Overview of Grid Planning with High Penetration of IBRs

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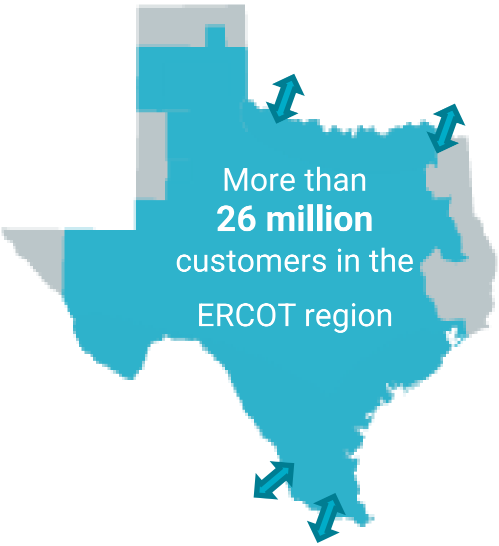
ERCOT Facts



Note: The total capacity of the DC tie is 1,220 MW

1,100+

generating units, including PUNs

52,700+

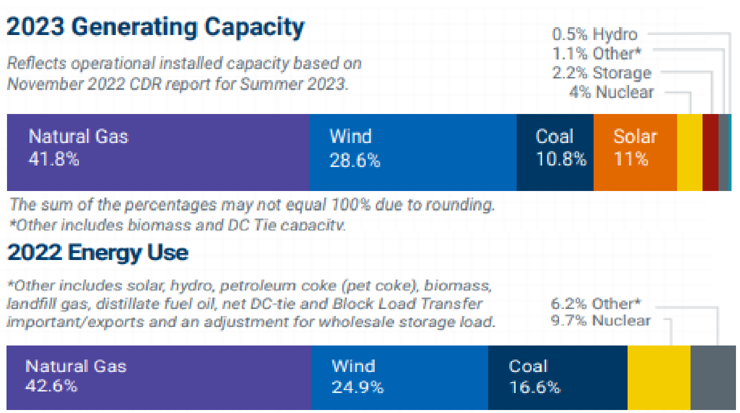
miles of high-voltage transmission

98,000+ MW

of expected capacity for summer 2023 peak demand

80,148 MW

Record peak demand (July 20, 2022)



36,909 MW

of installed wind capacity as of December 2022, the most of any state in the nation

27,044 MW

Wind Generation Record (May 29, 2022)

69.15 %

Wind Penetration Record (April 10, 2022)

14,813 MW

of utility-scale installed solar capacity as of December 2022

11,891 MW

Solar Generation Record (March 4, 2023)

