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Reliability Guideline

Electromagnetic Transient Modeling for BPS-Connected Inverter-Based Resources — Recommended Model Requirements and Verification Practices

NERC
Webinar
May 16, 2023

Introduction

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Program

1. Opening Remarks – Dr. Ryan Quint, Director, Engineering and Security Integration, NERC
2. EMT Modeling Guideline in a Nutshell – Aung Thant, Senior Engineer, NERC
3. ERCOT Experience with EMT Model Requirements – John Schmall, Principal Engineer, ERCOT
4. Recommendations for Generator Owners (GOs) – Andrew Isaacs, VP, Electranix
5. Recommendations for Equipment Manufacturers (OEMs) – Miguel A. Cova Acosta, Lead Specialist, Vestas
6. Q&A
7. Credits

Opening Remarks

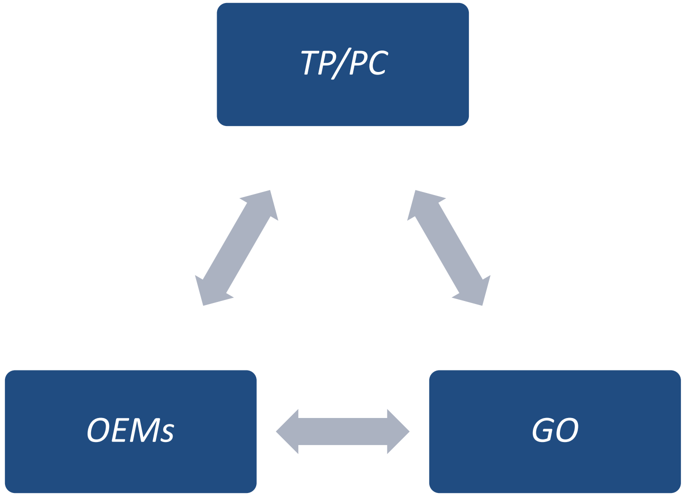
by

Dr. Ryan Quint, Director, Engineering and Security Integration, NERC

EMT Modeling Guideline in a Nutshell

by

Aung Thant (Senior Engineer, NERC EMTTF Coordinator)



EMT Modeling Adoption Visualized in Stages

Stage 1
Establishing EMT Model Requirements

→

Stage 2
EMT Model Quality Assurance

→

Stage 3
EMT Model-based Plant Performance Assessment

→

Stage 4
Screening and Integration in Interconnection Process

→

Stage 5
Conducting Interconnection & Planning Studies (where necessary)

EMT Modeling Adoption Visualized in Stages

EMT Guideline Goal (Stage 3)

NERC Disturbance Reports
- *Instantaneous AC OV, OC*
- *PLL loss of sync.*
- *Phase jump*
- *Unbalanced AC & DC*
- *DC OV*

Odessa disturbances,
San Fernando disturbance,
2021 CA disturbances

EMT SAR Project 2022-04

Stage 1 – Establishing EMT Model Requirements

Stage 2 – EMT Model Quality Assurance

Stage 3 – EMT Model-based Plant Performance Assessment

Stage 4 – Screening and Integration in Interconnection Process

Stage 5 – Conducting Interconnection & Planning Studies (where necessary)

Current EMT Guideline Scope (Stages 1–3)

Future EMT Guideline Scope (Stages 4–5)

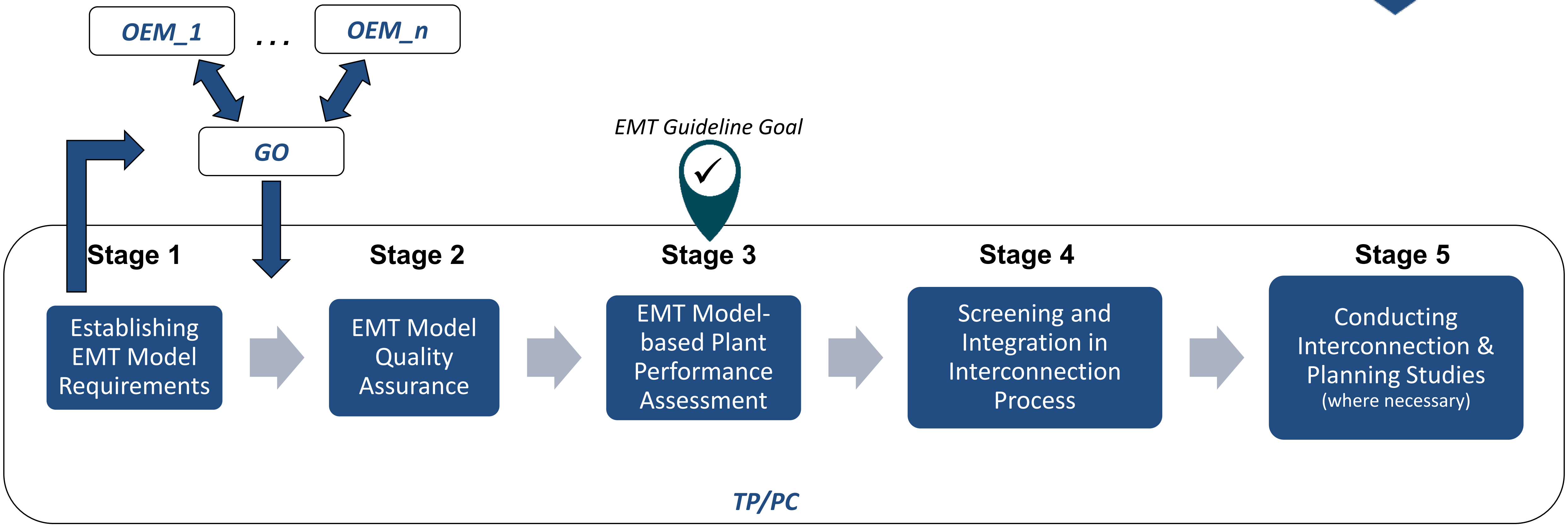
Chapter 1
- Recommended EMT Model Requirements
- Sample Checklist

