High Penetration of Inverter-Based Generation in ERCOT

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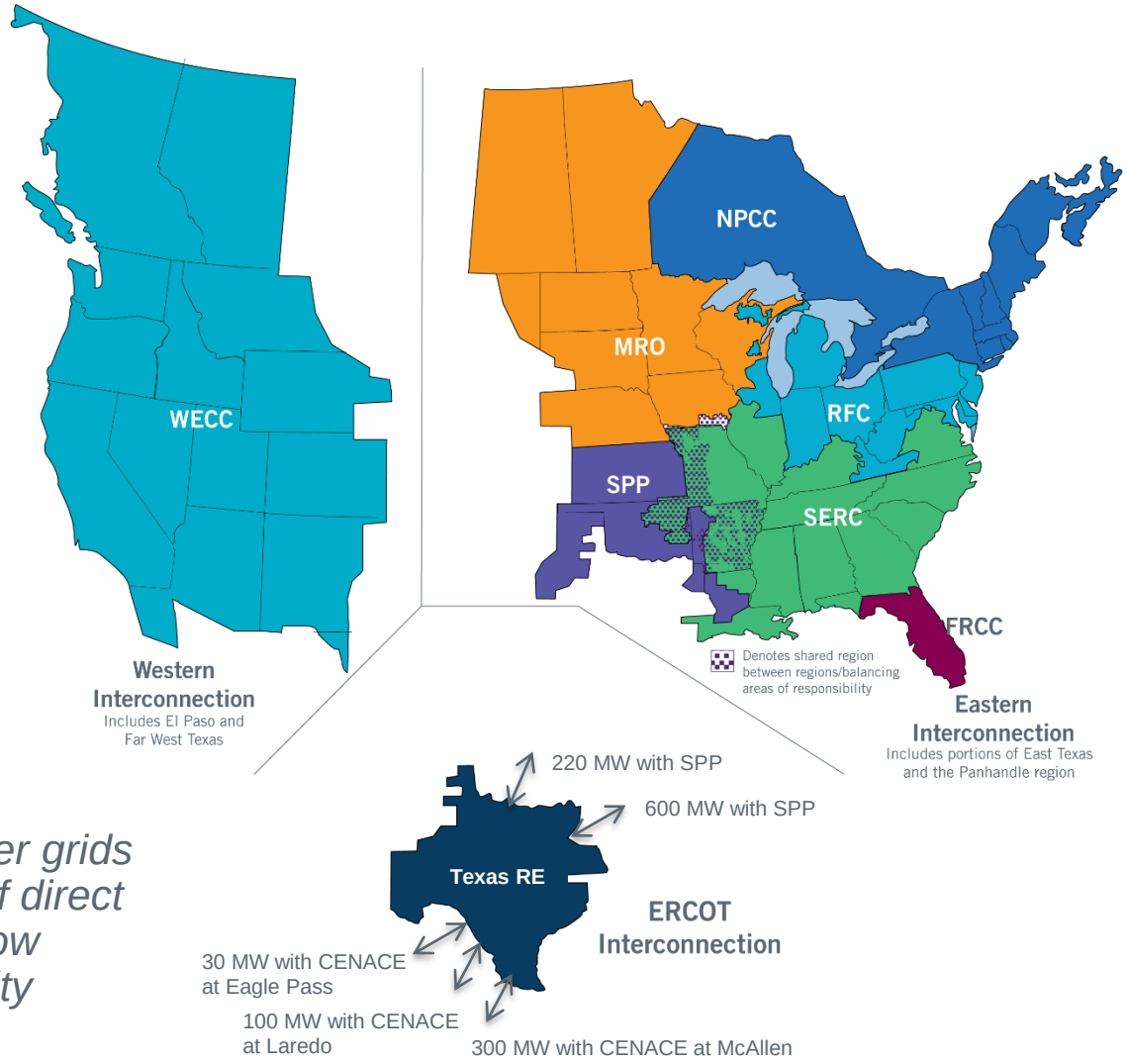
The ERCOT Region

