INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

Efforts to Maintain the Reliability, Resiliency, and Security of Grid Interconnection

December 3rd, 2024

An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office

Meeting Recording Announcement

This call is being recorded and may be posted on DOE's website or used internally. If you do not wish to have your voice recorded, please do not speak during the call or disconnect now. If you do not wish to have your image recorded, please turn off your camera or participate only by phone. If you speak during the call or use a video connection, you are presumed to consent to recording and to the use of your voice or image.

Agenda

- DOE i2X Program + Roadmap Overview (10 min)
- Panel Presentations: Maintaining Reliability, Resiliency, and Security in Interconnection (60 min)
  - ERCOT's practices on model collection, quality testing and validation, John Schmall, ERCOT
  - Developer's perspective on model collection, quality testing and validation, John Zong, EPE
  - NERC recommended practices for EMT modelling during interconnection process, Aung Thant, NERC
- Open facilitated discussion (45 min)
- Future i2x Activities & Upcoming Events (5 min)

Speakers

Julia Matevosyan – Associate Director, Chief Engineer, *Energy Systems Integration Group (ESIG)*

John Schmall – Principal, Grid Planning, *Electric Reliability Council of Texas (ERCOT)*

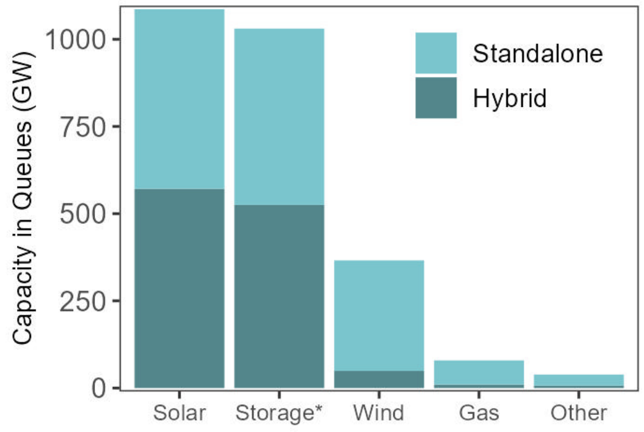
John Zong – Associate Director, *Electric Power Engineers (EPE) Consulting*

Aung Thant – IBR Specialist, *North American Electric Reliability Corporation (NERC)*

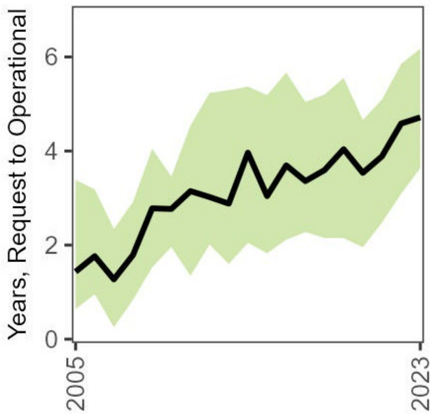
State of Transmission Interconnection

Developer interest in solar, storage, and wind is strong

- Nearly 11,600 projects with 2,600 GW actively seeking interconnection
- Active capacity in queues increased ~8X since 2014



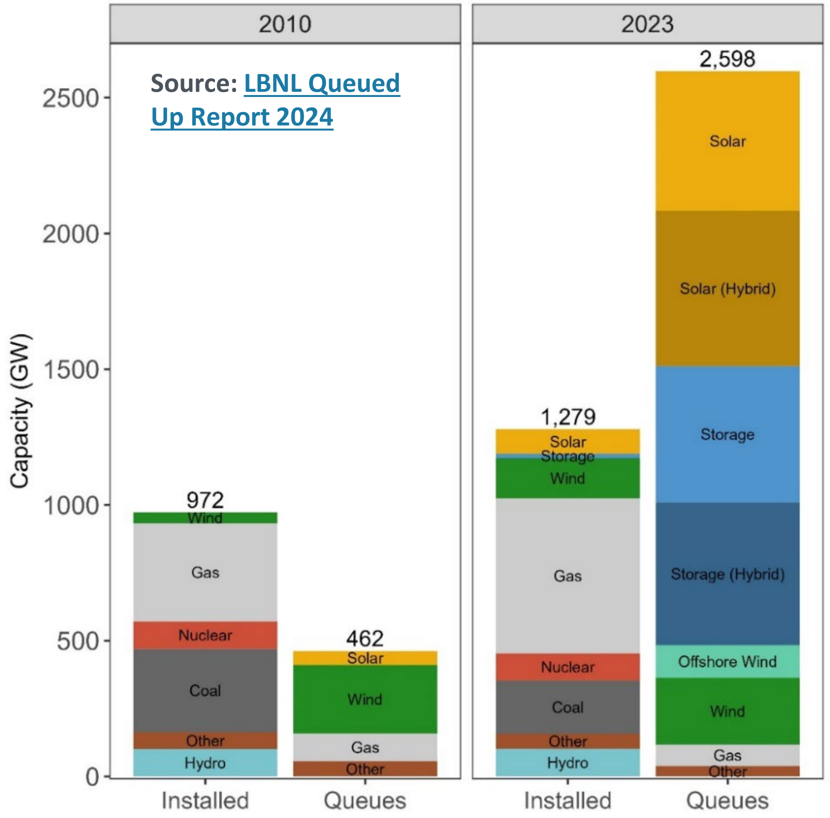
Completion rates are generally low; wait times are increasing



- For projects built in 2023, the average time from request to commercial operations is 5 years compared to 3 years in 2015 and <2 years in 2008
- Interconnection *costs* also increasing

Proposed capacity is more than 2x installed capacity!

- >95% of capacity in queues is zero-carbon



Source: LBNL's Queued Up Report 2024

Interconnection Innovation e-Xchange (i2X)

Mission: To enable a **simpler**, **faster**, and **fairer** interconnection of clean energy resources while enhancing the **reliability**, **resiliency**, and **security** of our **distribution and bulk-power electric grids**

Stakeholder Engagement
Nation-wide engagement platform and collaborative working groups

Data & Analytics
Collect and analyze interconnection data to inform solutions development

Strategic Roadmap
Create roadmap to inform interconnection process improvements

Technical Assistance
Leverage DOE laboratory expertise to support stakeholder roadmap implementation

i2X is a collaboration among DOE offices and National Labs

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

BERKELEY LAB

GDO GRID DEPLOYMENT OFFICE

Pacific Northwest NATIONAL LABORATORY

NREL Transforming ENERGY

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ENERGY.GOV

SCIENCE & INNOVATION ENERGY ECONOMY SECURITY & SAFETY SAVE ENERGY, SAVE MONEY

Department of Energy

DOE Releases First-Ever Roadmap to Accelerate Connecting More Clean Energy Projects to the Nation's Electric Grid

APRIL 17, 2024

Energy.gov »

DOE Releases First-Ever Roadmap to Accelerate Connecting More Clean Energy Projects to the Nation's Electric Grid

Report Details Recommendations to Streamline Interconnection with Near- to Long-Term Solutions to Add Clean Energy Resources to the Transmission Grid and Boost Our Clean Energy Economy

WASHINGTON, D.C. — The U.S. Department of Energy (DOE) released a **new roadmap** outlining solutions to speed up the interconnection of clean energy onto the nation's transmission grid and clear the existing backlog of solar, wind, and battery projects seeking to be built. The Transmission Interconnection Roadmap, developed by DOE's Interconnection Innovation e-Xchange (i2X), serves as a guide for transmission providers, interconnection customers, state agencies, federal regulators, transmission owners, load serving entities (LSEs), equipment manufacturers, consumer advocates, equity and energy justice communities, advocacy groups, consultants, and the research

www.energy.gov/i2x

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Transmission Roadmap Key Components and Implementation Actors

35 solutions organized in four goals

Solutions with different implementation time frames

- *Short-term:* within 1-3 years (by 2027)
- *Medium-term:* 3-5 years (by 2029)
- *Long-term:* beyond 5 years (2030 and after)

Solutions describe collaborative actions among key actors

- Transmission providers (Utilities, ISOs, BAs)
- Regulators (FERC/NERC, State PUCs)
- Interconnection customers
- Consumer Groups
- Research community (including DOE)
- OEM and software vendors
- State, local, tribal governments
- Equity and public benefit organizations

Measurable 2030 success targets

DOE has multiple potential roles in enabling Roadmap implementation

- Convene Stakeholders
- Provide Technical Support
- Fund Research and Innovation
- Evaluate Progress

Measurable Success Targets for 2030

Evaluating success relies on accessible data for tracking and auditing!

	Target Value by 2030	Recent Value
Reduced interconnection process time Average time from request to agreement	< 12 months	33 months (2022)
Lowered cost uncertainty Standard deviation of interconnection costs	< $150/kW	$551/kW (2020-2021)
Increased Completion rates Completion rate for projects that entered facility study phase	> 70%	45% (2016)
Maintained system reliability Number of annual NERC disturbances events involving unexpected tripping of IBRs not identified in offline analysis due to IBR modeling inaccuracy	Zero	4 (2022)

Four Interconnection Goals with 35 Solutions

Goal #1: Increase Data Access and Transparency

Goal #2: Improve Process and Timeline

Goal #3: Promote Economic Efficiency

Goal #4: Maintain a Reliable, Resilient, and Secure Grid

- Solutions are a collection of strategies rather than a rigid package of prescriptive fixes.
- Some solutions are complementary: to be effective, they would need to be implemented in tandem with others.
- Other solutions are exclusive: adopting one might obviate the need for another.
- Solutions may be topically specific (e.g., Cost Allocation)

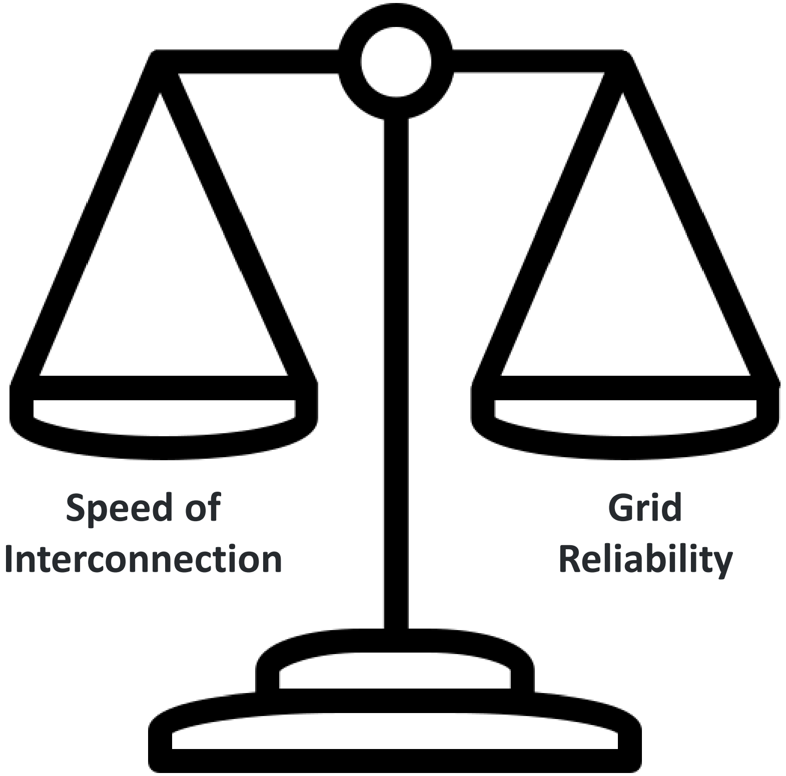
Roadmap does not assess the costs of implementing the solutions.

