

EMT Models and Study Needs



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8/24/2023

Energy Systems Integration Group



- Energy Systems Integration Group is a non-profit membership-base educational association that provides workshops, discussion forum, resources and education on the evolving electricity and energy systems.
- ESIG supports engineers, researchers, technologists, policymakers and the public with the transformation of energy systems in a way that is economic, reliable, sustainable, thoughtful and collaborative.
- Through a number of working groups ESIG facilitates member discussions on the latest challenges related to energy systems transformation.
- ESIG independent and trusted, forward leaning but not advocating, keeping everyone at the table



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EMT Studies Historically



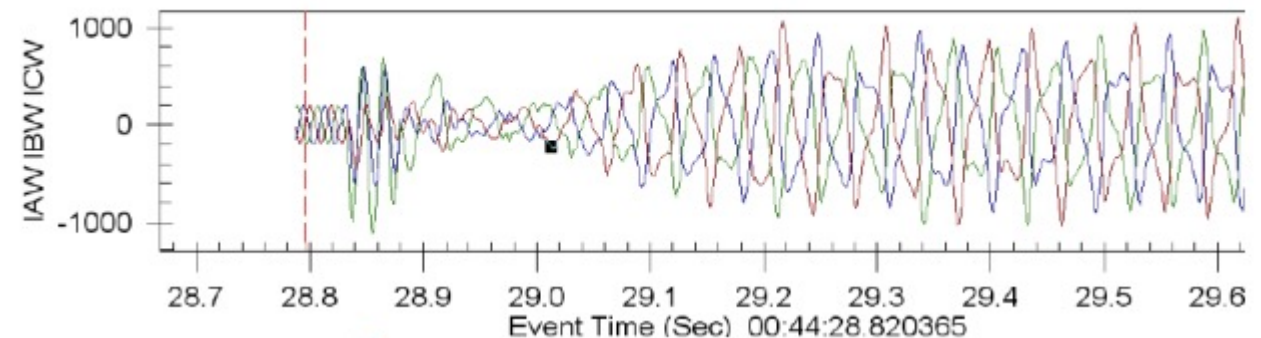
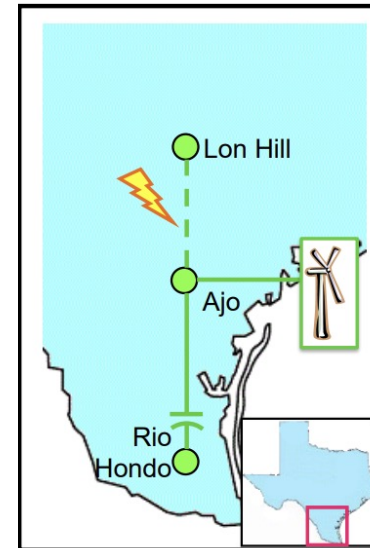
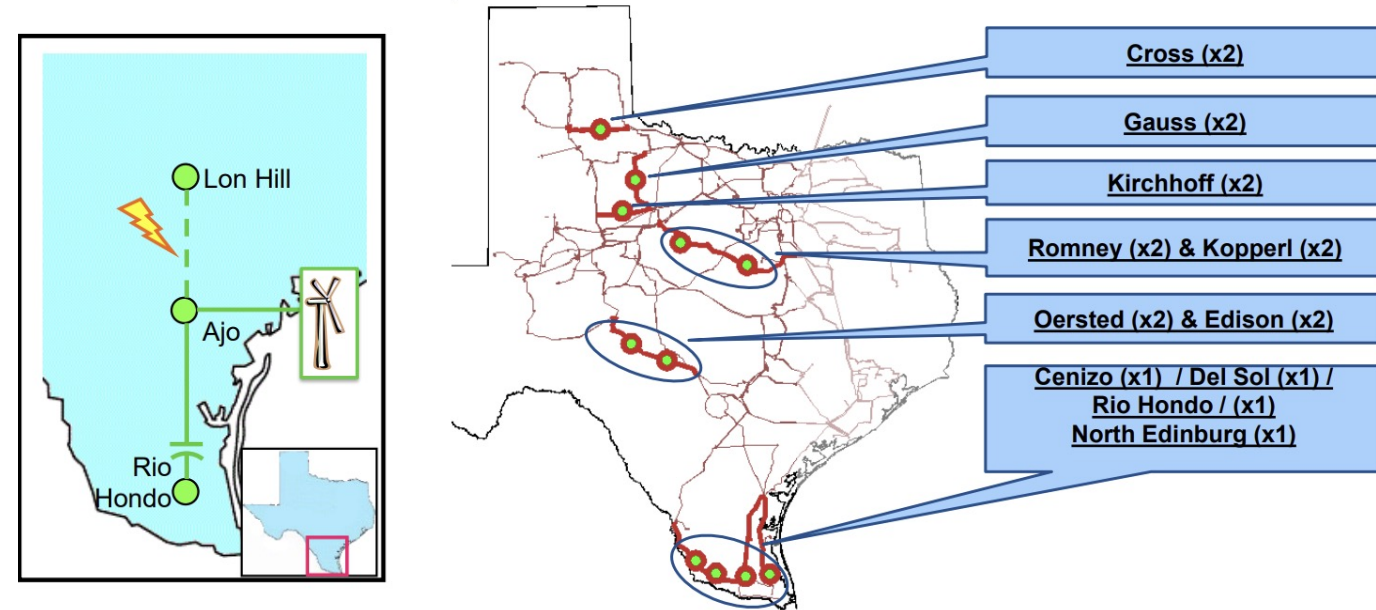
Previously, EMT analysis was used for specific very local phenomena:

