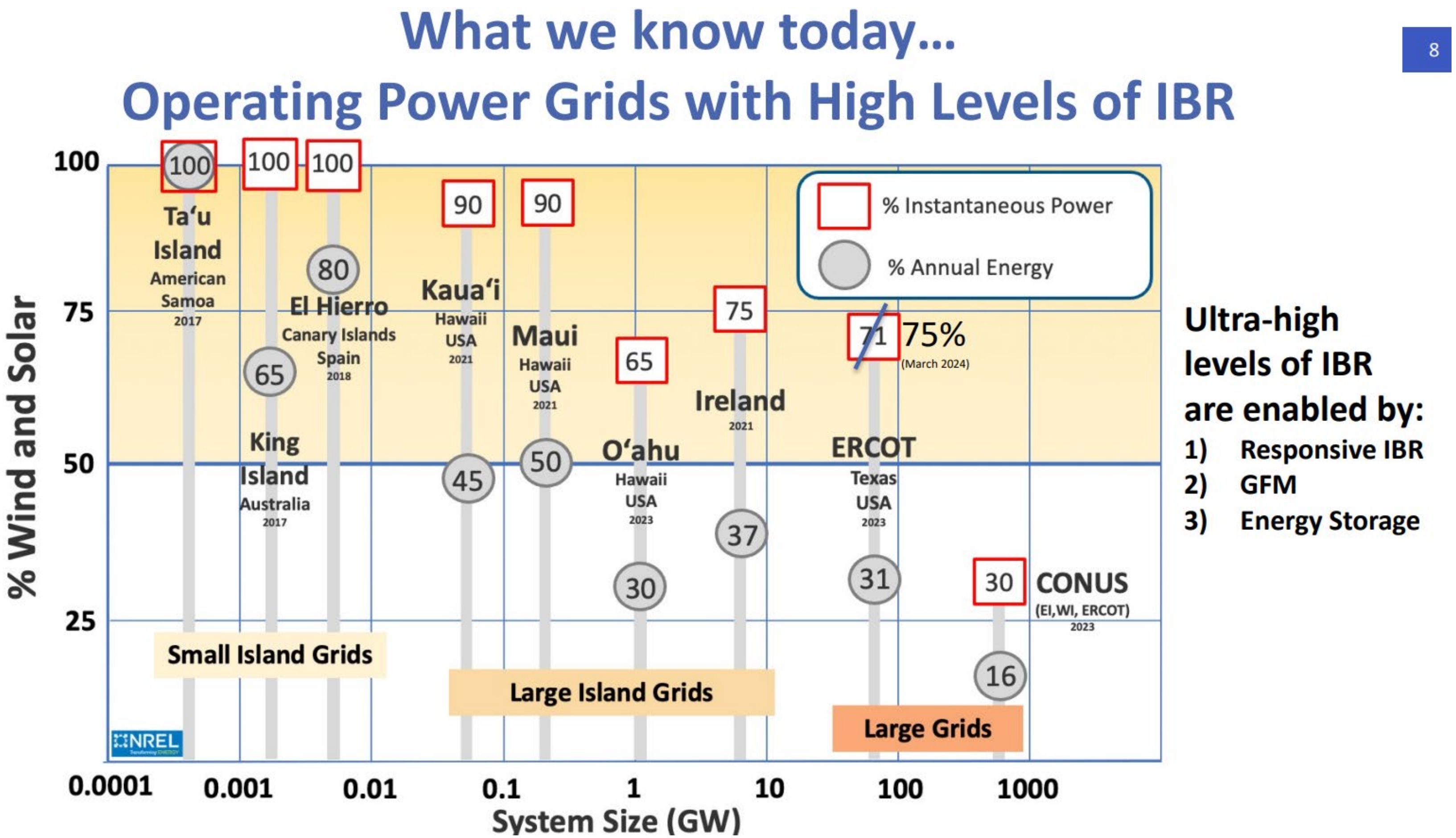
Operations: Yunzhi Cheng, Amro Quedan, Ali Yazdanpanah, Hamzeh Davarikia
Planning: Sun Wook Kang, John Schmall, Poria Astero, Jonathan Rose, Scott Zuloaga