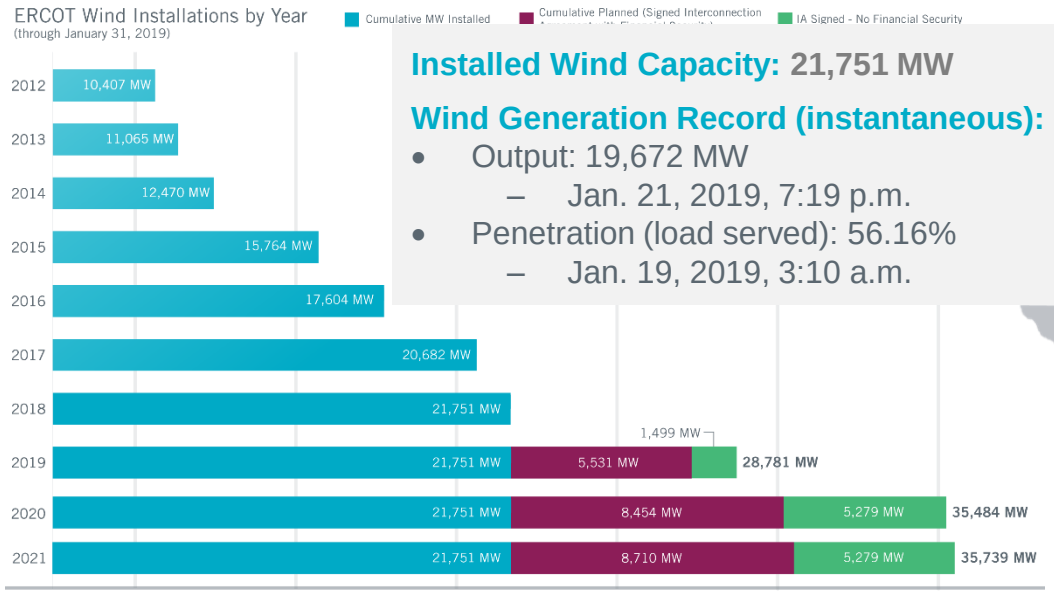
The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 73,473 MW peak, July 19, 2018
- More than 46,500 miles of transmission lines
- 600+ generation units



ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity

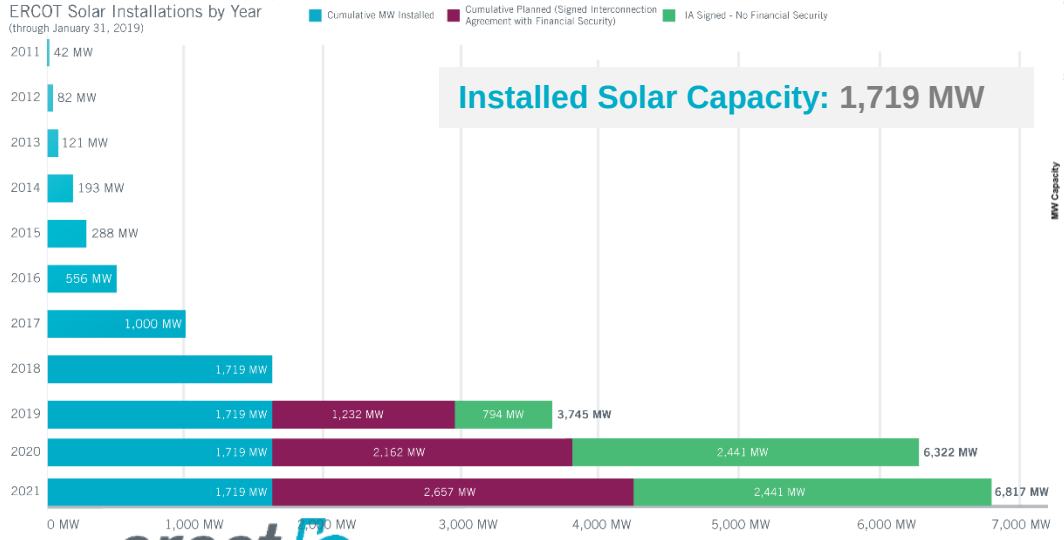
ERCOT Renewable Generation Overview



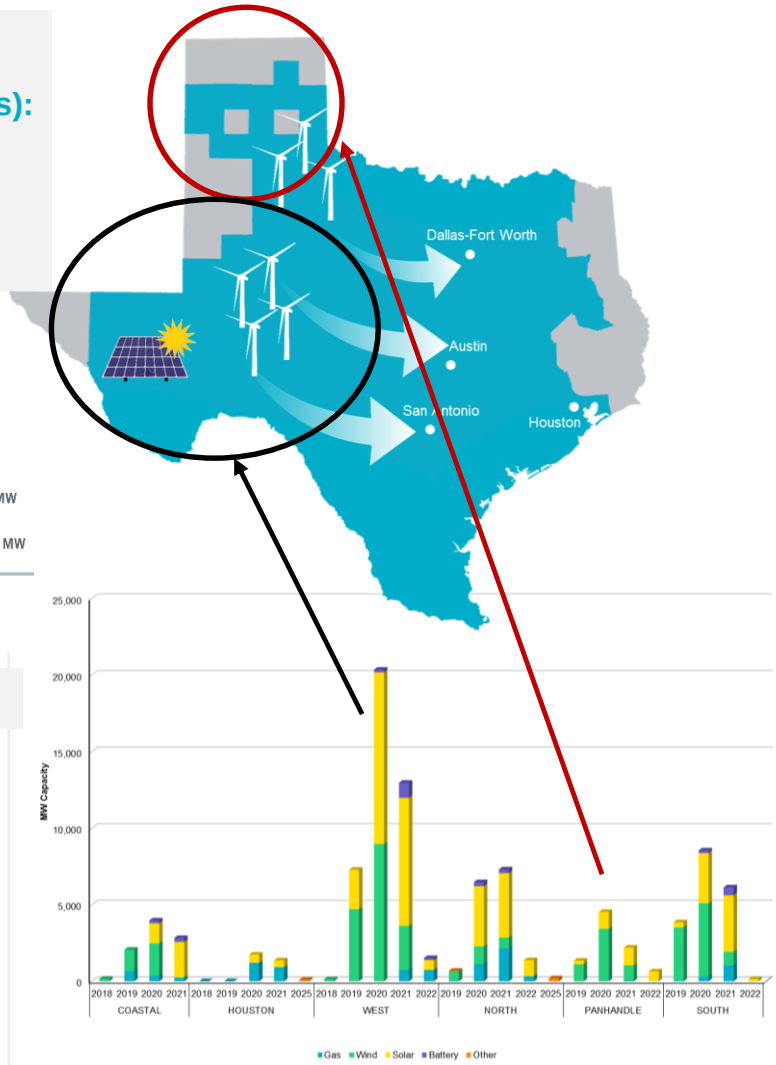
Installed Wind Capacity: 21,751 MW

Wind Generation Record (instantaneous):

- Output: 19,672 MW
  - Jan. 21, 2019, 7:19 p.m.
- Penetration (load served): 56.16%
  - Jan. 19, 2019, 3:10 a.m.