- Lightning evaluation
- Insulation coordination
- Transformer & line energization
- Line switching/energization
- Harmonic analysis
- Sub-synchronous resonance
- HVDC/FACTS control design and analysis

With growing shares of power electronic devices, application of EMT analysis is becoming broader (, SSR/SSCI, weak grid interactions, fault-ride through evaluation, etc.) and larger parts of the grid may need to be included.

Interest in EMT with Growing shares of IBRs: SSR/SSCI Studies

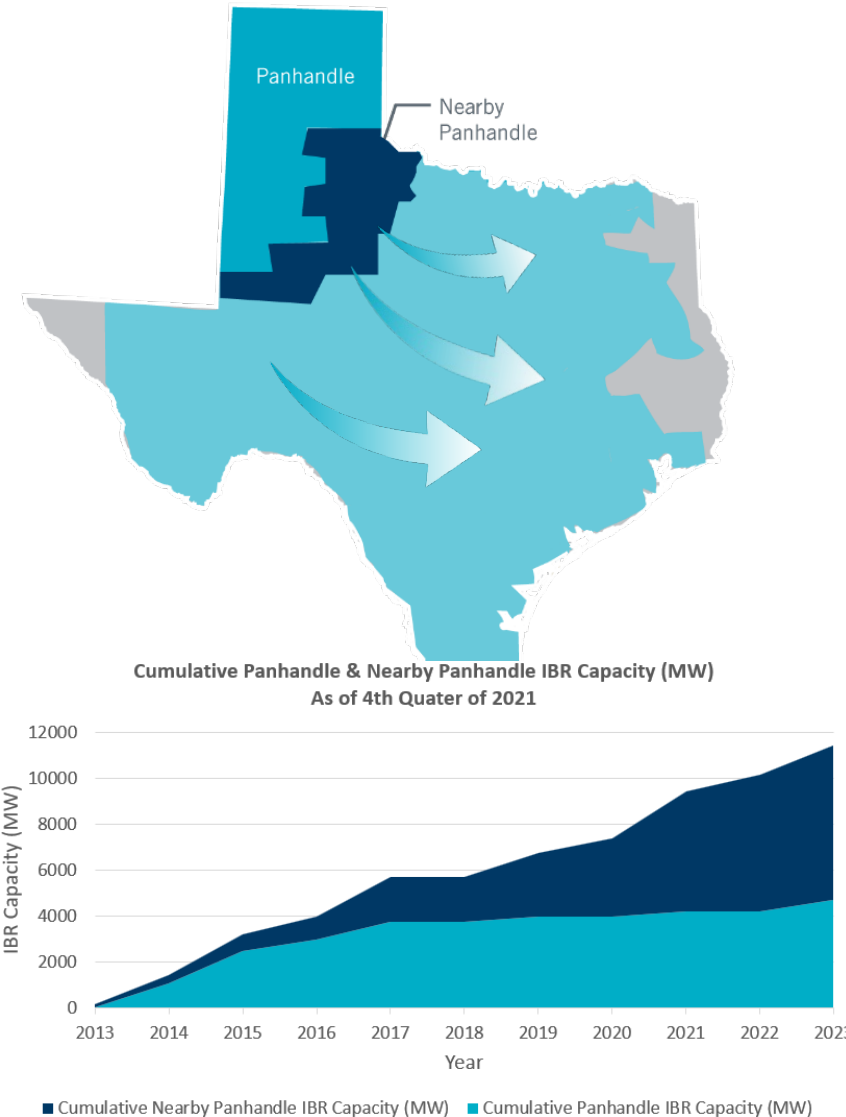
- South Texas events in 2009 and 2017
- Sub-synchronous control interactions between radially-connected series capacitors (after outage) and Type III wind generation resource
- Since 2013, ERCOT requires SSR study, if N-x set of contingencies is leading to radial connection with series capacitor
- SSR study includes running EMT analysis for limited set of contingencies (identified through frequency scan)
- Requirement for EMT models of involved generation resources