Takeaways

- ERCOT plans to propose standards for advanced grid support (grid-forming-like) inverter-based Energy Storage Resources (ESRs)
  - Voluntary first; mandatory for new inverter-based ESRs at a near future date

- Inverter-based ESRs are commercially available today to provide advanced grid support; and generally, only require software/control changes with no impact to the hardware or commercial operations

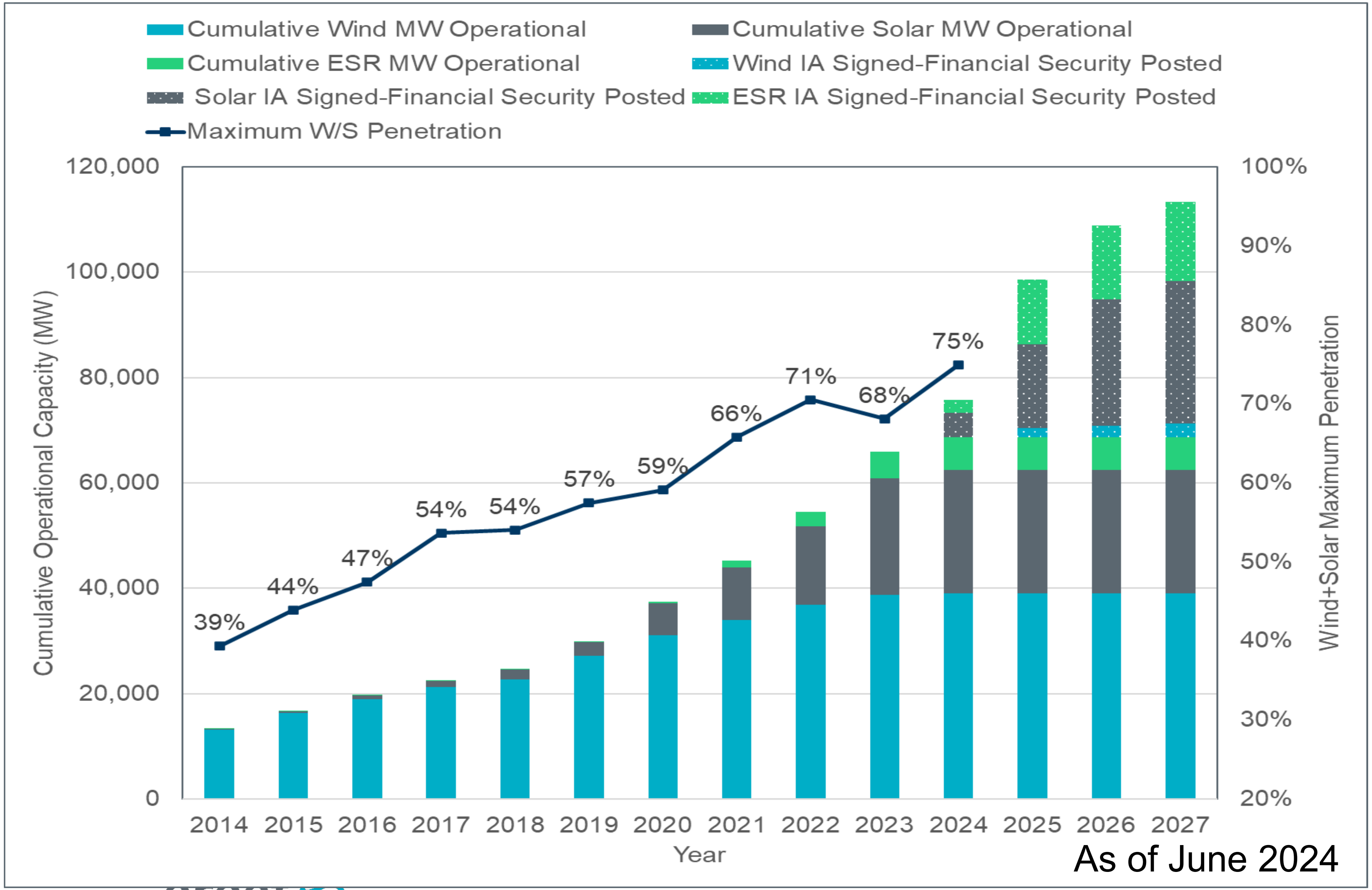
- ERCOT's preliminary assessments have identified the improvement of system stability performance and the benefits to the generic transmission constraints (GTCs)