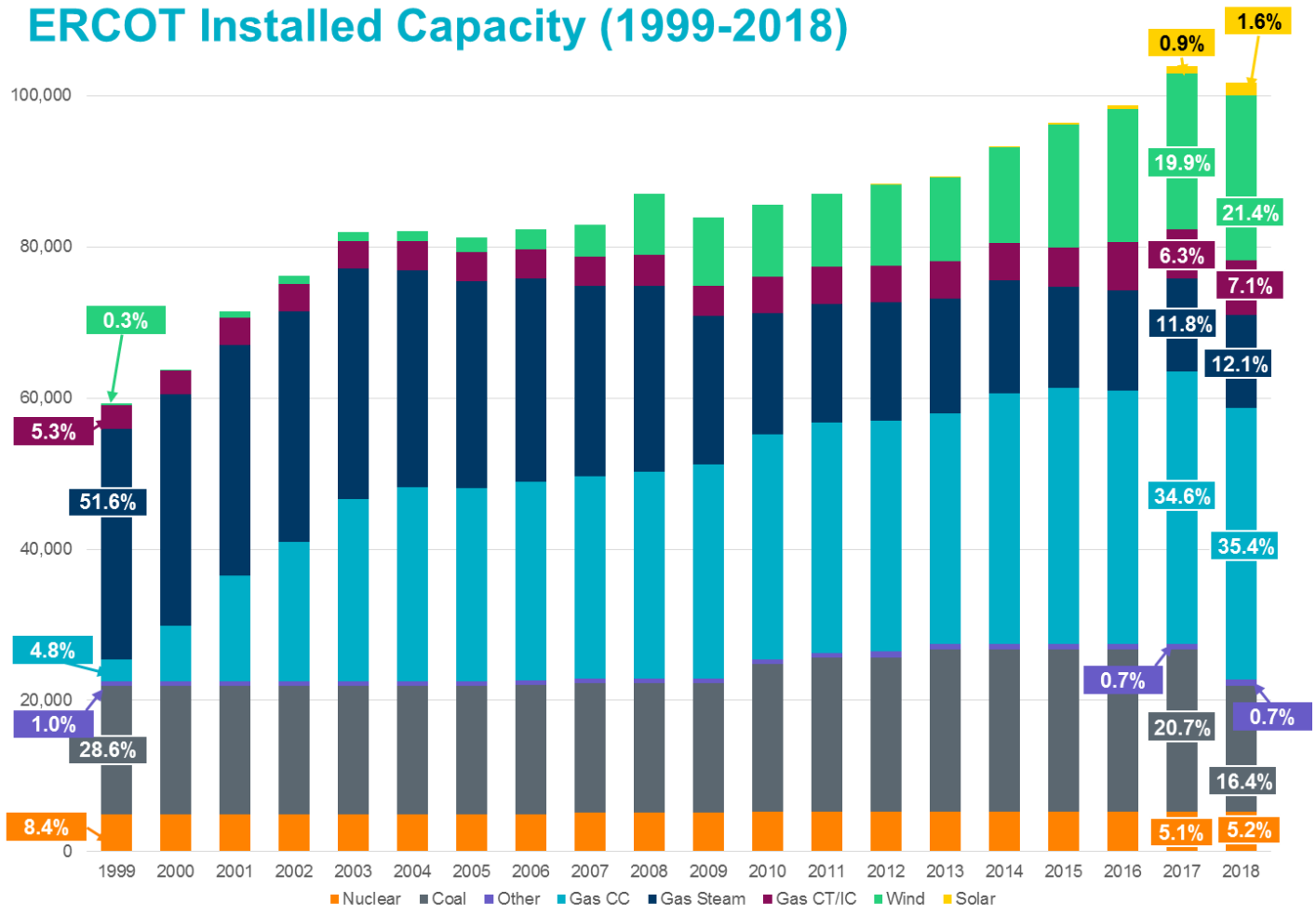
Installed Solar Capacity: 1,719 MW



Potential new generation capacity based on expected in service year under various interconnection stages. Not all generation will be built.

Recent Generation Retirements

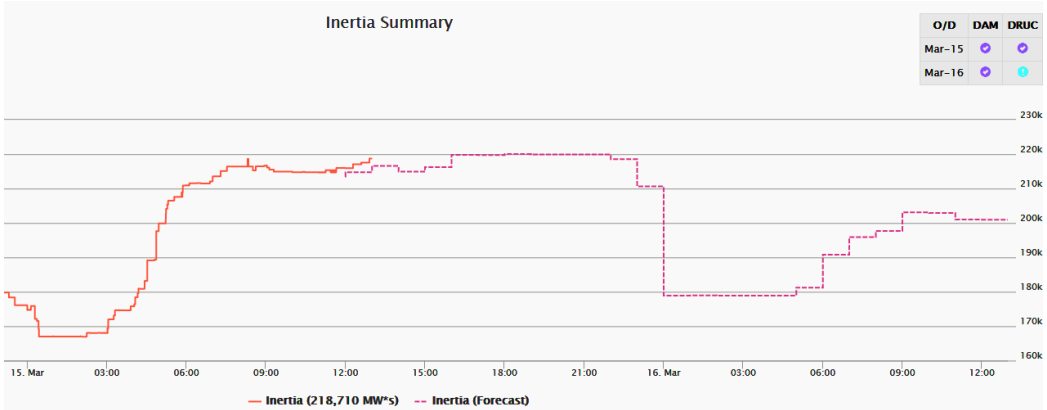
Year	Recent Synch. Generation Retirements, MW
2016	534
2017	1,191
2018	4,273
2019	280