Chapter 2
- Principles of Model Quality
- Verification Processes
- Attestations – unit models & plant model
- Unit Model Validation

Chapter 3
- Model Adequacy Tests
- Functional Tests
- Disturbance Ride-through Performance Tests

Chapter 4
- EMT Study Use Cases
- Common situations needing an EMT study

EMT Modeling Visualized by Functional Entities

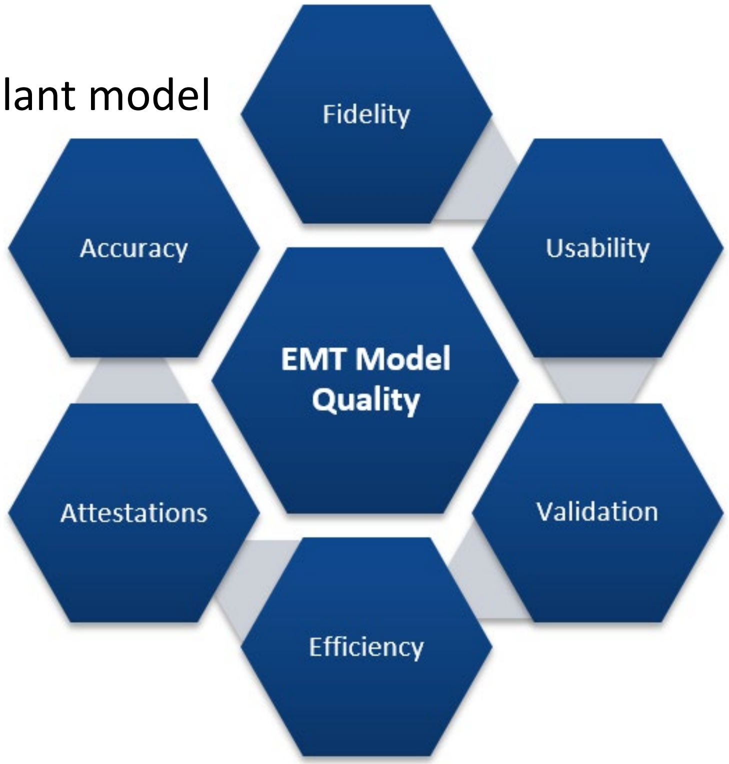


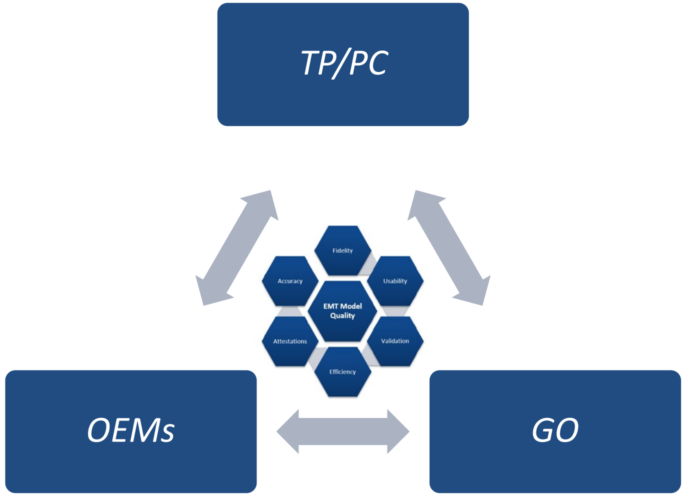
Recommended EMT Model Requirements

- Establish EMT modeling requirements per FAC-002 for all new IBR resources
- Create a "checklist" of EMT model requirements for GO and equipment manufacturers
- Require high quality EMT models as a prerequisite of interconnection
- Require the EMT models accurately represents all pertinent controls, and protections that could affect the electrical output of the facility during and after grid disturbances
- Require all submitted EMT models include
  - Attestations by the equipment manufacturers and
  - Attestations by GO that aggregate model represents the entire plant includes site-specific models, settings, protections, and controls
- Include change management requirements and protocols regarding how changes should be reflected in EMT models by the GO
- Clearly define the purview and duration of EMT simulations

Chapter 2

- **Principles of Model Quality**
- Verification Processes
- Attestations – unit models & plant model
- Unit Model Validation

