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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Welcome to the Milestone 3 of FERC Order 901 NERC Industry Engagement Workshop Day 1

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Opening Keynote Speaker

Mark Lauby Senior Vice President and Chief Engineer, NERC
Milestone 3 of FERC Order 901 NERC Industry Engagement Workshop
June 3, 2025

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Panel Discussion 1: Ensuring Accurate Models throughout the Lifecycle of IBRs

Moderators: Aung Thant, NERC

Panelist: Julia Matevosyan (ESIG/i2X), Samir Dahal (Siemens), Miguel Acosta (Vestas), Mohamed El Khatib (Invenergy),

Slido Q&A

- Option 1
  - Navigate in browser to www.slido.com
  - Enter event code: NERC901
  - Provide email address when requested

- Option 2
  - Scan the QR code to be directed to the website

IBR Modeling Needs during Interconnection Process

Julia Matevosyan

Associate Director and Chief Engineer

ESIG

ESIG
ENERGY SYSTEMS
INTEGRATION GROUP

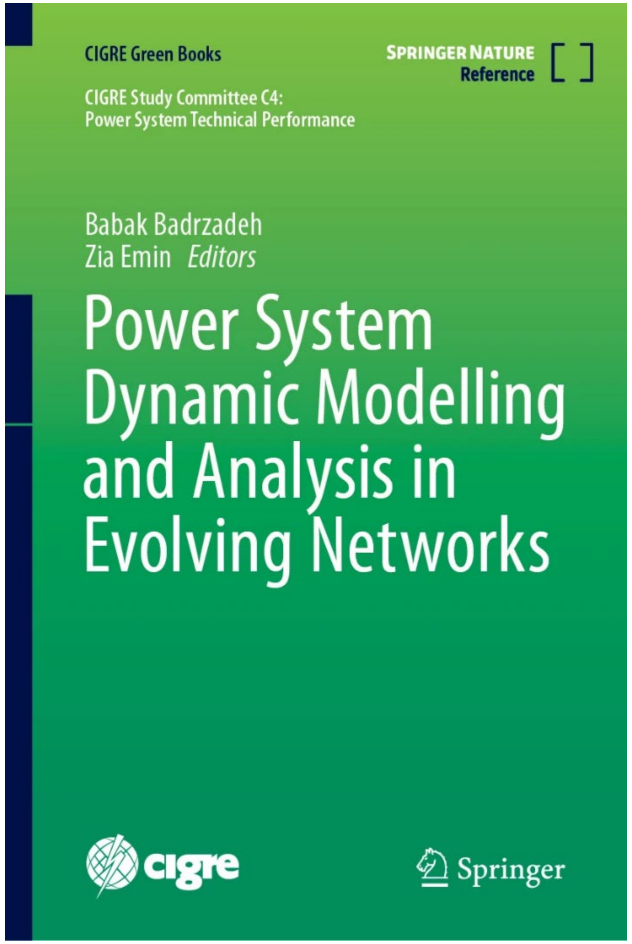
6/3/2025

Inputs into This Presentation

ESIG i2X FIRST website: https://www.esig.energy/i2x-first-forum/

i2X INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

ESIG Tutorial: Electromagnetic Transient Analysis Simulation Tools



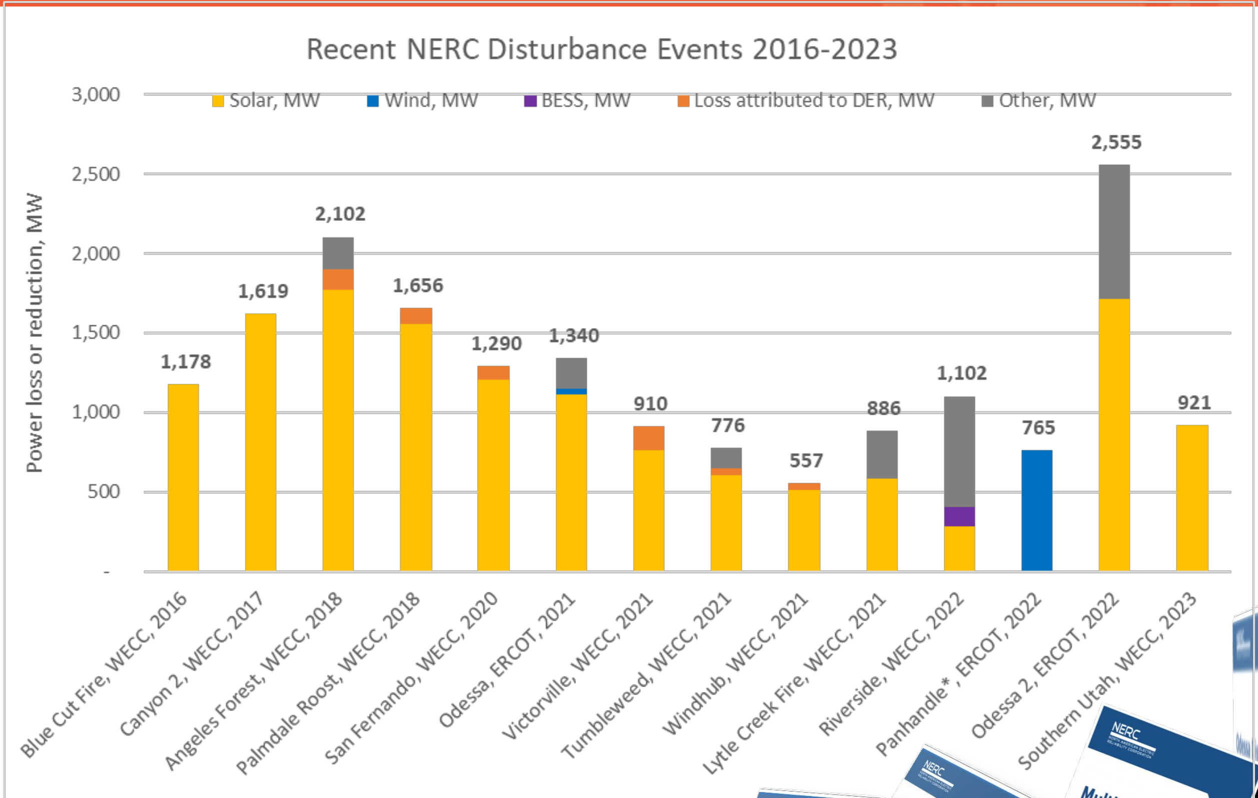
NERC Disturbance Events – Importance of Fault Ride-Through Evolution and Model Accuracy

ESIG

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



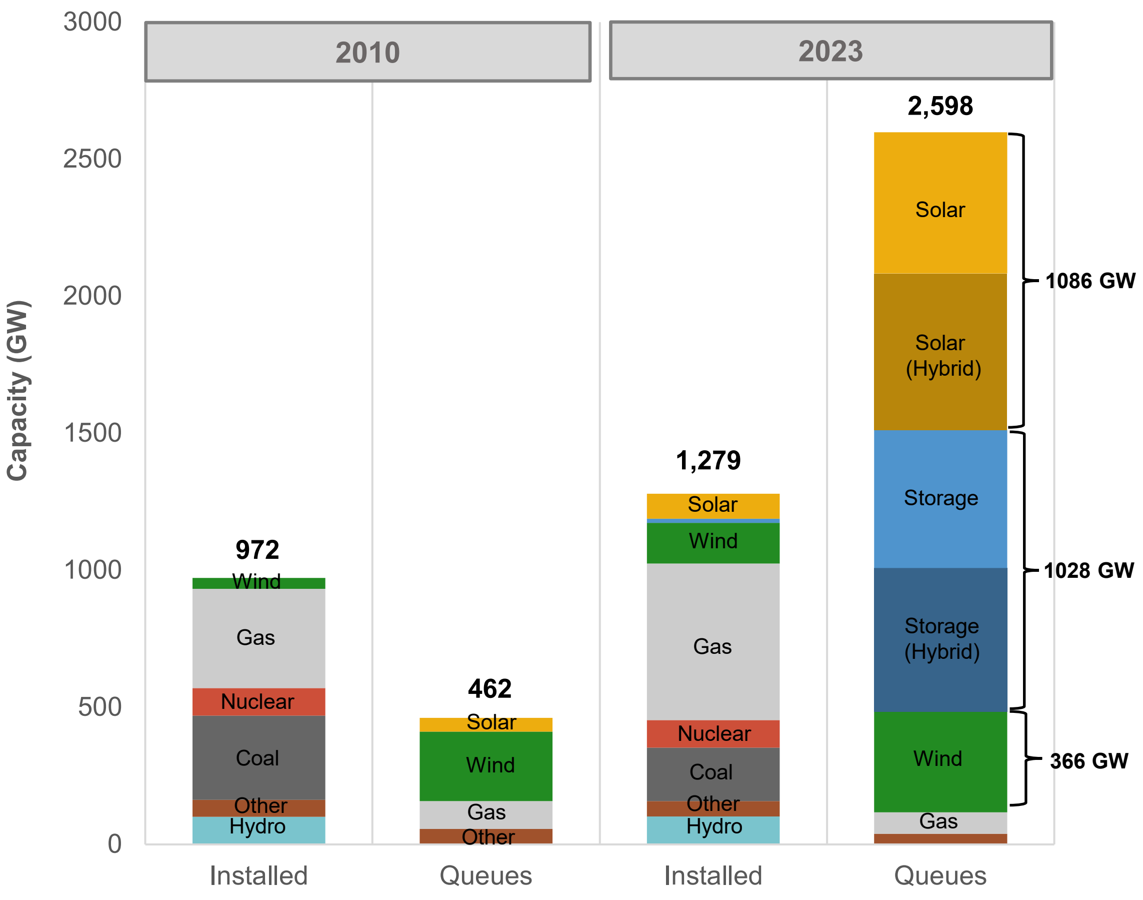
* Two disturbances occurred the same day. The larger of the two is shown on the plot

Source: NERC Event Reports

Growth of IBRs and Importance of EMT Models

- Over 2500 GW of total generation and storage capacity in the U.S. interconnection queues, as of the end of 2023, majority are inverter-based resources (IBRs)
- Growing need for EMT modeling as the system evolves to weaker grids and more advanced controls
- EMT models are important not just for EMT studies but for IBR conformity assessment with applicable interconnection requirements and benchmarking with PSPD 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: Adapted from LBNL, [Queued Up: 2024 Edition, Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023]

Types of Power Plant Models

Generic Positive Sequence Models

- Model structure is fixed, only parameters are provided
- White-box structure
- Suitable for large system, transmission planning studies
- Software tools like PSSE, PSLF, TSAT

OEM-Specific Positive Sequence Models

- Model structure is determined by the OEM
- Black-box structure
- Suitable for studies requiring more detail, some interconnection studies
- Software tools like PSSE, TSAT

OEM-Specific EMT Models

- Proprietary models are created by the OEM
- Black-box structure
- Required for special applications (weak grid, series-compensation, etc.)
- Software tools like PSCAD, EMTP, ATP

Reduced detail and complexity — Increasing detail and complexity

Large studies, many assets modeled — Focused studies, critical assets modeled

The “right” (most appropriate) model to use depends on the application, risk, and data available

Source Andrew Isaacs & Lukas Unruh, Electranix, ESIG Tutorial: Electromagnetic Transient Analysis Simulation Tools

Modeling Requirements for Various Study Types

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STUDY TYPE / MODEL TYPE	IBR Design Studies	Grid Impact Studies	Long-term Planning Studies	**Special Scenario Studies** (e.g. low system strength, SSO, etc.)
Vendor-Specific EMT	Detailed	Aggregated	Aggregated	Aggregated or Detailed
Generic EMT	X	X	Aggregated	X
Vendor-Specific PSPD	Detailed	Aggregated	Aggregated	X
Generic PSPD	X	X	Aggregated	X

Source: CIGRE Green Book, Power System Dynamic Modelling and Analysis in Evolving Networks, Workshop at CIGRE Paris, September 2024

Examples of IBR Studies and Related Simulation Models

Required Study	**Extent of System Model**	**Simulation software (Aggregate Model)**
IBR plant response to frequency disturbances	Single Machine Infinite Bus (SMIB)	PSPD
IBR plant response to voltage disturbances	SMIB	PSPD
	SMIB	EMT
IBR plant response to disturbances following a contingency	SMIB	EMT
	Full network model	PSPD
Partial load rejection	Full network model	PSPD
Protection of generating units from power system disturbances	SMIB	PSPD
IBR plant protection systems that impact power system security	Full network model	PSPD
Frequency control	SMIB	PSPD
Impact on network capability	Full network model	PSPD
Voltage and reactive power control	SMIB	PSPD
	Full network model	PSPD
Active power control	SMIB	PSPD

Source: Adapted from CIGRE Green Book, Power System Dynamic Modelling and Analysis in Evolving Networks, August 2024

Approach to Model Validation

ESIG

Unit Level IBR Type Testing and Model Validation

↓

Build Plant Model + aggregated collector model → Test Model Quality (EMT & PSPD) Benchmark EMT and PSPD models

↓

Commissioning Testing and Model Validation (PPC: volt/var + PFR)

↓

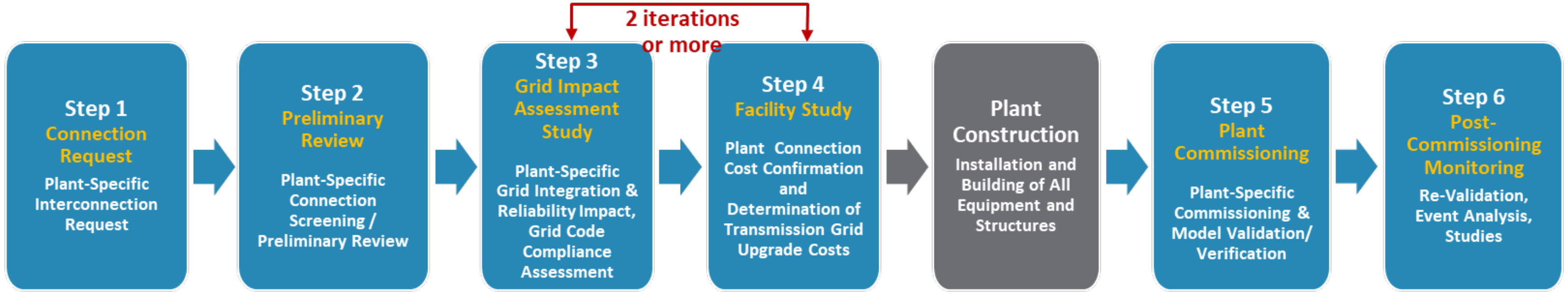
Monitoring and Post-Commissioning Updates

The value of interconnection and planning studies is severely reduced if the models used are not representative of the actual equipment. More stringent requirements for model quality testing and model validation are needed.