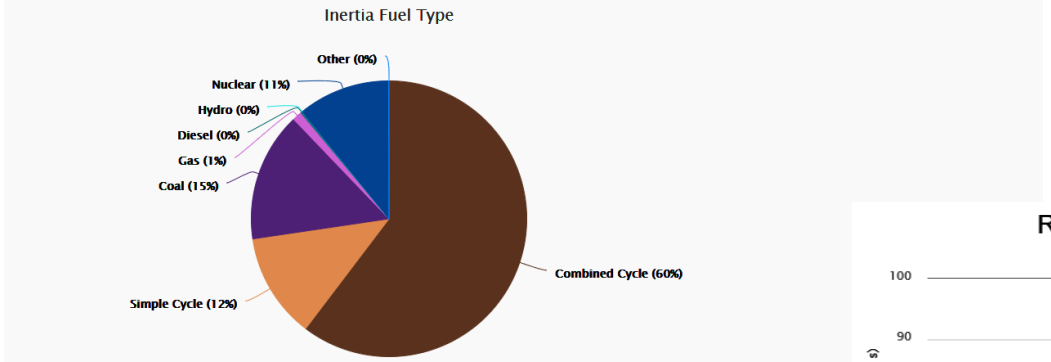


Existing Challenges with High Penetration of IBRs

- Declining inertia, critical inertia
- Undesired voltage performance under to low system strength
- Expansion of existing weak grid areas and
- New weak grid areas being identified
- Model Adequacy

Critical Inertia and Inertia Monitoring



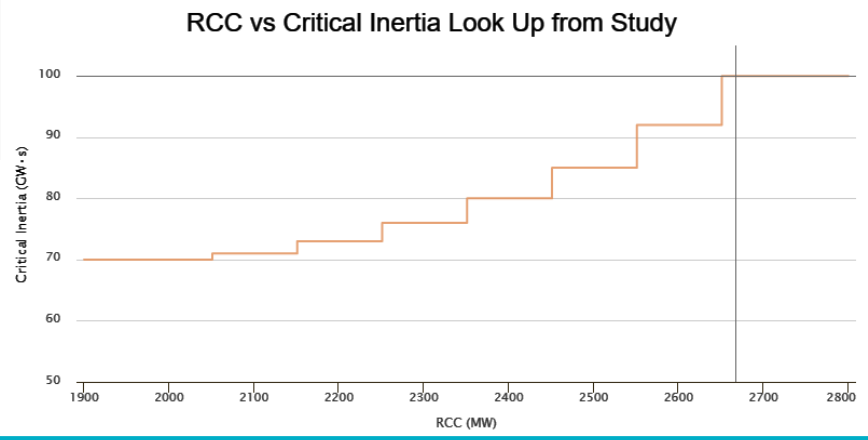


Inertia Monitoring

Critical Inertia

- 120 GW*s >= Inertia Normal
- 120 GW*s > Inertia >= 110 GW*s Yellow
- 110 GW*s > Inertia >= 100 GW*s Orange
- 100 GW*s < Inertia Red

Emergency BPs	Inactive
System Inertia	99,999 MW-s
SCED	00:04:00
RLC	00:00:06
STLF Forecast High	21.6
STLF Next 30 Mins	Normal
QSE ICCP	Normal