ERCOT is one of the largest power grids with significant IBRs growth and penetration, having IBRs meet IEEE 2800-2022 as well as provide advanced grid support are imperative to maintain grid security and reliability

Source: https://www.ercot.com/files/docs/2024/06/10/4.3%20Emerging%20Technology%20-%20Intro%20to%20Grid%20Forming%20Inverters_revised.pdf

ERCOT IBR Growth



ERCOT could exceed 100 GW IBRs connection by 2025. Further growth is also projected based on the current ERCOT resource capacity trend.

https://www.ercot.com/gridinfo/resource

Evolution of IBR Grid Support Capability and ERCOT Grid Support Requirement Revisions

Maximum Output → Voltage & Frequency Control → Ride Through Capability → IEEE 2800-2022 → Advanced Grid Support (like grid-forming)

Grid Following (GFL)

2006	2008	2014	2016	2023-2024
• 1st low voltage ride through requirements	• Voltage & frequency control requirements	• Included high voltage ride through requirements	• Clarified no momentary cessation	• NOGRR 255, NOGRR 245, etc.

GFL	Advanced Grid Support
• All IBRs connect to ERCOT today are considered GFL • Rely on sufficient grid strength to remain synchronism • Do not inherently provide system strength nor inertia response	• IBRs can work independently of a sync. grid • Informative in IEEE 2800-2022 as the industry does not yet have universally accepted definitions of advanced grid support

In an GFL-IBR dominated power grid

<table>
<tr><th>Service/Capability</th><th>Sync. Gen</th><th>GFL IBR</th><th>(Sync Gen↓ + GFL IBR↑)</th></tr>
<tr><td>Reactive support</td><td>Yes</td><td>Yes</td><td></td></tr>
<tr><td>Frequency support</td><td>Yes</td><td>Yes</td><td></td></tr>
<tr><td>Ride through capability</td><td>Yes</td><td>Yes</td><td></td></tr>
<tr><td>System strength support</td><td>Yes</td><td>No</td><td rowspan="7">• Declining system strength => increasing voltage volatility
• Declining inertia => increasing frequency volatility
• Declining short circuit => protection challenges
• Increasing stability constraints
• Increasing event impact
• Increasing complexity for situation awareness and security assessment</td></tr>
<tr><td>Active power damping</td><td>Yes</td><td>No</td></tr>
<tr><td>Weak grid operation</td><td>Yes</td><td>No/Limited</td></tr>
<tr><td>Inertia support</td><td>Yes</td><td>No</td></tr>
<tr><td>Fast frequency support</td><td>No</td><td>Maybe</td></tr>
<tr><td>Short circuit current</td><td>Yes</td><td>Limited</td></tr>
<tr><td>Subsynchronous Resonance with series capacitors</td><td>Vulnerable</td><td>Vulnerable</td></tr>
<tr><td>Black start</td><td>Yes</td><td>No</td><td></td></tr>
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Potential Advanced Grid Support by IBRs