Interest in EMT with Growing Shares of IBRs: Weak Grids



- Remote from synchronous generators and load centers
- GWs of power export
- All inverter-based resources (IBR)
- IBR capacities keep growing
- Challenges and Needs:
 - Voltage stability (phasor-domain tools)
 - Control stability (EMT tools)
- [Panhandle renewable energy zone study report](#) , 2014 (phasor-domain)
- [System Strength Assessment of the Panhandle System PSCAD Study](#), 2016 (EMT and phasor domain)
- [Panhandle and South Texas Stability and System Strength Assessment](#), 2018 (EMT and phasor domain) – recommended periodic EMT assessment, requirement for provision of EMT models followed



Source: [Xiaoyu \(Shawn\) Wang](#), "EMT Modeling and Studies in ERCOT", ESIG Fall Technical Workshop, 2021

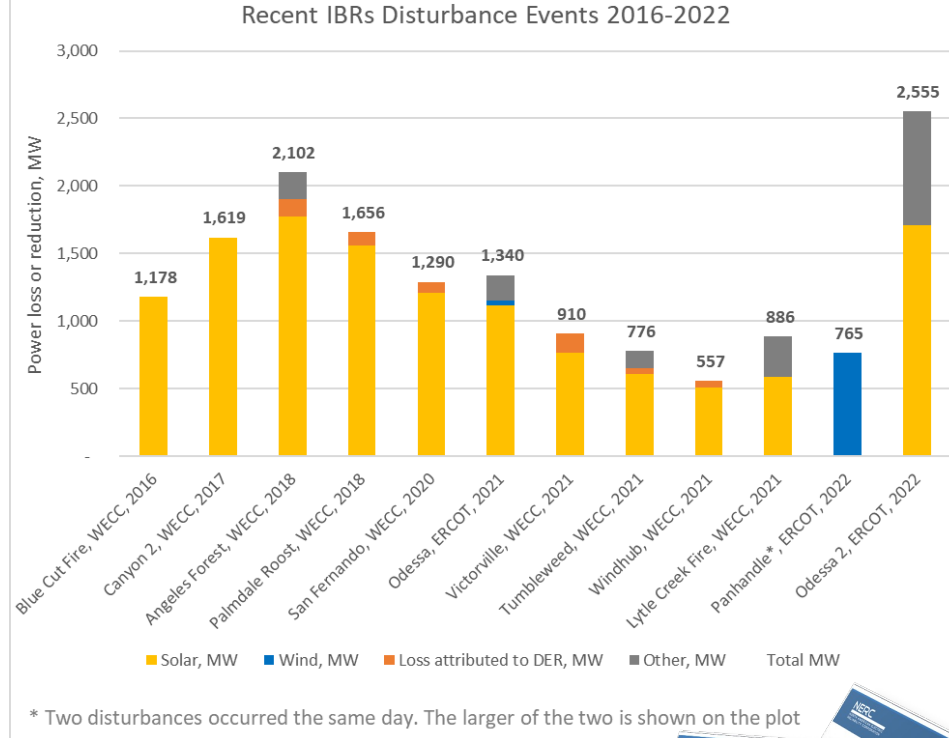
NERC Disturbance Events – Importance of Fault Ride-Through Evolution and Model Accuracy