- Purpose of the Model Quality Test is to ensure that
  - model initializes properly
  - model passes interconnection performance requirement checks (high level)
- Purpose of EMT vs PSPD benchmark is
  - to ensure model performance agrees (where relevant)
  - to be used in model validation if type test data is not available

Source: Adapted from Pouyan Pourbeik, PEACE, Importance of Models, Model Validation and Lack of Follow-up Past Commissioning, ESIG-NAGF-NERC-EPRI Generator Interconnection Workshop, August 10, 2022

Recommended Study Approach



Interconnection Application

- 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

Final Design Determined

- 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

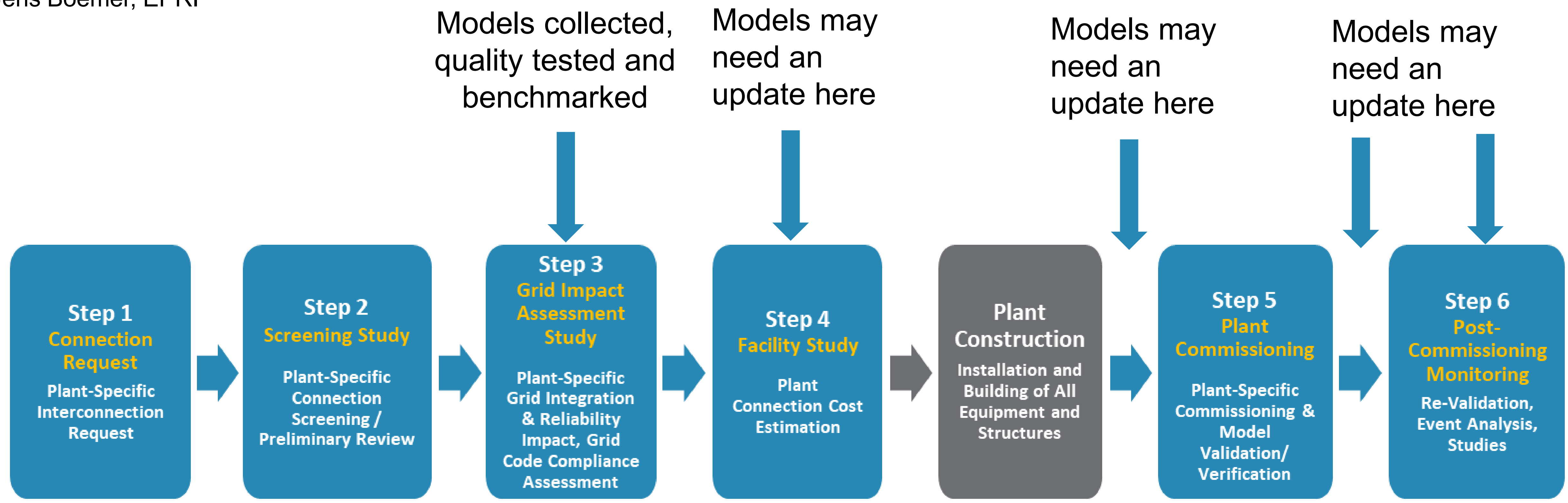
Commissioning of IBR Plant / **Lifetime of IBR Plant**

- 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

Collect, Verify, Benchmark and Quality Test Models at the Interconnection!

Figure adapted from
Jens Boemer, EPRI



* Every time a plant model is updated, quality testing, validation/benchmarking steps are repeated, and some relevant studies may need to be repeated depending on the model change

Detailed Models ≠ Accurate Models
Need for Model Validation, Verification and Quality Testing

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Generation Interconnection → **QSA**** → **Commissioning** → **Operations**

Generation Interconnection
- Provide PSPD model
- PSPD model quality tests
- EMT model and tests request may be triggered at this stage*

QSA**
- EMT model and quality tests
- EMT model validation
- Benchmark PSPD↔EMT using model quality tests onwards

Commissioning
- Verification of key settings of EMT models
- Model quality tests (PSPD and EMT) are required for any model or setting changes during Commissioning

Operations
- Keep dynamic models up to date
- Verification of key settings within two years and every ten years thereafter or if there is a settings change
- Model quality tests and verification are required for any model or setting changes during Operation

Is the model:
- **Accurate**
- **Usable**
- **Site-Specific**
- **Performance** conforms with interconnection requirements?

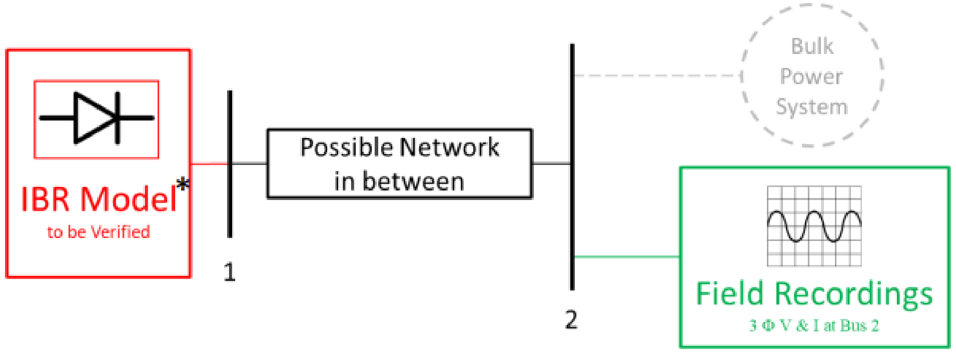
* If SSR or others EMT studies are deemed necessary in the interconnection process
** QSA: Quarterly Stability Assessment

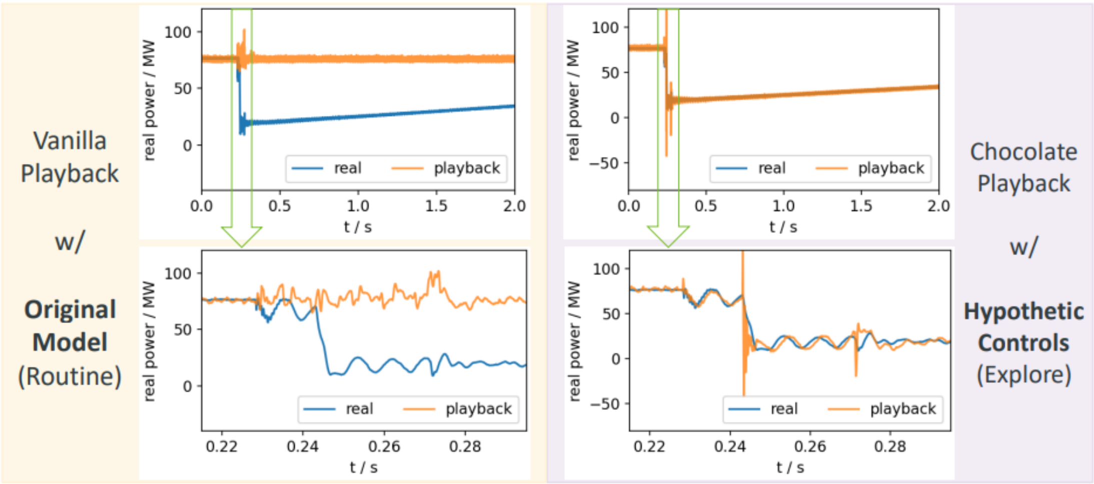
Resource Entities are responsible for all these requirements, from model validation, model quality tests, to model verification

Source: Xiaoyu (Shawn) Wang, "EMT Modeling and Studies in ERCOT", ESIG Fall Technical Workshop, 2023

Post-Commissioning Model Validation is in Early Stage

- High resolution data recording on site is currently 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
- While NERC PRC-028 introduce data recording and retention requirements the implementation timeline is long, and requirements are resolution is lower than IEEE2800.
- 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]

Key Takeaways

- The value of interconnection and planning studies is severely reduced if the models used are not representative of the actual equipment.
- More stringent requirements for model quality testing and model validation are needed.
- Different models in different simulation domains are needed for studies of different phenomena – “horses for courses”
- EMT models are important not just for EMT studies but for IBR conformity assessment with applicable interconnection requirements and benchmarking with PSPD models
- Detailed models ≠ accurate models, there is a need for model validation, verification and quality testing
- Post-commissioning model validation is still in early stage, PRC-028 and PRC-030 are steps in the right direction, but more work is needed

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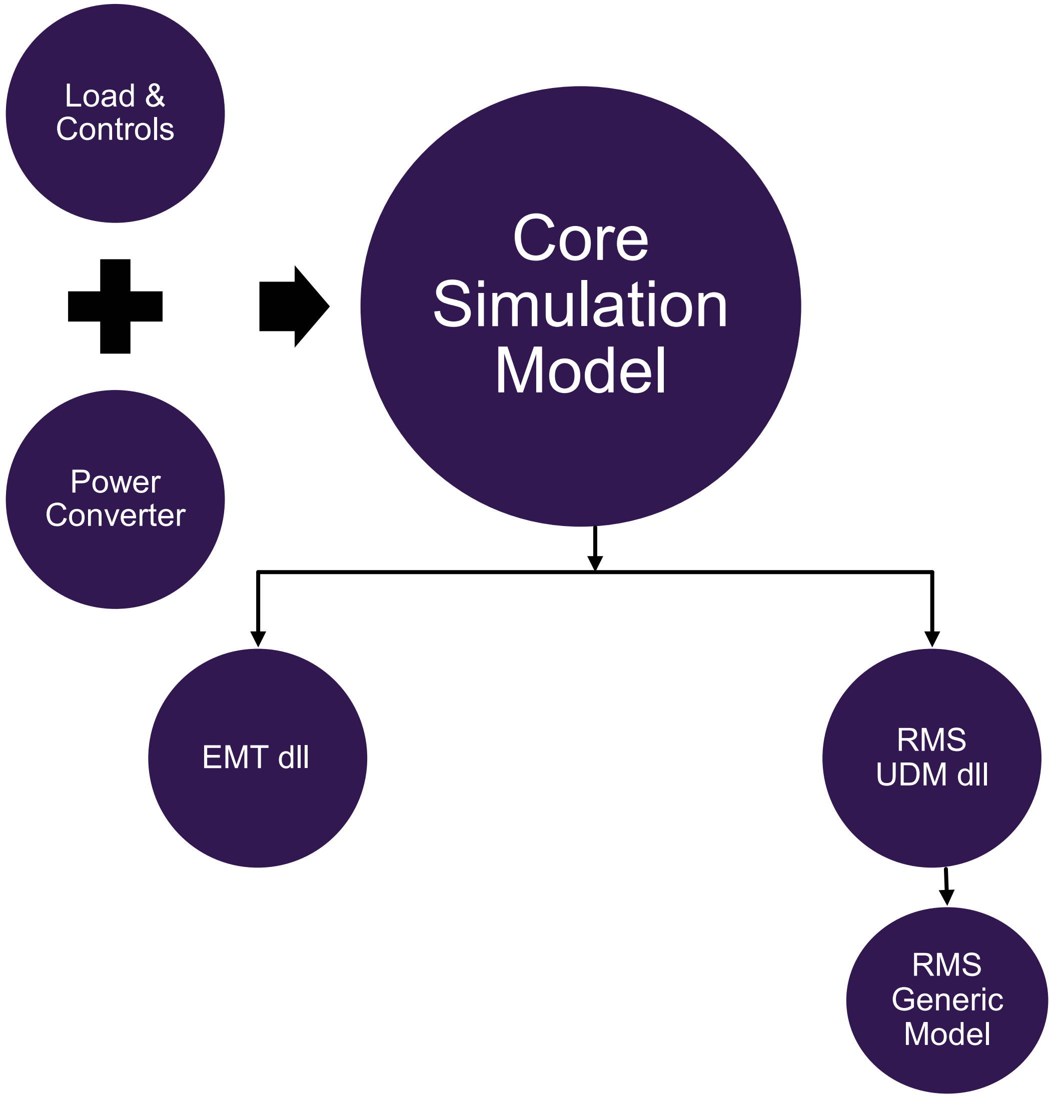
Managing Model Accuracy in IBR Plants

Samir Dahal
Senior Key Expert
Siemens Wind Power
06/03/2025

AGENDA

Electrical Simulation Model Creation



Model Validation

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- Aerodynamic Models + Controls ➔ Loads & Controls
- Converter Model ➔ HIL Validation + Full scale Grid Simulator Validation + type testing
- Full WTG Model ➔ HIL Validation + Full scale Grid Simulator + Prototype testing + Operation Experience

↓

Core Simulation Model + EMT Model + RMS UDM (certain tests)

