OAK RIDGE National Laboratory

# Before Clicking Run: Quality and Goals of EMT

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ERCOT

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U.S. DEPARTMENT OF ENERGY

# Typical Use for EMT Studies in ERCOT

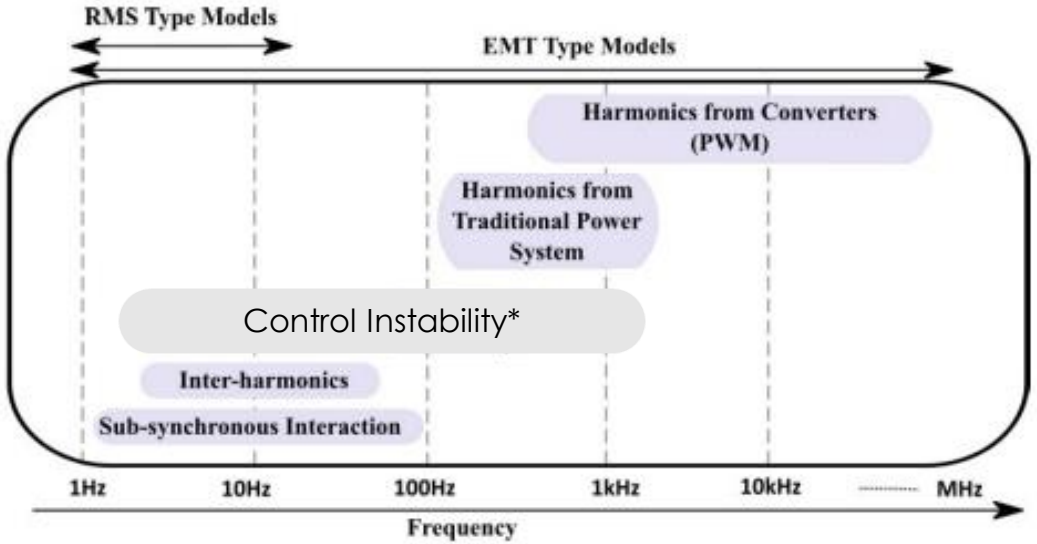
- Subsynchronous Oscillation studies
- Weak Grid / Low Short Circuit Ratio studies
- Model Accuracy Verification
- Ride Through Performance Verification

# History of EMT Modeling in ERCOT

- 2009: Subsynchronous oscillation event with wind farm
- 2009 – 2015: CREZ Transmission Plan studies, EMT analyze subsynchronous resonance (SSR) and voltage imbalance (Summary)
- 2011: First subsynchronous oscillation (SSO) of inverter resource studies
- 2013: EMT models required for IBRs connecting near series capacitors
- 2015: EMT models required for all new IBR interconnections (DWG Procedure Manual 3.1.2)
- 2016: Panhandle PSCAD System Strength Study (Link), updated 2018, 2020
- 2021: PSCAD Model Quality & Hardware Benchmark Requirement (DWG Manual 3.1.5-3.1.6)
- 2023: Grid-forming inverter studies → ERCOT looking at benefits
- 2023: PSCAD model & grid disturbance benchmarks

# Challenges with Phasor-Domain ("Dynamic" Stability) Studies

- The Texas Panhandle was identified as having a stability limit caused by **low short circuit ratio** in 2014-2015.
  - This limit was collaborated using EMT studies.
- Dynamic model accuracy concerns
  - Incorrect parameterizations, generic model simplifications
  - Benchmarking EMT models v. RMS models
- Voltage Ride Through study accuracy
  - Odessa event identified various protections that are not typically modeled in RMS models but may be more likely modeled in EMT.