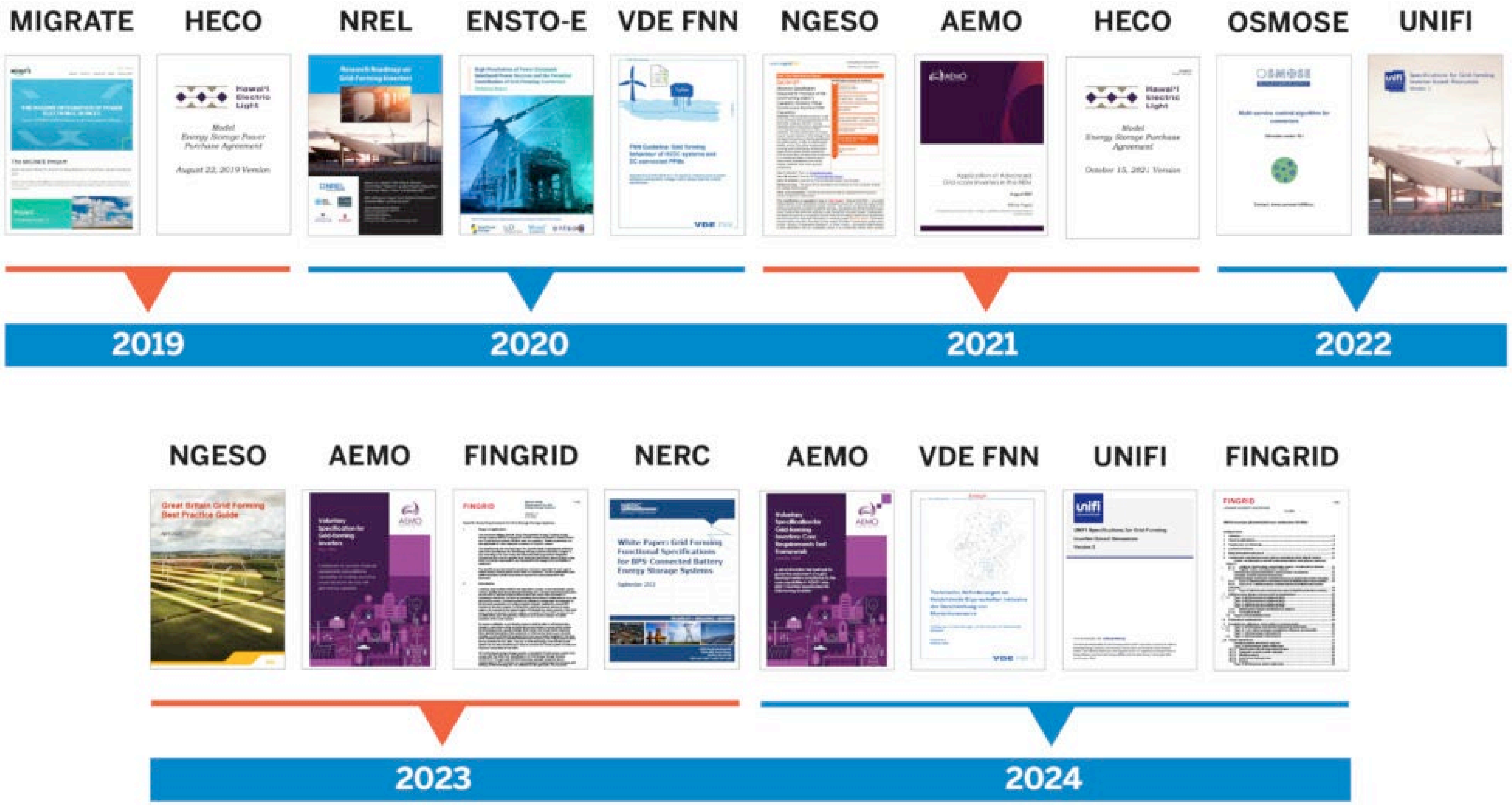
Service/Capability	Sync. Gen	GFL IBR	Advanced Grid Support IBR
Reactive support	Yes	Yes	Yes
Frequency support	Yes	Yes	Yes
Ride through capability	Yes	Yes	Yes
System strength support	Yes	No	Yes
Active power damping	Yes	No	Yes
Weak grid operation	Yes	No/Limited	Yes
Inertia support	Yes	No	Yes
Fast frequency support	No	Maybe	Yes
Short circuit current	Yes	Limited	Limited
Subsynchronous Resonance with series capacitors	Vulnerable	Vulnerable	Positive Damping
Black start	Yes	No	Feasible

Mitigation Options for Notable Grid Challenges for an IBR Dominated Grid

Grid Challenges (Sync Gen↓ + GFL IBR↑)	Reduced power transfer (for example, GTCs)
	Increasing unit trip due to increasing voltage/frequency volatility
	Reduced simulation confidence and situation awareness
Mitigation Options for Grid Stability and Security	Transmission circuit upgrades and or addition
	IEEE 2800-2022
	Synchronous Condensers
	Advanced Grid Support by IBRs and grid dynamic support devices

- The complexity of the power grid increases due to growth of IBRs, however, the use of IBRs also provide a range of potential capabilities and solutions, like advanced grid support
- Improvements on both transmission and resources are expected to provide the most effective system reliability benefits
- Rely on certain technology only, like synchronous condensers, could have diminished reliability benefits (as identified when six condensers were proposed in 2022)

Advanced Grid Support Inverter-Based ESR Specification Overview



Source: https://www.esig.energy/working-users-groups/reliability/grid-forming/gfm-landscape/specifications-and-requirements/

