Item 10: Mitigating Dynamic Events on the Changing ERCOT Grid

Dan Woodfin
Vice President, System Operations

Board of Directors Meeting

ERCOT Public
June 23-24, 2025

Overview

- **Purpose**
  Provide broader context for several on-going and upcoming initiatives for improving grid strength and resilience

- **Voting Items / Requests**
  No action is requested of the ERCOT Board; for discussion only

- **Key Takeaway(s)**
  - Recent and on-going changes to the grid make uncontrolled dynamic events (e.g. Iberian outage) more likely if not mitigated.
  - Mitigating these types of events require both Grid Improvements and improved requirements for Resources and Large Loads
    - **Grid**: ERCOT is implementing grid projects that will help mitigate these risks (synchronous condensers, 765 KV projects)
    - **Resources**: Implementation of NOGRR 245 and approval/implementation of grid-forming inverter requirements in NOGRR272/PGRR121 will help mitigate this risk from the Resource side
    - **Loads**: Improved dynamic models and establishment of ride-through requirements will be needed to handshake with the capability of the grid from the large load side

Changes to the System are Increasing Potential for Dynamic Risks

System Evolution

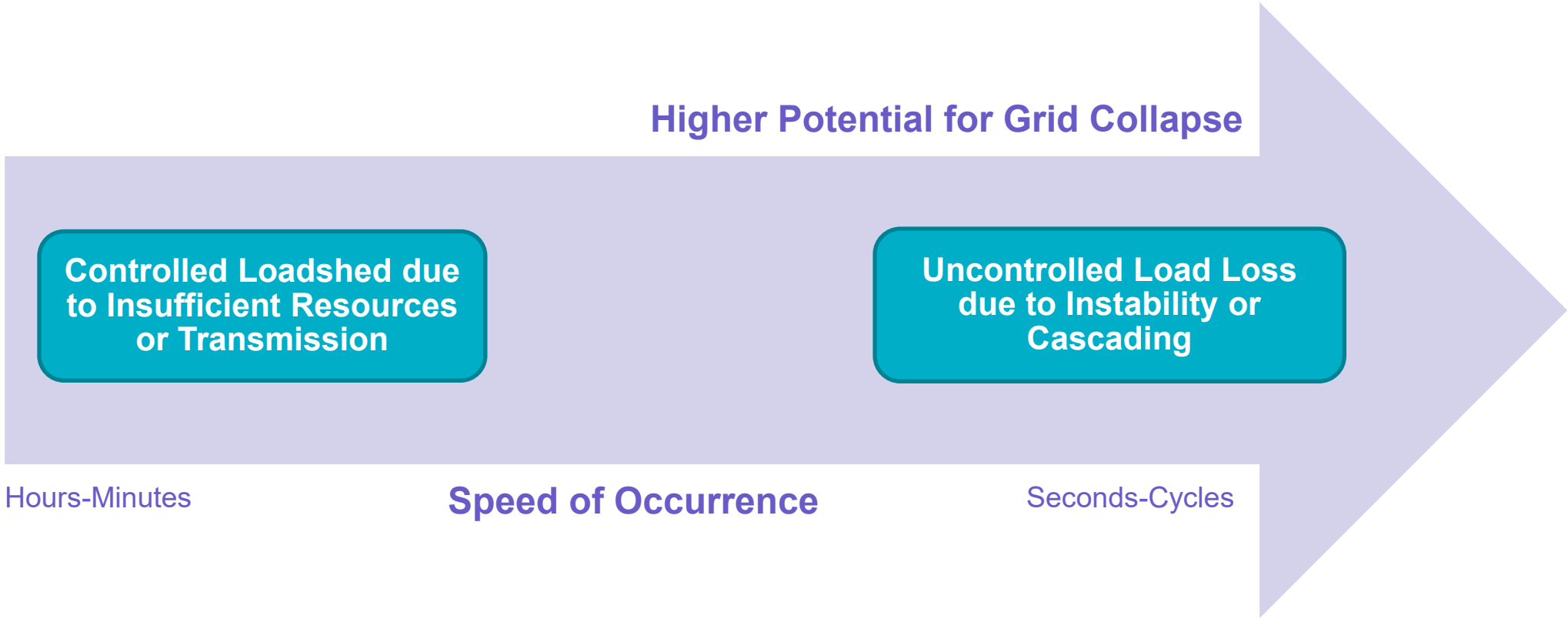
- Grid-following IBRs rather than synchronous generators
- Resources located remotely from load centers require large power transfers
- Single loads with consumption greater than a large city
- Programable electronic controls for resources and loads

Resulting Dynamic Risks

- Control system interactions and oscillations
- Lack of ride-through by Resources and Loads
- Power transfer limited by stability not overloads
- Unknown or inaccurate stability limits due to:
  - Generator or Load control model inaccuracy
  - Insufficient analysis of specific operating conditions

Key Takeaway: Recent and on-going changes to the grid make uncontrolled dynamic events more likely if not mitigated.