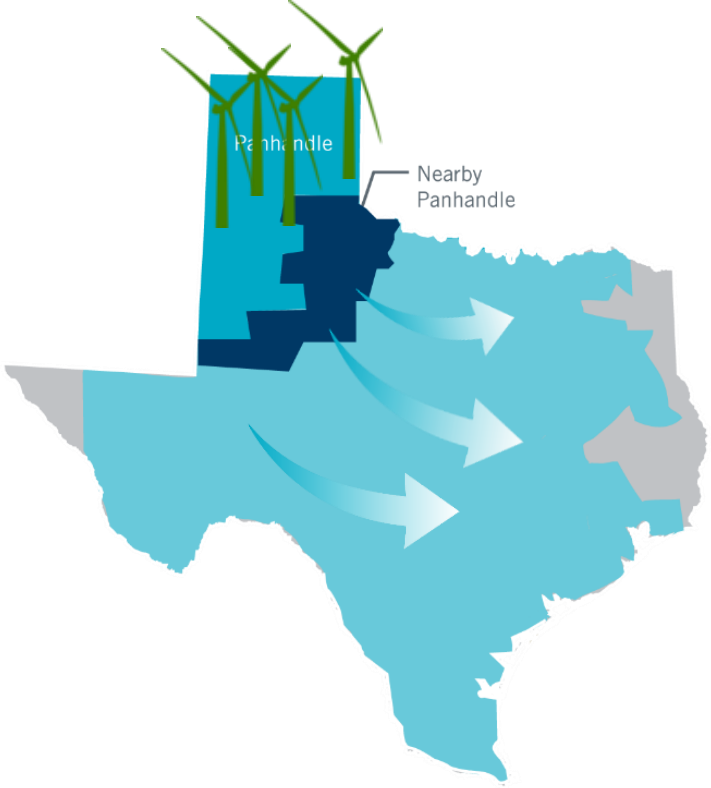


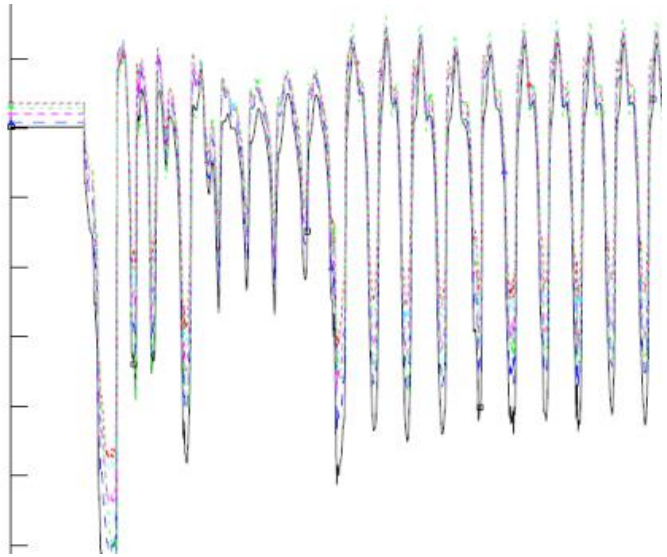

Dynamic phenomena and applicability to different tools, from [1]. Note that similar but varying figures appear in literature, for example showing Control Instability extending into RMS type models, thus I have modified the original figure*.

[1] Subedi, Sunil; Rauniyar, Manisha, "Review of Methods to Accelerate Electromagnetic Transient Simulation of Power Systems", IEEEAccess, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9459192

# ERCOT Panhandle Study

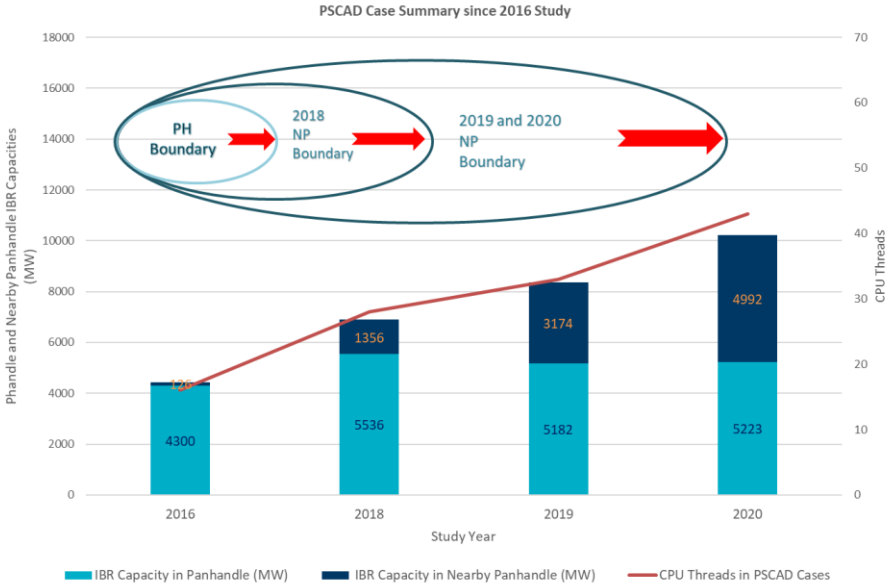
- High IBR Penetration (>10 GW) in/near Panhandle
  - Long distance to load → high impedance
  - Few nearby synchronous generators → low system fault current
- Panhandle exhibits weak grid
  - Low WSCR (weighted short circuit ratio) and high ΔV/ΔQ ratio
  - High frequency oscillation / numerical instability in PSS/E
  - Voltage overshoot, overvoltage tripping after fault
- EMT studies performed 2016, 2018, 2019
  - Verify 1.5 WSCR criteria for stability
  - Verify PSS/E benchmarks well under this WSCR value
    - Permits continued usage of PSS/E for everyday studies
- Panhandle strengthened with Lubbock Integration
  - New transmission and load → removed the 1.5 WSCR stability limit