Table 1.1: Causes of Solar PV Active Power Reductions		
Cause of Reduction	Odessa 2021 Reduction [MW]	Odessa 2022 Reduction [MW]
Inverter Instantaneous AC Overcurrent	–	459
Passive Anti-Islanding (Phase Jump)	–	385
Inverter Instantaneous AC Overvoltage	269	295
Inverter DC Bus Voltage Unbalance	–	211
Feeder Underfrequency	21	148*
Unknown/Misc.	51	96
Incorrect Ride-Through Configuration	–	135
Plant Controller Interactions	–	146
Momentary Cessation	153	130**
Inverter Overfrequency	–	–
PLL Loss of Synchronism	389	–
Feeder AC Overvoltage	147	–
Inverter Underfrequency	48	–
Not Analyzed	34	–

* In addition to inverter-level tripping (not included in total tripping calculation.)

** Power supply failure



* Two disturbances occurred the same day. The larger of the two is shown on the plot



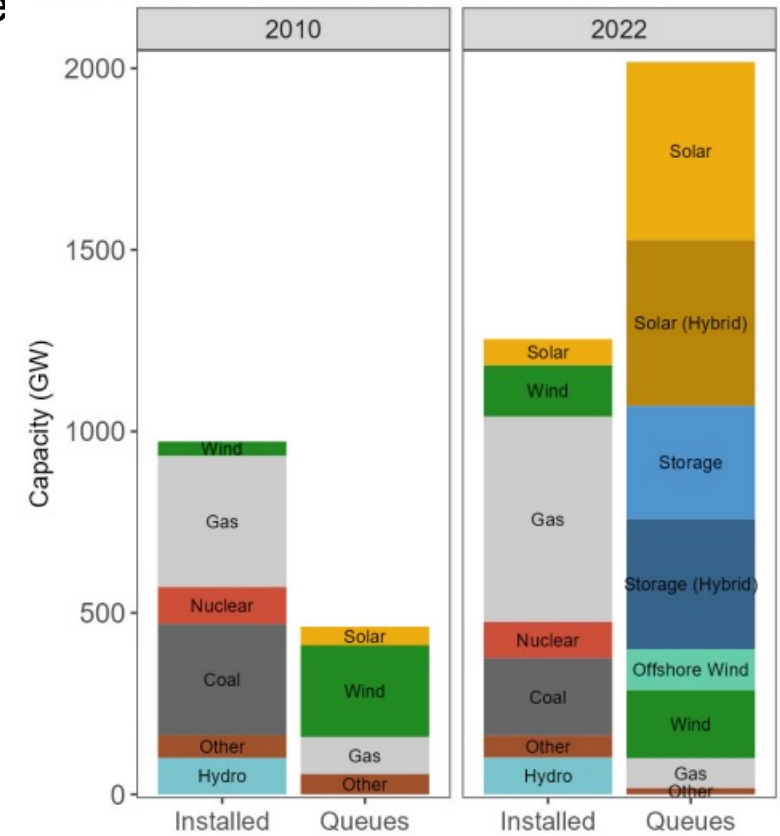
Source: [NERC Event Reports](#)