Goal 4: Maintain a Reliable, Resilient, and Secure Grid

Challenge: In recent years there has been a series of disturbance events leading to inverter-based resource (IBR) disconnection. How do we build the foundation to manage high penetration rates of IBRs & minimize disturbances?

Objectives for Solutions that Maintain a Reliable, Resilient, and Secure Grid

- Increase ability to process higher volumes of requests and thereby promote faster interconnection of new resources
- Ensure openness and competitive access to the transmission network
- More efficiently utilize limited human resources



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Topical Area 1 – Interconnection Reliability Assessment Models and Tools

Solutions should help improve the models and tools used in interconnection in order to avoid large disturbance events that could threaten grid reliability

Solution 1: Require submission of EMT models and develop screens that determine when EMT studies are necessary.

SHORT TERM

Solution 2: Develop rules for dynamic model quality testing and validation for both RMS and EMT simulations.

SHORT TERM

Solution 3: Develop a study process flow that is better aligned with project development timelines.

MEDIUM TERM

Solution 4: Advance the computational speed of interconnection studies.

MEDIUM TERM

Key tradeoff: Providing accurate and precise resource modeling without significantly slowing down the interconnection study process

Topical Area 1 – Interconnection Reliability Assessment Models and Tools

Solutions should help improve the models and tools used in interconnection in order to avoid large disturbance events that could threaten grid reliability

Modeling Requirements:
- Unified modeling package across simulation domains
- Requirements wherein model reflects the proposed facility
- Model quality checks – plant compliance to requirements and benchmarking

Model Quality Automation:
- Streamlined and standardized model quality tests
- Model quality test automation tools
- Standardized model assessment reporting
- Model validation tools

Modeling Process Improvements:
- Integration of modeling requirements enhancements throughout process
- Change management procedures and expectations
- Roles and responsibilities across entities

Computation Speed Increases:
- Faster simulation times
- Speed up interconnection studies
- Enable larger EMT system studies
- Tackle more complex reliability issues

Topical Area 2 – Interconnection Standards

Solutions should help ensure more consistent capabilities of IBRs once they reach commercial operations

Solution 1: Adopt and implement IEEE 2800-2022.

SHORT TERM

Solution 2: Adopt and implement requirements for plant conformity assessment as a part of generator interconnection procedures

MEDIUM TERM

Solution 3: Assess need for new standards to cover emerging technologies.

MEDIUM TERM

Solution 4: Evaluate cyber and physical security concerns during interconnection.

MEDIUM TERM

Solution 5: Investigate relationship between interconnection process and system reliability.

MEDIUM TERM

Key tradeoff: Providing clear upfront requirements that ensure reliability in real-time operations while allowing enough flexibility to leverage innovation and technology efficiencies

Topical Area 2 – Interconnection Standards

Solutions should help ensure more consistent capabilities of IBRs once they reach commercial operations

General Reference *Cite IEEE 2800 in Full*	Detailed Reference *Cite IEEE 2800 Clauses*	Hybrid Integration *Organic Integration*	Detailed Spec *Recreate Specs of IEEE 2800*
“Point to standard in existing requirements”	“Point to specific clauses in existing requirements”	“Point to specific clauses and add clarifying language in existing requirements”	“Recreate requirements language entirely”
✓Minimal effort to adopt × **Limited system-specific details*** × Lacks clarity and specificity × **Leaves gaps in implementation and understanding**	✓Targeted enhancements ✓Allows phased approach × **Limited system-specific details***	✓Targeted enhancements ✓Allows phased approach ✓Allows adaptation and additional requirements ✓**System-specific and clear** ✓Enables conformity language additions	✓Targeted enhancements ✓Allows phased approach ✓Allows adaptation and tailored solution for specific rules framework ✓Enables conformity language × **Significant work and duplication for AGIR** × Copyright concerns

* Industry practice has tended to not provide the necessary AGIR-specific details (i.e., functional settings) needed for complete adoption of IEEE 2800-2022.

Discussion and Q&A

Website: energy.gov/i2X
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Virtual Meeting Code of Conduct during Discussion

- *Assume good faith and respect differences*
- *Listen actively and respectfully*
- *Use "Yes and" to build on others' ideas*
- *Please self-edit and encourage others to speak up*
- *Seek to learn from others*

Mutual Respect . Collaboration . Openness

Discussion topics:

1. What processes and incentives are needed to prevent inaccurate modeling or submission of models that “tick” modeling checklist?
2. How to ensure that models are updated during interconnection process despite the fear of possible restudies?
3. How to better align project development timelines and study process to ensure that the most accurate models are used for reliability assessment?

Word Cloud

What procedures, requirements, or agreements need to be enhanced to close the currently observed deficiencies related to IBR plant modeling?

Go to slido.com use event code **MQT**

Questions for Goal 4

Model Accuracy

- What are the biggest challenges observed with respect to getting accurate, verified models from IBR owners/developers?
- Which model types are preferred - user-defined or generic - when performing interconnection assessments?

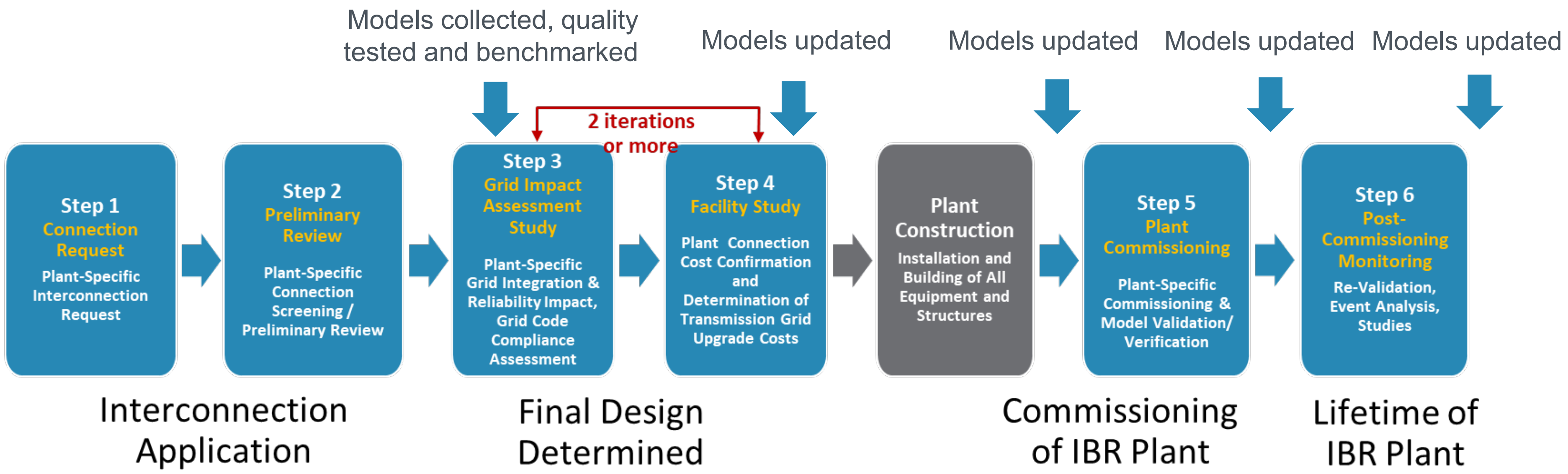
Model Quality Checks, Verification, Validation

- What are the biggest obstacles or barriers to faster, more efficient, and improved model verification/validation and model quality check processes?
- Do you use automated tools or processes for model quality testing?

Alignment of a Plant Development Timelines and Interconnection Study Timelines

- At what stage of the interconnection process does modeling accuracy improve, when should EMT studies, including plant conformity assessment be initiated?

Model Development, Iterations and Updates



- Full plant model
- Reasonable plant design and parameters (some aspects may be generic)
- Reasonable response to a site-specific equivalent grid
- Good model quality and initialization
- Model useful for preliminary interconnection study / design

- Project-specific plant design and parameters (nothing generic)
- Plant controller gains tuned for the specific connection
- Model useful for final interconnection study, design evaluation and operations studies

- Post-commissioning model update (should be minor)
- Model updates as a result of post-event validation or settings change due to performance concerns
- Model maintenance as modelling state of the art changes

Source: Adapted from Jens Boemer, EPRI & Matt Richwine, Telos Energy

i2X FIRST Initiative

i2X Forum for the Implementation of Reliability Standards for Transmission (FIRST)

Interconnection Innovation e-Xchange

Interconnection Innovation e-Xchange » i2X Forum for the Implementation of Reliability Standards for Transmission (FIRST)

To ensure the reliable and secure operation of clean energy resources connected to the electric grid, interconnection standards need to address inverter-based generator capabilities, expected performance, cybersecurity requirements, and other relevant issues. Some of these standards, such as Institute of Electrical and Electronics Engineers (IEEE)-2800, have been developed, but still need to be widely adopted and implemented. Other standards, as well as procedures for assessing and verifying plant conformity with them, have yet to be developed.