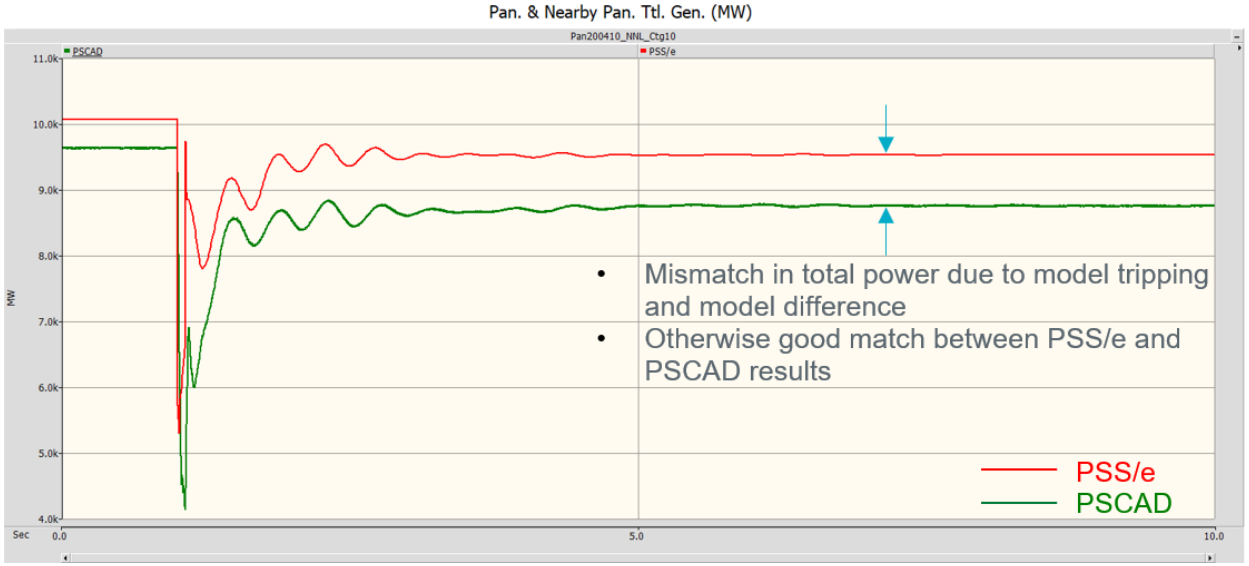


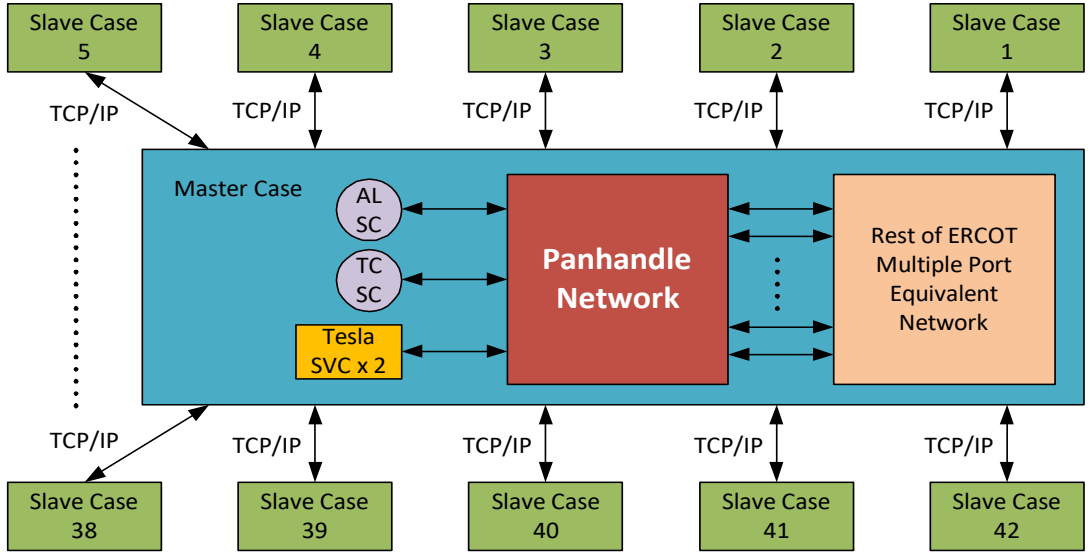



# ERCOT Weak Grid EMT Studies

- Periodic PSCAD studies
  - To assess instability that may not be visible in RMS
  - To confirm adequacy of dynamic models
  - To confirm application of WSCR threshold
- Large area cases
  - Sufficient for study not to include entire ERCOT system in EMT



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# Approach: EMT Simulation for Interconnection Studies

- EMT studies have generally not been considered necessary for interconnection
  - (with exception of subsynchronous oscillation studies)
- However, EMT models are used for:
  - Model verification
  - Voltage Ride Through confirmation