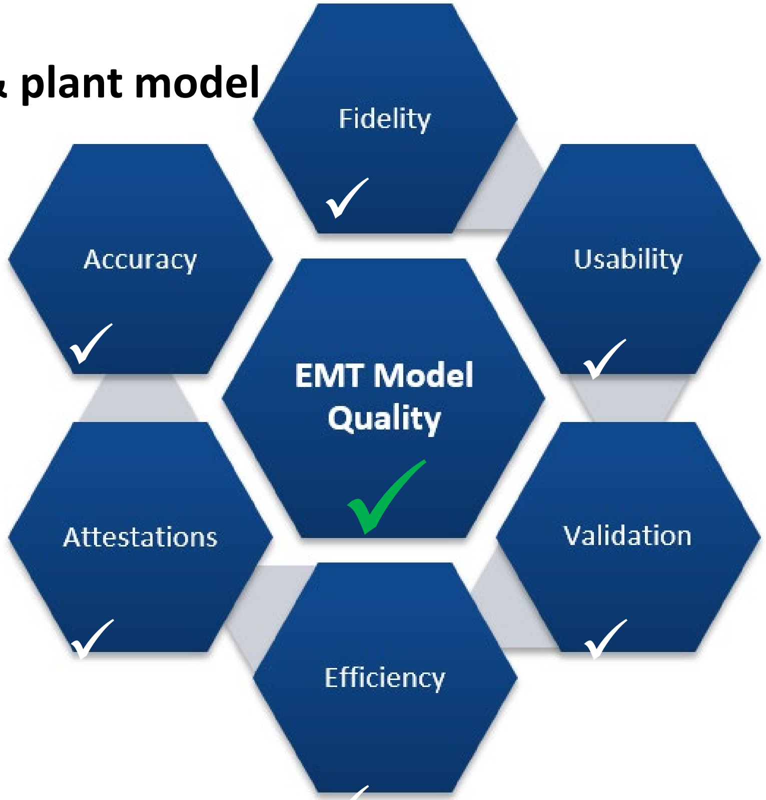


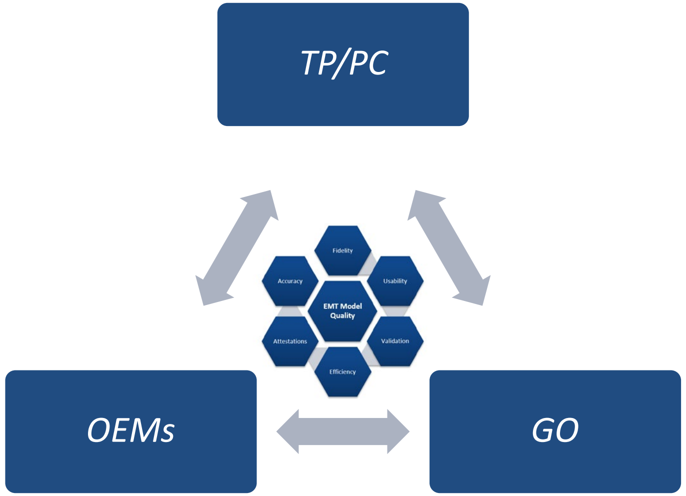


Chapter 2: Model Quality Verification

Chapter 2

- Principles of Model Quality
- **Verification Processes**
- **Attestations – unit models & plant model**
- **Unit Model Validation**





Chapter 2: Model Quality Verification Processes

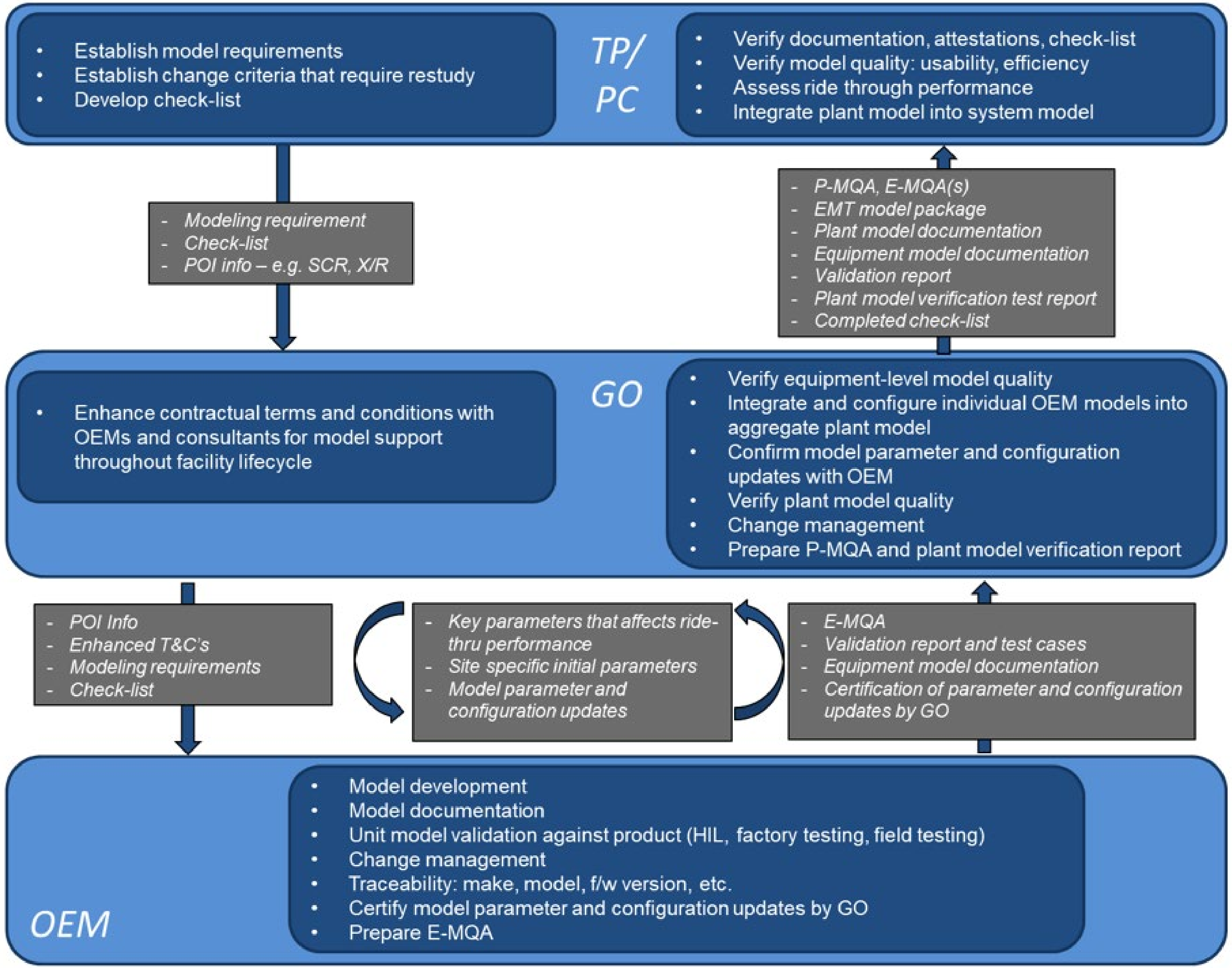
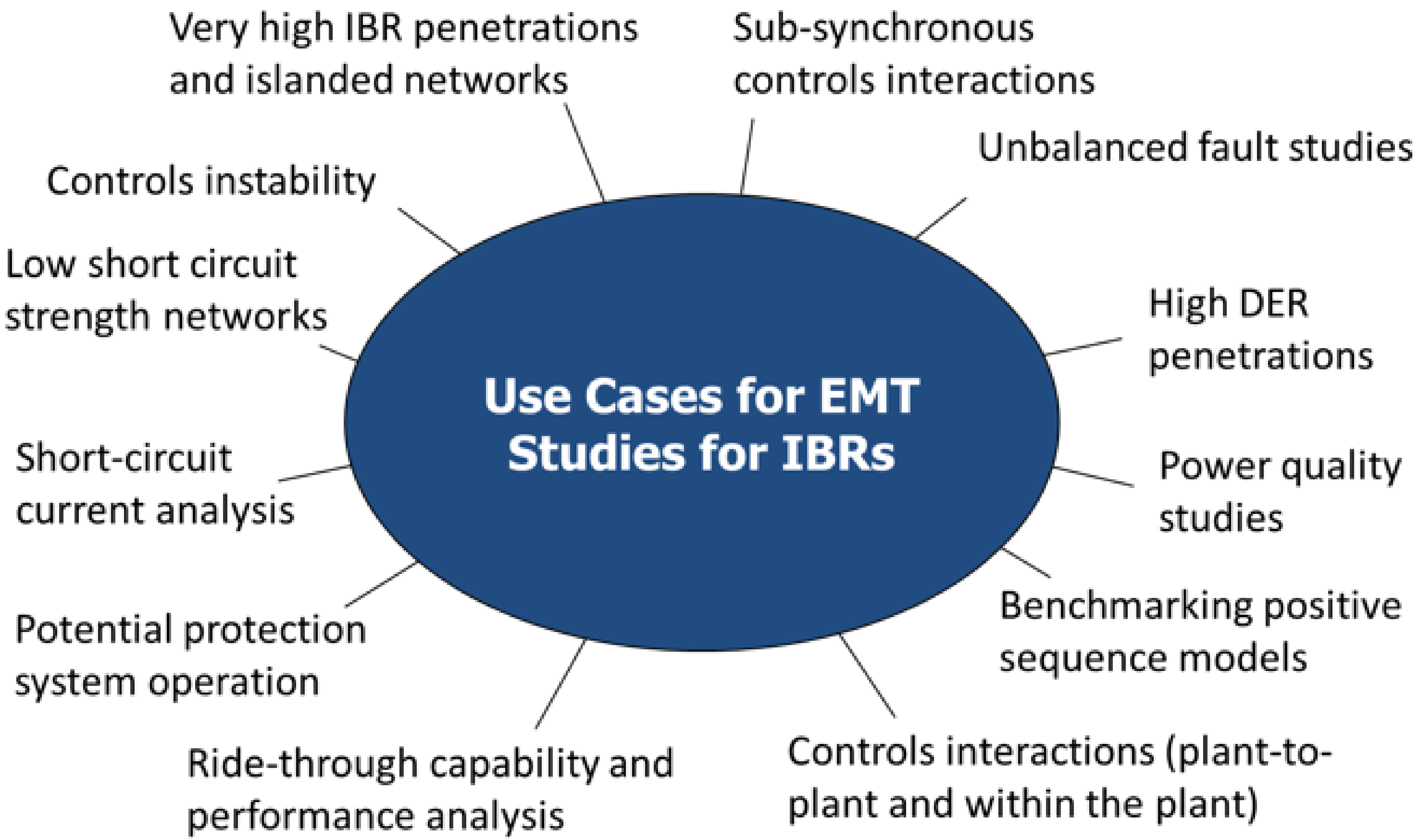