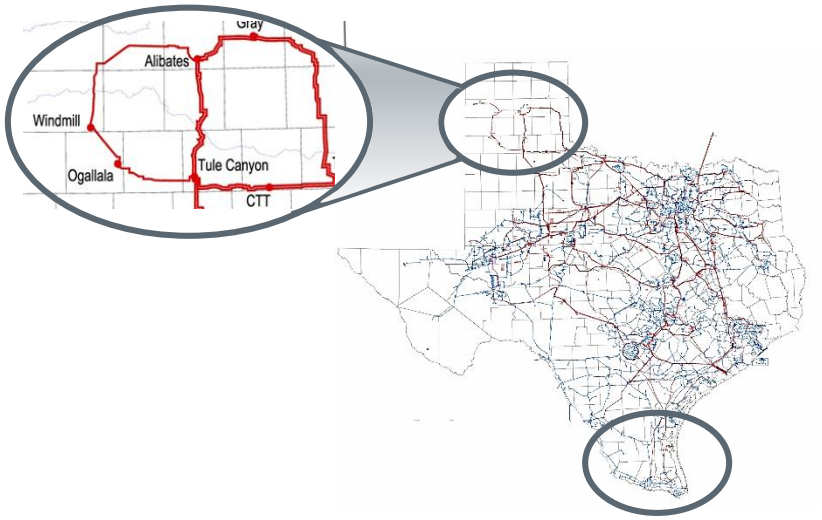


Real-Time Contingency Criteria vs Critical Inertia

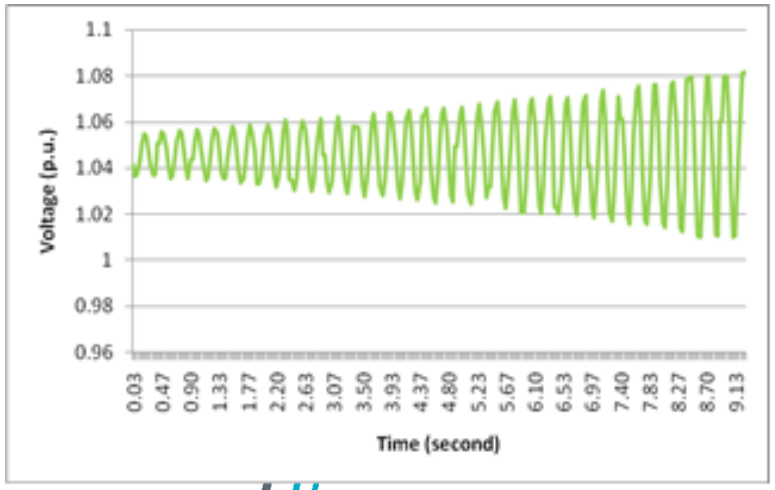
Weak Grid Issues

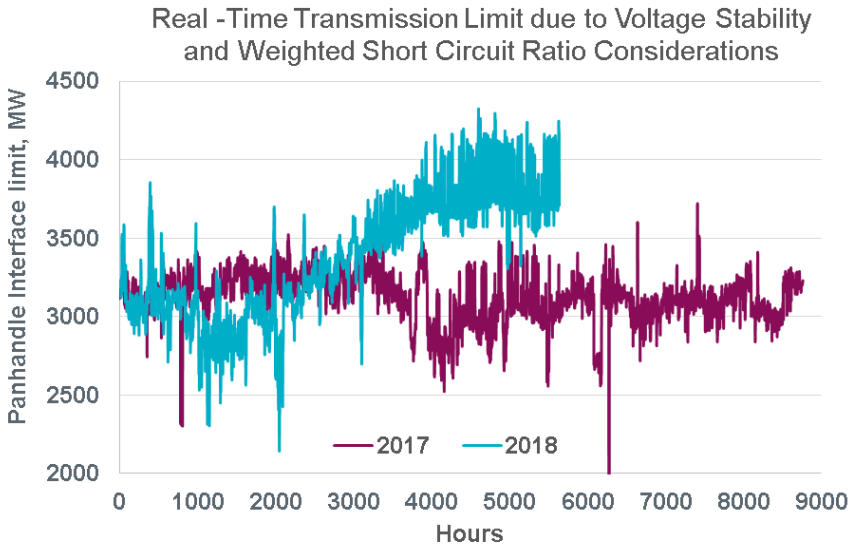
Texas Panhandle:

- IBRs ~ 5.5 GW planned, ~4 GW in service
- No local load or synchronous generators
- Voltage support and system strength issues managed through export constraints
- New IBRs are being built just outside of the constrained area – weak grid area is expanding



Other areas in ERCOT may start experiencing similar issues as well.