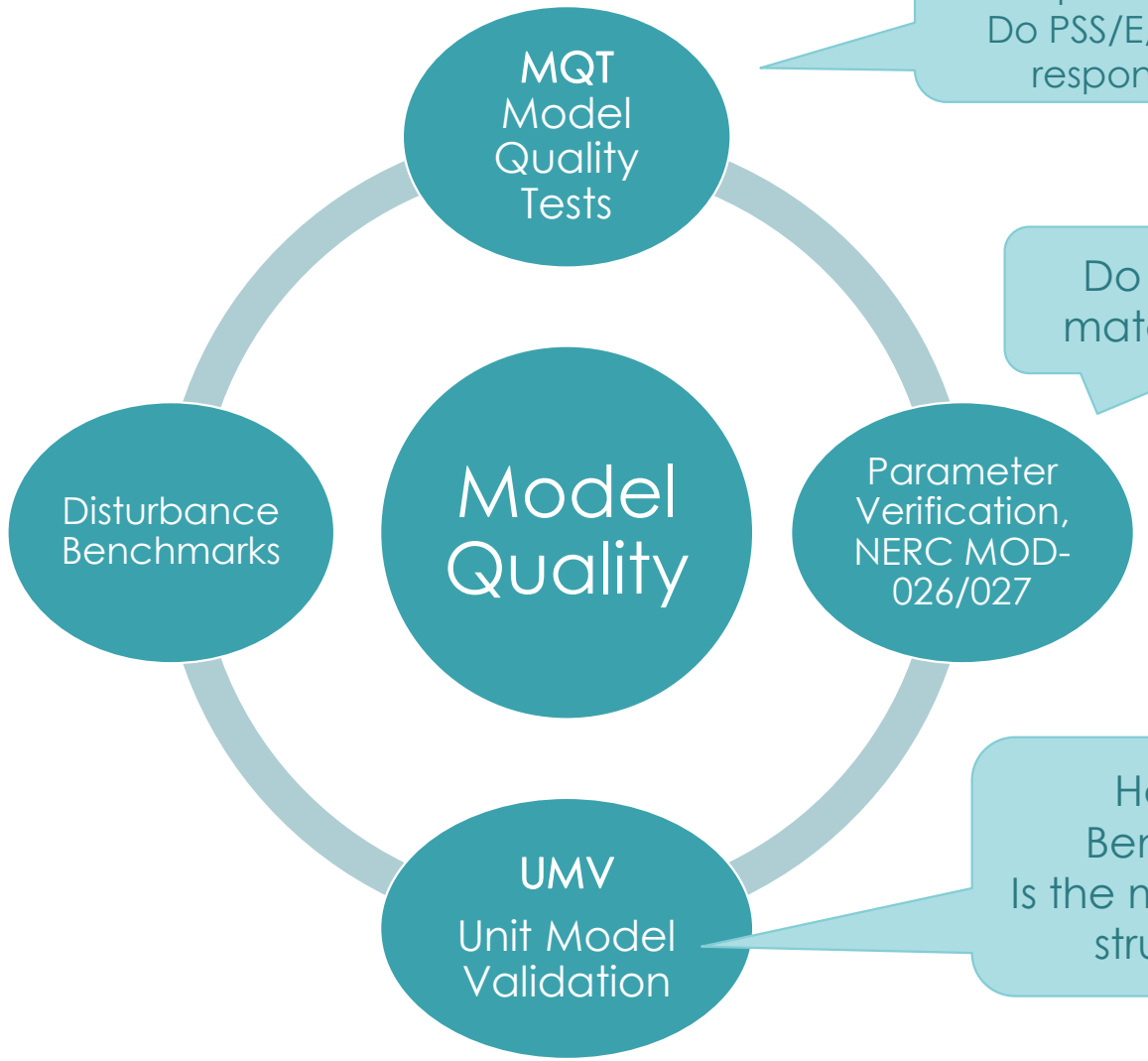
Public Domain Image credit: https://www.goodfreephotos.com/

# ERCOT's Model Quality Process

→ *Generator owners must submit proof to ERCOT of model quality*

**ERCOT**
Model Quality Guide

Site Direct Link



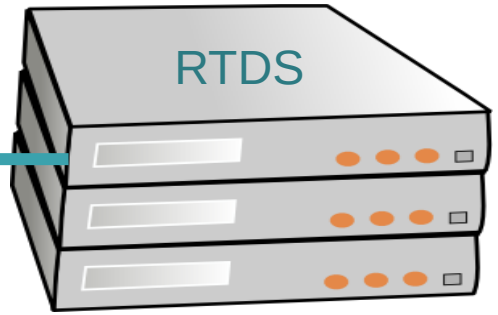

Model rules: Planning Guide sections 5.5, 6.2, DWG Procedure Manual section 3

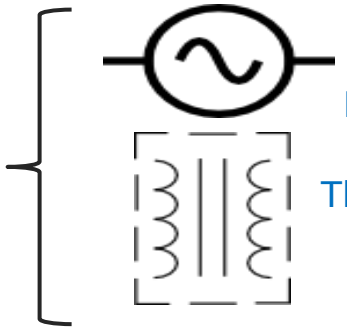

8

# EMT - Hardware Benchmarking Requirement

- Called "Unit Model Validation" (UMV)
  - Required for new projects after 3/1/21 once during the interconnection process
  - Non-site-specific hardware benchmarking report.
  - Generally performed in OEM's laboratory using default settings.
    - Usually performed once for a certain model or family of inverters.

Control Board from IBR



*HIL, "Hardware in the Loop":* (Rest of IBR represented virtually in Real-Time Digital Simulator)…
This is permitted but less valuable than a full-scale test

- Successes:
  - Identified an inaccurate subsynchronous PSCAD model
  - Has identified a ride through performance model accuracy issue

- Overall, most PSCAD models easily pass the UMV benchmarking

# Parameter Verification for Model Accuracy

- Augments MOD-026/027 for stronger model accuracy
  - MOD-026/027 benchmarks model measurements
  - Parameter verification checks that model parameters match equipment settings

- Either PSCAD or PSS/E model acceptable to verify
  - ERCOT requires verification of site-specific / tunable parameters and protection settings

Example:

- *"On 3/1/2023, plant personnel checked plant equipment. These were compared against model parameters."*

| Parameter | Model | Field | Match? |
|---|---|---|---|
| Kiv (PPC) | 2.0 | 2.0 | ✓ |
| Hz1 (Protection) | 58.6 | 58.9 | ✗ |
| Tw1 (Stabilizer) | 0.02 | 0.02 | ✓ |

(Shortened table for illustration; all tunable / site-specific parameters should be verified.)

*Many model inaccuracies are caused by incorrect parameters.*

*This year, all plants were required to submit verification reports. Several showed at least one inaccurate parameter.*

# ERCOT Model Quality Testing

**Benchmark RMS versus EMT**

- Generator owners must submit MQT reports with model updates, demonstrating model performance to standard disturbances
- ERCOT compares PSS/E, TSAT, and PSCAD performance for match
- Unit Model Validation (hardware benchmark) requires similar tests plus subsynchronous impedance

(Tests and criteria defined in DWG Procedure Manual chapter 3.)