↓

RMS UDM benchmarked against EMT Model

↓

RMS generic model benchmarked against

Model Validation – Why it Matters to OEMs

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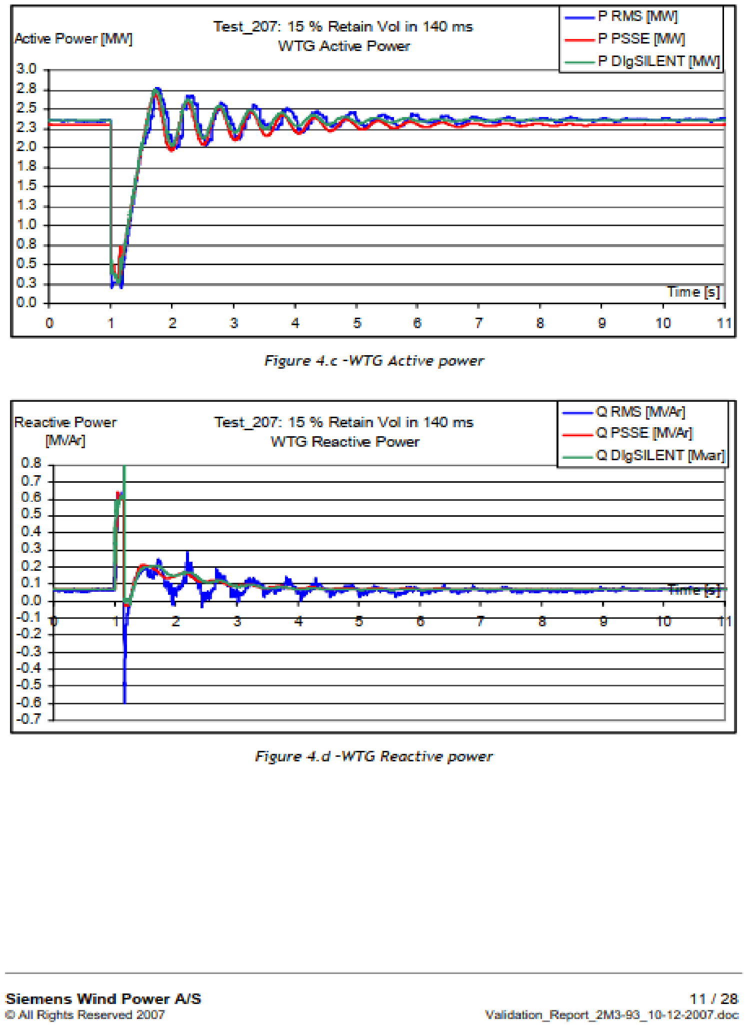
Need for accurate models does not arise solely from regulation

- OEMs rely on simulations early in the design phase—running over 100,000 scenarios
- Simulations support design validation, guide lab/field testing, and build confidence for warranties
- Accurate models enable root cause analysis and corrective actions
- Also essential for interconnection approvals, compliance audits, and performance benchmarking
- Model issues may lead to misoperation, regulatory fines, or delayed COD



Harmonization between Software/Firmware

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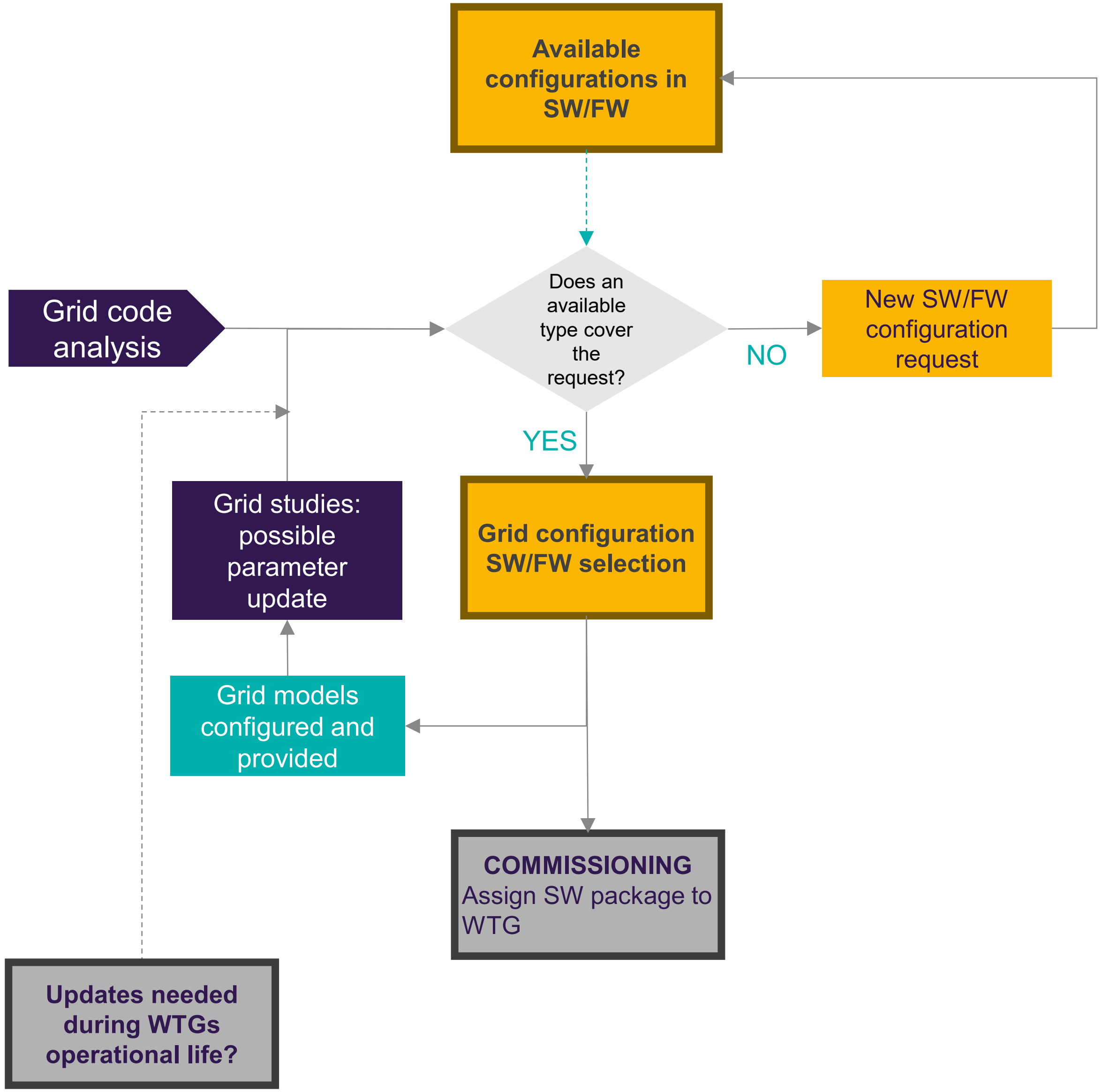
- Firmware defines the operational logic embedded in inverters/WTGs
- Software models are abstractions that must mirror firmware behavior
- Every simulation model corresponds to a specific software version called a “class”
- When generating a model, this class must be selected to automatically generate the associated software
- There is no simulation model without its corresponding software

Model Lifecycle (Pre Sales)

- The following process is followed to create model parameters:
  - **Grid Code Analysis** → Default parameter set creation for specific country (WTG platform and PPC)
  - **Model Development** → Model created with as many "public" parameters as needed
  - **Model Configuration** → WF-dependent parameters configured using "public" inputs (e.g., number of WTG, aggregation factor)
  - **Grid Study Adjustments** → Feedback from grid studies may lead to tuning (e.g., voltage control, SSCI damping activation)
- Models configured with grid default parameters may be valid for long-term planning
- EMT and frequency-domain models might not be valid for long-term planning (they represent real control behavior)
- Suitability for long-term use is limited by evolving Grid Codes



Model Lifecycle (Commissioning)

- During commissioning, measured plant behavior is compared with model predictions

- If discrepancies are found:
  - Model may be updated to reflect field behavior
  - Or, plant settings may be adjusted to match the studied model

- Changes require joint review with OEM and developers

- Poor commissioning data or mismatches can delay COD and validation

Model Lifecycle – Post-Commissioning Management

After COD: GO assumes responsibility for model accuracy

- OEM Models are updated because of:
  - Change in specific parameter affecting WTG or plant electrical performance/dynamics
  - Altered grid conditions (e.g., low SCR, nearby power electronics)
  - Unexpected response during grid events
  - New firmware from converter vendor (e.g., updated DLL)
  - Attenuation or maximization of specific grid harmonics
  - Implementation of new grid performance requirements

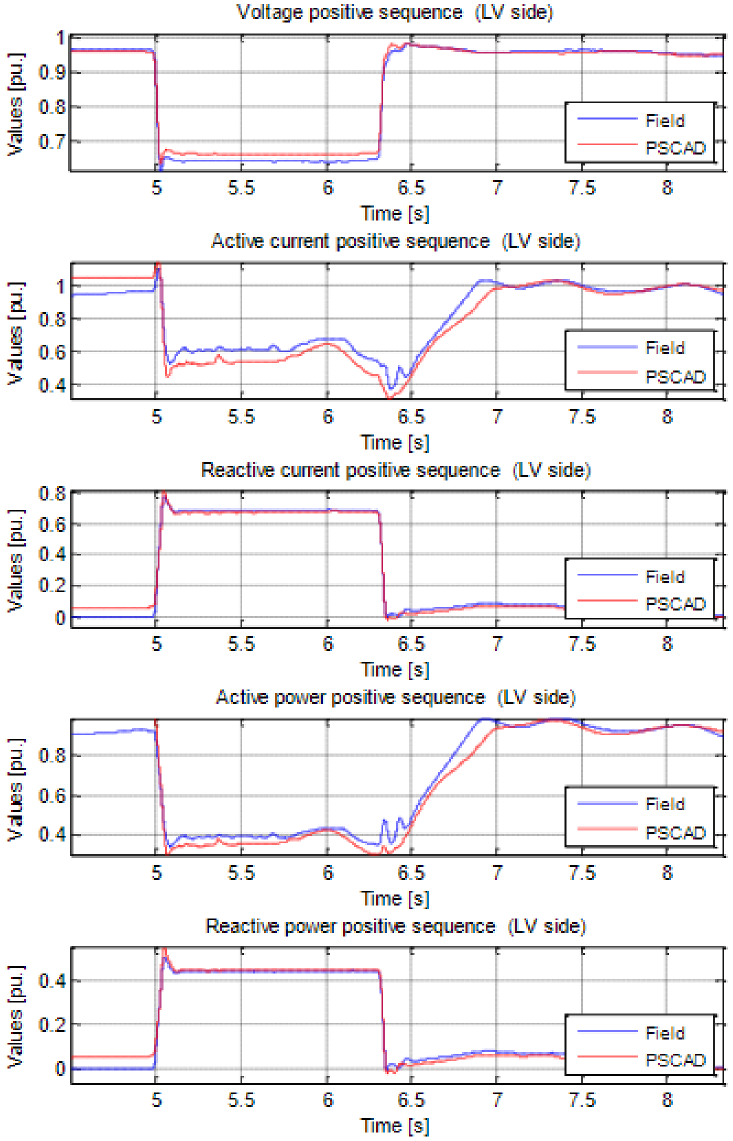
- Change management process required to track updates and assess model impact

- OEM support may diminish over time; proper documentation is critical

- Periodic revalidation advised (e.g., after retuning, equipment replacement)

Unit Model Validation Vs Plant Model Validation

- Simulation model presents aggregated turbines and PPCs
- Remaining plant elements (MPT, collector, gen-tie, etc.) are generic and require developer inputs
- Developers must integrate accurate representations of these elements and perform appropriate studies
- Any parameter change must be authorized:
  - Within manual-specified range: requires confirmation to update software
  - Outside range: may require load analysis and formal SGRE authorization



Model Submission Discrepancies and Risks

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- Plant models submitted to RTOs/ISOs are not visible to us
- We have identified significant discrepancies between provided and submitted models
- Common issues occur with WECC generic models:
    - Generic models, though open, are black-boxed and benchmarked against UDM/EMT models
    - Some WECC models are built from EMT results using limited comparisons
- Detailed WTG/PPC models often paired with oversimplified external equipment models (e.g., transformer saturation curves, cap bank switching, surge arresters)

Challenges to Model Maintenance and Support

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- **New Installations:** OEMs provide dedicated support during interconnection studies
- **Older Facilities:**
  - Legacy firmware and discontinued models hinder updates
  - OEM field support may be unavailable
- Retrofitting legacy models is resource-intensive
- Hybrid plant modeling is complex – hard to isolate issues
- SGRE support backlog >6 months, adding delays to maximization efforts

Field Measurements and Validation Challenges

- Field data is critical for validating model accuracy
- Challenges include:
  - Lack of high-speed recording infrastructure
  - Noise in measured data or poor time synchronization
  - Limited test windows during operation
- Requires specialized tools and experienced personnel
- Data must be mapped to model outputs for meaningful validation

Value of Periodic Field Testing

- Routine field testing offers:
  - Confirmation of models effectiveness on the changing grid condition
  - Early detection of drifting parameters or degraded performance
  - Evidence for regulatory audits and grid code compliance
- Recommended after firmware updates, grid upgrades, or plant retuning

Timelines for Model Updates and Validation

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- Appropriate timelines vary depending on model type and change:
  - RMS model: typically updated within weeks of firmware change
  - EMT model: longer lead time, especially if converter behavior is recharacterized
  - PSPD validation may take months if retuning is required
- RTO/ISO expectations may include fixed timelines post-COD or after field commissioning

Summary and Path Forward

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- Accurate models are essential at all lifecycle stages of an IBR plant for all stakeholders.
- Harmonization of software, firmware, and field settings is critical
- Early engagement with OEMs and clear change management processes reduce validation risk
- Coordination across OEM, Developer, and GO roles ensures model accuracy and grid compliance
- Industry should work toward standardized practices for legacy model management and EMT validations

Disclaimer

The information given in this document only contains general descriptions and/or performance features, which may not always specifically reflect those described, or which may undergo modification in the course of further development of the products. The requested performance features are binding only when they are expressly agreed upon in the concluded contract.

Vestas

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Ensuring Accurate Models throughout the Interconnection Process

Miguel A. Cova Acosta
Director – Grid Solutions

Introduction

OEM Perspective – Vestas

Wind turbine models are essential to ensuring safe and reliable grid integration.

As an OEM, Vestas contributes by delivering validated, high-fidelity models that reflect real turbine behavior across a range of conditions.

This session offers an opportunity to share how we, as OEMs, support Developers and Grid Operators by:

- Aligning models with actual performance and controls
- Navigating practical challenges in the modeling workflow
- Enabling long-term model maintainability beyond interconnection approval

Our goal is to strengthen trust, transparency, and technical accuracy throughout the entire lifecycle of a project.