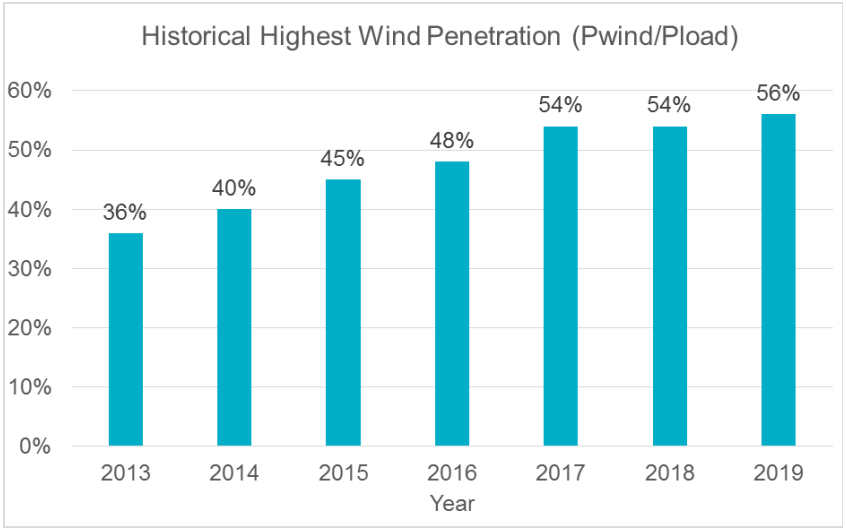
Modeling and PSCAD Studies

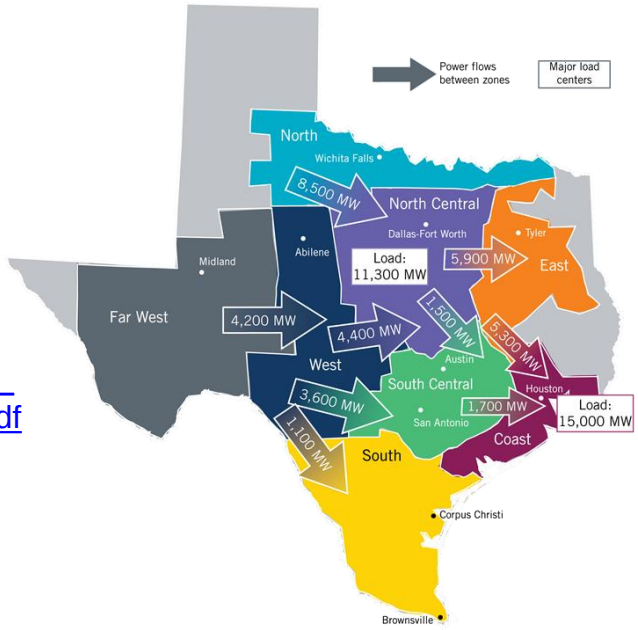
- IBRs connecting to ERCOT are now required to provide PSCAD models.
- ERCOT has conducted number of PSCAD studies for Panhandle and South Texas.
- Going forward PSCAD studies are expected to be performed more frequently due to the evolving grid and increasing IBRs share.
- PSCAD studies are computationally intensive. For example, Panhandle PSCAD study (400 busses), requires 40 threads and ~2 hours to simulate one contingency.

ERCOT High Penetration Study

- ~70% Penetration of Inverter-Based Wind and Solar Resources
- Less Synchronous Generators
- Reduced System Strength

http://www.ercot.com/content/wcm/lists/144927/Dynamic_Stability_Assessment_of_High_Penertration_of_Renewable_Generatio....pdf





Load: 42.2 GW (includes PUNs)
Solar output: 17 GW (90% dispatch)
Wind output: 11 GW (48% dispatch)
West Texas Exports: 15.5 GW (major 345 kV circuits)
Losses (MW): 6%

Ongoing Initiatives

In ERCOT:

- Stakeholder Workshop to review NERC Reliability Guideline (BPS-Connected IBR Performance) Recommendations and identify changes needed to ERCOT's interconnection requirements for IBRs.
- Continue Panhandle and South Texas PSCAD studies

Industrial Involvement:

- Coordinating and contributing to IEEE PES Power and Energy Magazine, Nov/Dec issue's article "Could Grid Forming be a Silver Bullet for High Inverter-Based Penetration?"
- PS173A: System Planning Methods, Tools, and Analytics
- A number of CIGRE WG on impacts from high share of IBRs
- ESIG High Share of Inverter-Based Generation Task Force under Reliability Working Group

Key Takeaways

- How to better identify and manage stability constraints in the real time operations?
- How to perform reliability assessment for a system with high penetration of inverter-based generation?
  - Model, Tool adequacy?
- Is synchronous condensers a viable long term option for system strength?
- Can IBR be more robust and provide more reliability support? (voltage, frequency, short circuit current, weak grid, damping, …etc.)
- In addition to 100% IBR, a roadmap to 100% IBR is equally or more important to system operators.
  - Operation, Planning, Market, Protection, …etc.