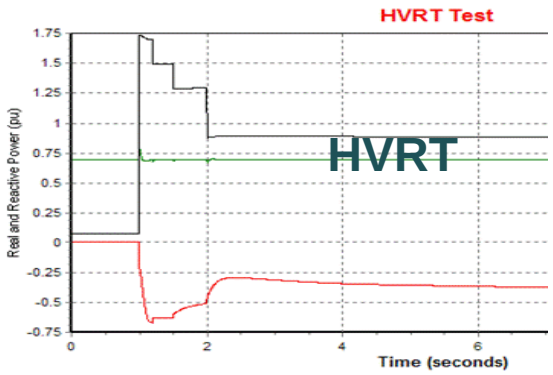
**7 Tests for IBRs:**

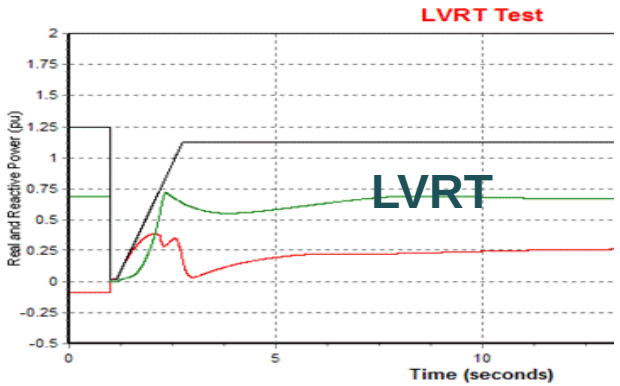
**HVRT LVRT Voltage Step (+/-) Frequency Step (+/-) Short Circuit Ratio**

- PSCAD models also check angle step

**5 Tests for Synchronous:**

**Voltage Step (+/-) Frequency Step (+/-) Fault**



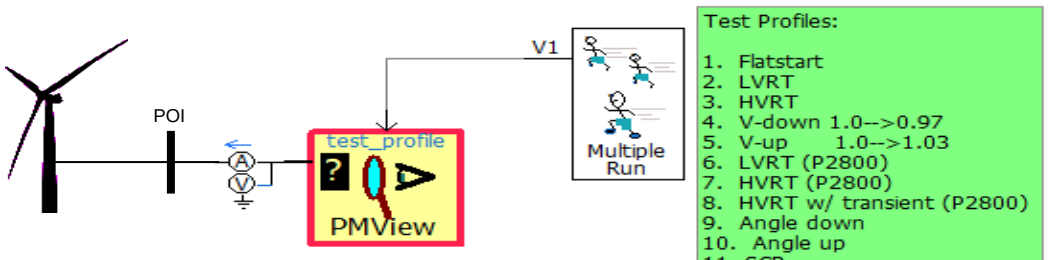



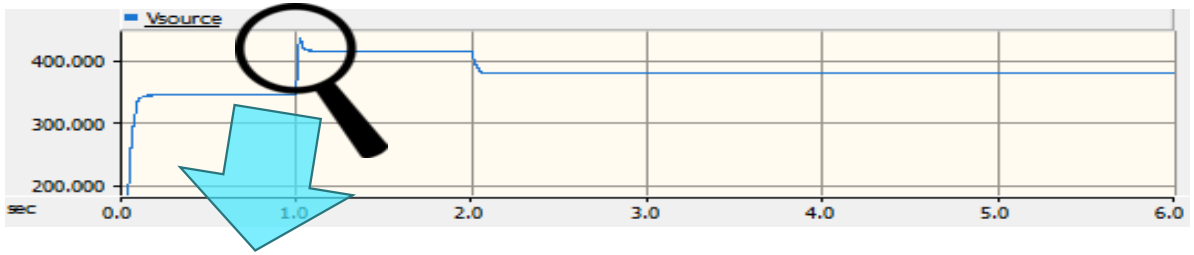

ERCOT will revise tests as needed per rule proposal NOGRR245 to align with IEEE 2800.

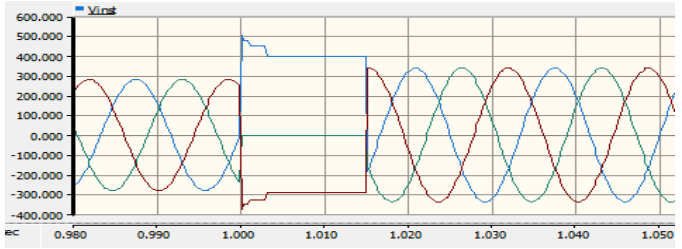
# Testing Tools

- To facilitate testing, ERCOT publishes two tools. Use of the tools is not required.
  - DMVIEW for PSS/E and PMVIEW for PSCAD
    - Tools can test a variety of customizable profiles (voltage / angle / frequency). PMVIEW can test IEEE 2800 transient as well.
    - Available: https://sites.google.com/view/pmview/home (Video tutorials on website!)