Technical Topics:

- IEEE 2800 Requirements and Clauses
- Equipment Manufacturer Readiness
- Transmission Provider Perspectives
- Ongoing Regulatory Activities
- Generation Owner/Operator Perspectives
- Changing System Conditions and Dynamics
- Emerging Technologies

Upcoming Events:

- December 17 – Virtual
- January 28 – Virtual
- February 25 – Virtual
- March 20 – Hybrid Event (ESIG Workshop)

https://www.energy.gov/eere/i2x/i2x-forum-implementation-reliability-standards-transmission-first

Thank you for joining and participating

Website: energy.gov/i2X
Email: i2x@ee.doe.gov

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EMT Modeling and Studies for Interconnection of IBRs

NERC Reliability Guidelines and Recommended Dynamic Modeling Practices

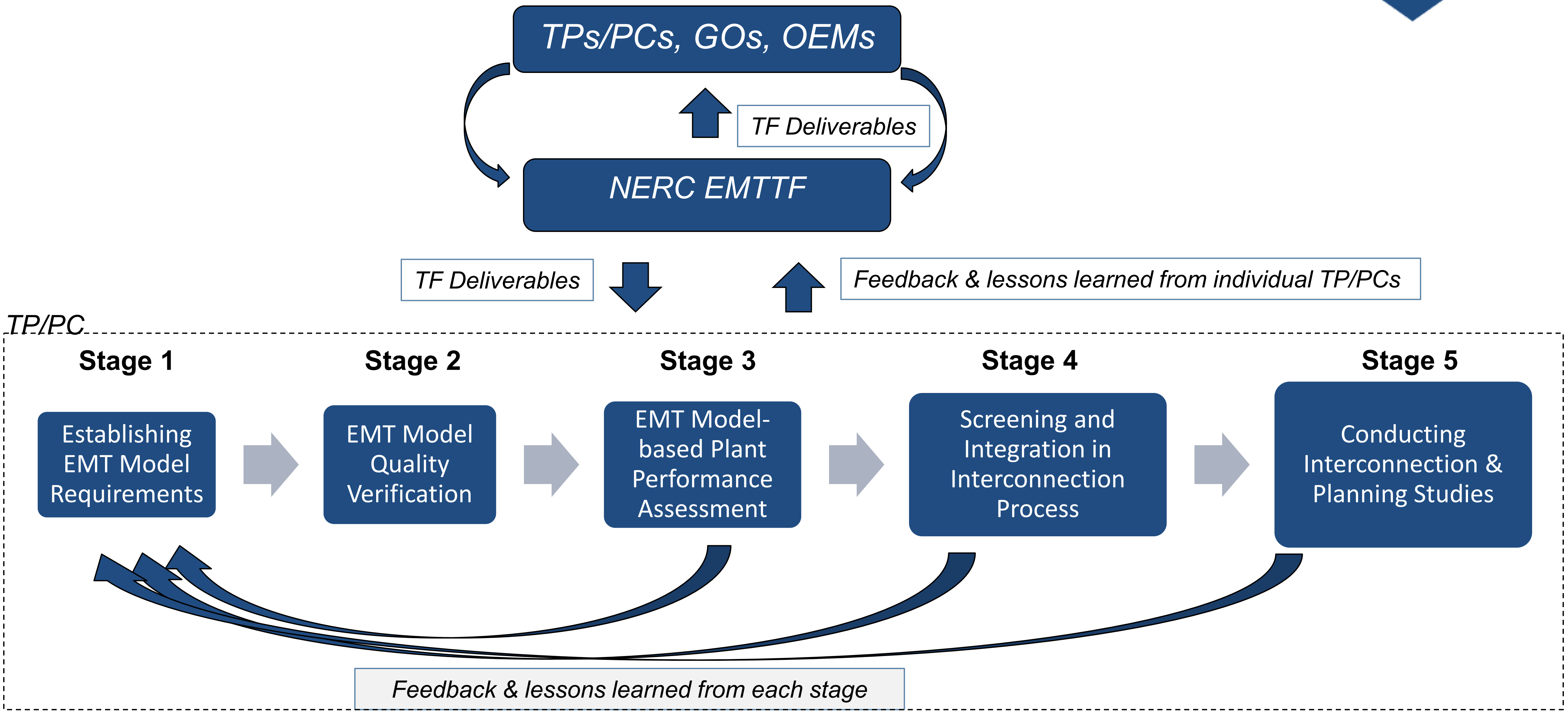
Aung Thant, Senior Engineer, IRPS, EMTTF Coordinator

i2X Solution e-Xchange Season 2: Interconnection Reliability Assessment Models and Tools
December 3, 2024

Outline

- EMTTF Supporting EMT Adoption Across NA
- NERC Reliability Guidelines on EMT Modeling
  - “Vol 1” – March 2023: model quality requirements and verification practices
  - “Vol 2” – pending RSTC approval: EMT system studies for interconnection of IBRs
- Recommended Dynamic Modeling Practices

EMTTF Supporting EMT Adoption Across NA



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EMT Reliability Guidelines

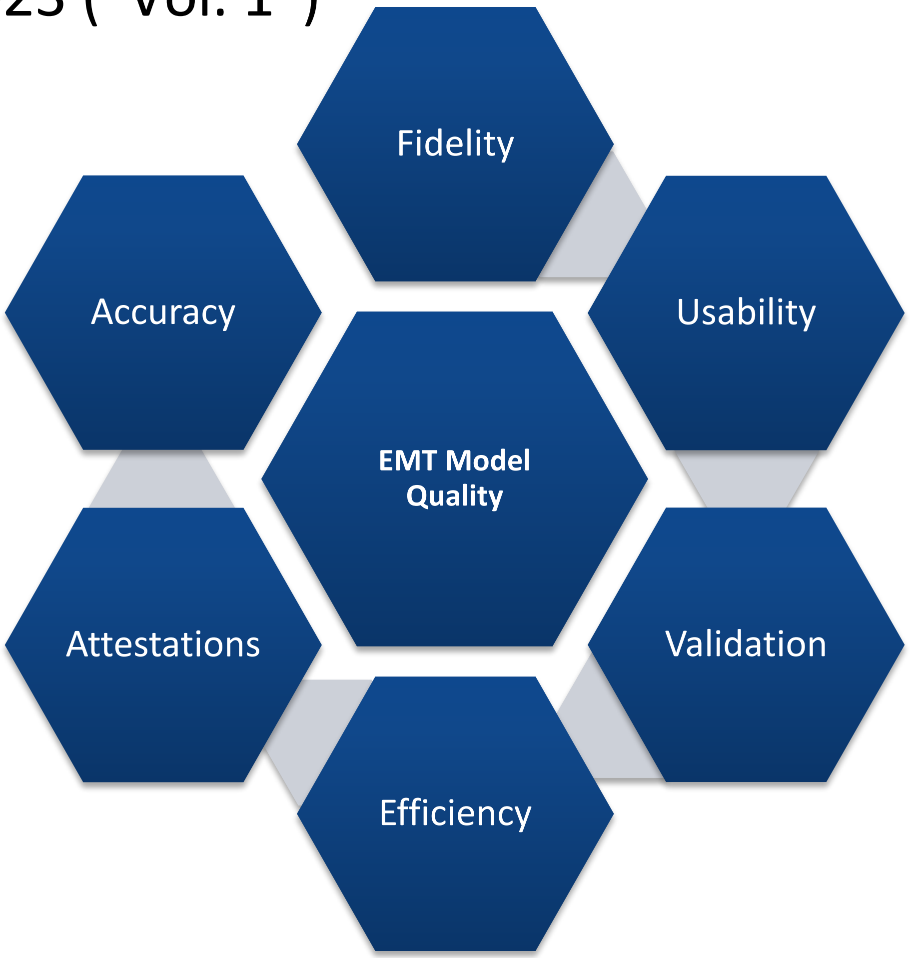
Establishing EMT Model Requirements → EMT Model Quality Verification → EMT Model-based Plant Performance Assessment → Screening and Integration in Interconnection Process → Conducting Interconnection & Planning Studies (where necessary)

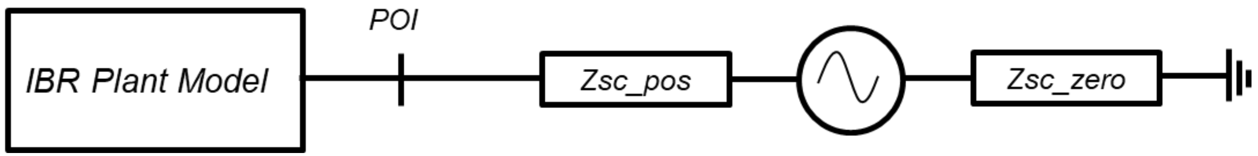
Reliability Guideline: EMT Modeling for BPS-connected IBRs: Recommended Model Requirements and Model Quality Verification
March 2023 ("Vol. 1")

Draft Reliability Guideline: Recommended Practices for Performing EMT System Studies for IBRs ("Vol. 2")
(Targeting publication in December 2024)

EMT Guideline "Vol 1"

- Reliability Guideline: EMT Modeling for BPS-connected IBRs: Recommended Model Requirements and Model Quality Verification, March 2023 ("Vol. 1")
  - Model Quality, Verification and Attestations – E-MQA, P-MQA
  - Sample Model Checklist
  - Equipment-specific EMT Model Validation Reports
  - Benchmark Positive Sequence Dynamic Models
  - Model Verification Tests
    - **Model Adequacy Tests**: To verify usability, efficiency and accuracy requirements
    - **Functional Tests:** To verify model configuration and response
      - Follow command? Limit output? Limit ramp rate? PFR? AVR? Iq injection?
    - **Disturbance Ride-through Performance Tests**





Single Machine Infinite Bus Test Case

EMT Guideline "Vol 1"

TP/PC

- Establish model requirements
- Establish change criteria that require restudy
- Develop check-list

- Verify documentation, attestations, check-list
- Verify model quality: usability, efficiency
- Assess ride through performance
- Integrate plant model into system model

- Modeling requirement
- Check-list
- POI info – e.g. SCR, X/R

- P-MQA, E-MQA(s)
- EMT model package
- Plant model documentation
- Equipment model documentation
- Validation report
- Plant model verification test report
- Completed check-list