Importance of EMT Models



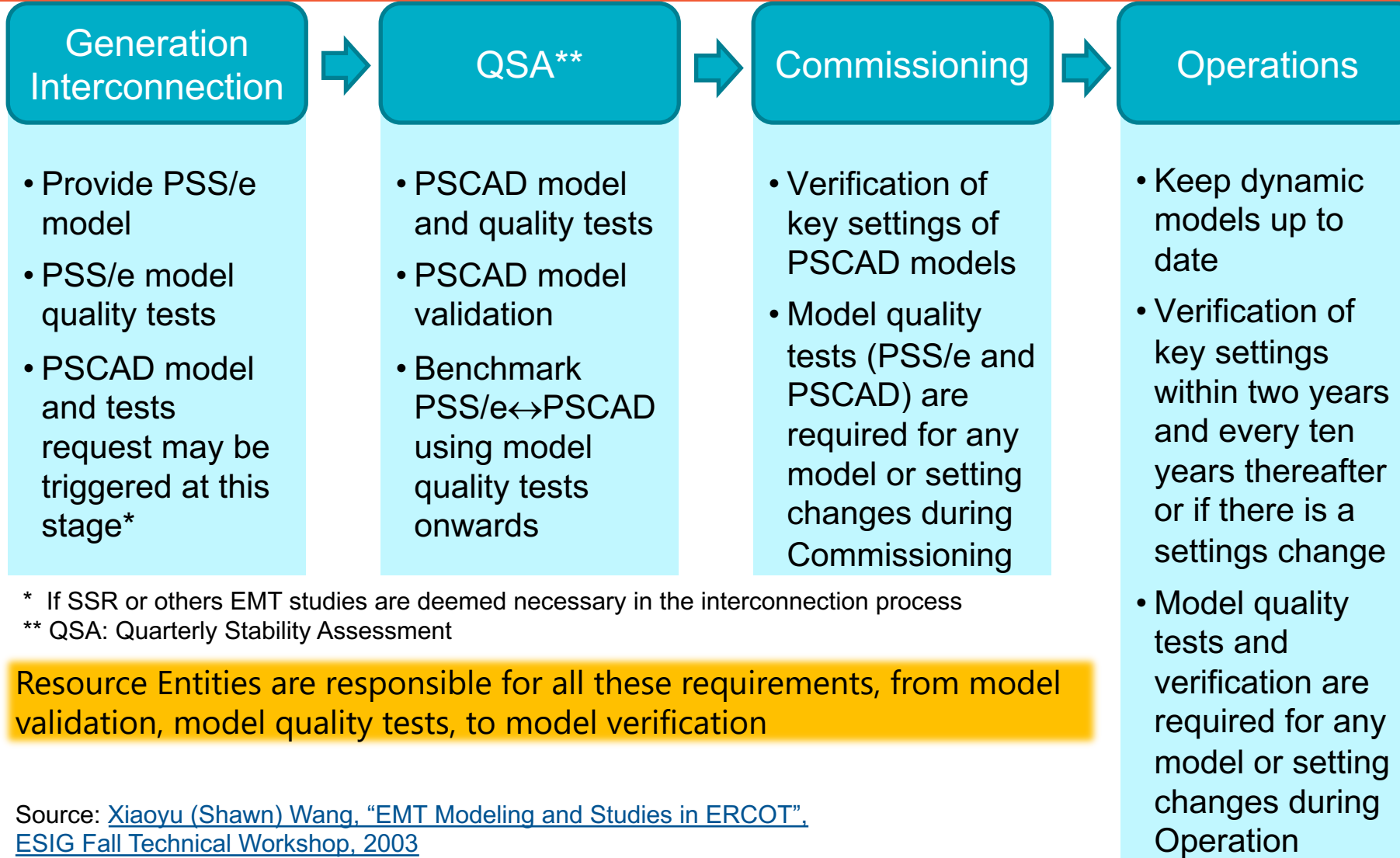
- Over 2000 GW of total generation and storage capacity in the U.S. interconnection queues, as of the end of 2022, of which over 96% are inverter-based resources (IBRs)
 - 947 GW of Solar
 - 300 GW of Wind
 - 680 GW of Storage
- EMT models are important not just for EMT studies but for IBR conformity assessment with applicable interconnection requirements and benchmarking with phasor domain models
- Only a few areas in the U.S. currently are collecting EMT models during interconnection process
- Manufacturers are discontinuing products or going out of business – EMT models are hard to obtain at that stage
- Missed opportunity of post-commissioning model validation
- **By the time EMT study is needed collecting models is too late!!!!**