Figure 2.2: Model Quality Verification Processes, pg. 18

Chapter 4: EMT Study Use Cases



Chapter 5 and Appendices

- Chapter 5: Other Relevant Topics
  - **Benchmarking Positive Sequence Dynamic Models against the EMT Model**
  - Resourcing for Future EMT Study Needs
  - Applicability and Use of IEEE 2800 Guidance
- Appendix A: EMT Model Terminology
  - Generic versus Equipment Specific Models
  - Equipment-Specific **Model Types**
    - Transparent EMT Models
    - "Black Box" EMT Models
    - "Real Code" EMT Models
  - Detailed and Aggregate EMT Modeling
- Appendix B: **References for EMT Model Requirements**

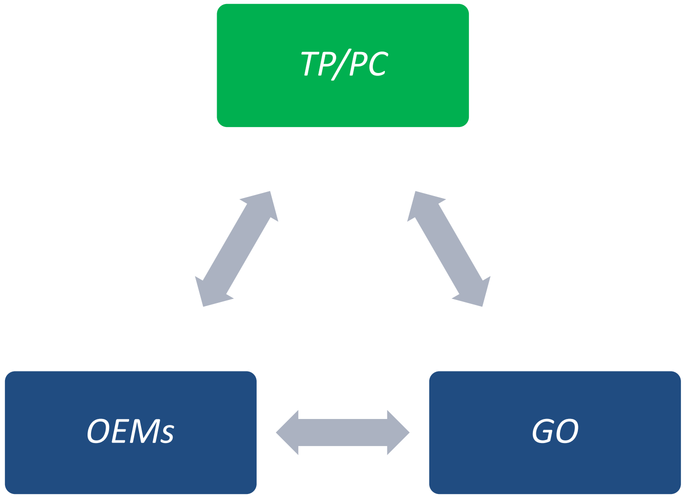
Key Takeaways

- Help industry close EMT modeling knowledge gaps
- Provide a foundation of knowledge for new modeling requirements and practices
- Guidance to make quality-vetted EMT models available to TPs and PCs for the purposes of reliability studies – interconnection studies per FAC-002 and planning assessments per TPL-001
- Help industry close current gaps between interconnection studies and installed equipment

ERCOT Experience with EMT Model Requirements

by

John Schmall (Principal Engineer, ERCOT Transmission Planning)



Evolution of ERCOT EMT Model Requirements

- 2009 – SSR/SSCI Event in ERCOT
- 2013-2017 – SSR/SSCI Evaluation Requirements
- 2015 – Panhandle Study
  - Large-Scale Application Beyond the SSR/SSCI Realm
- 2016 – EMT Models Required to be Submitted
  - All New IBR Interconnections
  - EMT Model Guidelines/Checklist
- 2021 – Implemented More Thorough Review Processes
  - Planning Guide Revision Request (PGRR) 085
  - Validation
  - Benchmarking (PSCAD versus PSS/e)