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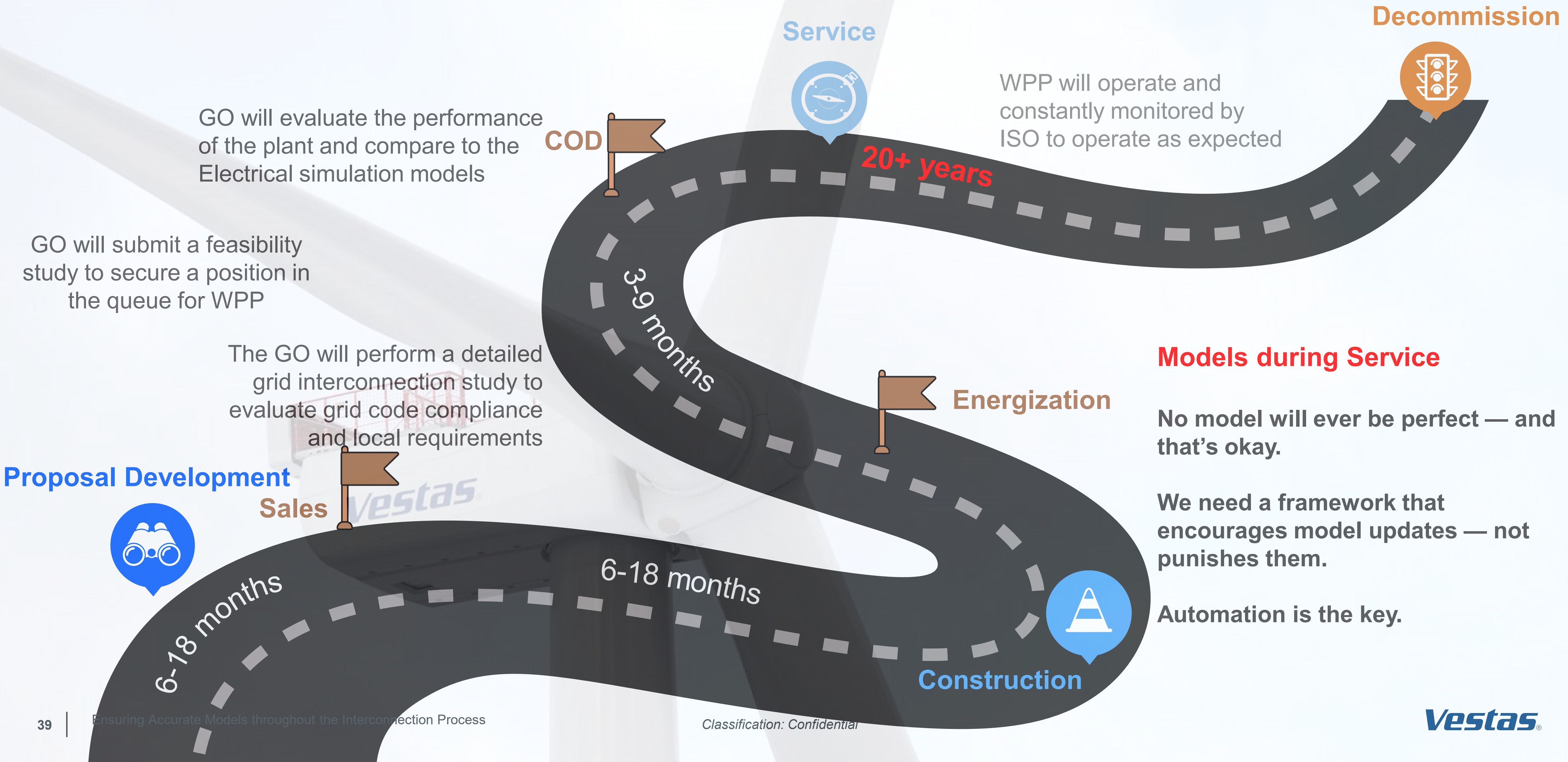
Plant Lifecycle



Models during Service

No model will ever be perfect — and that's okay.

We need a framework that encourages model updates — not punishes them.

Automation is the key.

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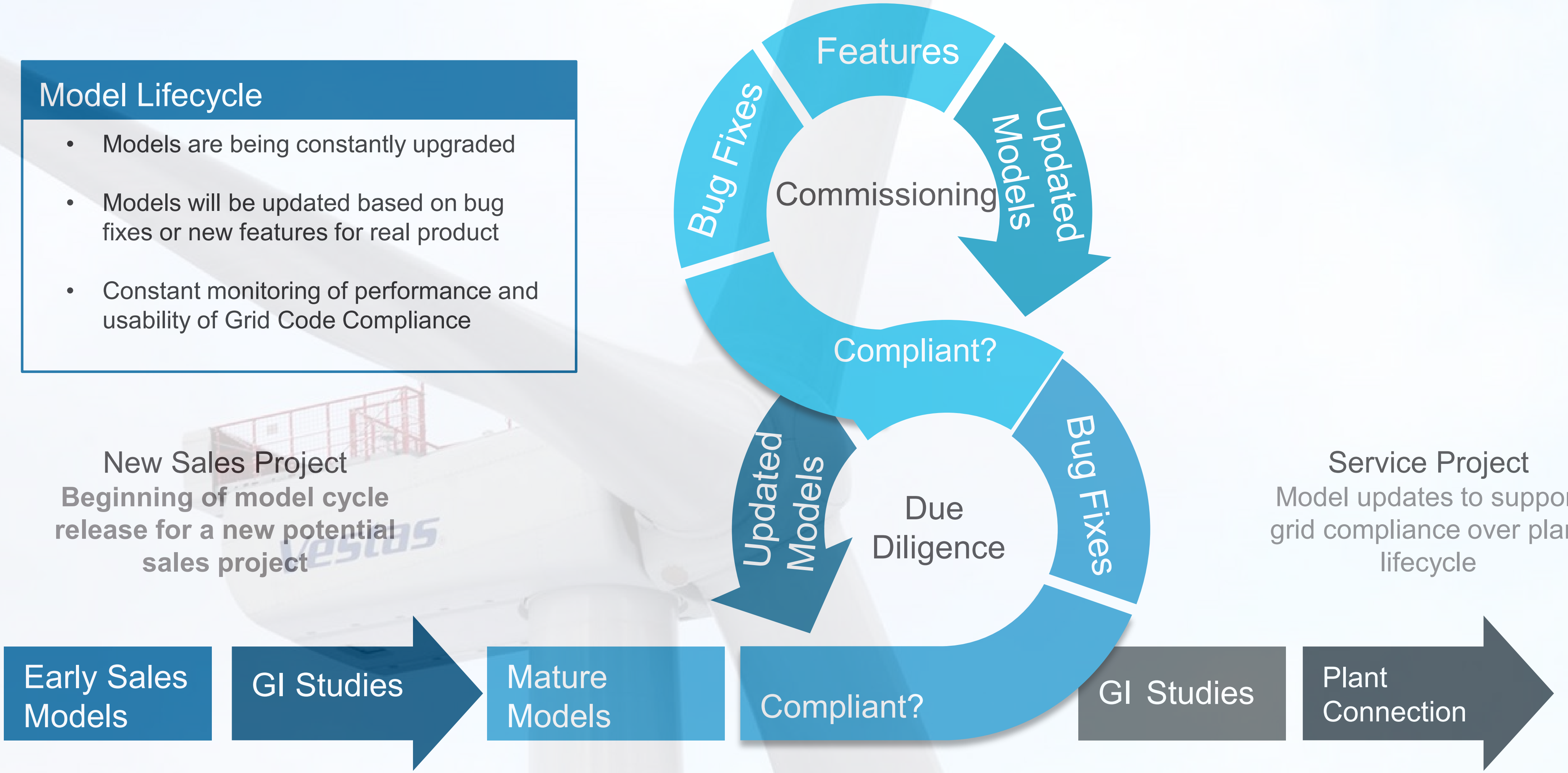
Electrical Simulation Model Lifecycle

Model Lifecycle

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



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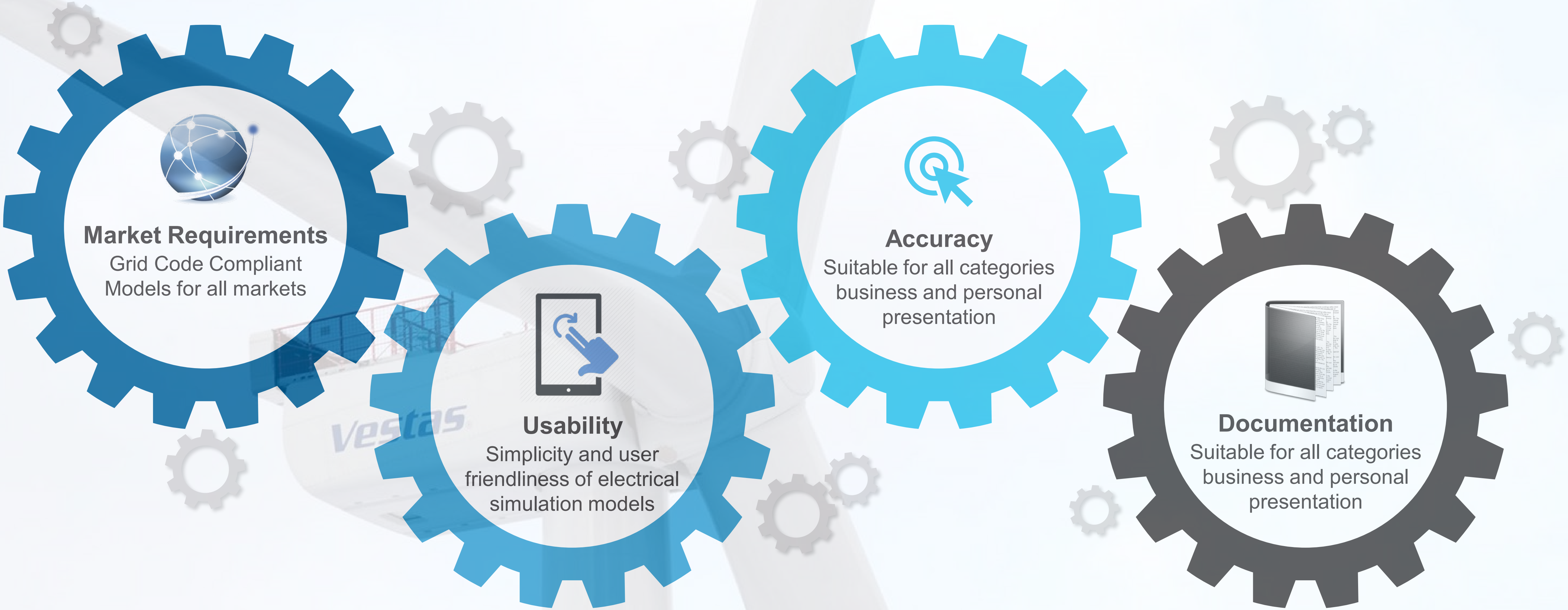
Vestas Model Development

Model Products Gears



IBR Plant Compliance

Requirement Interpolation – PoI vs WTG

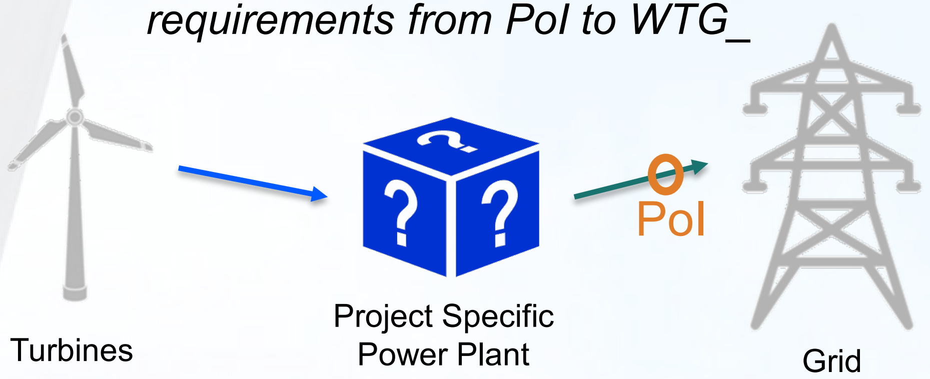
Evaluation Criteria

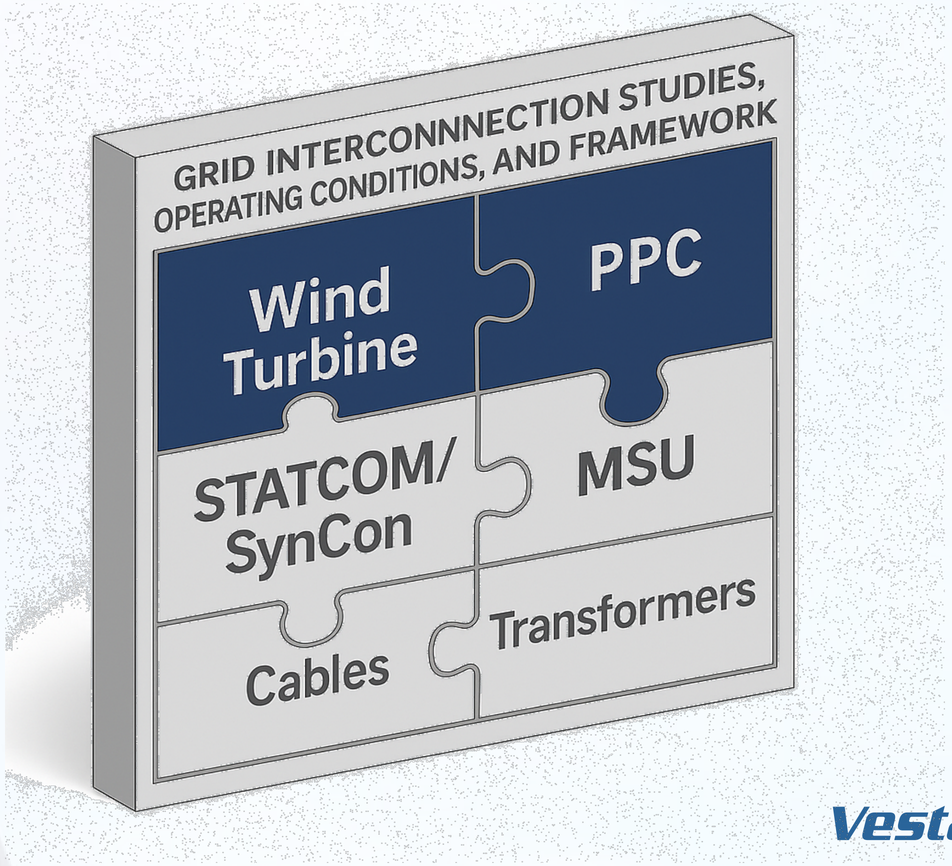
- Operational Points
- Loading Factor
- Project specific control tuning

Project Specific Conditions that will affect the compliance outcome:

- Grid Stiffness
- Single Line Diagram/Reactive Compensation devices
- Series Compensation
- PPC Configuration (Control strategy)
- Nearby IBR plants
- Others

*Isn't straightforward to translate requirements from PoI to WTG_*





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Promoting Reliable Grid Integration of IBR Modeling

Effective

Parameter Verification Reports
Ensure that submitted model parameters are rooted in validated field or factory test data. These reports demonstrate traceability and build trust in model accuracy.