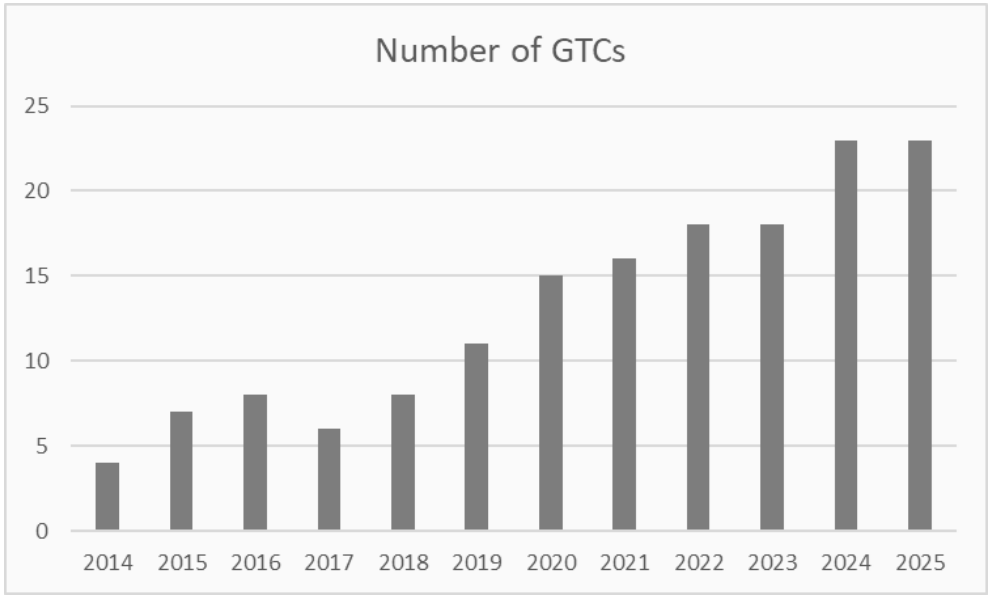
All System Risks are Not the Same



Key Takeaway: Dynamic events are a higher risk for uncontrolled grid collapse than issues that can be resolved by controlled loadshed, and they happen much faster.