PGRR-075

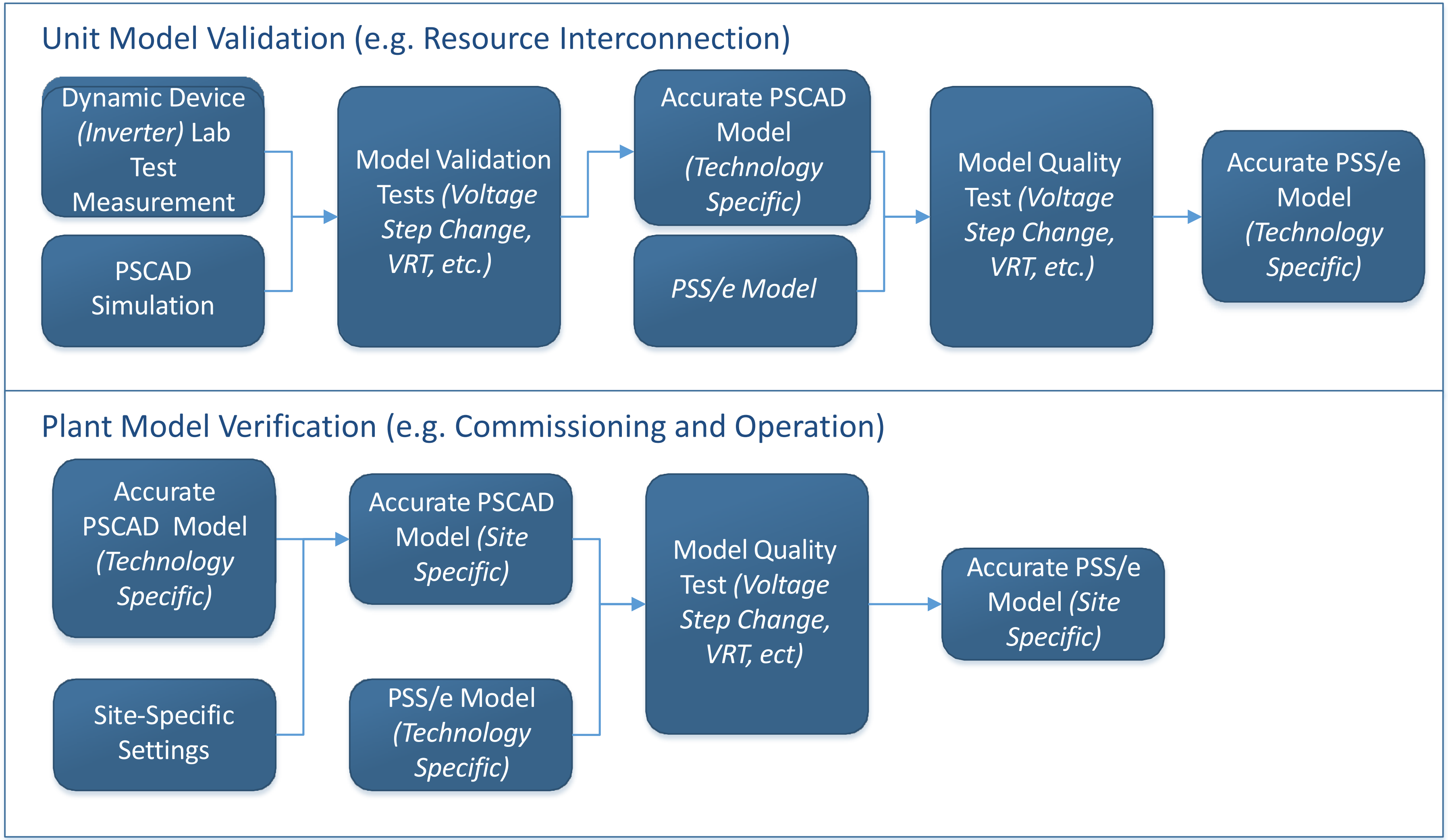
- Effective May 1, 2020
- Introduced model quality test (MQT) requirements (for PSS/e dynamic model)
- Performed/submitted by resource owner
- Demonstrate basic reasonable model performance
  - Flat Start Test (no disturbance test)
  - Voltage Step Change Test
  - Frequency Step Change Test
  - Voltage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

These are not EMT requirements, but ERCOT emphasizes model consistency between PSS/e and PSCAD.

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 match model parameters
- Performed/submitted by resource owner
  - Required prior to Quarterly Stability Assessment (QSA)

Model Validation and Verification Concept



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Summary of Dynamic Model Requirements

Requirement	Applicable Equipment	Required Tests[1]	When to Update	Responsible Entity	Language
Model Quality Test for PSS/e Model	All Resources and Dynamic Transmission Elements (system strength test is only required for inverter-based devices)	Flat start, small and large voltage disturbance, small frequency disturbance, and system strength tests	A new or updated model	Equipment owner (RE, IE or TSP)	PG 6.2(5)(c)
Model Quality Test for PSCAD Model	Inverter-based Resources (IBRs) and Dynamic Transmission Elements	All above tests plus phase angle jump test	A new or updated model	Equipment owner (RE, IE or TSP)	PG 6.2(5)(c)
Unit Model Validation for PSCAD Model[2]	Inverter-based Resources (IBRs)	Step change in voltage, large voltage disturbance, system strength, phase angle jump, and subsynchronous tests	A new PSCAD model provided after 3/1/21. (Validation tests should not need updating for model parameter updates on an existing model.)	Resource owner (RE or IE)	PG 6.2(5)(d)
Model Parameter Verification ("Verification Report")	All Resources and Dynamic Transmission Elements	Provide evidence that tunable model parameters match what is implemented in the field. Evidence can take the form of screenshots, nameplate photographs, signed manufacturer commissioning reports, etc.	1. Required within 30 days of COD (i.e., Part 3 approval), 2. 12 to 24 months after COD or 12-24 months after March 1, 2021 for existing resources, 3. A minimum of every 10 years. 4. Within 30 days of a change at the plant	Equipment owner (RE, IE or TSP)	PG 5.5, PG 6.2(5)(b)

(1) Detailed test information is available in the DWG Procedural Manual 3.1.5.