Model Quality Tests
Run standardized tests (e.g., V/F response, fault ride-through, etc) to demonstrate that the model replicates expected behavior across scenarios.

Verification & Validations
Provide documented evidence that the simulation model has been verified against measured or expected performance under a range of grid conditions.

Less Effective

OEM Attestations
Sole reliance on a signed statement from an OEM — without supporting data — is insufficient for confirming model accuracy or suitability for grid studies.

Model Compliance Checklist
While useful, checklists alone do not confirm dynamic performance fidelity or how a model will behave in realistic system events.

Generic RFI’s
Requests for information that lack context or specificity may delay modeling improvements and often result in incomplete or non-targeted responses.

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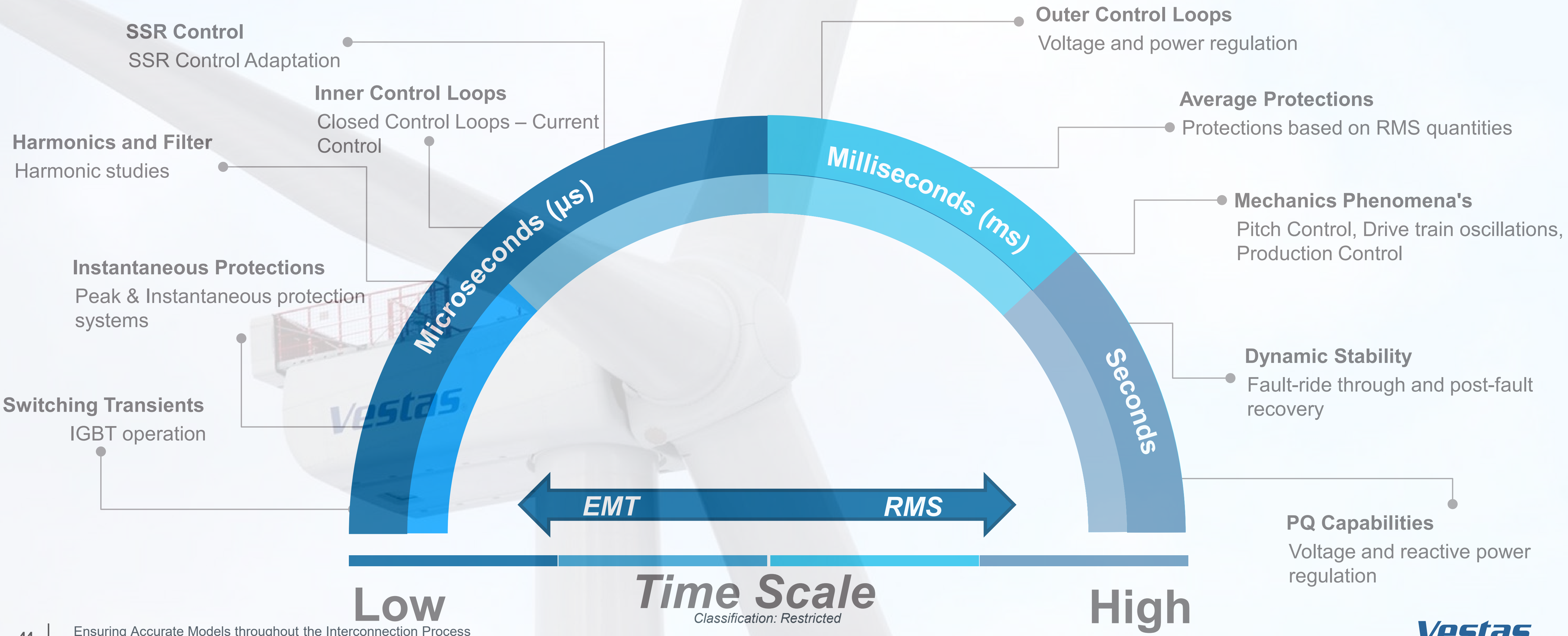
Power System Simulation Model Analyses

Model overview performance and intended uses



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Model Validation Variances

Power System Model Validation Types

Model Validation Types
Depending the purpose, different validation options are available for UDM

Model vs Real Contingencies
Model validation based on real contingencies occurring in operating wind farms

Model vs HiL
Model validation against Hardware in the Loop setup

Model vs Model
Model validation based on the power system tool nature (RMS/EMT)

Model vs SiL
Model Validation against Software in the Loop setup

Model vs Park Performance
Model validation used for plant commissioning

Model vs Field Test
Model validation based on measurement campaigns during product design

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How is a UDM model inside?

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

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

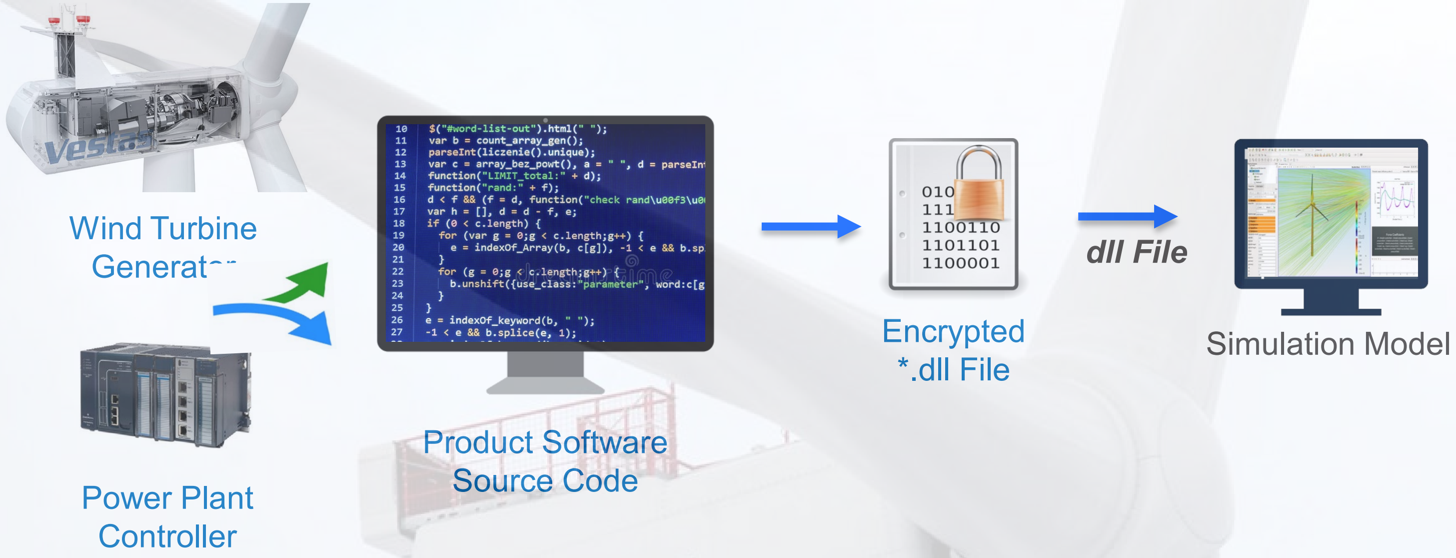
Interface
User Interface to control and configure the model performance. Normally resides in the visual interface of the power system simulation tool

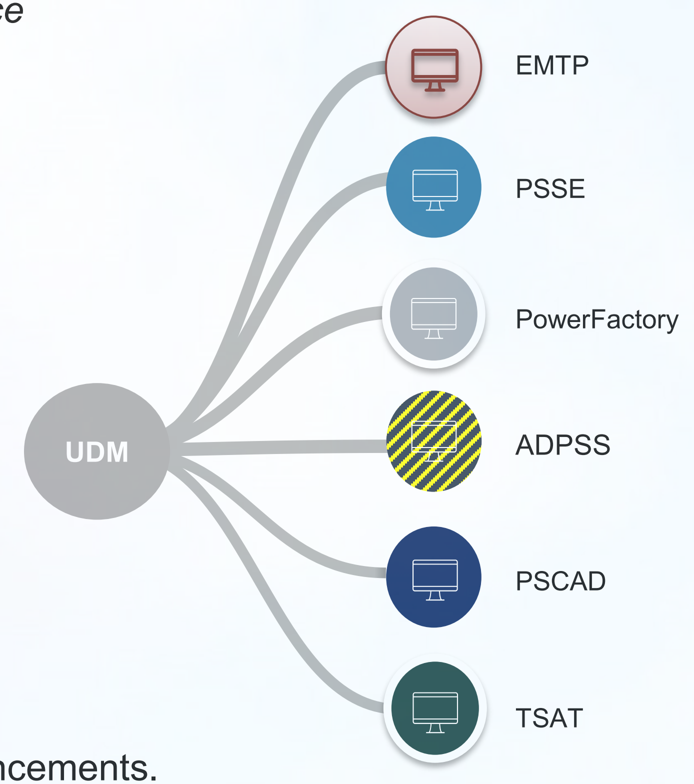
Parametrization
Set of site-specific set of parameters required for grid code compliance in every different market

Digital Twin: Electrical Simulation Models vs. Product

Proven framework for product improvement feedback through simulated environments

Source code represents the main control code for wind turbines and/or Power Plant Controller. *Source code* is the actual control code that is installed in the real hardware and operates the real product.





Unified Model Framework (UMF)

(Used Across Commercially Available Power System Simulation Tools)

Main Benefits:

- Improved time to market of new functionalities – regular update of models to follow Product advancements.
- The representation of Vestas technology functionalities can be as detailed as the Products functionalities.
- Models are used to tune Vestas's products for site specific performance.
- It is easy to adapt Simulation Models parameters to reflect real site performance.
- The support for Simulation Tools versions evolves with the Industry needs (versions).

Conclusions/Recommendations

- *The model development process should always follow a source code integration concept.*
- *Source Code Integrated Model must preserve a mirror parametrization and performance.*
- *Industry standardization should focus on interfacing source-code-integrated models, rather than standardizing control structures*

*"**All models are wrong**; the practical question is **how wrong do they have to be to not be useful**."*

George E. P. Box

How accurate a model must be to perform grid interconnection studies considering the future challenges in a power system with high penetration of inverter-based generation sources?

Source code integrated models!

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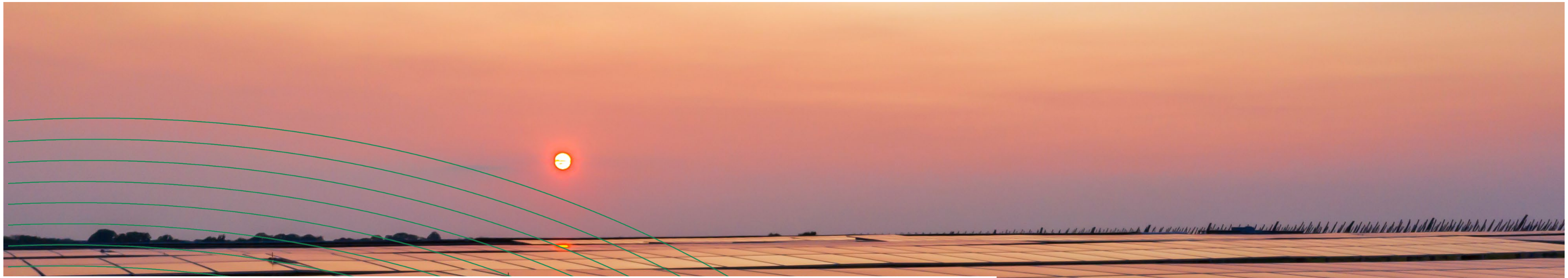
Thank You



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IBR Plant Modelling

Generator Developer Perspective

Mohamed El Khatib
Director – Grid Modelling and Compliance

Invenergy

World's Leading Privately Held Clean Energy Company

Wind
119 projects
19,548 megawatts

Solar
53 projects
7,119 megawatts

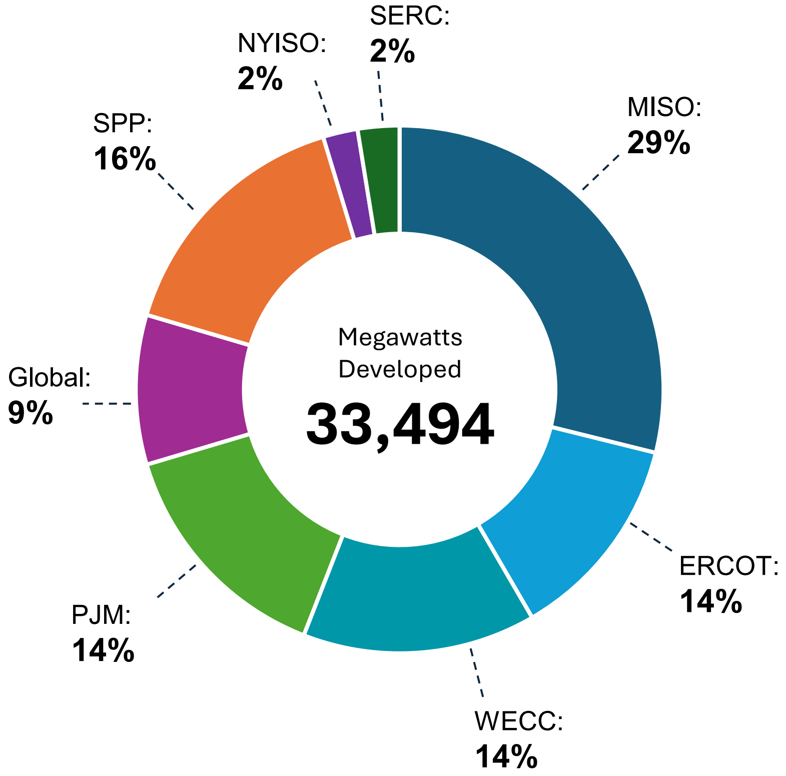
Storage
21 projects
2,617 megawatt hours
756 megawatts

Transmission
4 projects
4,100+ miles of transmission & collection lines developed

Natural Gas
13 projects
6,071 megawatts

Offshore Wind
2 projects
4,000+ megawatts in development

MARKETS



Invenergy

IBR Plant Model Overview

IBR Plant Model

Tuned IBR Unit Model

IBR Unit Model
default model of the specific inverter/turbine vintage received from the OEM

Inverter Settings
tuned specifically for each project. Updated based on the project stage (as-designed, as-build, etc.)