GO

- Enhance contractual terms and conditions with OEMs and consultants for model support throughout facility lifecycle

- Verify equipment-level model quality
- Integrate and configure individual OEM models into aggregate plant model
- Confirm model parameter and configuration updates with OEM
- Verify plant model quality
- Change management
- Prepare P-MQA and plant model verification report

- POI Info
- Enhanced T&C's
- Modeling requirements
- Check-list

- Key parameters that affects ride-thru performance
- Site specific initial parameters
- Model parameter and configuration updates

- E-MQA
- Validation report and test cases
- Equipment model documentation
- Certification of parameter and configuration updates by GO

OEM

- Model development
- Model documentation
- Unit model validation against product (HIL, factory testing, field testing)
- Change management
- Traceability: make, model, f/w version, etc.
- Certify model parameter and configuration updates by GO
- Prepare E-MQA

EMT Reliability Guidelines

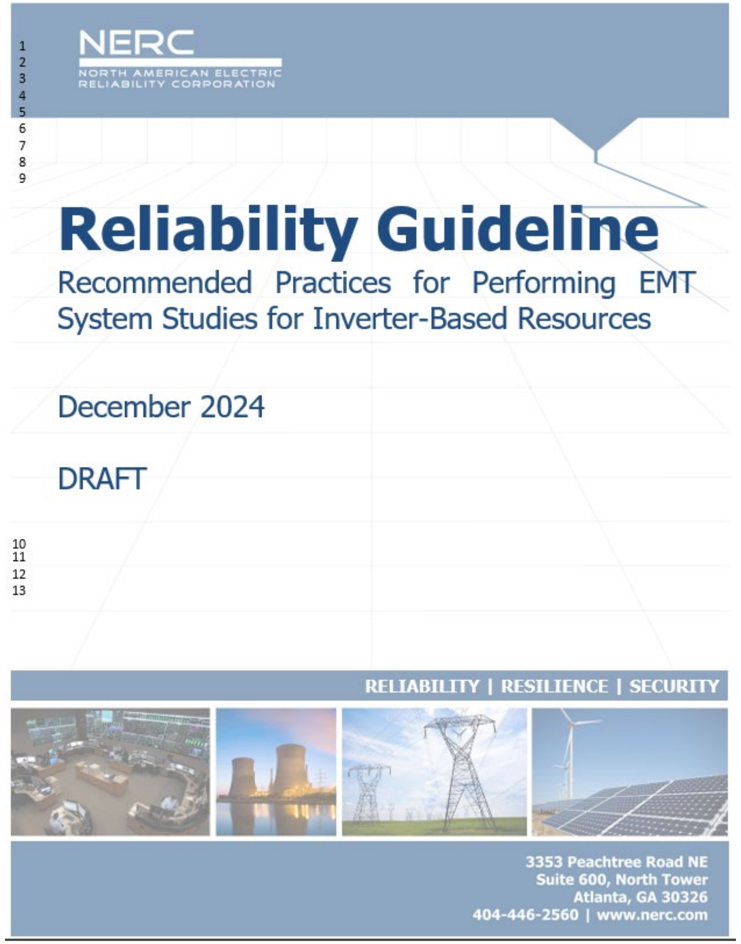
Establishing EMT Model Requirements → EMT Model Quality Verification → EMT Model-based Plant Performance Assessment → Screening and Integration in Interconnection Process → Conducting Interconnection & Planning Studies (where necessary)

Reliability Guideline: EMT Modeling for BPS-connected IBRs: Recommended Model Requirements and Model Quality Verification
March 2023 ("Vol. 1")

Draft Reliability Guideline: Recommended Practices for Performing EMT System Studies for IBRs ("Vol. 2")
(Targeting publication in December 2024)

Work Item 2 : EMT Guideline “Vol 2”

- **Reliability Guidelines – Recommended Practices for Performing EMT System Studies for Inverter-Based Resources**
  - **8** Chapters and **4** Appendixes
  - Out for 45-day industry review on July 1
  - Review period ended on August 15
  - Target publishing in December 2024



NERC
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Reliability Guideline

Recommended Practices for Performing EMT System Studies for Inverter-Based Resources

December 2024

DRAFT

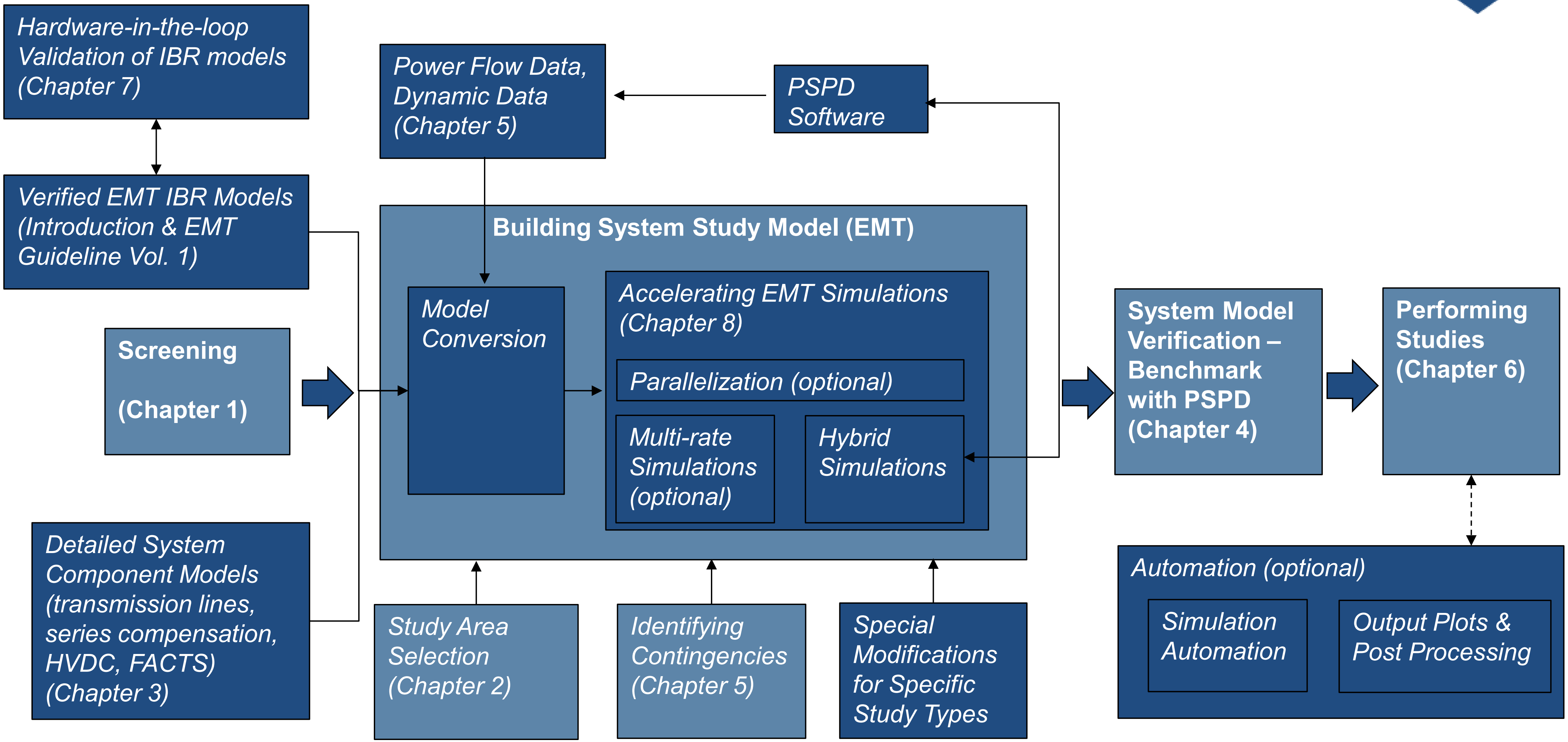
RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

Purpose

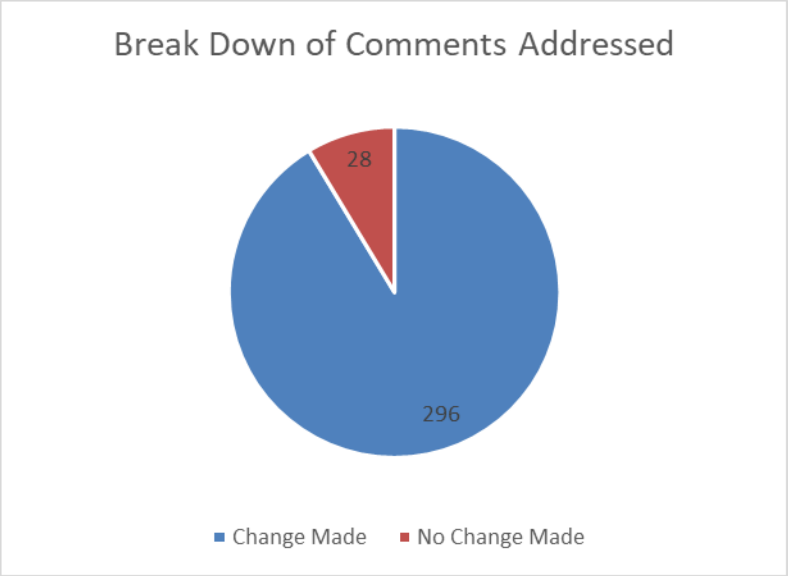
- For transmission planning **engineers to know when and how to study** the impact of IBRs on the BPS in EMT domain.
- The focus is **within the generator interconnection studies proc**ess, primarily system impact studies, and not conventional EMT studies such as insulation coordination, etc.