Entire U.S. Installed Capacity vs. Active Queues



Source: LBNL, [Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection](#)

Detailed Models ≠ Accurate Model Need for EMT Model Validation



Is the model:

- **Accurate**
- **Usable**
- **Site-Specific**
- **Performance** conforms with interconnection requirements?

* If SSR or others EMT studies are deemed necessary in the interconnection process

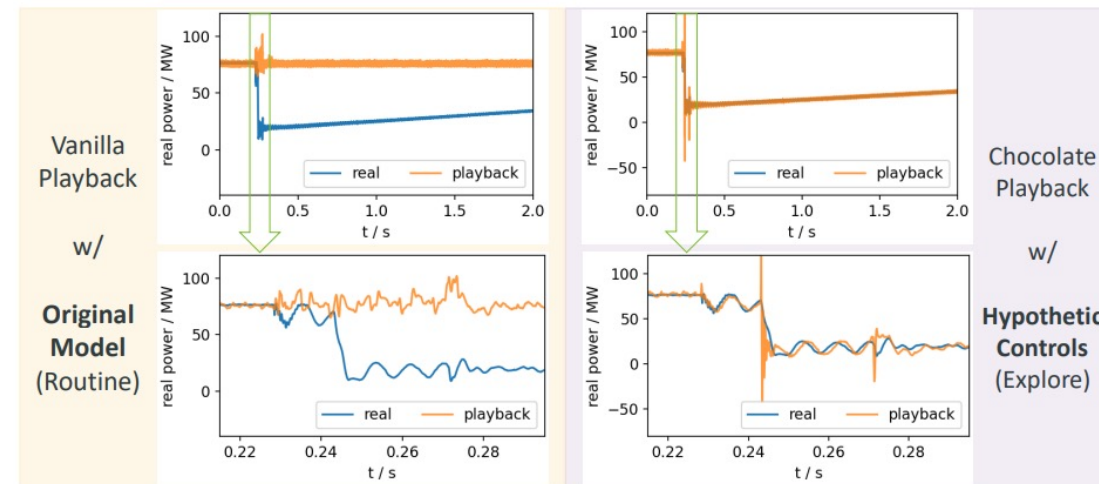
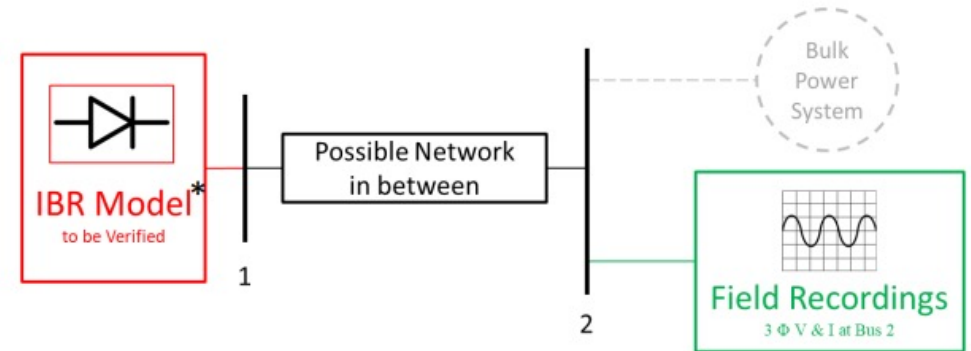
** QSA: Quarterly Stability Assessment