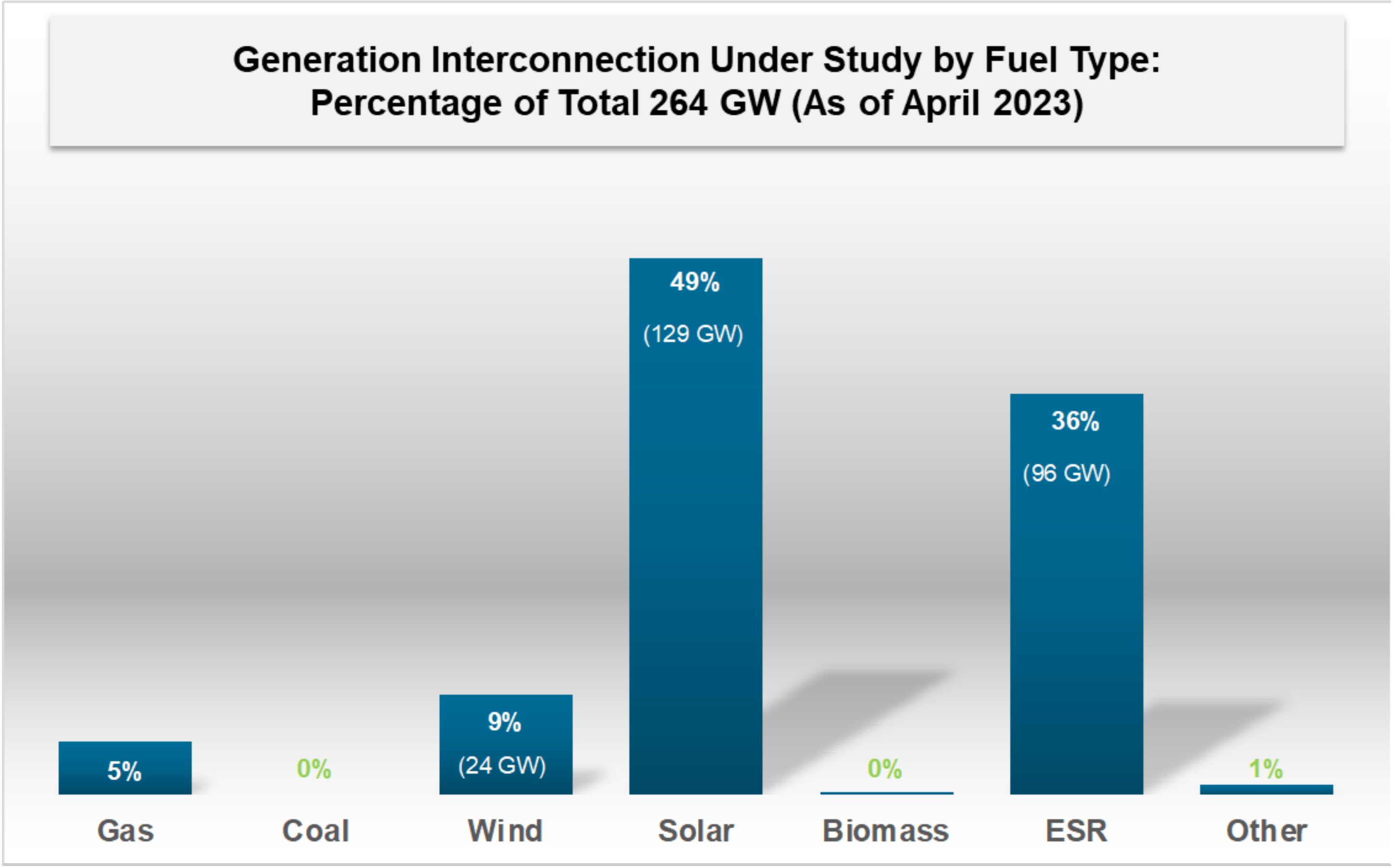
29.77 %

Solar Penetration Record (March 4, 2023)

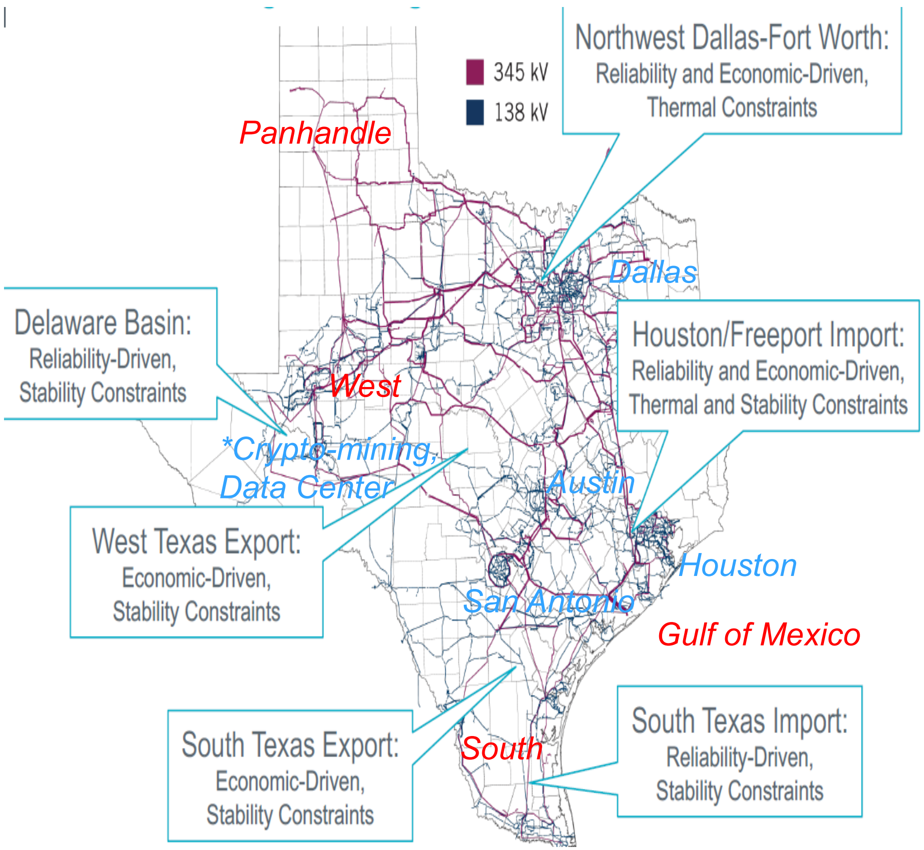
2,788 MW

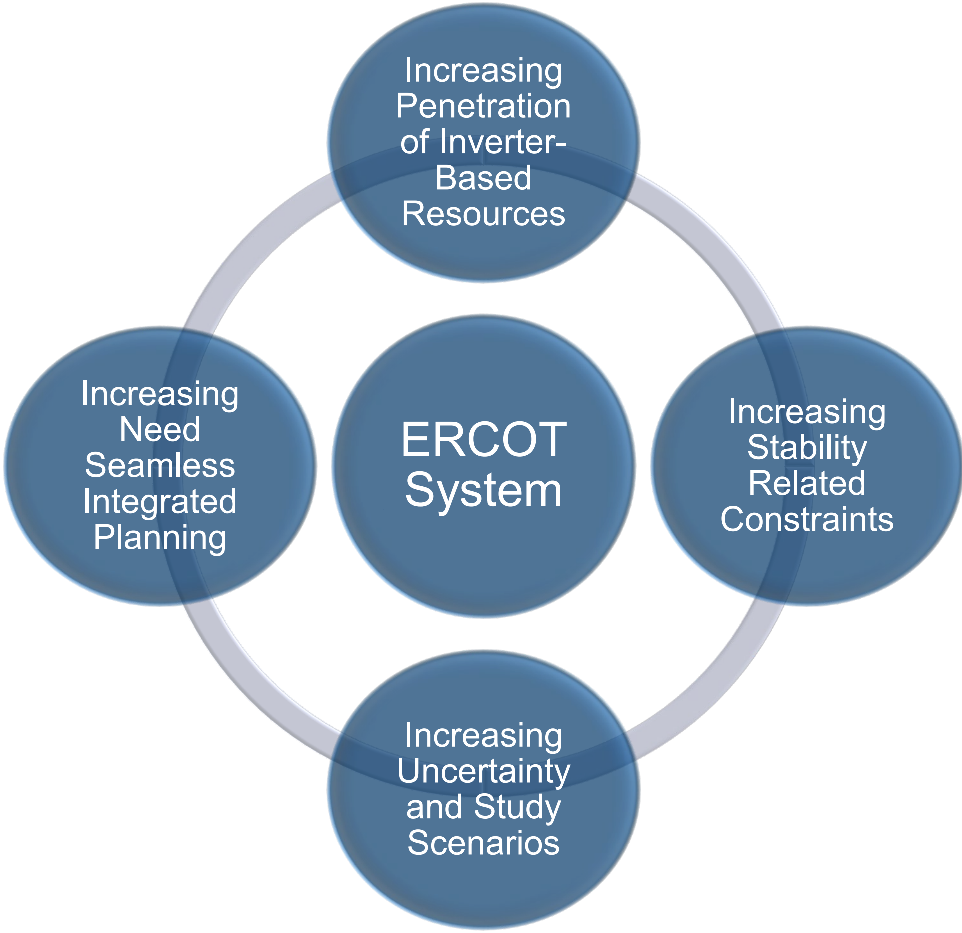
of installed battery storage as of December 2022