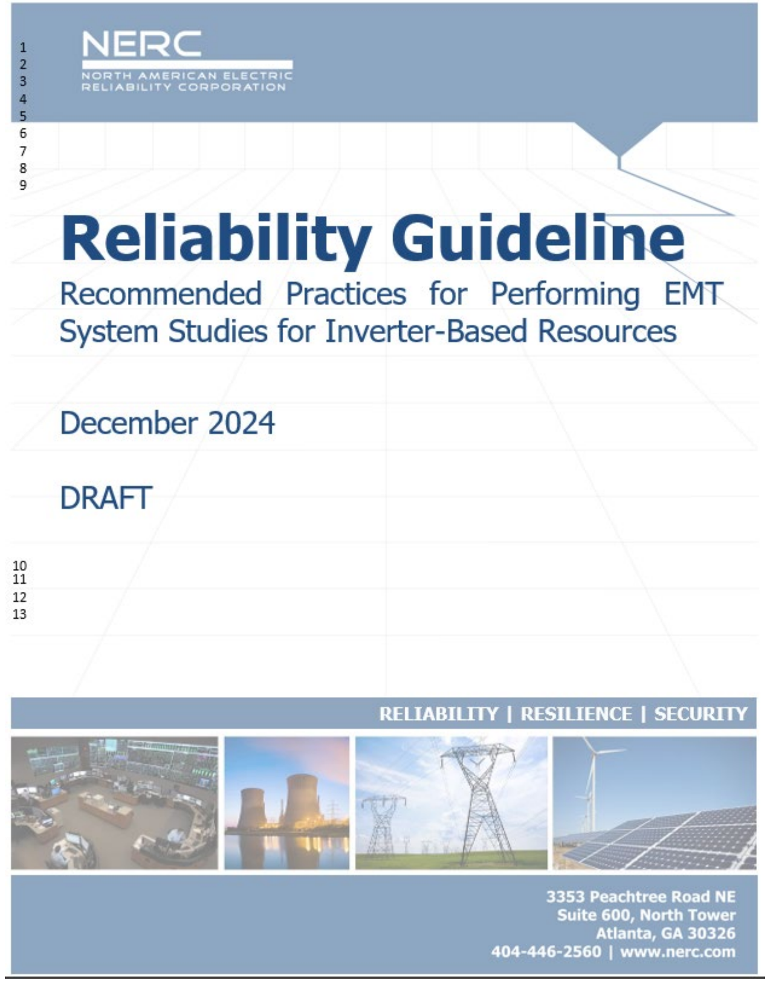
Work Item 2 : EMT Guideline "Vol 2"



Work Items – Resources to set Industry up for Success

- Draft Reliability Guidelines – Recommended Practices for Performing EMT System Studies for Inverter-Based Resources
  - Comments Stats
    - 296 comments
    - 7 organizations + 1 NERC WG (SPCWG)
  - IRPS consensus to publish
  - Seeking RSTC approval at December meeting





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Reliability Guideline

Recommended Practices for Performing EMT System Studies for Inverter-Based Resources

December 2024

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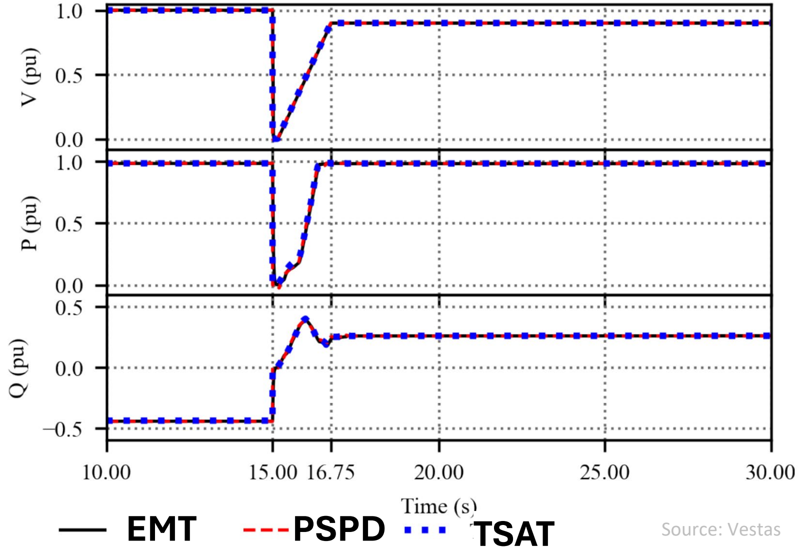
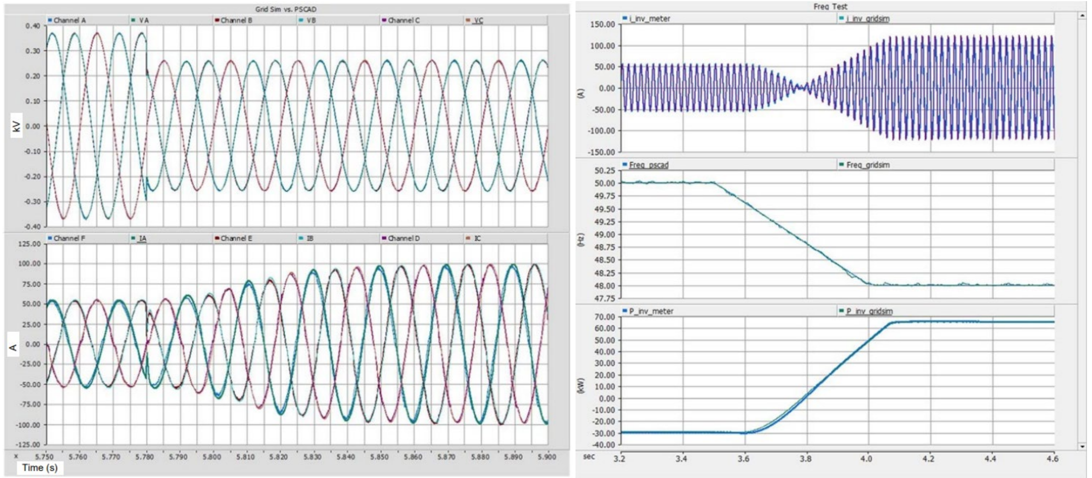
Model Quality and Benchmarking

- All models should be:
  - Detailed and accurate representations of expected or as-built facilities
  - Verified by the equipment manufacturer to be accurately parameterized to represent site-specific (or to-be installed) controls, settings, and protections
  - Validated against actual product performance and benchmarked against each other
- 3 types of models:
  - Positive sequence standard library models,
  - Positive sequence user-defined models (UDMs), and
  - Electromagnetic transient (EMT) models



Source: Vestas



Source: https://arena.gov.au/assets/2022/03/hornsdale-power-reserve-virtual-machine-mode-testing-summary-report.pdf

Dynamic Model Types

Electromagnetic Transient

- Very detailed
- Often include some/all of the equipment's code and logic

Positive Sequence User-Defined

- Less detailed than EMT
- May include some/all of the equipment's code and logic

Positive Sequence Standard Library

- High level model structure with standardized control blocks
- Typically, do not have sufficient mapping between real equipment performance and parameters when compared to the model

Electromagnetic Transient

Should be used for any study where **detailed representations of plant controls and protections** are required

Needed to accurately identify possible reliability risks when integrating IBRs

Typically feasible only for **localized** or **small regional studies** due to computational demand and capability.

Dynamic Model Types

Electromagnetic Transient

- Very detailed
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Positive Sequence User-Defined

- Less detailed than EMT
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Positive Sequence Standard Library

- High level model structure with standardized control blocks
- Typically, do not have sufficient mapping between real equipment performance and parameters when compared to the model

Positive Sequence User-Defined Models

When an EMT model is not needed, should be used for detailed reliability studies as these models are more likely to identify reliability risks (compared to standard library models)

Should be used in the interconnection process and local reliability studies

Can be more feasibly utilized in large-scale studies (compared to EMT models); can include manufacturer-specific protections and controls not available in the Standard Library

Dynamic Model Types

Electromagnetic Transient

- Very detailed
- Often include some/all of the equipment's code and logic

Positive Sequence User-Defined

- Less detailed than EMT
- May include some/all of the equipment's code and logic

Positive Sequence Standard Library

- High level model structure with standardized control blocks
- Typically, do not have sufficient mapping between real equipment performance and parameters when compared to the model

Industry Approved Positive Sequence Standard Library

Can be sufficient for interconnection-wide model representations.

Should usually not be used in the interconnection process or for local reliability studies.

Typically don't include detailed logic or manufacturer-specific controls but are easy to parameterize, curve fit, and run

NERC Unacceptable Model List

- Unacceptable due to proven modeling errors, numerical issues, or those phased out of use for other reasons.

Update Process:

- NERC engages with industry experts to identify model issues

Table A.1: Unacceptable Model List	
Known Unacceptable Model Name	**Model Description**
Renewable Energy Models	
WT3G1,WT3G2, wt3g	Generic Type 3 WTG Generator/Converter Model - Doubly-fed induction generator
WT4G1,WT4G2, wt4g	Generic Type 4 WTG Generator/Converter Model - Variable speed generator with full converter
WT3E1, wt3e	Generic Type 3 WTG Electrical Control Model

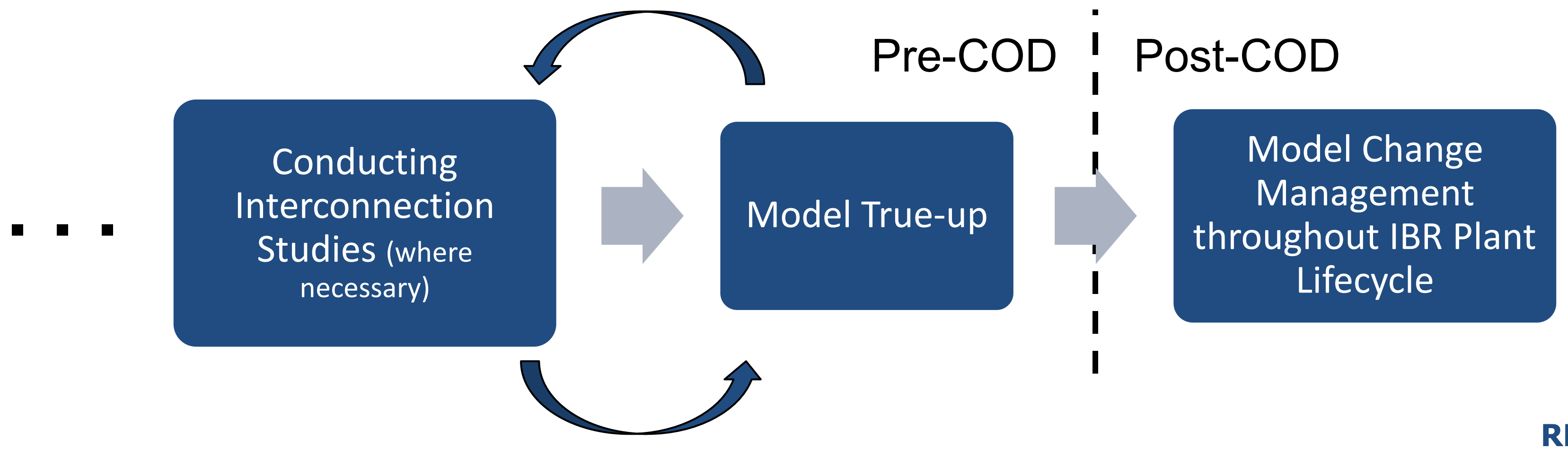
Recap

- EMT Modeling
  - Require EMT models of **all** newly interconnecting IBRs
  - Establish **model quality verification** practices
  - Require **unit model validation** – actual **inverter** response versus EMT model response
  - Use the **right** power plant controller (PPC) model!
    - Require PPC model validation too
  - **2 x** NERC Reliability Guidelines on EMT modeling
  - **EMTTF** – resources to support industry adoption of EMT modeling