Tuned PPC Model

PPC Unit Model
default model of the PPC representing the control architecture

PPC parameters
tuned specifically for each project. typically, tunning is done before PPC SAT

Balance of the Plant Model

Transformers
data from FAT testing

Collector system
impedance and length of each segment. Generate an aggregate equivalent of the collector system

Transmission Line
impedance and length

Reactive Compensation
capacitor banks information. Typically, from reactive power engineering study.

How do models change during different project development stages?

Project Development stages

Invenergy

- Several stages for IBR project development:
  - Pre-interconnection application
  - Generation Interconnection Process
  - Detailed Engineering design and construction
  - Commissioning
  - Commercial operation

- The project model and settings ***will*** change throughout the project development to reflect the latest project design.

Generation Interconnection Stage

- Project models are based on
  - Initial selection of OEM, subject to change
  - Initial design of the balance of the Plant
  - Settings are maximized where possible (ride-through, etc.)
  - Initial control tuning
  - Steady-state, dynamics, short-circuit, and EMT models.
- Once a GIA is signed, the project could move to the Engineering stage of development.

Detailed Engineering Stage

Invenergy

- Project design finalized:
  - final selection of equipment and supply agreement signed
  - final design for the balance of the plant
- Detailed EMT model is developed to capture the latest design
  - determine final Inverter/WTG settings
  - perform PPC controller tuning
  - assess plant performance and compliance
- All project models are trued up
  - material modification application

Commissioning and Operations

Invenergy

- Project settings could be further tuned during commissioning
  - PPC controllers fine-tuning based on field testing
- Models are trued up based on commissioning
  - As-built models are submitted to TSP before commercial operation
- Following COD
  - MOD testing is completed using the as-built models
  - Project models are archived for future use

Final thoughts…

Invenergy

- At any development stage, models reflect the latest design data of the project

- During the detailed engineering phase, maintaining close coordination among stakeholders can be challenging, yet it is essential to ensure that the project design is accurately represented in the models

- Building accurate models during project development is *significantly easier* than trying to build accurate models after the project is operational
    - *In some cases, it can be infeasible to develop detailed models for legacy in-service projects.*

Questions and Answers

Slido

- **Option 1**
  - Navigate in browser to www.slido.com
  - Enter event code: NERC901
  - Provide email address when requested
- **Option 2**
  - Scan the QR code to be directed to the website

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Panel Discussion 2: System and IBR Model Validation and ERO Criteria for Acceptable Models

Moderators: JP Skeath, NERC and Aung Thant, NERC

Panelist: Shounak Abhyankar (ISO New England), Trevor Schultz (Idaho Power), John Schmall (ERCOT), Enoch (WECC), Deepak Ramasubramanian (EPRI)

Slido Q&A

- Option 1
  - Navigate in browser to www.slido.com
  - Enter event code: NERC901
  - Provide email address when requested

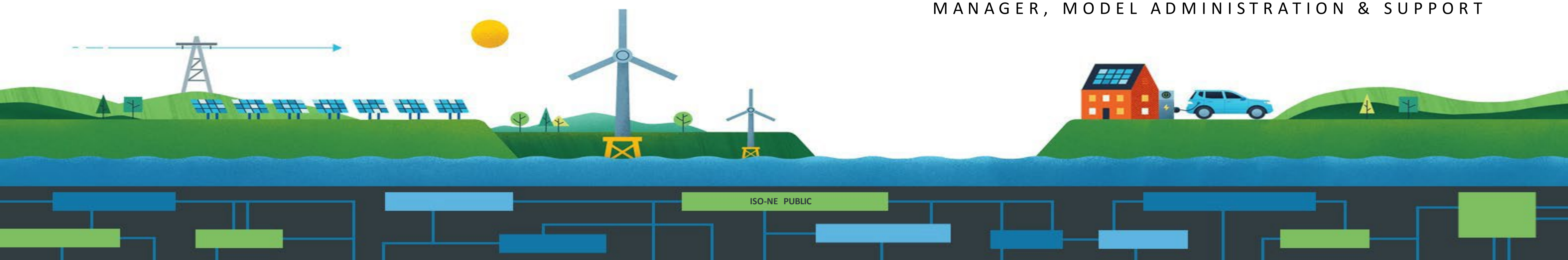
- Option 2
  - Scan the QR code to be directed to the website

MOD-033 Event Analysis

System Model Validation

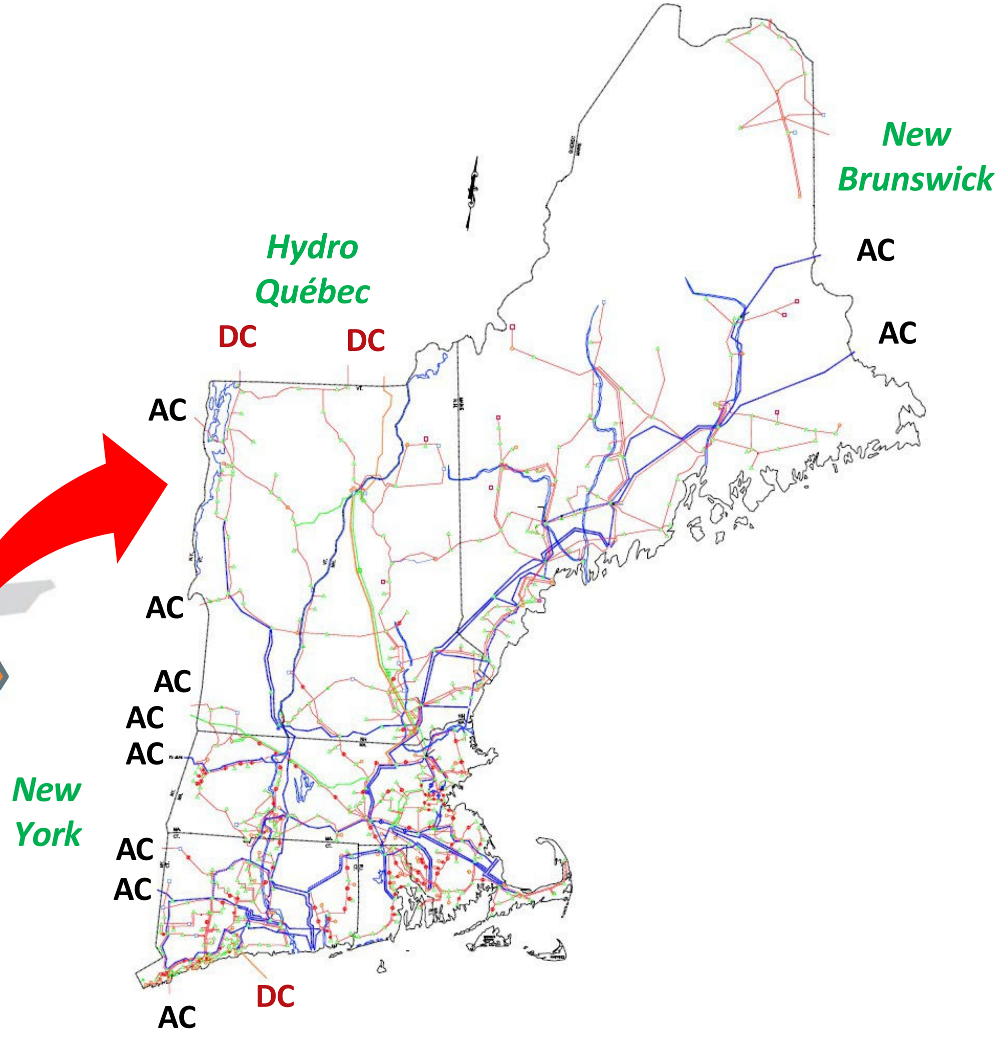
Shounak Abhyankar

MANAGER, MODEL ADMINISTRATION & SUPPORT



NEW ENGLAND POWER SYSTEM

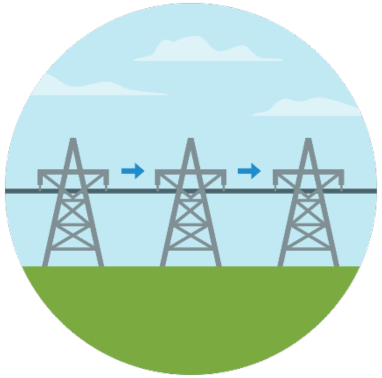
- **Planning Model**
  - Eastern Interconnection
- **EMS Model**
  - NE, NB, NS, NY



ISO New England Performs Three Critical Roles to Ensure Reliable Electricity at Competitive Prices

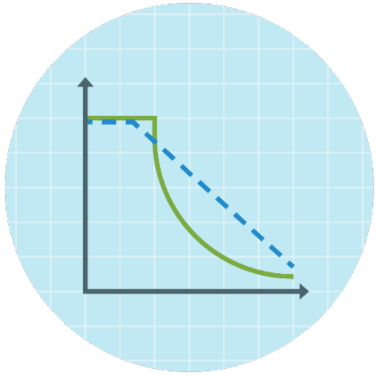
Grid Operation

Coordinate and direct the flow of electricity over the region’s high-voltage transmission system



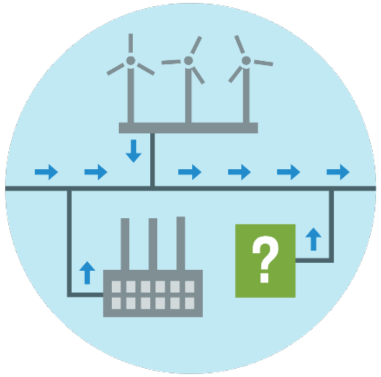
Market Administration

Design, run, and oversee the markets where wholesale electricity is bought and sold



Power System Planning

Study, analyze, and plan to make sure New England's electricity needs will be met over the next 10 years



Things We Don’t Do

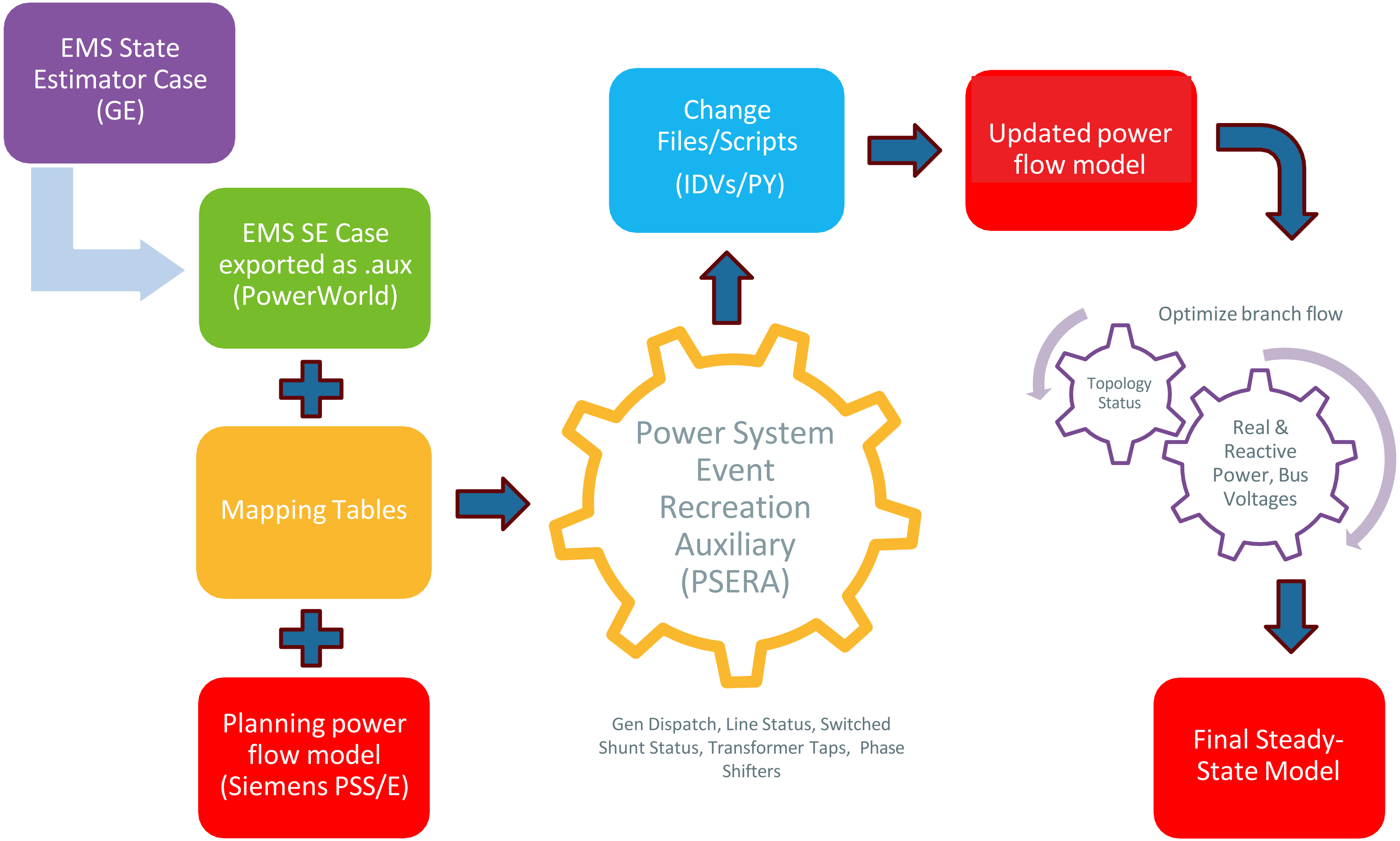
- Handle retail electricity
- Own power grid infrastructure
- Have a stake in companies that own grid infrastructure
- Have jurisdiction over fuel infrastructure
- Have control over siting decisions