Fuel Type Breakdown – Generation Interconnection Under Study (as of April 2023)



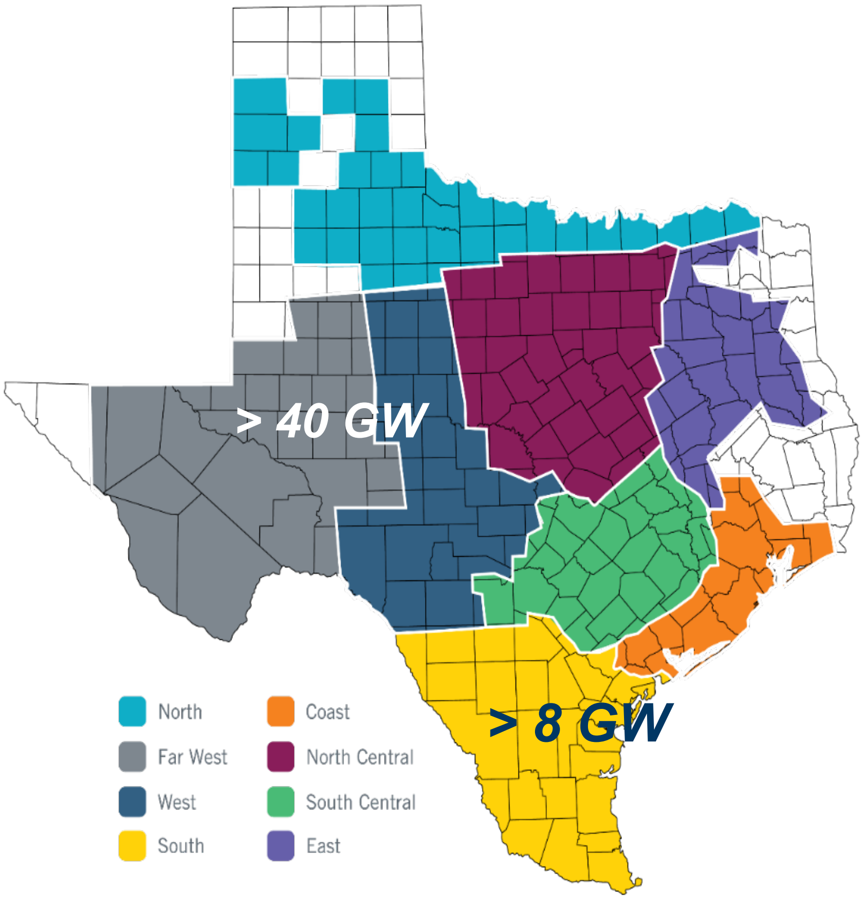
Some Key Challenges





** Large amount of Inverter-Based Load*

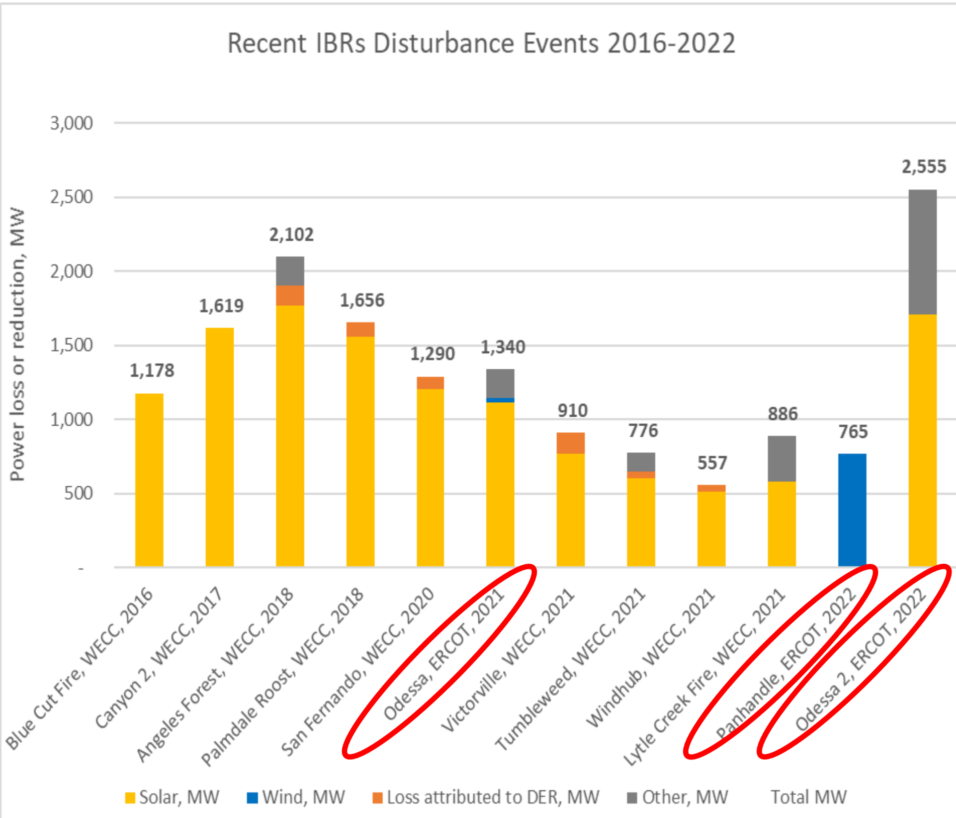
Increasing Penetration of IBRs



[Approximate Inverter-Based Resources capacities expected in West and South by December 2024]

- Performance is mainly driven by inverter controllers
- Complexity of control functions and detail model needs
- Evolving controls, design and features
- Sensitive and fast
- Adequacy and accuracy of models