Establishing EMT Model Requirements → EMT Model Quality Verification → EMT Model-based Plant Performance Assessment → Screening and Integration in Interconnection Process → Conducting Interconnection Studies (where necessary)

Recap

- Overall dynamic modeling recommendations
  - **Equipment-specific** positive sequence user-defined models should be used in the interconnection process and local reliability studies.
  - Positive sequence standard library models (aka. generic models) should usually **not** be used in the interconnection process or for local reliability studies.
  - **Benchmark** Positive Sequence models against EMT models and/or actual inverter response
  - **True-up** all models upon plant commissioning and any subsequent changes throughout its life
  - **Map** model parameters to actual inverter and plant controller settings



Questions and Answers

Contact:
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ERCOT Model Quality Practices

John Schmall
ERCOT Grid Planning

i2X: Interconnection Reliability Assessment Models and Tools
December 3, 2024

ERCOT Facts

85,508 MW

Record peak demand (August 10, 2023)

103,609+ MW

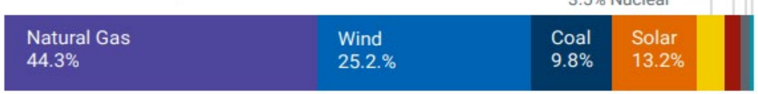
Expected capacity for summer 2024 peak demand

$3.23 billion

Transmission project endorsed in 2023

2024 Generating Capacity

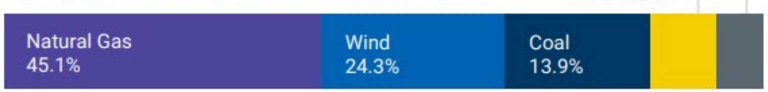
Reflects operational installed capacity based on December 2023 CDR report for Summer 2024.



The sum of the percentages may not equal 100% due to rounding.
**Other includes biomass and DC Tie capacity.*

2023 Energy Use

**Other includes solar, hydro, petroleum coke (pet coke), biomass, landfill gas, distillate fuel oil, net DC-tie and Block Load Transfer imports/exports and an adjustment for wholesale storage load.*



39,450 MW

Wind

of installed wind capacity as of June 2024, the most of any state in the nation

27,881 MW
Generation Record (June 17, 2024)

69.15 %
Penetration Record (April 10, 2022)

25,333 MW

Solar

of utility-scale installed solar capacity as of June 2024

21,667 MW
Generation Record (September 8, 2024)

44.17 %
Penetration Record (November 20, 2024)

~75 % (~34,900 MW)

Preliminary **Wind + Solar** Penetration Record (March 29, 2024)

7,702 MW

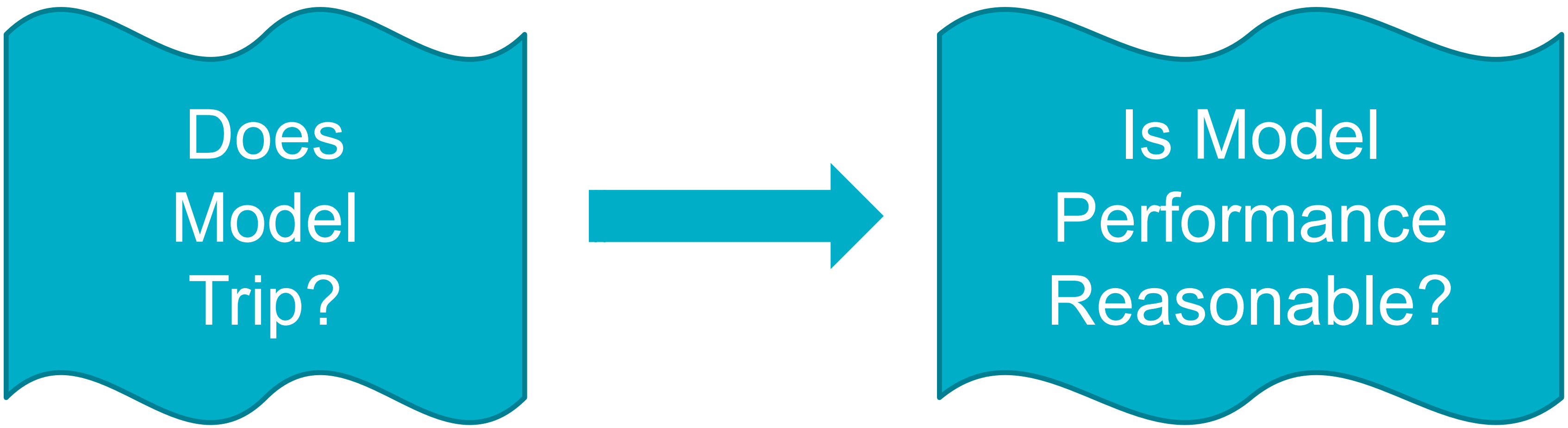
Battery Storage

of installed battery storage as of June 2024

4,056 MW
Storage Record (October 7, 2024)

Background

- Submission of high-quality accurate models has “always” been required
- NERC model validation requirements (MOD-026/MOD-027)
- Inverter-Based Resources (IBRs) require a different approach
- Voltage ride-through (VRT) test – purpose and evolution



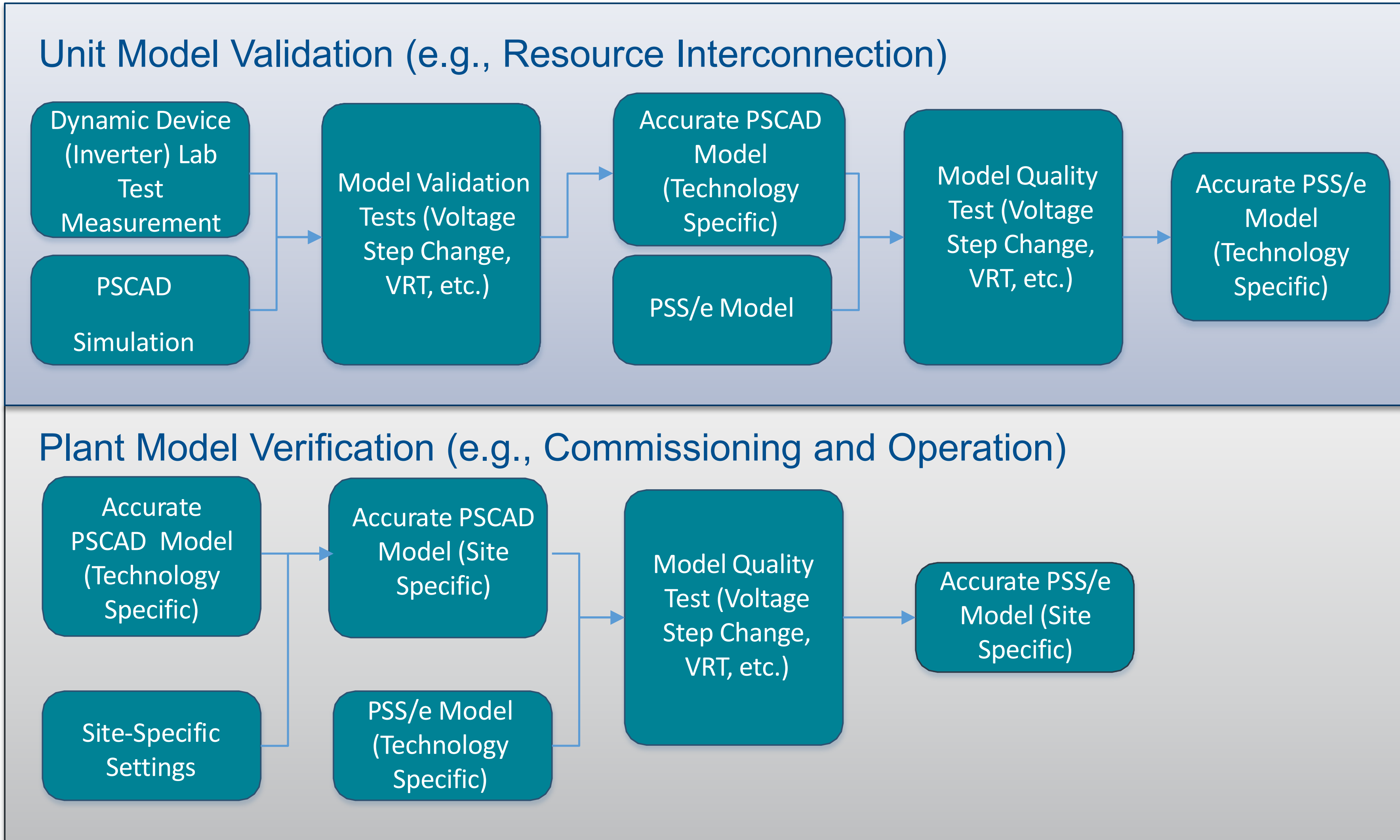
Planning Guide Revision Request (PGRR) 075