MOD-033-2 Model Validation

MOD-033 STANDARD REQUIREMENT R1

1. Comparison of the performance of planning power flow model to actual system behavior – within 24 calendar months
2. Comparison of the performance through simulation
3. of a dynamic local event, at least once every 24 calendar months
4. Determine unacceptable differences in performance
5. Establish guidelines to resolve the unacceptable differences

R1.1 STEADY-STATE MODEL VALIDATION



R1.1 STEADY-STATE MODEL VALIDATION

- An engineer supported by the review team dispatches the planning model to steady state conditions just prior to the event selected

  - ✓ Obtains EMS cases before during and just after the event
  - ✓ Uses ISO developed software (PSERA) to adjust generation, transformers and shunt devices to steady state conditions, sets transfers
  - ✓ Software utilizes mapping tables showing EMS facility characteristics and PSS/e planning model characteristics and conditions
  - ✓ Solve steady state planning model case
  - ✓ Rerun software to produce mapping tables showing flows and equipment characteristics for comparison and analysis

- The review team checks the steady state flows and bus voltages

R1.2 DYNAMIC MODEL VALIDATION

- Utilize the finalized power flow case to set up the PSS/E fault file with the most accurate sequence of events and run the fault
- Obtain PMU traces for various substations during the event
- Plot the PSS/E and PMU fault traces
- Review real power, reactive power and voltage dynamic traces
- Engineering analysis is used to determine whether the traces are acceptable
  - ✓ Swings at same time
  - ✓ Similar magnitude and settling

R1.3 ACCEPTANCE CRITERIA

Quantity	Acceptable Differences
Bus voltage magnitude	±2% (≥500 kV) ±3% (230≥kV≥345 kV) ±4% (100>kV>230 kV)
Generating Bus voltage magnitude	±2%
Real power flow	±10% or ±100 MW
Reactive power flow	±20% or ±200 Mvar
Difference in % normal loading	±10% based on branch normal continuous rating

Table 1 – Guidelines to identify acceptable differences between simulated and real-time data for steady-state validation

ISO uses the NATF MOD-033 Methodology Reference Document that was approved by NERC as ERO Enterprise-endorsed Implementation Guidance as the basis for establishing acceptable variances between actual EMS and PSS/E simulation comparisons.

https://www.natf.net/docs/natfnetlibraries/documents/resources/planning-and-modeling/natf-mod-033-1-methodology-reference-document---open.pdf

R1.4 GUIDELINES TO RESOLVE UNACCEPTABLE DIFFERENCES

If it is determined that difference between real-time and simulation is unacceptable:

- ✓ Cross check accuracy of real-time data source with other sources.
- ✓ Review type of fault, fault impedance, fault distance, duration and sequence of event with TO/TP.
- ✓ Conduct outreach to equipment owners in accordance with MOD-026/MOD-027 or MOD-032.

CHALLENGES

Process:

- Event recreation is tedious and largely manual process
- Data required for completing successful event recreation currently uses five industry software(s)
  - Cost of licenses, engineer training
- Depending on complexity and location of fault/event, gathering of accurate disturbance data can take substantial time

CHALLENGES

Technical:

- Ensure aux file obtained from EMS for the event time doesn't have solution issues
  - Consider the effect of EMS pseudo loads (small loads used by EMS programs to solve power flow) in the recorded data
- Which Planning Model to use?
  - Basic Bus – Branch model or add Node-Breaker details
    (Event location and observability may help guide the decision)
- Mapping of Loads & DER
  - EMS loads are modeled at 34.5 kV or higher whereas PSS/E case has most loads at much lower kV levels.
  - How is the load modeled for dynamic analysis?
    - CMLD vs ZIP
    - Traditional ZIP models do not capture FIDVR and may underestimate DER tripping
  - How is DER modeled, netted or DERAU1?

OBSERVATIONS

- Dedicated mill loads that were no longer applicable in planning case were found & removed
- Limited problems with automated impedance bridging tool from EMS to planning case were fixed
- A few small generation facilities that could not be identified were found in the planning case
- Several transformer tap setting differences were corrected
- MOD-033 event analyses performed since 2017 highlighted issues with load mapping. ISO New England has since worked tremendously to improve load modeling/mapping
- CMLD load model provides more realistic response than the traditional ZIP model

Questions

About the Presenter

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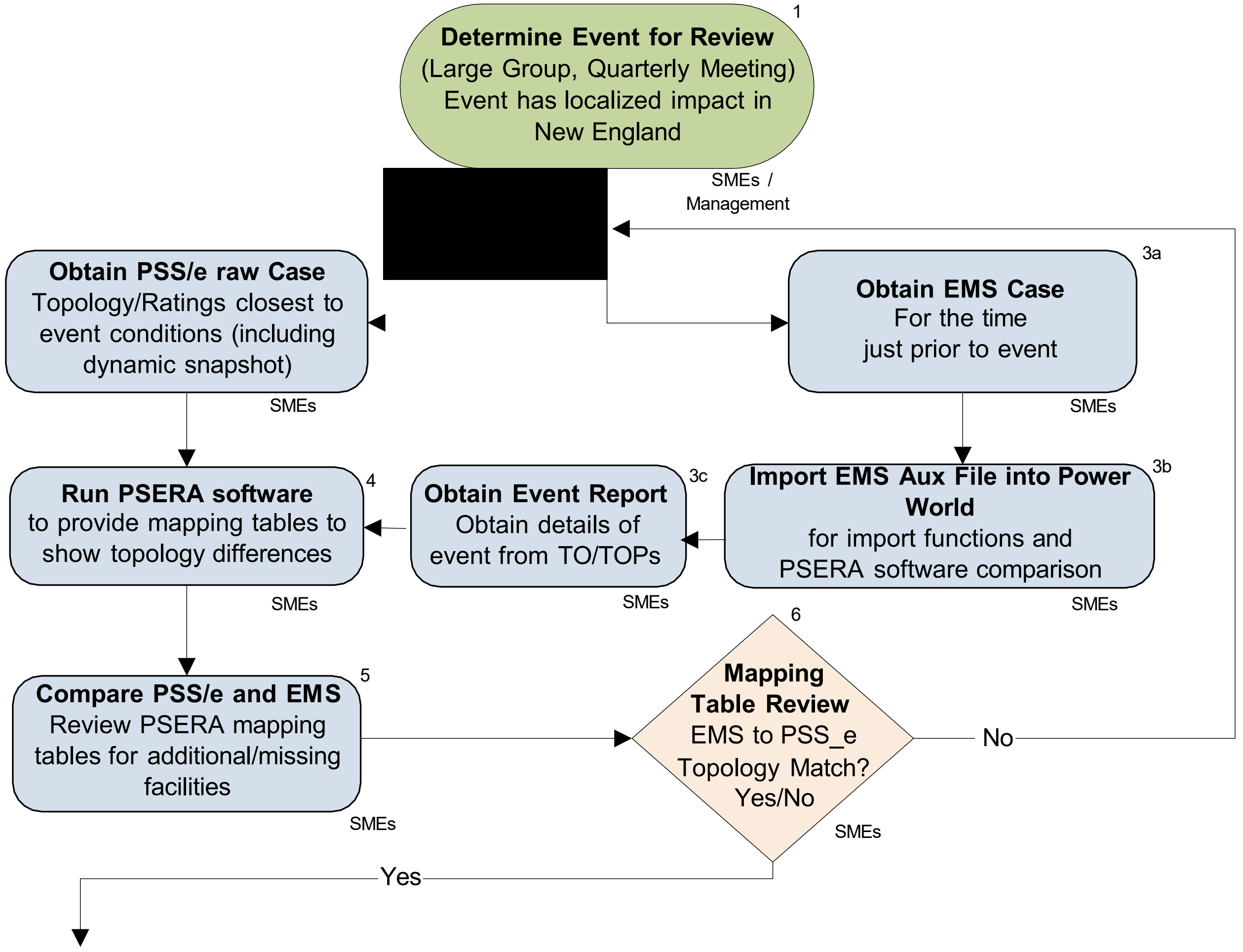
https://www.linkedin.com/in/shounakabhyankar/

ISO-NE MOD-033 PROCESS FLOW CHART

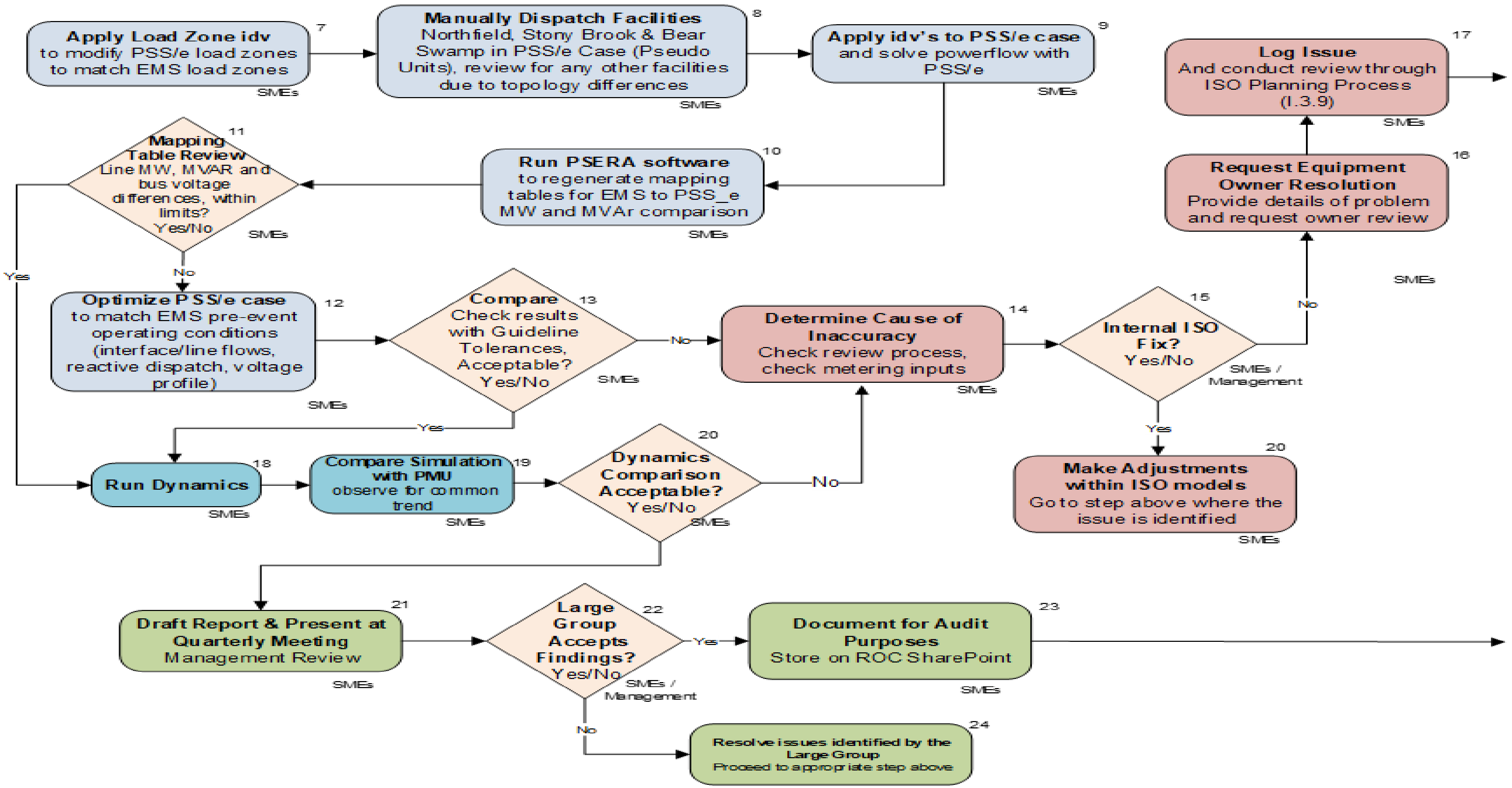
MOD-033 Event Review Process



Steady State reviews must be completed at least once every 24 calendar months per R1.1.

Dynamics reviews at least once every 24 calendar months (Per R1.2 using a dynamic local event that occurs within 24 months of the last dynamic local event and complete the comparison within 24 calendar months of the event.