Increasing Penetration of IBRs (Continued)

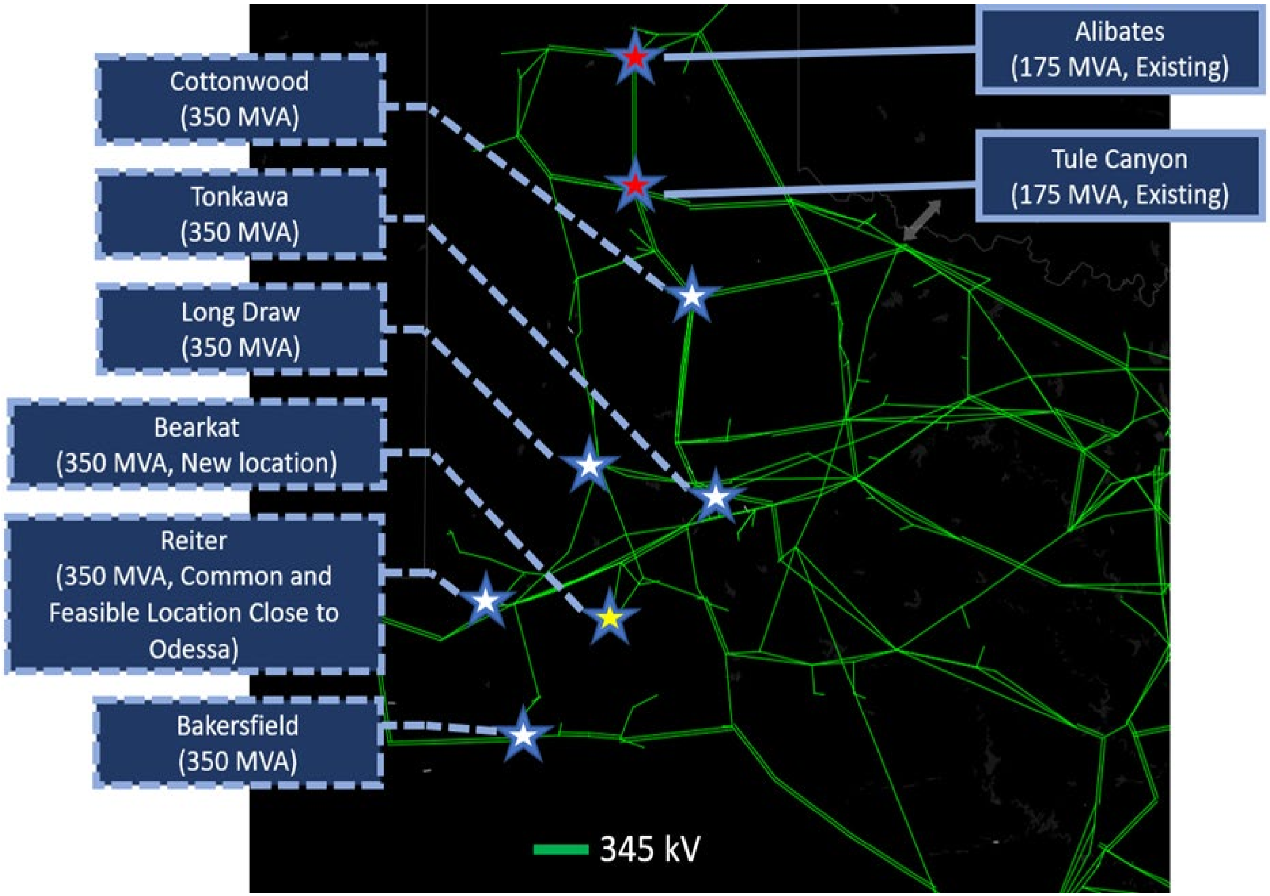


- Resource capability and performance deficiency, and the need to improve models when compared to actual performance and as built control settings and parameters
- The MW impact of these events is likely to increase as more IBRs and voltage-sensitive load are added in West Texas
- Unexpected loss of generation and load during the disturbances poses an increasing and significant reliability risk to the ERCOT system

Source: NERC Major Event Analysis Reports, https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx