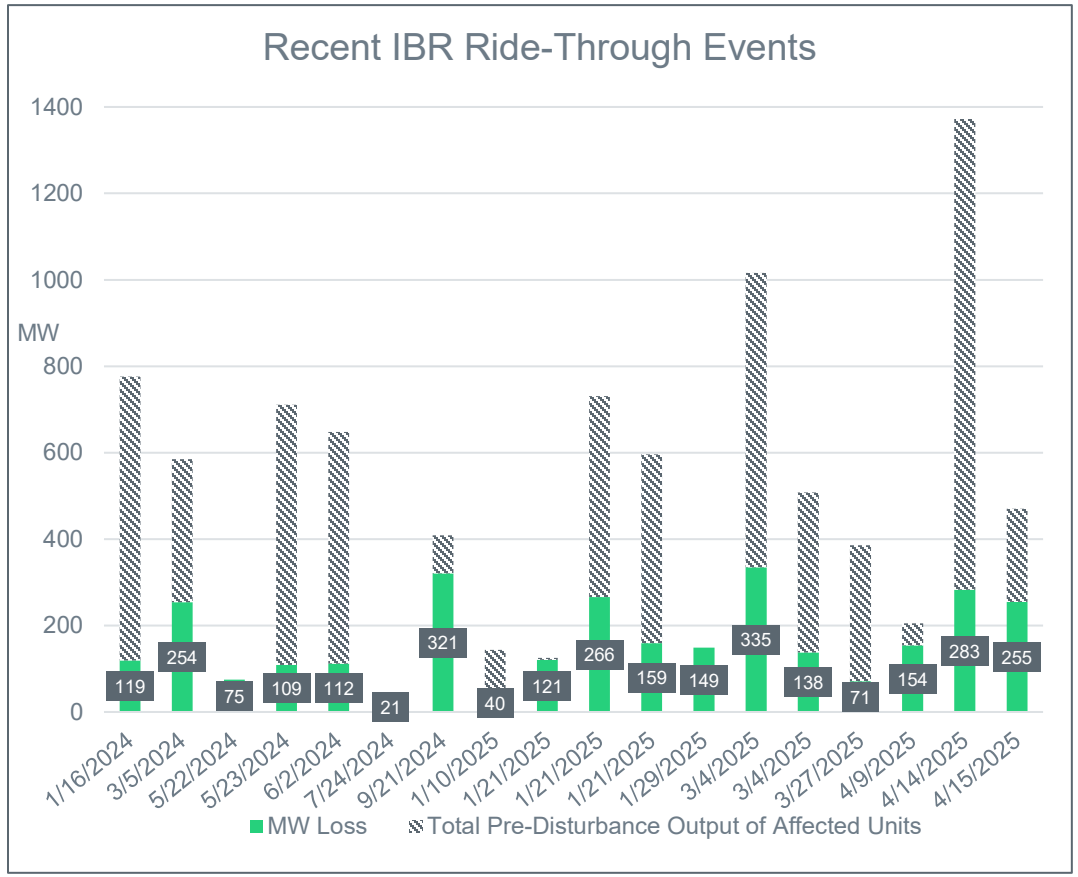
Stability Limits

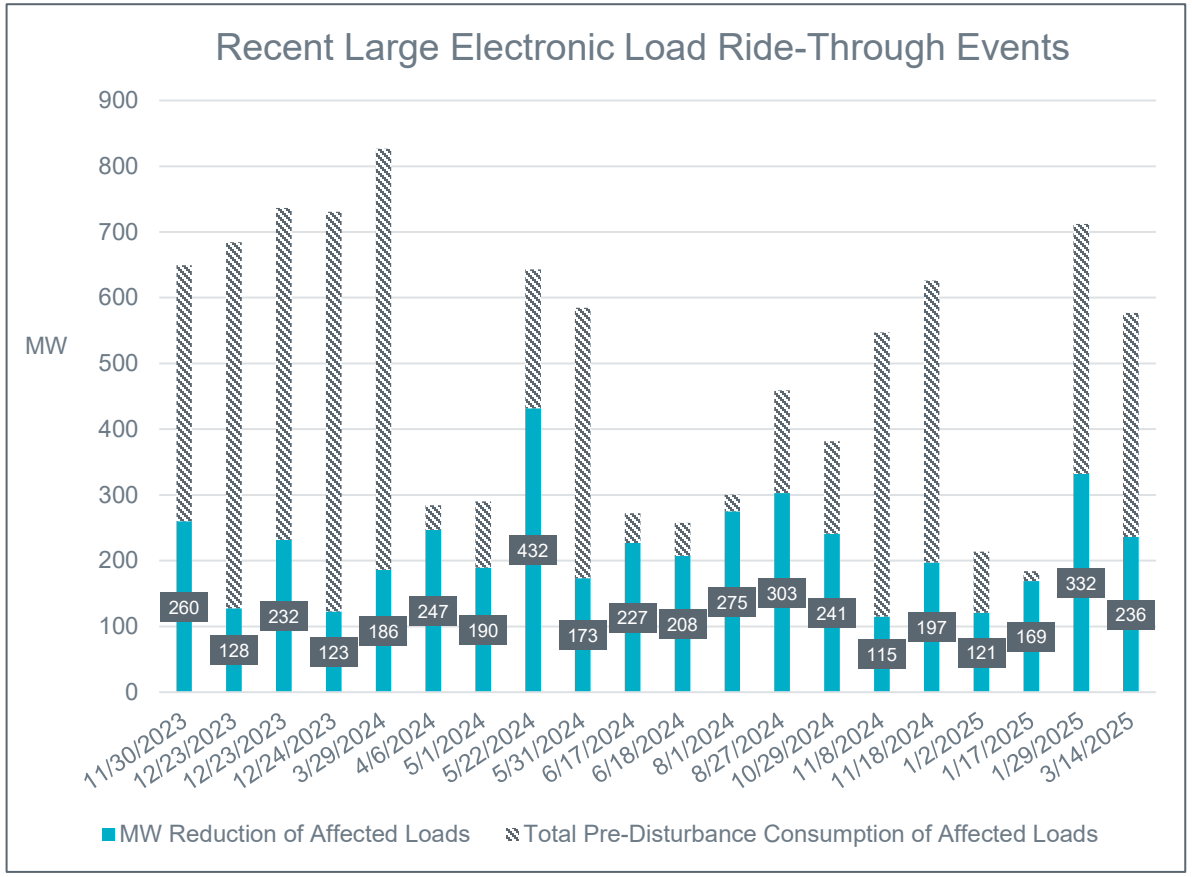
- Historically, most stability issues have been able to be avoided by limiting power transfers
- ERCOT identifies these stability issues through dynamic studies, calculates the stable transfer limits, and implements these limits through the use of Generic Transmission Constraints (GTCs)
- GTCs can then be used by the dispatch optimization to limit those transfers in the most economic way
- As the system has changed, an increasing number of GTCs have been needed



Key Takeaway: For stability issues that occur due to power transfer levels, ERCOT manages these stability issues through GTCs where possible.

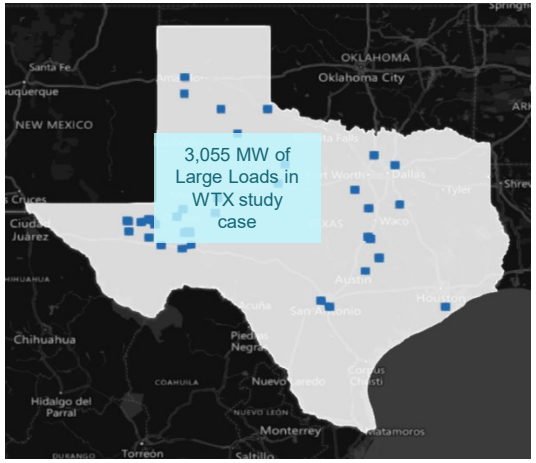
Numerous Ride-Through Events





Key Takeaway: ERCOT System continues to see large number of resources and loads that are not riding through relatively common occurrences on the grid. As the number and size of affected resources continues to grow, the risk of a major event increases.

Large Load Ride-Through Studies

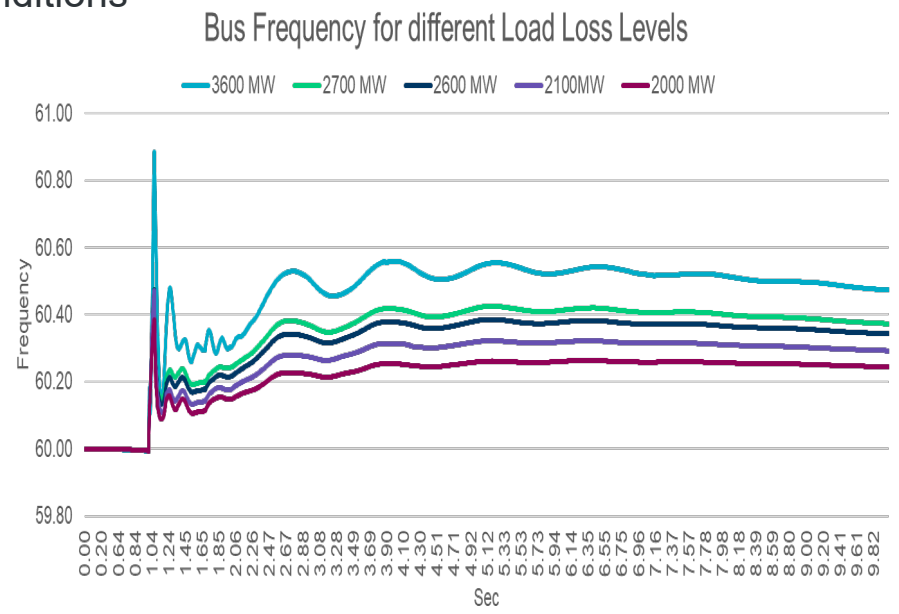


Due to the number of large electronic load (LEL) trips, ERCOT performed a dynamics study of severe fault in West Texas