## PMVIEW, PSCAD Model Test




PMVIEW running
Test #8, HVRT w/ IEEE 2800 Transient



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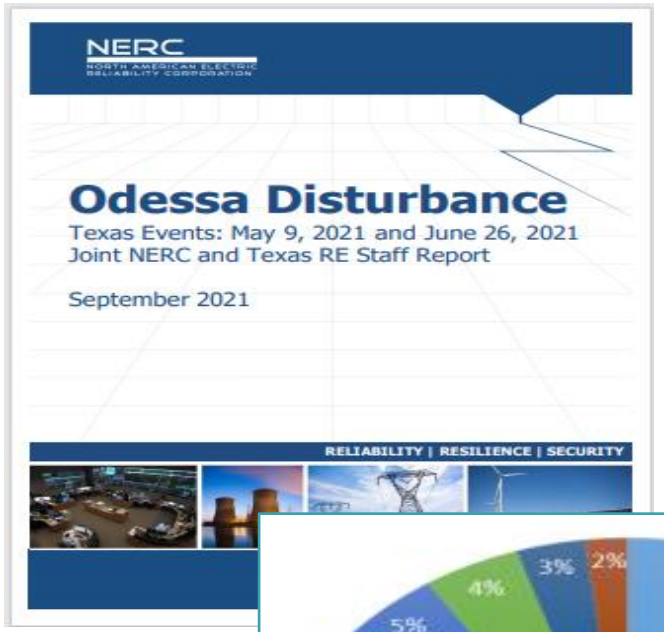
12

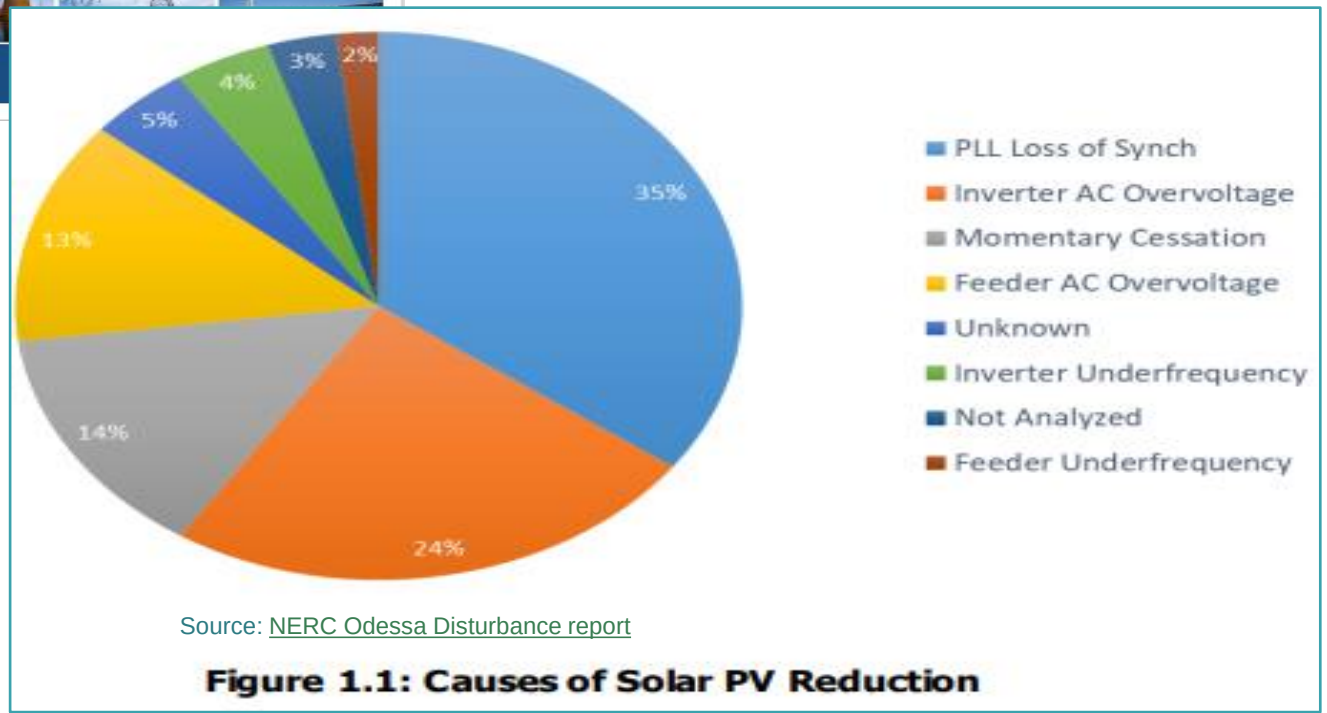
# Odessa Event and Ensuring Ride Through

https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_2022_Odessa_Disturbance_Report%20(1).pdf




- Many of these model requirements were coming into force when the Odessa event happened. Most of the involved generators had not previously been evaluated under these new model requirements.

- The majority of Odessa ride through issues were caused by inverters tripping
  - EMT MQT testing may help identify certain ride-through issues.




Source: NERC Odessa Disturbance report

**Figure 1.1: Causes of Solar PV Reduction**

These protections/functions should generally be modeled. Refer:

**ERCOT**
**PSCAD Modeling Requirements,**
Part of the
Model Quality Guide

Site Direct Link

Feeder & other protection should be modeled if may cause tripping. Sometimes such protection is designed for internal faults but is mis-coordinated.