Increasing Penetration of IBRs - Transmission Upgrades Under Study

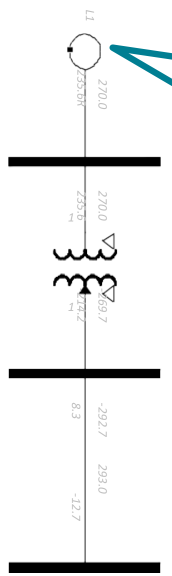
- Potential Mitigation Measures
  - Potential synchronous condensers
  - Other transmission upgrades in West Texas for large load growth related oil/gas business development and datacenter/crypto mining



Source: https://www.ercot.com/calendar/05162023-RPG-Meeting

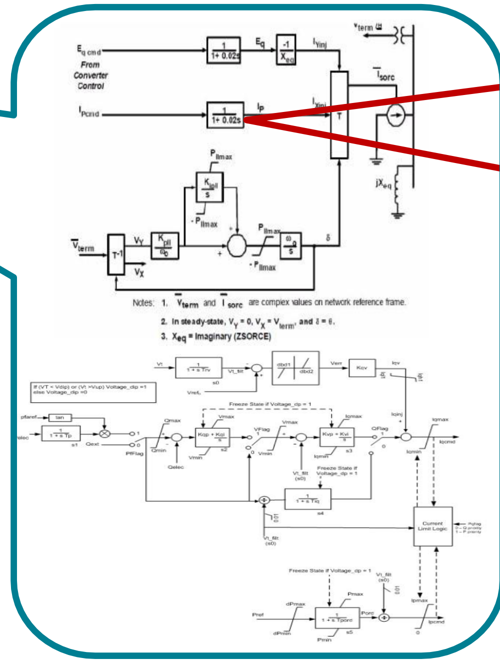
Increasing Penetration of IBRs - Modeling Complexity

Power Flow



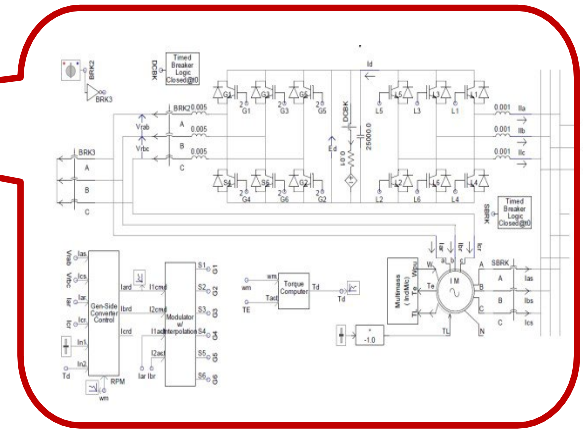
- Algebraic equation with no time step
- 60 Hz
- Positive sequence
- Balanced system
- Steady state
- Solution in < 1 sec
- Tools: PSS/e, PowerWorld, VSAT

Traditional Dynamics



- Time step of 1 ~ 4 ms
- Fundamental frequency assumption
- Positive sequence & balanced system
- Electro-mechanical machine dynamics
- Simulation time: 1 ~ 20 mins
- Tools: PSS/e, PowerWorld, TSAT