- Study showed voltage dip < 0.70 p.u. for more than 20ms (ITIC curve) impacting a wide area
- This dip would result in reduction of ~1500 MW of the approximately 3000MW large power electronic loads in West Texas in the study case (*if* their ride-through is as good as the ITIC curve) for a particular fault location (could be worse)
- As the volume of LELs in West Texas continues to grow, the MW of reduction for a single fault is expected to grow as well
- Result would be different under other operating conditions

ERCOT has also performed a study of system frequency response to a significant large load (multiple LELs in same area) trip

- Under certain critical conditions, the loss of more than 2600MW would cause system frequency to increase to a level (60.4Hz) at which generators are concerned that they might not ride through, resulting in an uncontrolled cascading event

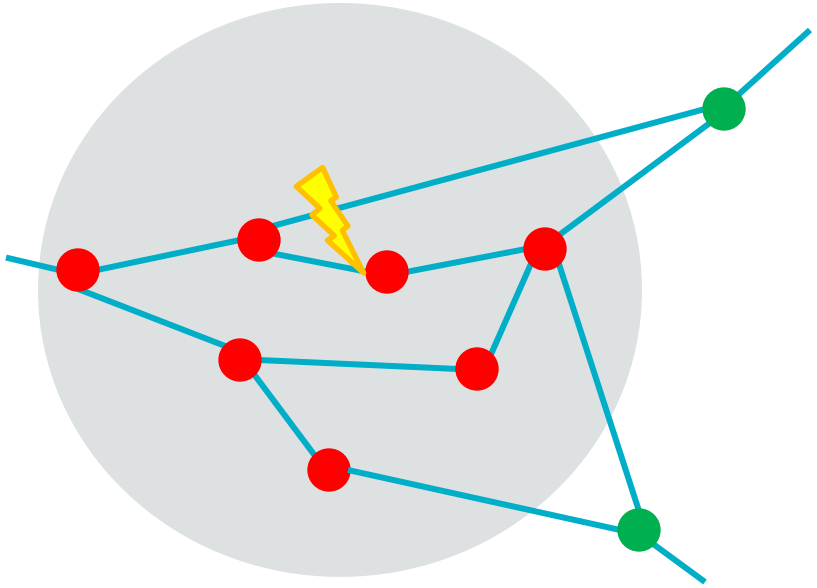


Key Takeaway: If the volume of large electronic loads continues to increase, and they cannot ride-through system faults, it could result in a major event.

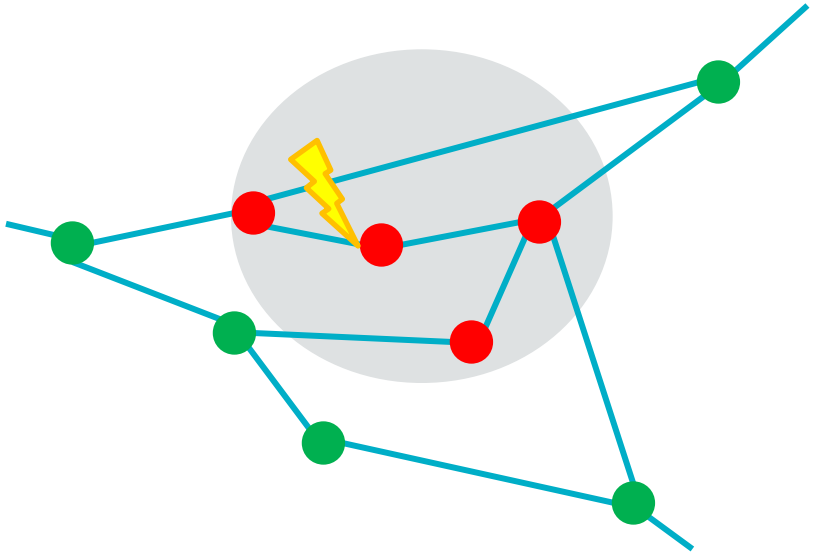
ITIC = Information Technology Industry Council