- Effective May 1, 2020
- Introduced model quality test (MQT) requirements for PSS/E dynamic model
- Performed/submitted by resource owner
- Demonstrate basic reasonable model performance
  - Flat Start Test (no disturbance test)
  - Voltage Step Change Test
  - Frequency Step Change Test
  - Voltage Ride Through Test (HVRT & LVRT)
  - Short Circuit Ratio Test
- Performance guidance published in Dynamics Working Group (DWG) Procedure Manual

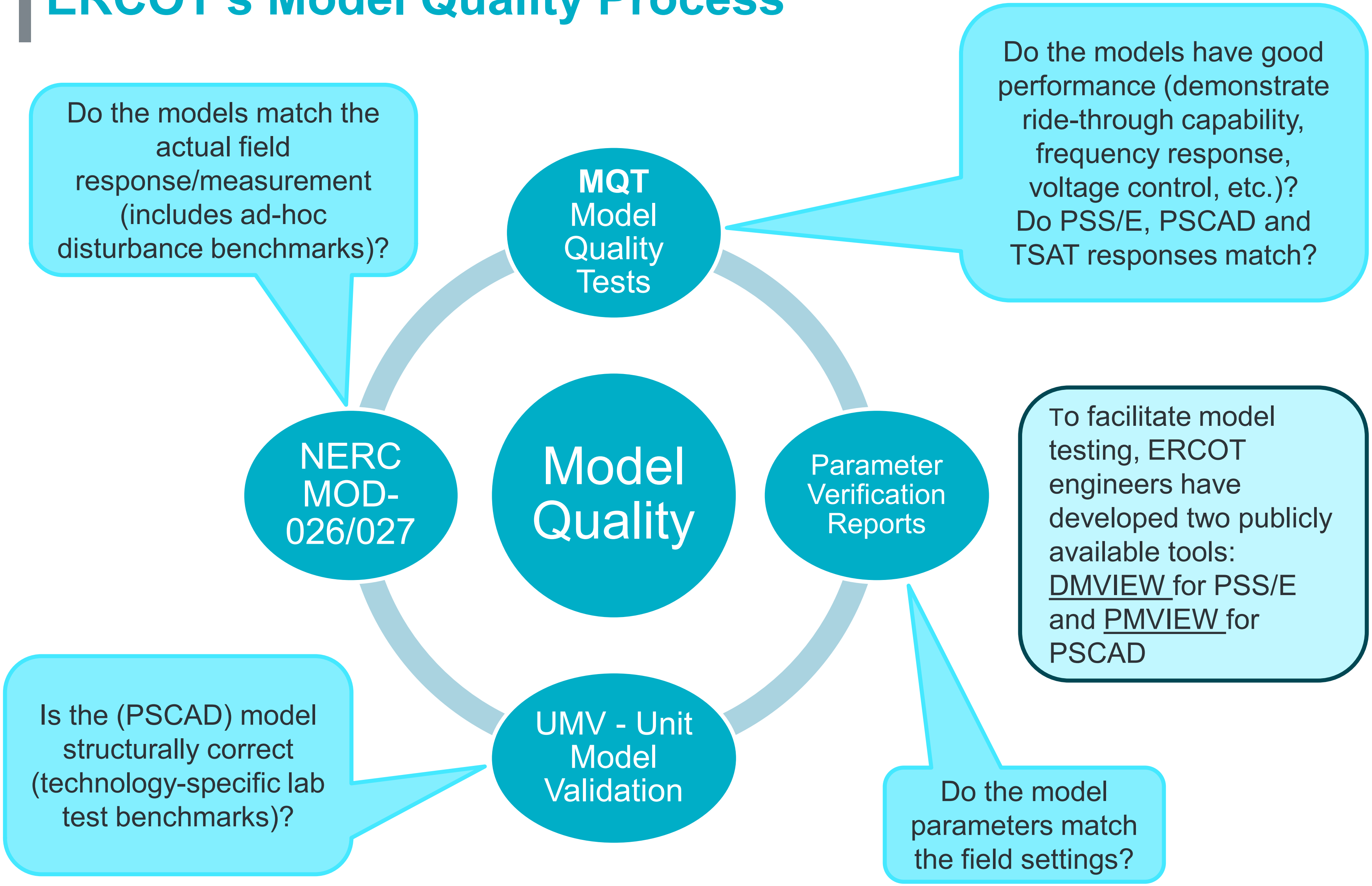
Planning Guide Revision Request (PGRR) 085

- Effective March 1, 2021
- Introduced MQT requirements for PSCAD model
  - Same reasonability tests as PSS/e MQT plus added phase angle jump test
  - Performance consistency across software platforms (PSS/e, PSCAD)
- Introduced unit model validation (UMV) requirements (for PSCAD model)
  - Intended to be a lab test model validation
  - Technology specific rather than site specific
- Introduced parameter verification requirements
  - Document that site specific tunable field settings to match model parameters
- Performed/submitted by resource owner
  - Required milestone in interconnection process

Model Validation and Verification Concept



ERCOT's Model Quality Process



Maintaining High Quality Models: PGRR-109

- Effective May 1, 2024
- Introduced model review process prior to implementation of any IBR modifications that impact dynamic response
  - Compares MQT performance before and after the proposed modification (both PSS/e and PSCAD)
  - Observation of significant differences or degradation in performance may trigger more detailed studies
  - Identifies any adverse impacts prior to implementation of modifications in the field
  - Confirms appropriate model performance
- Introduced a similar process to review and compare “as-built” models with the models used for interconnection studies prior to final commissioning

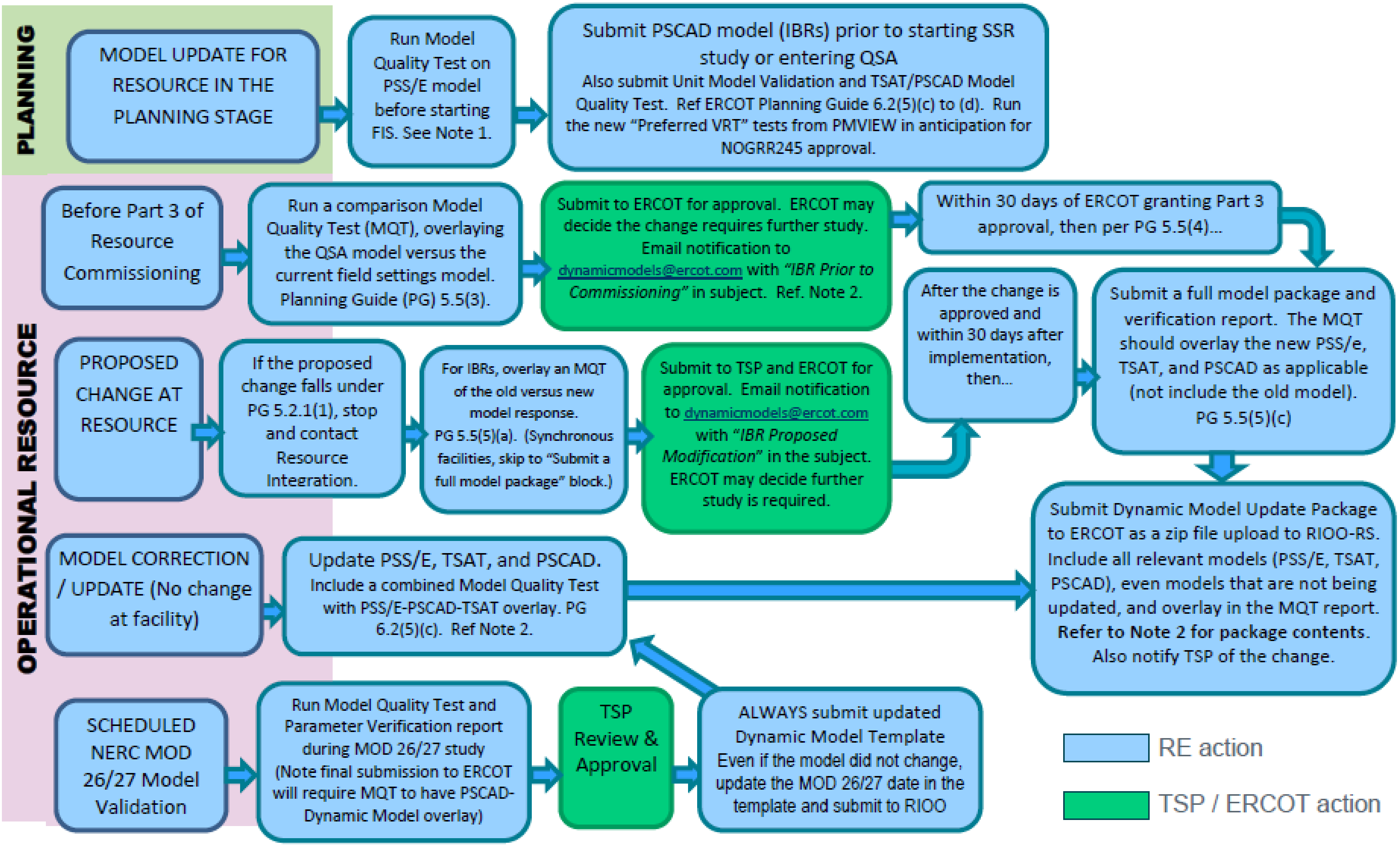
ERCOT accepts either generic or user-defined models (UDM) so long as performance is validated and benchmarked across software platforms.

MQT Applicability (from DWG Procedure Manual)

<table>
<tr><th colspan="2">Test</th><th>Applicable Models</th><th>Applicable Technologies</th><th>Notes</th></tr>
<tr><td colspan="2">Flat Start</td><td rowspan="6">PSCAD
PSS/E
TSAT</td><td rowspan="3">ALL</td><td></td></tr>
<tr><td colspan="2">Small Voltage Disturbance</td><td></td></tr>
<tr><td colspan="2">Small Frequency Disturbance</td><td></td></tr>
<tr><td rowspan="3">Large voltage disturbance tests</td><td>Low Voltage Ride Through “Legacy” Test</td><td rowspan="3">IBRs* and WGRs and IBTEs</td><td rowspan="3">Both LVRT tests should be run for both new and legacy resources.</td></tr>
<tr><td>Low Voltage Ride Through “Voltage Dip” Test</td></tr>
<tr><td>High Voltage Ride Through (HVRT)</td></tr>
<tr><td colspan="2">Large voltage disturbance via a fault test</td><td>PSS/E, TSAT</td><td>Synchronous machines (including synchronous condensers)</td><td>(Synchronous condensers installed as part of an IBR or WGR would not require this test but instead would be included in the VRT tests.)</td></tr>
<tr><td colspan="2">System Strength</td><td>PSCAD, PSS/E, TSAT</td><td>IBRs*, WGRs and IBTEs</td><td></td></tr>
<tr><td colspan="2">Phase Angle Jump</td><td>PSCAD</td><td>IBRs*</td><td></td></tr>
</table>

*For Inverter-Based Resource (IBR) definition, refer to Nodal Protocols Section 2. IBRs includes Solar, Battery, and Type 3 and Type 4 Wind Generation Resources (WGRs).