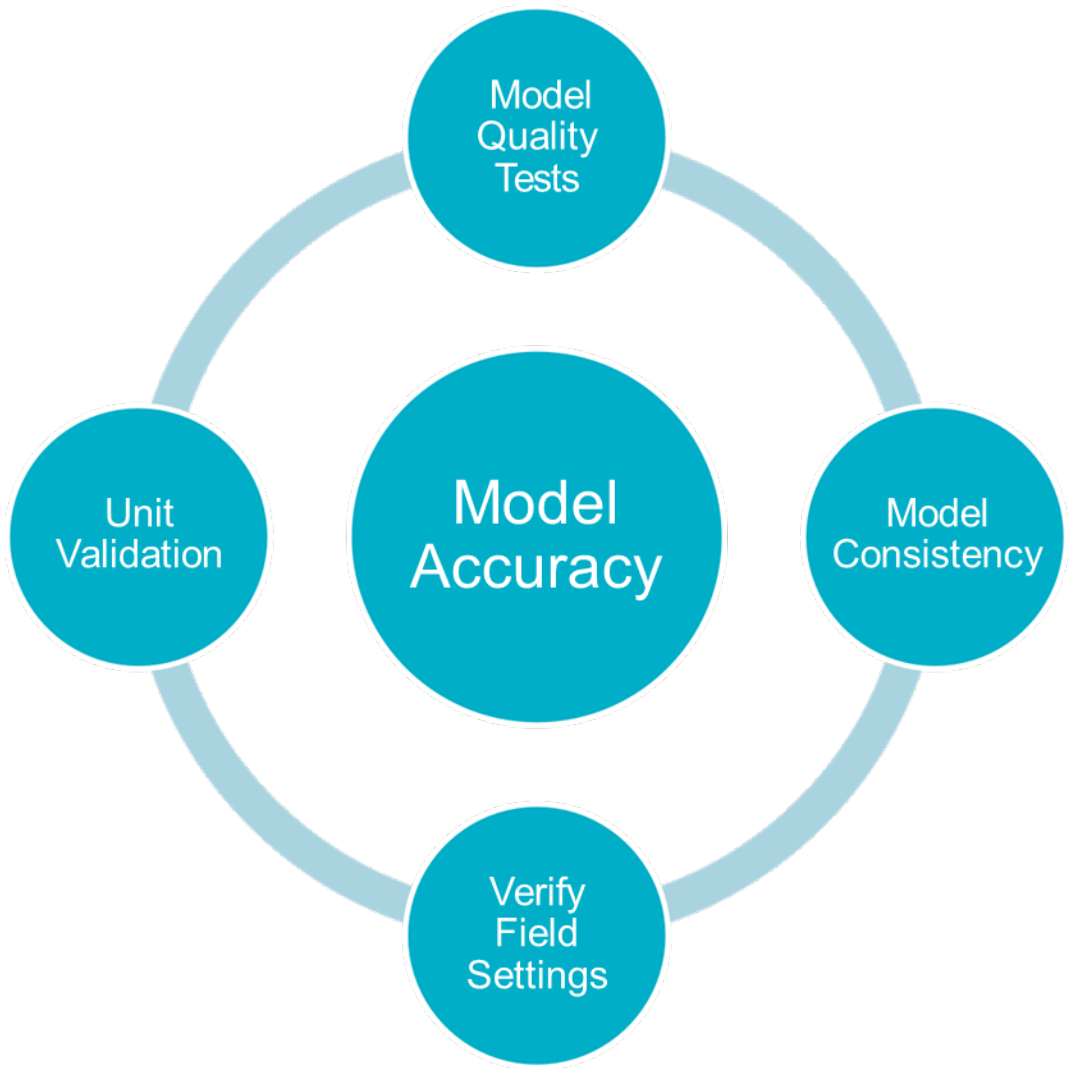
EMT



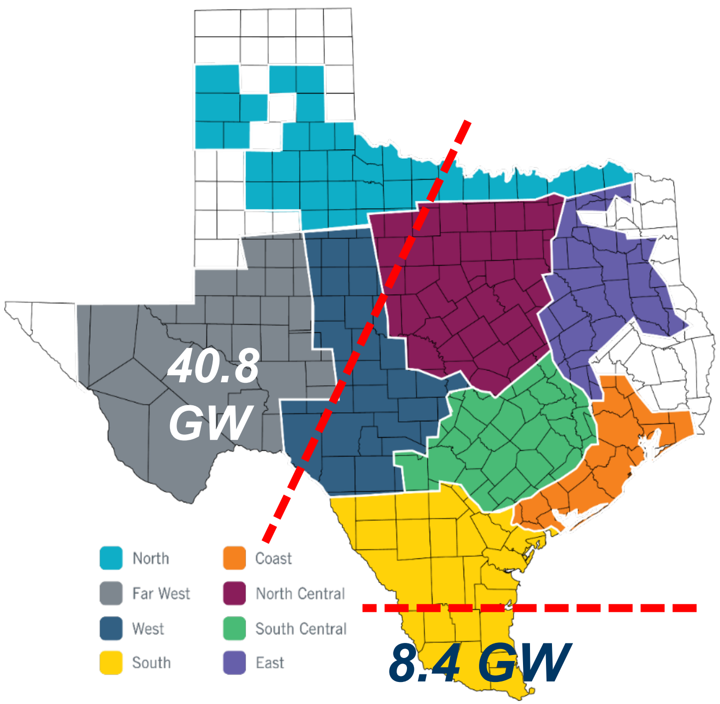
- Time step of 10 ~ 50 us
- Frequency impacts included
- Full three-phase representation
- Phase imbalances represented
- Fast dynamic controls explicitly modeled
- Need for detailed SSR analysis
- Need for high IBR penetration analysis?
- Simulation time: 10 mins ~ hours
- Tools: PSCAD

Increasing Penetration of IBRs - Dynamic Model Performance and Accuracy Improvements

- PGRR075 and PGRR085 approved in 2020 and 2021: model quality tests (PSS/E, PSCAD), unit model validation, plant verification reports
- NOGRR245 under development: revision to the ride through requirements
- Process to review any proposed modifications to settings and equipment associated with IBRs
- Participation in industry forum, adoption of standards and best practices