Significant Impacts may be Widespread or Localized

Weaker Grid

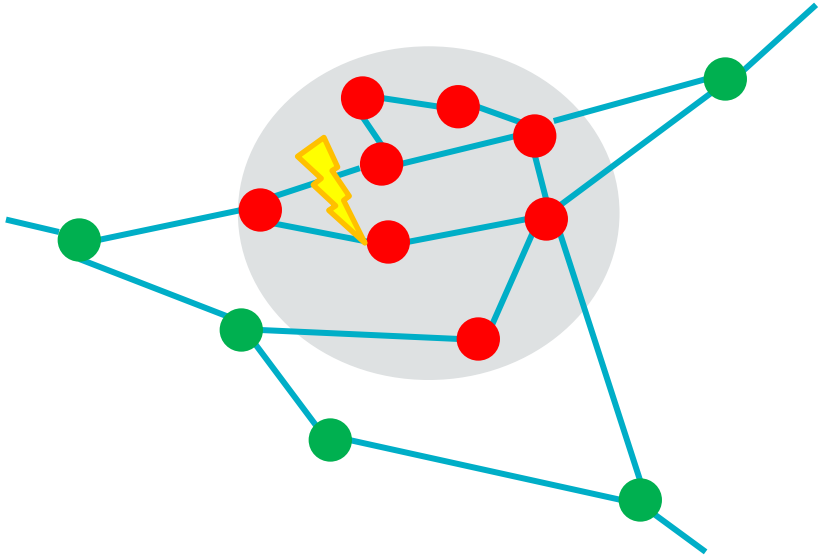


Stronger Grid



Strengthening the grid reduces the area affected by voltage dip during a fault

Stronger Grid with Dense Concentration of Voltage-Sensitive Equipment

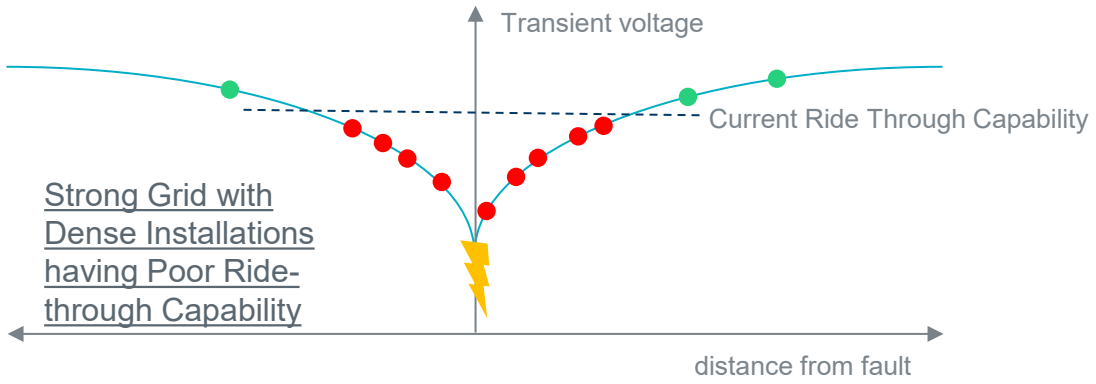


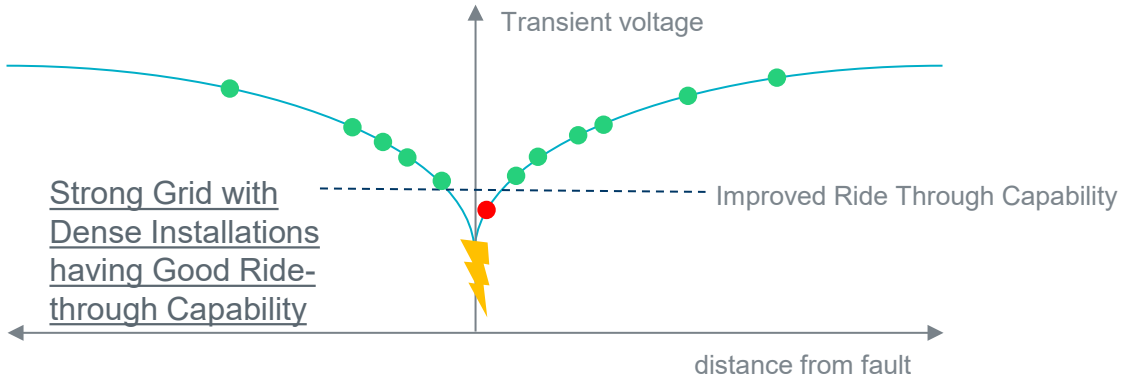
The area affected by the voltage dip is the same size as stronger grid, but there is more equipment concentrated in that smaller affected area

- Location of the fault
- Area affected by voltage dip resulting from the fault
- Equipment located outside the area of voltage dip
- Equipment located inside the area of voltage dip (may trip if unable to ride-through)

Key Takeaway: System upgrades can limit the area impacted by a fault, but there may still be a problem if too many generators or loads in an area cannot ride through.

Improved Ride-Through Capability will Reduce Risk

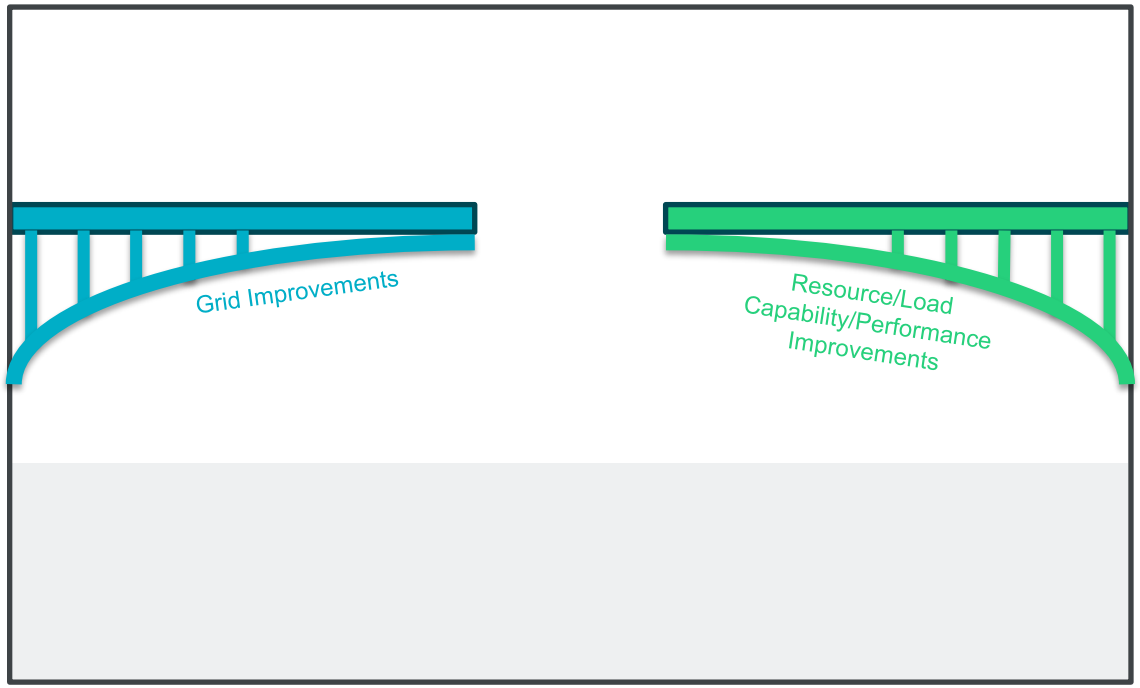




- If that amount of generation or load affected by the voltage dip is too high, it may cause instability or cascading if it does not ride through
- Improvement of ride through capability at each facility will reduce aggregate risk

Key Takeaway: Improved Ride-Through Capability is needed.