(2) Benchmark the PSCAD model against actual hardware measurements. This is not a site-specific test; the same report can be submitted for different projects whenever that the same inverter is used.

EMT Model Process Challenges

- Timing and availability of EMT model
  - Resistance/barriers to providing EMT model early in the interconnection process
- Proprietary models (issues largely resolved with black box models)
- EMT model does not automatically equal good/accurate model
  - Testing and review is needed
  - Model functionality and usability (troubleshooting)
  - Need for EMT model "Template"?
  - Beneficial to use single plot axes for performance comparisons cross software platforms
  - Cannot test everything - need to strike an appropriate balance

EMT Model Usage Challenges

- When Is an EMT system study needed?
  - Largely based on **engineering judgment** - Industry does not agree on a bright-line criterion
  - ERCOT does not routinely require an EMT system study during interconnection process unless needed to assess a potential SSR vulnerability
  - Incorporation of legacy units in the study area
  - Impact on interconnection timelines for new generation
  - More complex models > Unexpected study challenges > More uncertainty in study timelines
- Stability is primarily assessed with positive sequence tools in ERCOT
  - EMT studies are conducted when deemed necessary

References

- Model Quality Guide, published on the RE webpage at ercot.com
- Includes ERCOT PSCAD model guidelines/checklist
- Links to external PSCAD tools: PMVIEW and PCAR
- Dynamic Model Templates, published on the RE webpage at ercot.com
- Planning Guide Revision Request PGRR-075 (approved & effective)
- Planning Guide Revision Request PGRR-085 (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

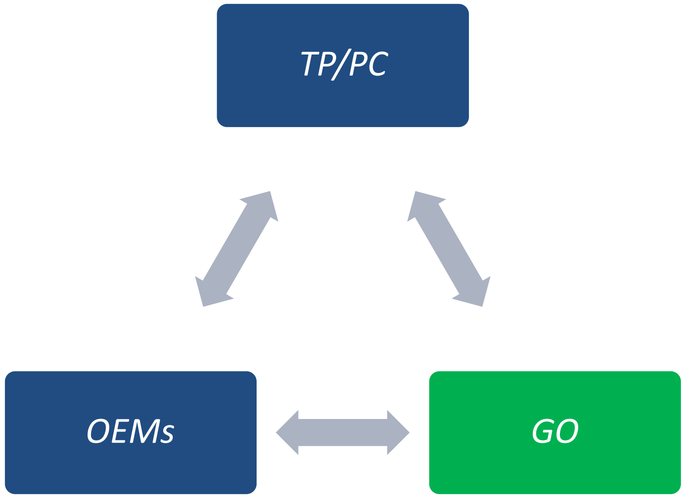
ERCOT model requirements are intended to complement NERC MOD-026/027 model verification requirements.

Recommendations for Generator Owners

What to do and what to look out for …

by

Andrew Isaacs (VP, Electranix)



Recommendations for GOs

- Recommendations for Generator Owners (GOs) and their consultants (pg. 18-20) include:
  - Verification of component models and the overall facility, including a set of detailed suggestions for what constitutes verification
  - Suggestions for working with the OEM and for how to continue support for the model going forward
  - The EMT models need to be very detailed and accurate!

Why the recommendations for GOs?

- **Why though? Pandering (but short) lecture to follow**
  - Models are the basic components of the studies that are (or will be) relied upon. If they are badly wrong, we are all wasting our time and the lights may go off.
  - EMT models in particular are used for special situations, or when we have insufficient confidence that Phasor Domain tools are correctly predicting outcomes.
  - Note that if we can't replace the pieces we're missing from PD tools, then **why do the study at all**? Hence, the models need to be accurate in the ways that PD tools cannot be.
    - e.g. *Why does a plant fail to ride through a fault? Why might a PD tool miss this?*

How are plant models built?

- How are the plant models built in a way that matches recommendations?
  - Design your plant to the best degree you can. Try to be as certain as possible about equipment choices, plant design, etc. The more certainty you can commit at an early stage, the smoother your path will be down the road. People will make decisions based on your choices, and changing your mind may have consequences!
  - Review local specific requirements
  - Collect component models from OEMs, including information and assistance regarding parameterization.
  - Batteries, PV inverter modules, wind turbines, power plant controllers, etc.
  - Test the component models (use quality, accuracy and usability tests publicly available, or develop your own based on industry guidance)

How are plant models built?

- How are the plant models built in a way that matches recommendations (cont.)?
  - Collaborate with site design engineers/EPC to understand plant layout. Focus on high level plant electrical SLDs, inter-device communication and coordination, and protection.
  - Perform aggregation exercise for collector and generator systems.
  - Assemble the plant model in applicable tools (Phasor domain and EMT).
  - Perform final quality tests and likely performance tests which match requirements for the utility as well as they are known and to the extent possible (note that you may not have much system info).
  - Requires continued collaboration with OEMs… note recommendation to enhance contractual relationship with OEMs.
  - Best practice and sometimes required: compare responses between tools to ensure basic parameterization is correct.
  - Document, submit, and prepare to support the model going forward. Your job isn't done after submission.

Key Challenges (cont.)

- Expertise/experience is in high demand.
  - *Tip:* Develop in-house expertise to the degree possible.
  - *Tip:* Plan resourcing in advance. Please don't leave it until 1 week before a submission deadline! Everyone is busy, and the work can be complex. Line up resources months in advance if possible.
- Early plant designs may be very preliminary.
  - *Tip:* Use best available information, but understand that many process will be using these models for studies, and changing equipment in material ways can have implications on project.
  - *Tip:* Try to build commitment into your project flow, contractually or otherwise. Changing horses (i.e. inverters) midstream usually results in re-study and delay, and may impact queue position.