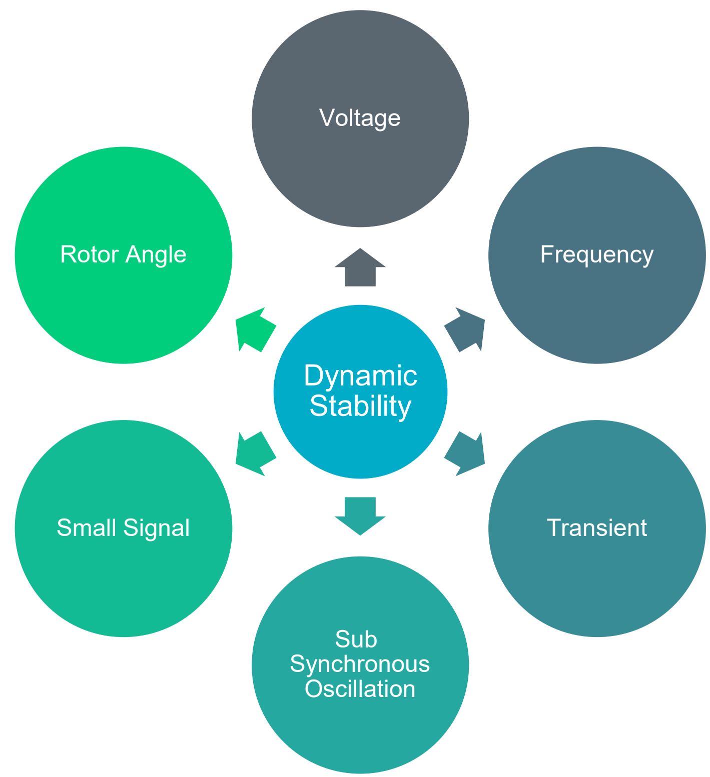


Increasing Stability Related Constraints



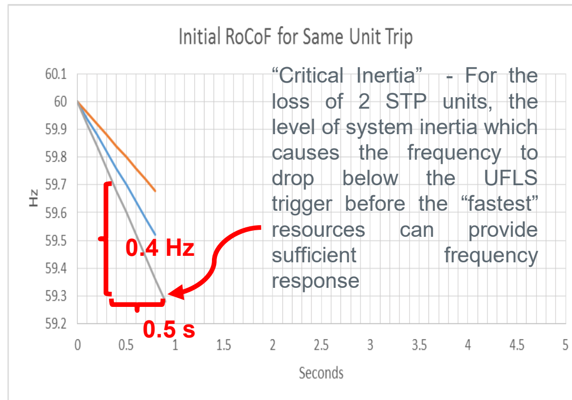
[Approximate Inverter-Based Resources capacities expected in West and South by December 2024]

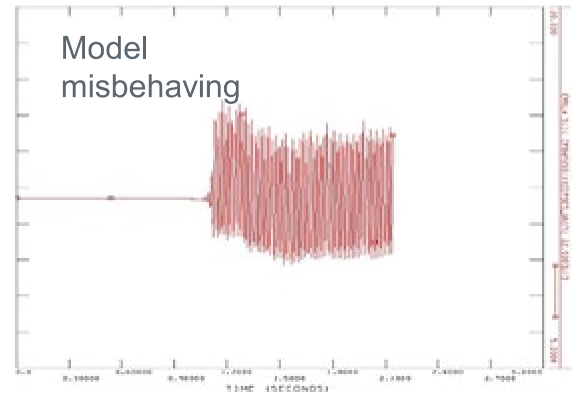
- Multi-circuit transfer limits (often caused by complex grid stability issues) are modeled as “Generic Transmission Constraints.”
- 18 regional or local GTCs add to the complexity of reliably operating the grid

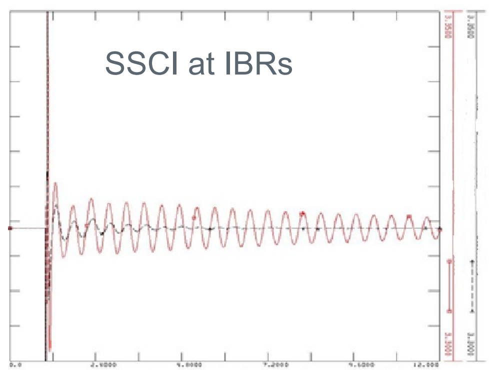


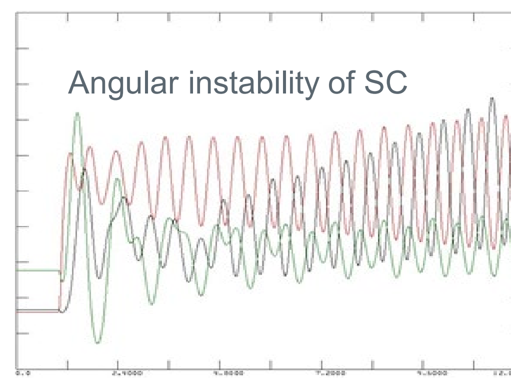
Increasing Stability Related Constraints (Continued)

- High penetration of IBR's resources causes a decrease of synchronous units being online. Frequency response of online generation fleet depends less on governor action and inertia
- Low system strength
- Minimum system Inertia
- Models not working properly
- Interaction of nearby IBRs' controllers
- Combination of outages and contingency could lead to a radially connection between a generator and a series capacitor
- EMT simulations
- Angular stability of synchronous condenser