Evaluation of IBR Advanced Grid Support Capability for the ERCOT Grid

- ERCOT contracted Electranix in late 2023 to help recommend the required IBR advanced grid support capability and test framework
- ERCOT also reached out to major IBR OEMs to understand the existing and potential advanced grid support capability (like GFM)
  - OEMs for inverter-based ESRs, including Tesla, SMA, Sungrow, and Power Electronics, shared their GFM BESS models to support this project
  - OEMs for wind and solar currently **don't** have commercially available product
- Several system operators in other regions with high penetration of IBRs have GFM-BESS deployed or under construction to support their grid reliability needs. (e.g., Australia, UK, Hawaii, Finland, Germany,…)
  - Reference: https://www.esig.energy/working-users-groups/reliability/grid-forming/gfm-landscape/projects/

Based on the feedback from OEMs and industrial experience, ERCOT currently focuses on the advanced grid support provided by inverter-based ESRs

Preliminary comparison of advanced grid support inverter-based ESRs test framework for selected system operators(*)

Test Items	ERCOT	NERC	AEMO	Fingrid	NGESO
loss of synchronous machine - discharging	√	√	√	√	
loss of synchronous machine - charging	√	√	√	√	
loss of synchronous machine - limit test	√	√	√	√	
loss of synchronous machine - power balance	√		√	√	
Stability of Plant with Changing Frequency	√		√	√	√
SCR Step Down with Fault	√		√	√	
Angle Step Change-Speed of Response	√		√	√	√
Series Compensation Step Test	√				
Voltage Magnitude Step Test	√				
Energy Response Test	√				
Frequency Scan Test	√		√	√	√
Power Oscillation Damping			√	√	√

Reference: https://www.esig.energy/working-users-groups/reliability/grid-forming/gfm-landscape/specifications-and-requirements/

* This is a preliminary comparison and may be changed with further revisions or changes by each system operator.

Preliminary -- The impact of Advanced Grid Support Inverter-based ESRs to the ERCOT Grid

Study	Short Description	Preliminary Observations of Advanced Grid Support BESS
1(1)	A 3-buses Panhandle-equivalent system	Improves the stability performance under weak grid conditions
2(1)	West Texas stability assessment	Reduces unit trips, voltage and frequency volatility, numerical instability, and improves voltage recovery
3(1)	An actual local GTC with wind/solar/ESR projects	Improves the stability performance and potentially mitigates the stability issues identified in this GTC
4	Grid stability and GTC assessment	Potentially increases WESTEX, McCamey, and Panhandle GTC limits approximately 5~10% based on the tested cases(2). For several other GTCs, the constraints could also be mitigated.

- Noted that there is currently no advanced grid support inverter-based ESRs connected to the ERCOT grid. Generic models based on PNNL and EPRI are used in these assessments.

(1). More details were presented at IBRWG in August, 2023. https://www.ercot.com/files/docs/2023/08/11/GFM_ERCOT_IBRWG(08112023).pdf

(2). The cases were based on the selected existing operations conditions and didn't include the future transmission additions and resources.

System improvements, including grid stability and resilience, have been observed in ERCOT assessments with advanced grid support inverter-based ESRs.

The adoption of the advanced grid support inverter-based ESRs

- Consideration and assumptions
  - Major OEMs for inverter-based ESRs have commercially available product
  - Minimum impact to the project physical design and commercial operations
  - Will need to meet all the existing ERCOT IBR requirements in Protocol and Guides
  - Like all the other generation resources, close coordination of control settings, modeling accuracy, performance monitoring, and studies will still be required

- Adoption proposal:
  - The existing inverter-based ESRs are not required but highly recommended to provide advanced grid support
  - New inverter-based ESRs will be required to provide advanced grid support
  - ERCOT and TSPs should also start consider advanced grid support provided by transmission devices like STATCOM

Next Steps

- ERCOT plans to submit the revision request by Q4 2024 to adopt the advanced grid support inverter-based ESRs
- ERCOT plans to continue assess the application of advanced grid support by wind and solar
- ERCOT plans to continue assess the application of black start capability by IBRs
- Stakeholders and market participants are encouraged to provide comments and suggestions to Shun-Hsien.Huang@ercot.com