Need Coordinated Requirements between System and Users



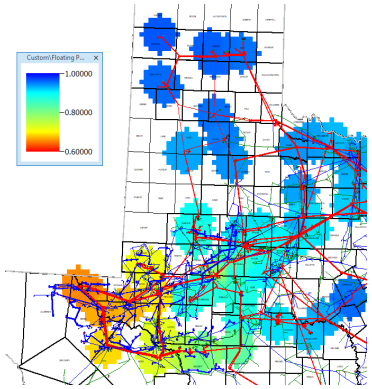
- As a bridge needs to meet in the middle, the System Planning and Operating Criteria needs to “handshake” with the requirements for Resource and Load capability and performance
- If there is a gap, it could result in load loss and, potentially, systemwide outages
- It does not appear to be feasible to sufficiently mitigate all of these dynamic issues from only one side of the bridge

Key Takeaway: Both grid upgrades and resource/load capabilities are needed to adequately address weak grid issues and avoid/mitigate dynamic events.

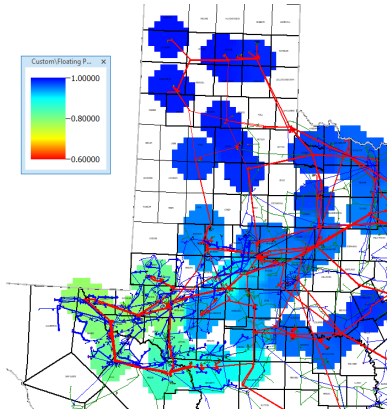
Improving Grid Strength

Synchronous Condenser Projects

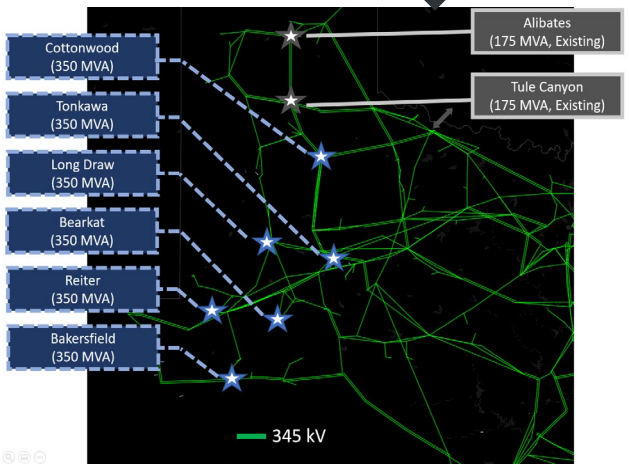
Late 2022 Study



Existing system

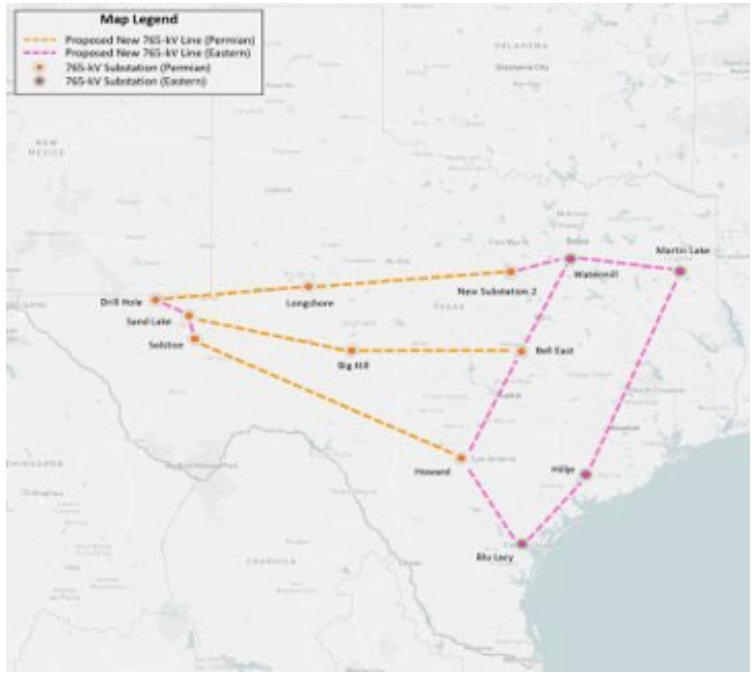


With 6 new Synchronous Condensers



One new synchronous condenser in-service in 2026; most in 2027

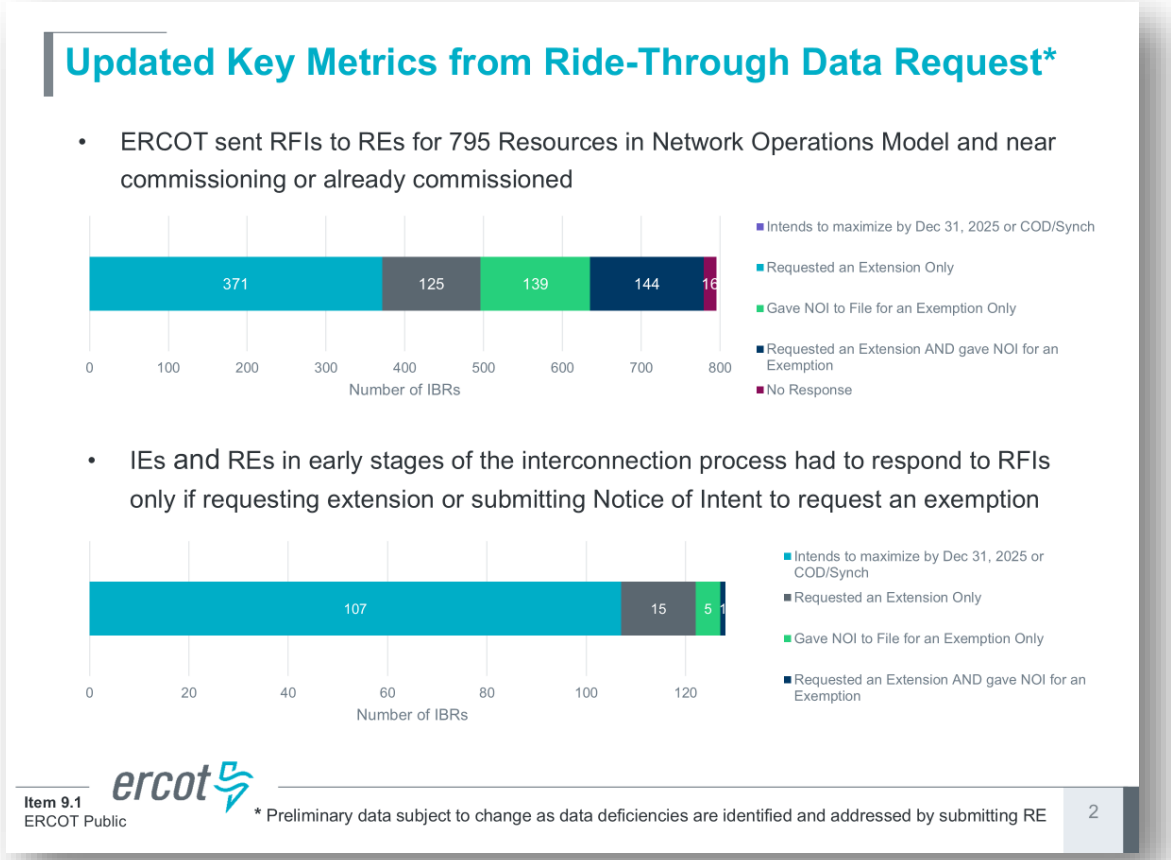
765kV Transmission Plan



Key Takeaway: Several grid improvements are underway that will help strengthen the system. However, these improvements cannot fully mitigate all of the risk.

Improving IBR Ride-through

- Approved NOGRR 245 in 2024 to require improved ride through and more accurate modeling by IBRs
- Resource Entities were required to provide updated models and plans to meet performance requirements by April 1, 2025
- ERCOT is reviewing submissions, as described in the System Planning report



Key Takeaway: Improvements are being made to IBR ride-through capabilities and the dynamic modeling thereof through the implementation of NOGRR 245.

Requirements/Incentives for Grid-Forming Inverters

Grid Forming Inverter Basics