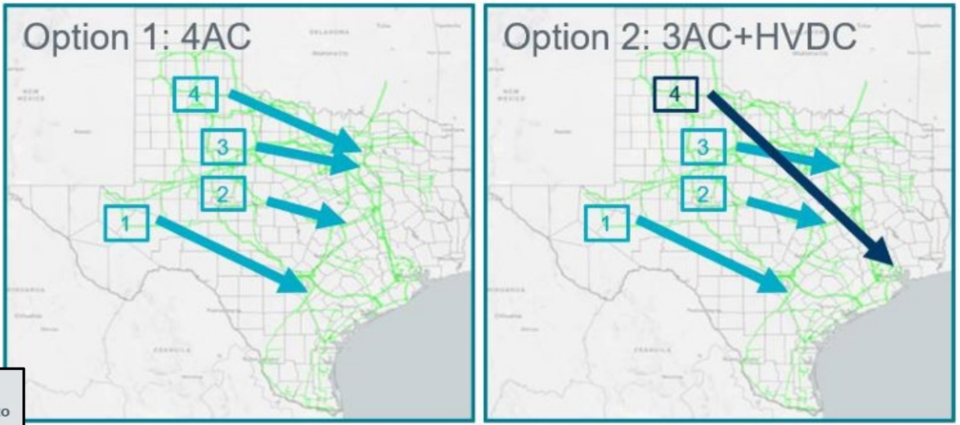


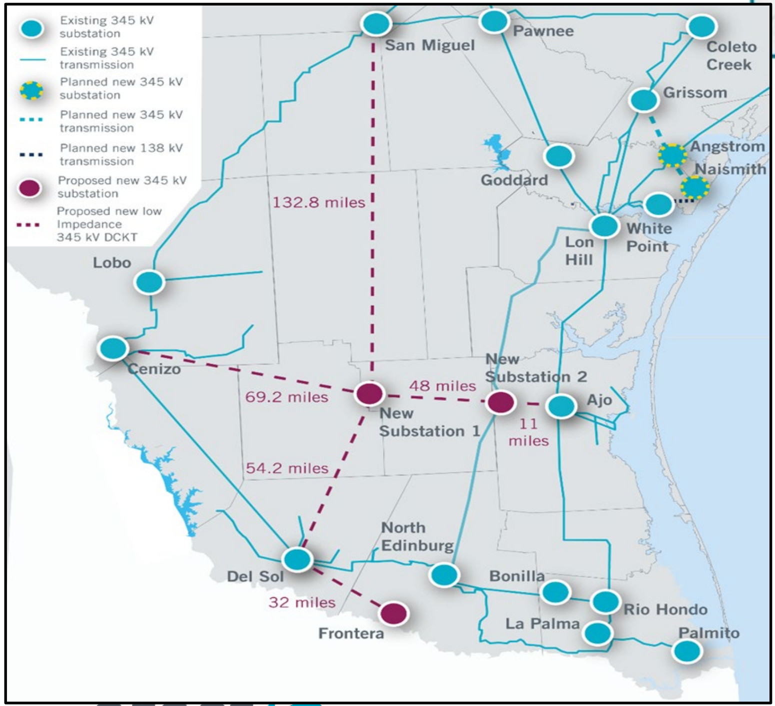




Increasing Stability Related Constraints (Continued) – Transmission Upgrades Tested

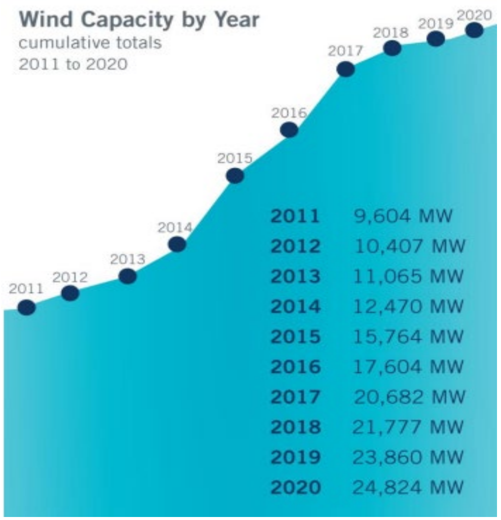
- West Texas Export Study (production cost saving test + congestion cost saving test + dynamic stability study)

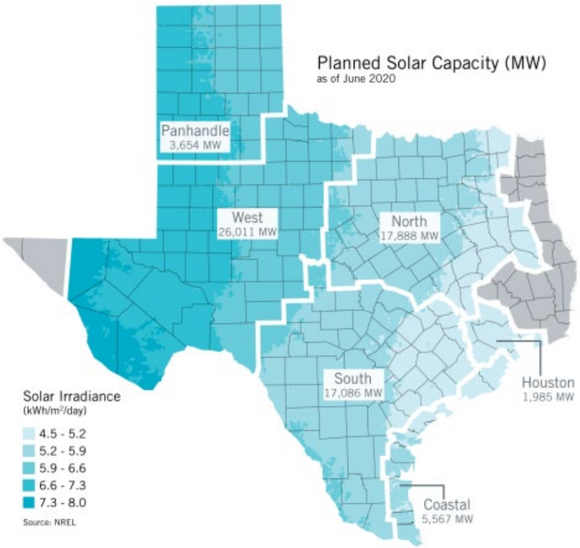




- Lower Rio Grande Valley Transmission Improvement Project
  (Reliability driven project, approved in 2021, ~$1.3B)

Increasing Uncertainty and Study Scenarios





- More scenarios and various events need to be assessed (e.g., Summer Peak, HWLL, HRLL, NWNS, Potential Generation Retirement, Large Load, DERs,…, N-k)

- Extreme network conditions (e.g. Low system inertia, Extreme weather conditions)

- Any additional stability criteria, new operating requirements or interconnection requirements moving forward (e.g., Frequency response characteristics, Voltage fluctuations, Short circuit ratio, Inertia, IBR control/coordination/optimization strategies)

- Tool adequacy:
  - Positive Sequence tool, EMT tools and Models
  - Hybrid tools (convergence of single model for planning and operation, transmission and distribution networks)

Increasing Seamless Integrated Planning Needs

- Observations of unprecedented phenomena are being reported by experts across the field
- By sharing knowledge and experiences, we can better understand these challenges and develop effective strategies to overcome them.
  - Comprehensive study: economic, steady state, and dynamic analyses
  - Continued interaction between planning, operations, and interconnection teams (seamless integrations)
  - Increasing interaction among industry
- Better understand new technology and industrial practices
- Consider ideas and recommendation to improve planning and operation process
- Staff Development and Recruiting
  - Understanding of various technologies (e.g., Synchronous generators, IBRs, SVCs, STATCOMs, Grid Forming)
  - Understanding of various stability subjects (e.g., Angular, Voltage, Frequency, Oscillation, Control Interaction, Weak Grid, SSR)
  - Ability to assess and address power system dynamics with high penetration of IBRs
  - Tools (e.g., PSS/E, TSAT, PSCAD) for effective and efficient system analysis in both planning and operations

Question or Comments

Any Question or Comments?

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