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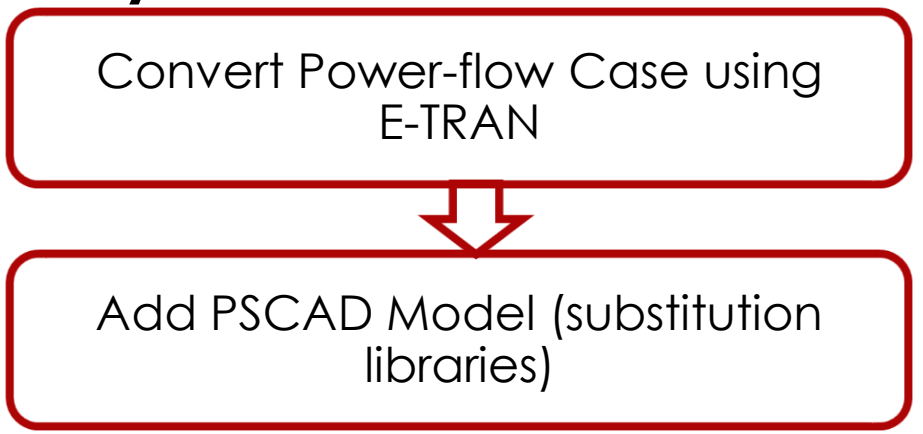
13

# ERCOT Area Studies (currently Ad-Hoc)

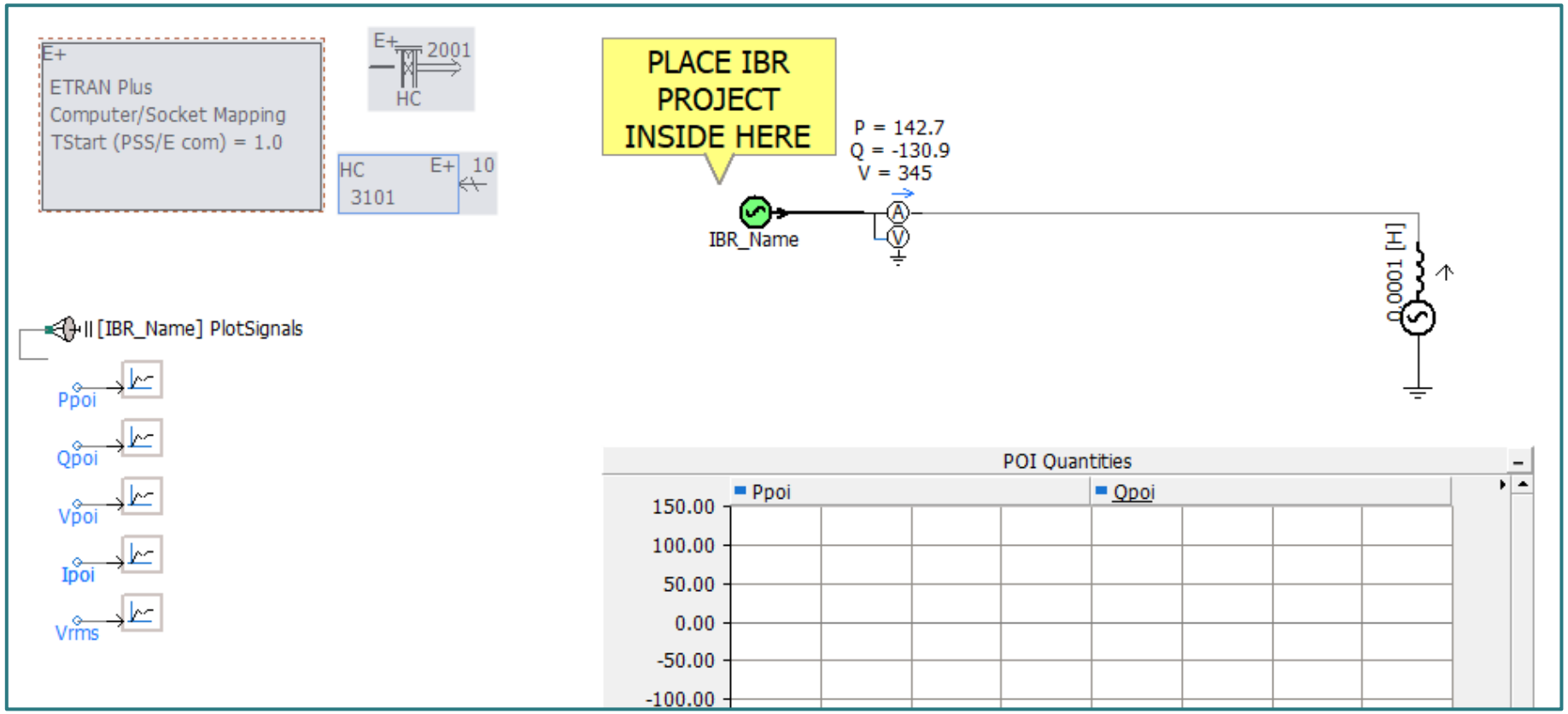
PSCAD Model Templates to the Rescue!



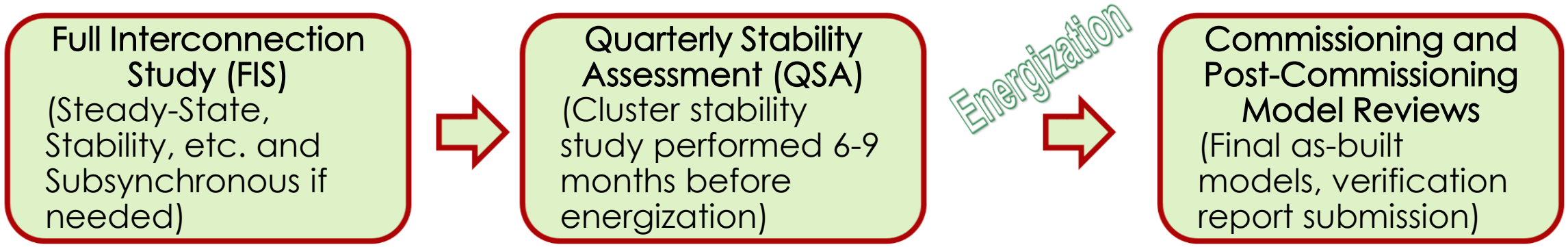

- Making this process easier with PSCAD model Templates
  - ERCOT is rolling out PSCAD model templates that double as E-TRAN substitution libraries
  - Thus, generator owners submit models which can be plugged into a larger simulation with less effort
  - Gen owners must also submit MQT reports, demonstrating their model yields acceptable performance