Model Update Process (from Model Quality Guide)



References

- Model Quality Guide, posted on the Resource Entity page at ercot.com
  - Includes guidance documents for UDM and PSCAD models
- Dynamic Model Templates, posted on the Resource Entity page at ercot.com
- Planning Guide Revision Request PGRR-075 (approved & effective)
- Planning Guide Revision Request PGRR-085 (approved & effective)
- Planning Guide Revision Request PGRR-109 (approved & effective)
- Planning Guide section 5.5 (in particular, paragraph (2) and (3))
- Planning Guide section 6.2 (in particular, paragraph (5))
- DWG Procedure Manual section 3.1
- DMView PSS/E model testing tool
- PMView PSCAD model testing tool

ERCOT model requirements are intended to complement NERC MOD-026/027 model verification requirements.

Questions

?

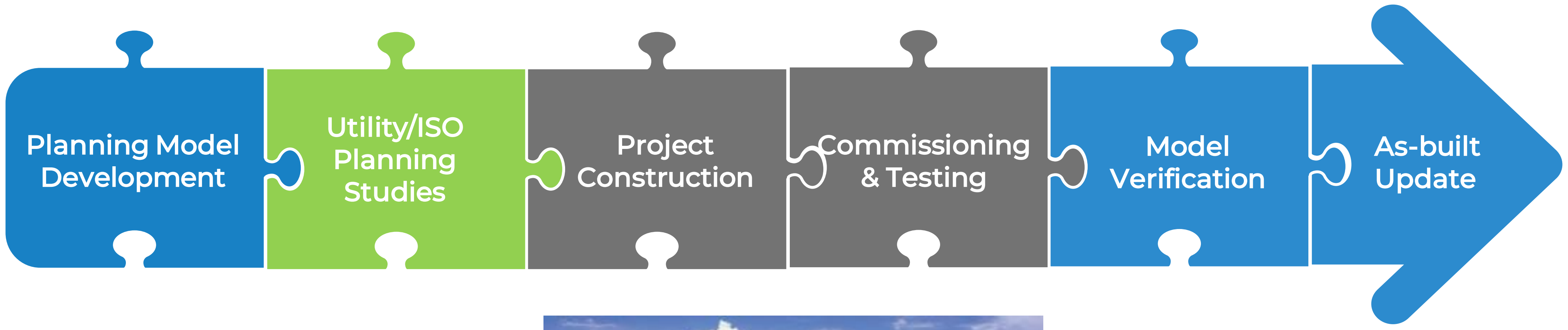
IBR Dynamic Modeling Challenges

- Developer's perspective

John Zong
Electric Power Engineers, LLC

Dec 4, 2024

Developer's View



Task required for interconnection application

Task required for achieving COD and NERC compliance

Planning Model Development

What are being asked:

- Positive sequence, e.g. PSSE, model is required BUT UDM is not encouraged
- If required, EMT model, e.g. PSCAD, is to be submitted after acceptance of PSSE
- Model Quality Tests (MQT)
- Selection of PPC (and its model) does not impact the interconnection application

Developer’s Challenges:

- Difficulties of obtaining PSSE UDMs, and/or TSAT UDMs from OEMs
- Hard to justify the cost of PSCAD model prior to PSSE model submission if it is not required
- Difficulties of obtaining equipment capabilities
- PPC vendor is not selected until later stage

Real-world “Solutions”:

- Use PSSE standard library model for easier and faster approval
- PSCAD models are “tuned” to **reverse benchmark (if required)** against PSSE, in order to avoid PSSE model revisions
- Models are tuned **very nicely** to pass MQT
- A “generic” PPC model is used as a placeholder

Planning Model Development

Real-world Solutions:

- Use PSSE standard library model for easier and faster approval
- PSCAD models are “tuned” to **reverse benchmark (if required)** against PSSE, in order to avoid PSSE model updates
- Models are tuned **very nicely** to pass MQT
- A “generic” PPC model is used as a placeholder

What could go wrong:

- PSSE standard library model cannot be used for development of actual equipment settings
- Reverse benchmarking could make PSCAD model less realistic of representing the actual equipment behavior
- Models are tuned **unrealistically** (without considering equipment limitations) to pass MQT
- Final PPC selection could have a completely different model structure than the generic PPC

What could end up

- Planning models, PSSE and/or PSCAD, cannot realistically and accurately represent the true equipment control logic/capability

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Commissioning and Testing

What are being asked:

- Nothing related to models

Developer's Challenges

- No good planning models to be used for commissioning
- Commissioning engineers do not look at the models

Real-world Solutions:

- Uses OEM default settings

ELECTRIC POWER ENGINEERS

Commissioning and Testing

Real-world Solutions:

- Uses OEM default settings

What could go wrong:

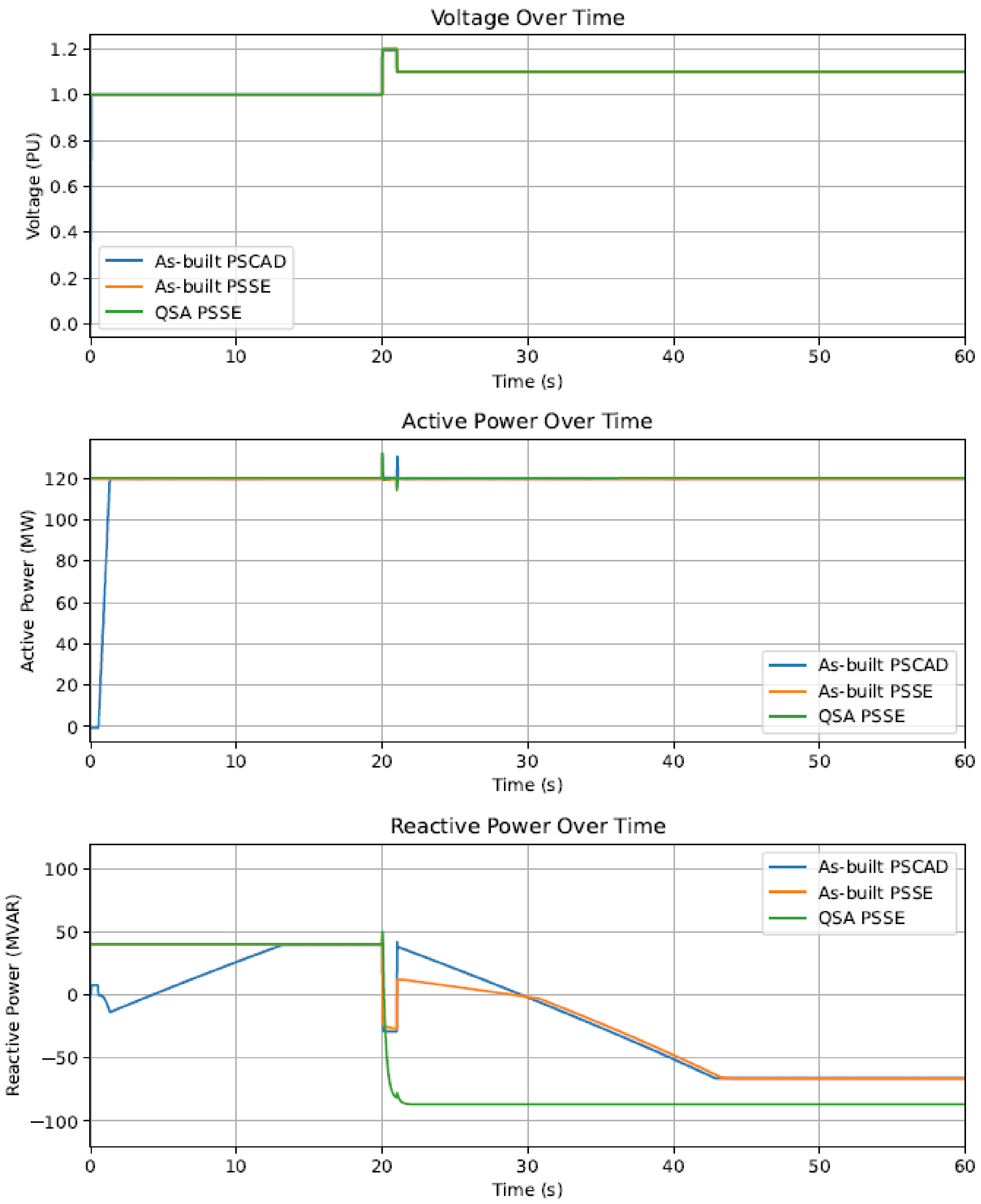
- OEM default settings may result in unplanned and undesirable plant responses, e.g. failing to ride through faults

What could end up:

- A completely different plant (dynamically) is commissioned comparing to what was planned for !

As-built Model

Overlay Data for HVRT - Lagging - POI



What has gone wrong

- As-built plant dynamic behavior is completely different than what was presented in planning model
- Even worse, as-built plant may not even be able to pass fault ride through requirement

ELECTRIC POWER ENGINEERS

Improvements

Utilities / ISOs

- PSCAD models should be required at the same time as PSSE models
- PPC Selection should be part of interconnection requirement
- Model benchmarking between PSSE and PSCAD should be mandatory

Developers

- Implement a more rigorous "model management" process to treat models the same fashion of treating engineering drawings, e.g. Preliminarily model, IFC model, As-built model

OEMs

- Improve model accuracy, e.g. Unit Model Validation (UMV) for both inverters/turbines and PPCs
- Disclose equipment capability information