- Existing IBRs are all "grid following," leading to stability issues in weak grid areas with a predominance of those IBRs
- Grid "forming" inverters have major benefits for stability and resilience
  - Can improve system voltage/frequency response and reduce event severity for both IBR and large load ride-through events
  - Moderately improve some GTC limits or, perhaps, avoid need for some existing and future GTCs, if ESRs in those areas are grid forming
- Energy Storage Resources (ESRs) with "grid forming" inverters that provide system strength are commercially available today
- Does not require changes to commercial operation (e.g. preserving headroom or state of charge) for ESRs

- ERCOT filed NOGRR272/PGRR121 to make grid forming capability a requirement for future ESRs
  - Will file NPRR with incentive program for existing IBRs which voluntarily add this capability
  - Does not preclude future revision requests to add paid services to use this capability *for other purposes, if needed in the future*

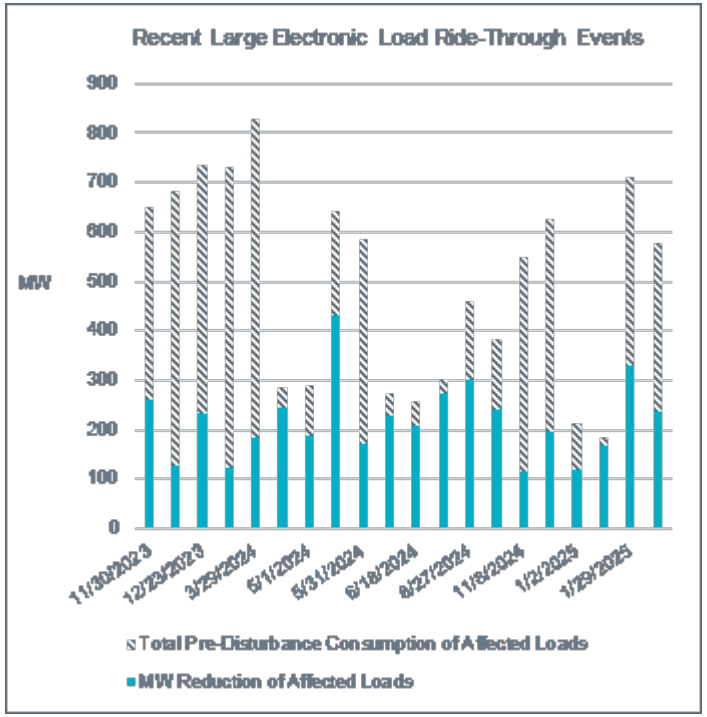
Key Takeaway: NOGRR272/PGRR121 need to move forward at September Board because number of ESRs expected to be added that need this capability.

Large Electronic Load (LEL) Ride Through Workshop

- Held workshop on June 13 to discuss:
  - Further description of the reliability risks associated with Data Center and Cryptomining Large Load ride-through failures and potential mitigation options;
  - Need for, and process for obtaining, more accurate models of the ride-through capability of Large Loads;
  - Need for changes to the Large Load Interconnection process to assess the joint ride-through impacts of multiple Large Loads in an area; and,
  - Methods for determining System Operating Limits that may impact operation of Large Loads that cannot ride through common system events.