Resource Entities are responsible for all these requirements, from model validation, model quality tests, to model verification

Post-Commissioning Model Validation is in Early Stage



- High resolution data recording on site is normally not required or may not be set appropriately to capture the events of interest
- Even if recorded, event data is at the site and may be overwritten
- IEEE 2800 data recording and retention requirements and IEEE P2800.2 proposes a procedure for capturing data and performing phasor domain and EMT model validation
- ERCOT developed a proposal (NOGRR255) for data recording and retention aligned with IEEE 2800, Table 19.
- At NERC IRPS and IEEE PES GM, ISO-NE has presented an example of an EMT model validation of a PV plant.

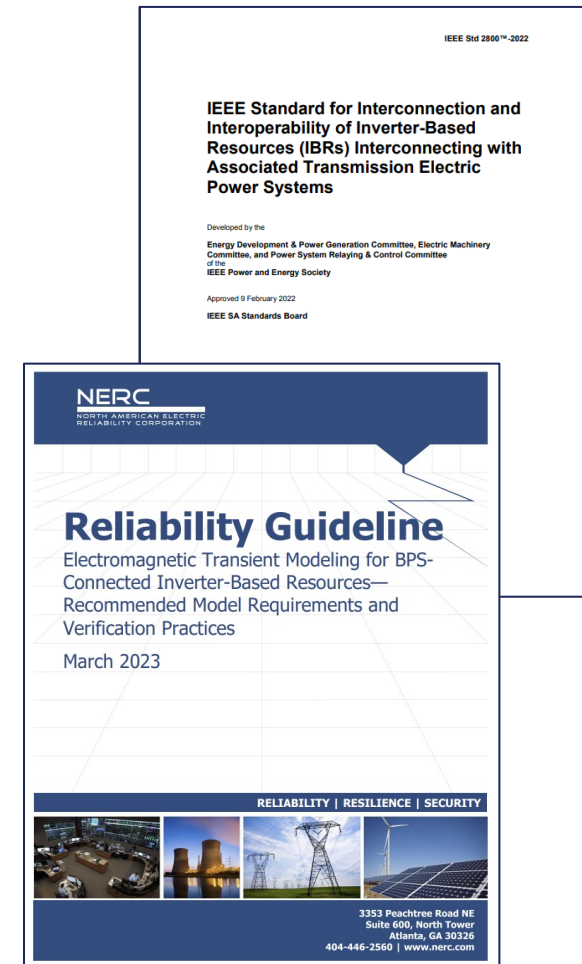


Source: [Qiang “Frankie” Zhang, “IBR Model Verification at ISO-NE Using Playback Method”, NERC IRPS Meeting, June 2023](#)