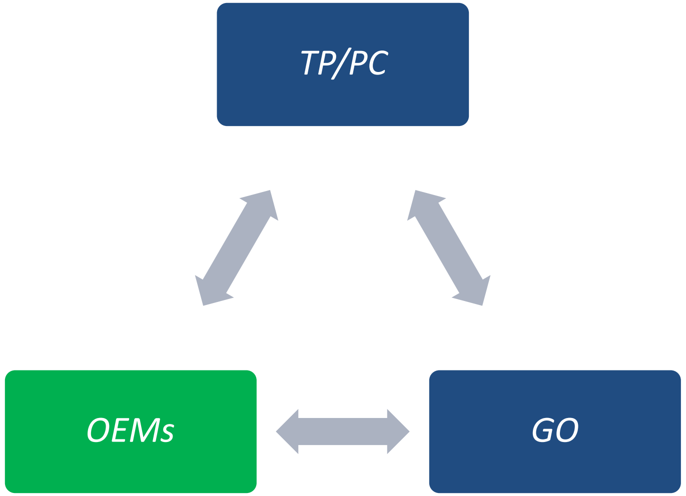
Key Challenges (cont.)

- Coordination of OEM models (e.g. Inverter, PPC, STATCOM) requires the EPC or integrator to have a good understanding of all the pieces.
  - *Tip:* Ask questions like:
    - How is voltage control coordinated?
    - Which component of the plant is responsible for meeting each performance requirement of the TO?
    - What are the communication or sampling delays involved between plant components?
    - What are the response timeframe does each piece operate under?
    - What degree of confidence do I have in each answer, and how does that impact risk for the project?
- Understanding the connection between hardware settings and model settings for correct parameterization and as-built confirmation. Field engineers speak a different language from modeling engineers.
  - *Tip:* OEMs are the key here! Build a relationship (or contract) with OEMs so that they can assist through the process. Consider this support as you make OEM selections.

Recommendations for Equipment Manufacturers (OEMs)

by

Miguel A. Cova Acosta (Lead Specialist, Vestas)

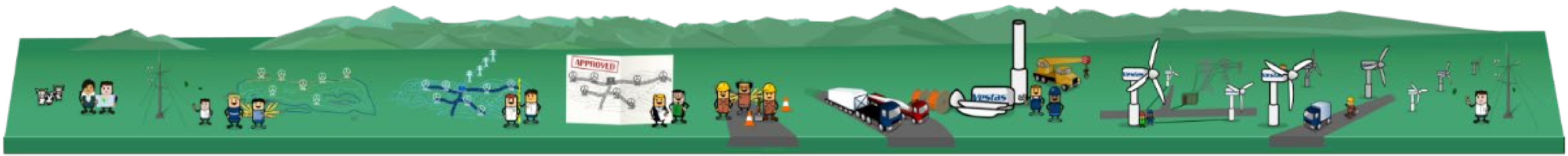


Recommendations for Equipment Manufacturers

- **OEM should consider system information provided by GOs and configure the equipment models accordingly to be site specific.**
- **OEM should not indiscriminately provide models with default parameters to GOs.**
- OEM should collaborate with GOs to review and approve any changes to the model parameters and configuration.
- **OEM should develop change management to ensure traceability of the equipment models to actual product model, variant, firmware version.**
- OEM should be prepared to provide unit model validation reports.
- OEM should make clear in model documentation the following:
  - Any built-in, hardcoded, or hardware-based protection that can affect the inverter current output during and post grid disturbances
  - User-settable settings that can affect the inverter current output during and post grid disturbances

Project Development Phases

OEM should develop change management to ensure traceability of the equipment models to actual product model, variant, firmware version.



Project Development
- PoI identification
- Preliminary conceptual eBoP design
- Grid Connection application

Sales
- Grid risk management
- Value engineering

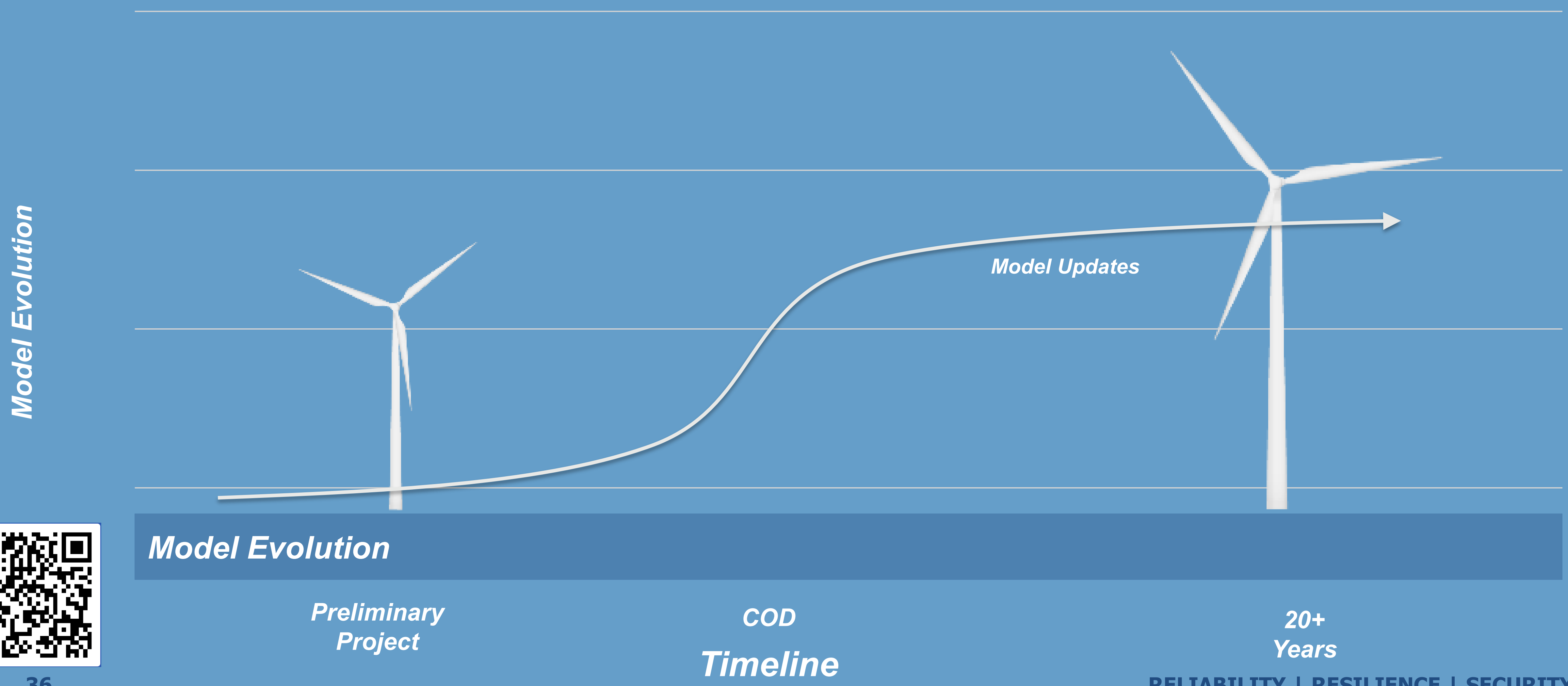
Construction
- Projects execution (WTG, PPC)
- Grid Compliance Tests