Improving Ride-Through Modeling and Performance of LELs

- Current models provided through TSPs from LELs do not seem to appropriately model ride-through behavior, based on experienced events
- Recent studies are assuming ITIC curve, but individual LELs may have ride through capability that is better or worse than that curve
- ERCOT will be requiring TSPs to work with their interconnected LELs to obtain more accurate and complete dynamic models and parameters
- ERCOT will be adding a step to the Large Load interconnection process to more fully study clusters of LELs earlier in process
- ERCOT will be developing a ride-through standard for LELs that TSPs can require of their interconnecting LELs
- ERCOT will continue to approve planning studies and energization plans for LELs with demonstrated ride-through capability

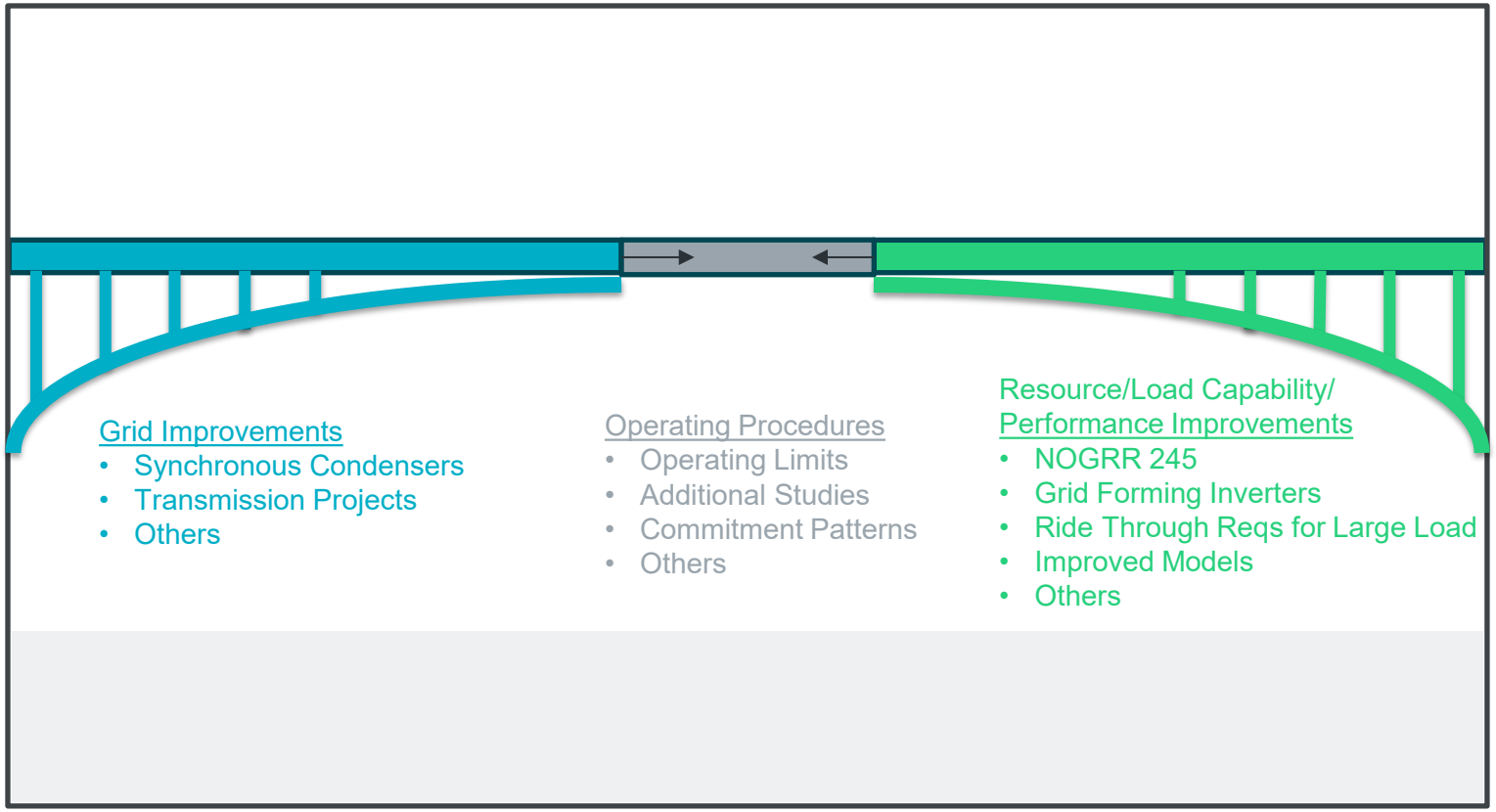


Key Takeaway: Improved models of LELs, based on observed events. Improvements will be developed and proposed to require better ride-through requirements for LELs and improved cluster studies earlier in interconnection process.

Maintaining Operational Reliability

- ERCOT is considering multiple operational initiatives to avoid or withstand LEL ride-through events to continue to add these loads reliably:
  - Include load trips in determining operating limits
  - Define new operating limits based on unacceptable amount of load reductions
  - Consider benefit of synchronous generation commitment in weak grid areas
  - Consider need for additional “down” Ancillary Service
  - Increase critical inertia level
  - Perform additional high-frequency studies for range of operating conditions
- Note that these are only items under consideration and may not be implemented if they are not found to be effective or efficient, and other potential solutions may also be considered

Building the Bridge



Key Takeaway: By continuing to resolve identified issues and implement grid solutions AND improved capabilities by Resources and Large Loads, we can maintain system reliability while supporting continued changes to the grid.

Questions?