Emerging Requirements & Standards for EMT modelling and Studies



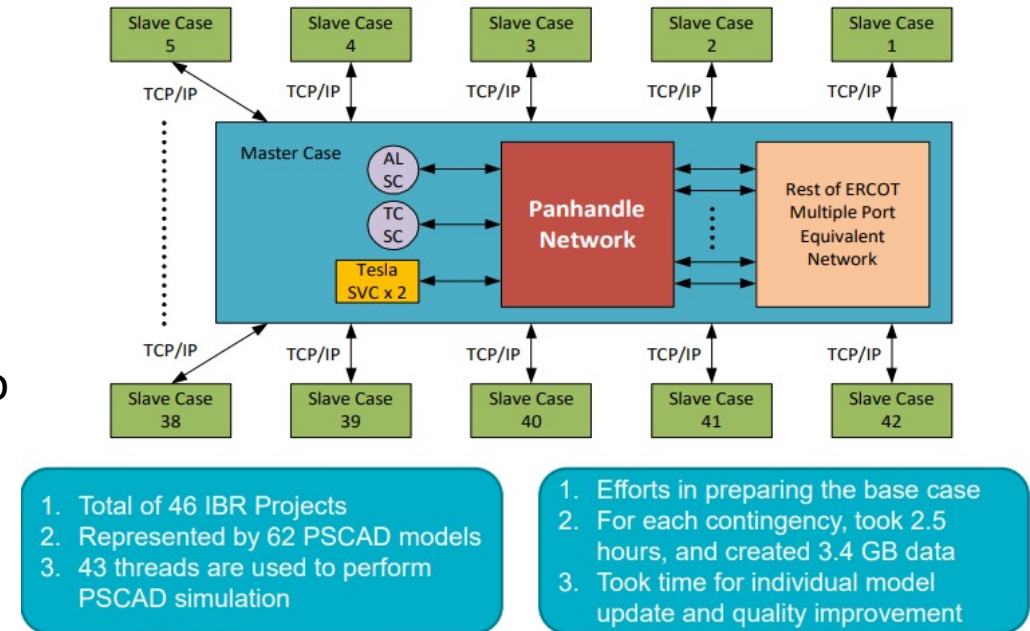
- **IEEE 2800-2022** Standard for Interconnection and Interoperability of IBRs Interconnecting with Associated Transmission Electric Power Systems – establishes EMT modeling data requirements (among other things)
- **NERC MOD-026-2** Verification of Dynamic Models and Data for BES Connected Facilities – to verify that the dynamic models and associated parameters represent the in-service equipment of BES Facilities
- **NERC Reliability Guideline** on EMT Modeling of IBRs
- **FERC Order 2023** requires submission of accurate/representative EMT models at the interconnection request stage (in areas that are conducting EMT studies)
- **NERC Project 2022-04** EMT Modeling – to address lack of accurate modeling data and the need to perform EMT studies during the interconnection process and long-term planning. Affected NERC Standards: FAC-002, MOD-032, and TPL-001
- ERCOT, ISO-NE and some other areas already require EMT models during interconnection process and have **detailed model quality testing and validation requirements.**



Challenges with EMT Models and Studies Today & Research Needs



- EMT models are detailed and complex and require thorough model validation – need for automation
- EMT studies are time consuming, e.g. one contingency in EMT model of Panhandle in ERCOT takes 2.5 hours to run
- But, with high shares of IBRs, need to increase study area and run studies closer to real time – need for speed
- Models of legacy equipment may not be available – need to collect models during interconnection process
- EMT models for system equipment, e.g. power electronic loads, DERs, HVDC and FACTS devices etc. – need to understand what equipment and to what level of detail is important to include?
- Need for workforce development and university curriculum development to include EMT modeling and studies



Source: [Xiaoyu \(Shawn\) Wang, "EMT Modeling and Studies in ERCOT", ESIG Fall Technical Workshop, 2003](#)

ESIG Reliability Working Group's Activities



- **Stability Assessment Methods with High Shares of IBR**
 - Focus on oscillations involving IBRs
 - Investigate stability margins, metrics and indicators of stability limits
 - Current understanding and gaps, synopsis of available tools & techniques, and recommendations for R&D
 - “Field guide to oscillations”: a practical document for analyzing oscillations
- **New Services**
 - What services are needed in absence (or scarcity) of synchronous machines?
 - Is it possible to ascertain the quantity of a service that is to be provided? If so, what methods can be used?
 - Can results be generalized across multiple systems?
 - Will additional system support devices be needed?
- **Grid Forming IBR Testing**
 - Several high-level requirements for grid forming (GFM) capability has been defined around the world
 - Demonstrate expected GFM performance using both frequency scans and time-domain characterization
 - The purpose is to provide more clarity to the industry on meaning of these requirements and behavior sought
 - The project may also inform development of the future interconnection requirements for GFM IBRs.



THANK YOU

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