# ERCOT's PSCAD Model Template

- Undergoing implementation; plan to require gen owners to submit PSCAD models in this format
- Template doubles as an E-TRAN substitution library
- Keeps generator models organized into a single block that can be pasted into a larger case



# ERCOT's Queue-less Interconnection Study Process




If no subsynchronous study, then EMT models are typically checked at QSA. This has caused a lot of rushed modeling issues. Perhaps a solution would be to check EMT models earlier at the FIS stage. Even if EMT models are not used for FIS studies, an EMT benchmarking helps ensure that the RMS dynamic stability models are accurate.

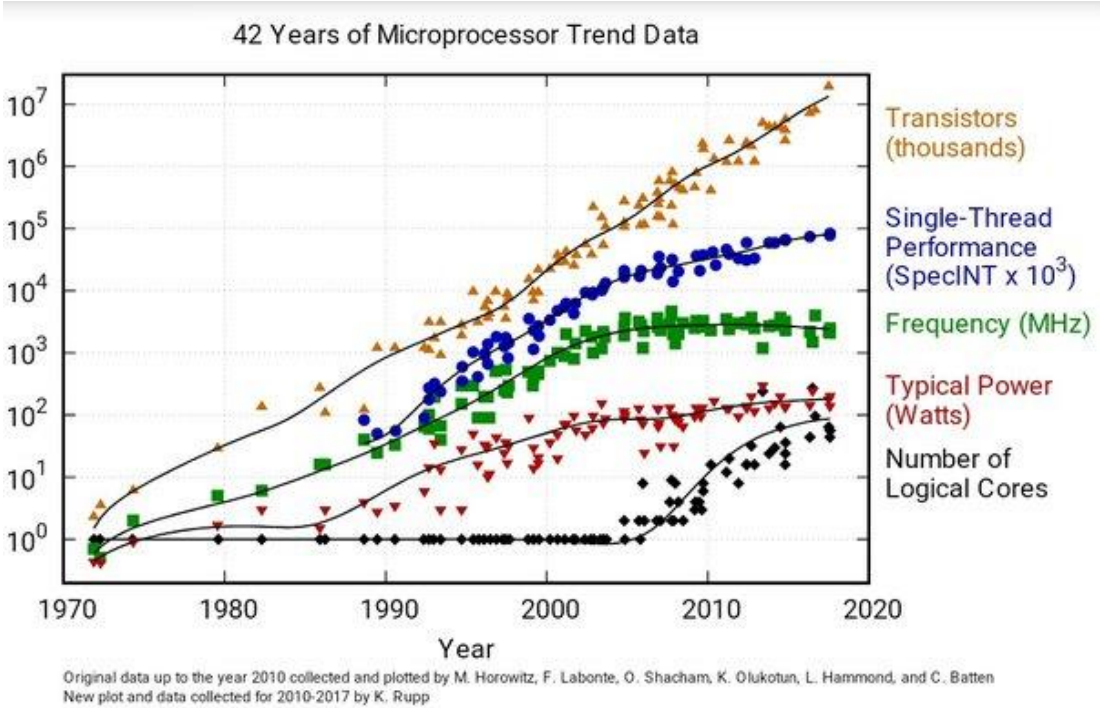
# Lessons Learnt

- Models must be checked for quality.  Simply asking for models is not enough!
- PSCAD models sometimes received with incorrect parameters.  Verification helps ensure that models receive site-specific settings.
- ERCOT's PSCAD Model Requirements, part of Model Quality Guide
  - https://www.ercot.com/services/rq/re
    - Download "Model Quality Guide".  Open the "PSCAD Guideline" document.

PSCAD Requirements

# Gaps & Challenges Observed (Not Solved Yet)

- EMT model usability / efficiency is still a challenge
  - Multi-parallel computers are great, but the simulation will only run as fast as the slowest model (depends on raw CPU clock speed and model time-step)
    - ERCOT requiring models to support 10µs – 20µs timestep
    - Majority of models do not support the "snapshot" feature. Thus, first ½ hr simulating each contingency is "wasted" (duplicated effort)
    - Models built utilizing real firmware code have difficulty accommodating snapshot feature and timestep flexibility
  - Setting up the initial reactive flow of EMT models is particularly difficult
- Simulations taking 1-2 hrs per contingency are common. And that's after parallel computing!
  - For most ERCOT studies, a 5.5 GHz 20 core computer would probably run faster than a 3 GHz 200 core computer
  - A typical ERCOT study has limited number of runs (contingencies x scenarios). (20 to 100, typically).
  - A typical study may take a few weeks setting up and one week running. Still requires a large amount of manual labor → EMT is used judiciously!




Single Thread Performance determines speed of slowest model and hence overall simulation. Performance has somewhat plateaued.

- Benefits of building your own 6.5 GHz over-clocked liquid cooled computer versus purchasing a cloud subscription?