COD

Service
- Grid Compliance along project lifetime
- After-Sales Grid solutions
- Site troubleshooting in relation to Grid

Product Management
- Regional Grid Working Groups & TSO/ISO interaction

Model Life Span



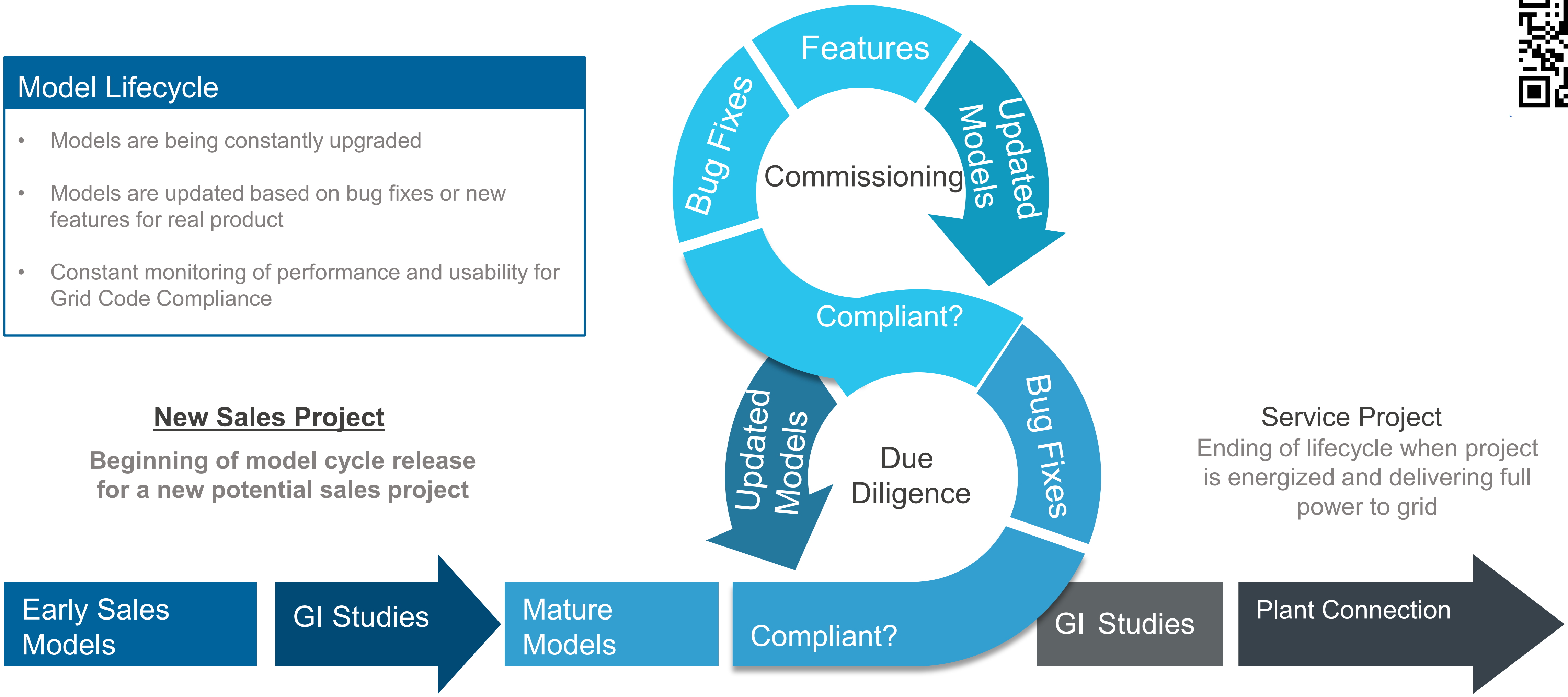
Models Traceability and Maintenance

Model Lifecycle

- Models are being constantly upgraded
- Models are updated based on bug fixes or new features for real product
- Constant monitoring of performance and usability for Grid Code Compliance

New Sales Project

Beginning of model cycle release for a new potential sales project



Service Project

Ending of lifecycle when project is energized and delivering full power to grid

EMT Model Overview

Hardware Circuit
Represents the electric circuit model for a wind turbine. The most common topologies will be Type-3 and Type 4

Control Code
Source Code from product controller that monitors the state of the input and takes decisions based upon user commands and parametrization

Interface
User Interface to control and configure the model performance. Normally resides in the visual interface of the power system simulation tool

Parametrization
Set of site-specific set of parameters required for grid code compliance in every different market

Model Parametrization

- Parametrization is a fundamental subpart of the electrical models is directly linked with the control code.
- Parametrization will contain several hundreds of parameters in the product that will determine the performance of the specific turbine or power plant control variant.
- Some of these parameters are accessible to the user for fine-tuning. However, most of them remain encrypted to guarantee the performance of the product and the grid code compliance.
- Regardless the parameter encryption, models should be flexible to provide the option for users to overwrite any single parameter of the model with without recompiling or reissuing the model dll’s or lib files.

Questions and Answers

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