ISO-NE MOD-033 PROCESS - CONTINUED



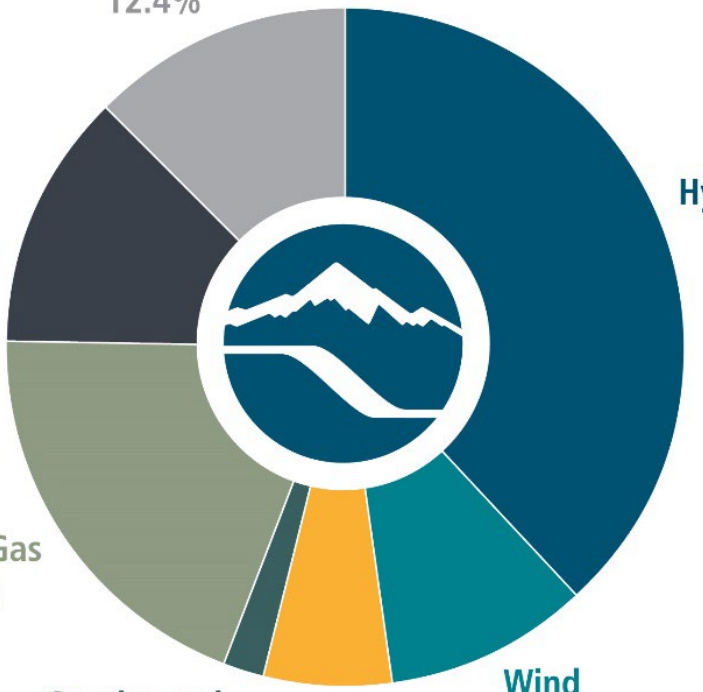
System Model Validation

Trevor Schultz
Idaho Power System Planning
June 3, 2025

Service Area

More than 650,000 customers

2024 Energy Mix



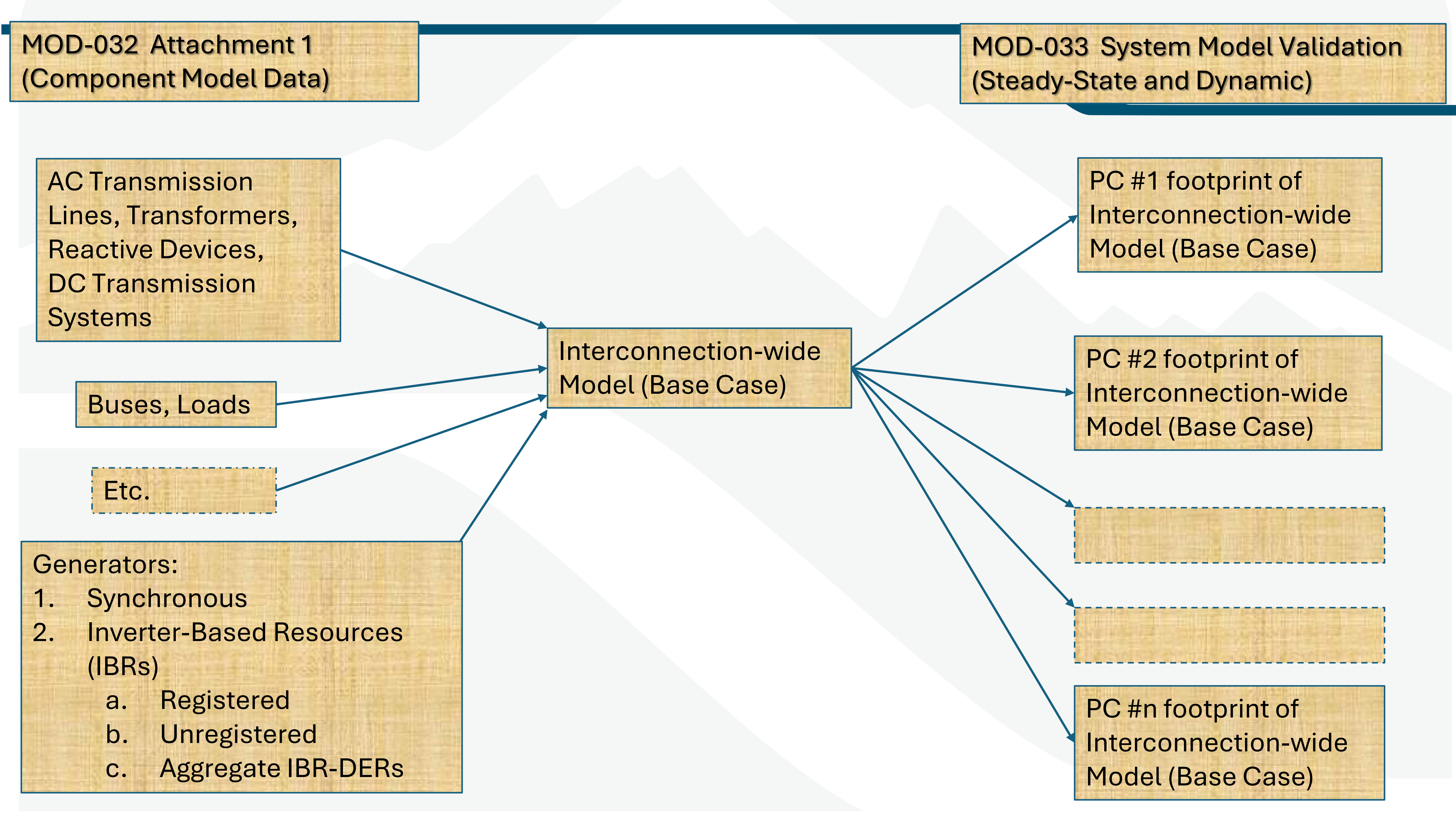
Data Source: U.S. Energy Information Administration.
Totals may not equal 100% due to rounding.

Peak Load

3751 MW (Summer 2024)

Utility-Scale IBRs Installed

2003: 0 MW
2018: ~800 MW
2025: ~1800 MW


MOD-032 Attachment 1
(Component Model Data)
MOD-033 System Model Validation
(Steady-State and Dynamic)
AC Transmission Lines, Transformers, Reactive Devices, DC Transmission Systems
Buses, Loads
Etc.
Generators:
1. Synchronous
2. Inverter-Based Resources (IBRs)
a. Registered
b. Unregistered
c. Aggregate IBR-DERs
Interconnection-wide Model (Base Case)
PC #1 footprint of Interconnection-wide Model (Base Case)
PC #2 footprint of Interconnection-wide Model (Base Case)
PC #n footprint of Interconnection-wide Model (Base Case)

Idaho Power MOD-033 Process

- Idaho Power PC participates in a voluntary multi-PC group for MOD-033 System Model Validation
- Western Power Pool (WPP) staff collaborates with participant PCs to perform steady-state and dynamic comparisons and write final report
- Participants agree on methodology, guidelines for determining unacceptable differences, and guidelines for resolution of unacceptable differences
  - Group assesses list of dynamic system events and chooses one to assess
  - Group chooses a WECC Base Case (planning case) for steady-state (R1.1) and dynamic (R1.2) comparisons
  - Group chooses a primary SE case to use for steady-state (R1.1) comparison
  - Participants gather and submit SCADA data and mapping for lines, transformers, gens, loads, etc for steady-state (R1.1) comparison
  - Participants gather and submit PMU, DFR, SER data for dynamic (R1.2) comparison
- MOD-033 Enhancements Workgroup

Challenges

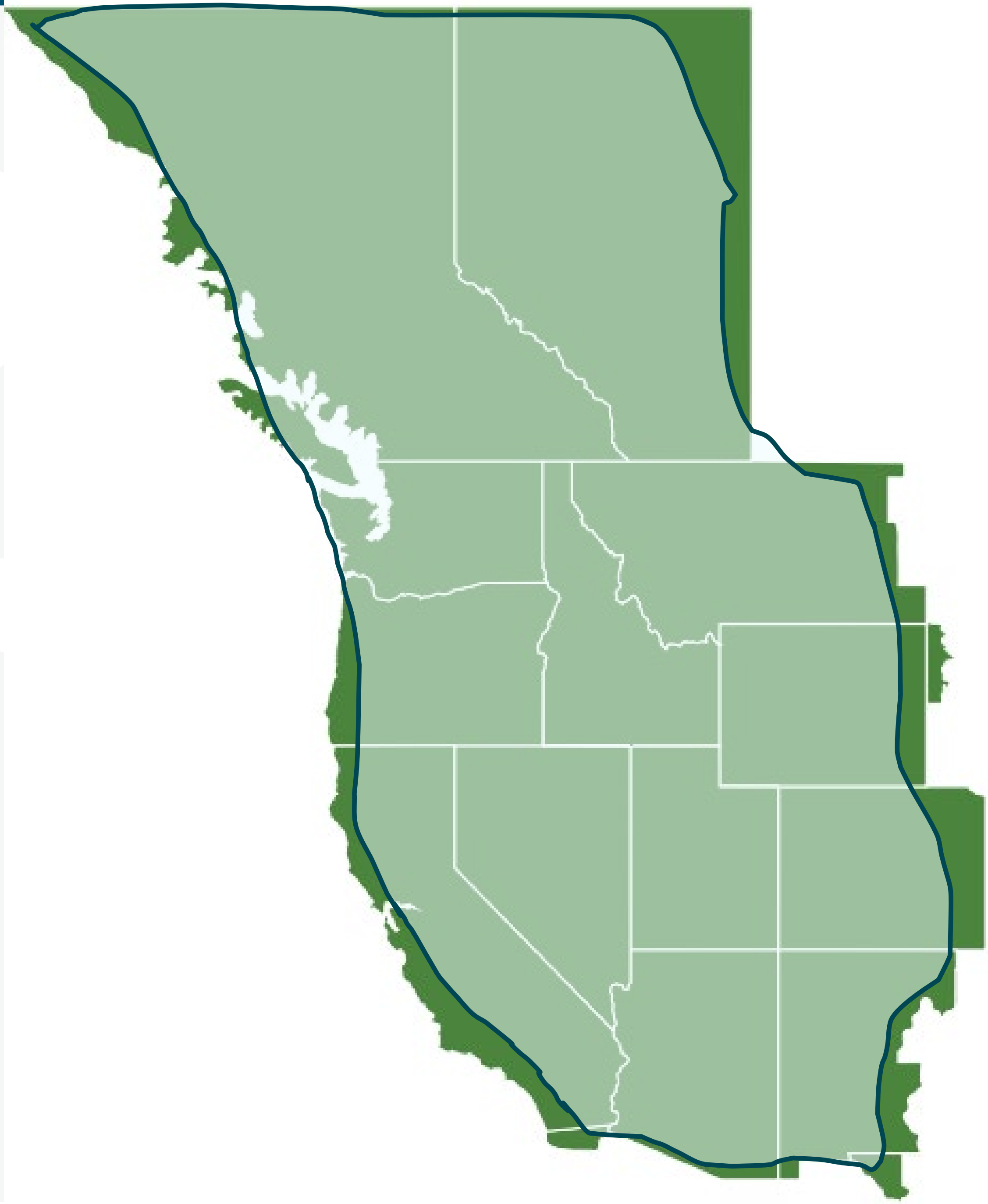
- Case setup outside study area
- Mapping between SE cases and WECC Base Case
  - Ideal would be to have centralized mapping dataset of entire WECC Base Case and wide-area SE case that is maintained
- Topological improvements could be made to better align SE and planning cases to real system
- SCADA data quality (stale data), time-zone issues

Dynamic Events

Wide-Area Events, e.g. frequency event: Dynamic response will be observable across wide area

Pros: efficiencies gained; multiple PCs can use same event and models, can validate multiple component models

Cons: potential difficulties arise from model data outside study area

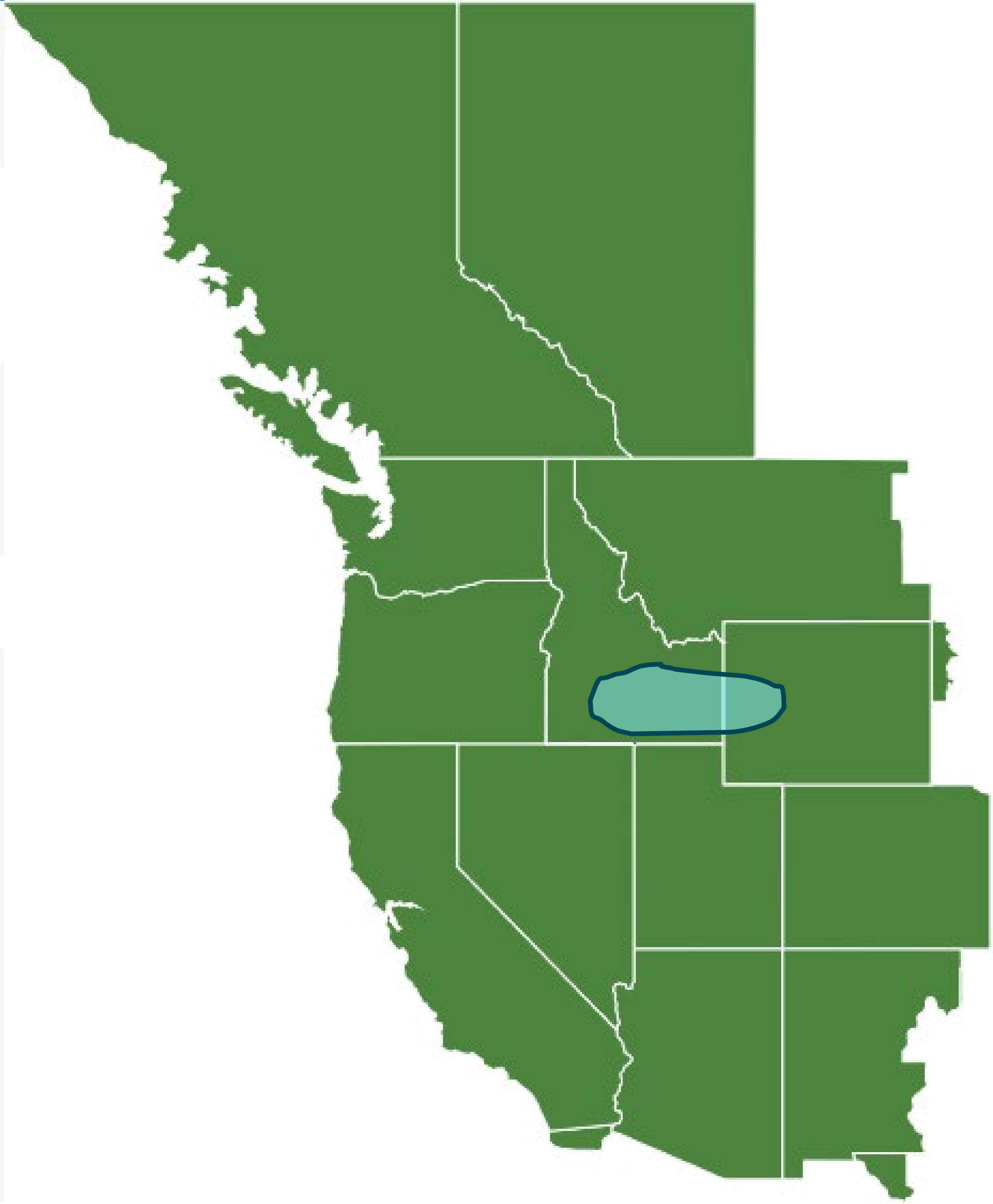


Dynamic Events

Local Events, e.g. voltage event:
Dynamic response observed in localized area

Pros: may result in larger response for local component models and capture more features of the models

Cons: fewer component models validated, might miss some model discrepancies



Some events are combination of local and wide-area

"Good" Dynamic Local Event

- Measurable transient response within PC area
- Must have data recordings
- Consider events that capture variations in system conditions that differ from past analyses
  - High or low penetration of IBRs
  - High or low load conditions
  - Stressed or unstressed transmission flow conditions
- Consider trade-offs of "wide-area" vs "local" dynamic events
- Ideal would be to use a combination of wide-area and local events

Questions?

NERC Industry Engagement Workshop – Milestone 3 of FERC Order 901

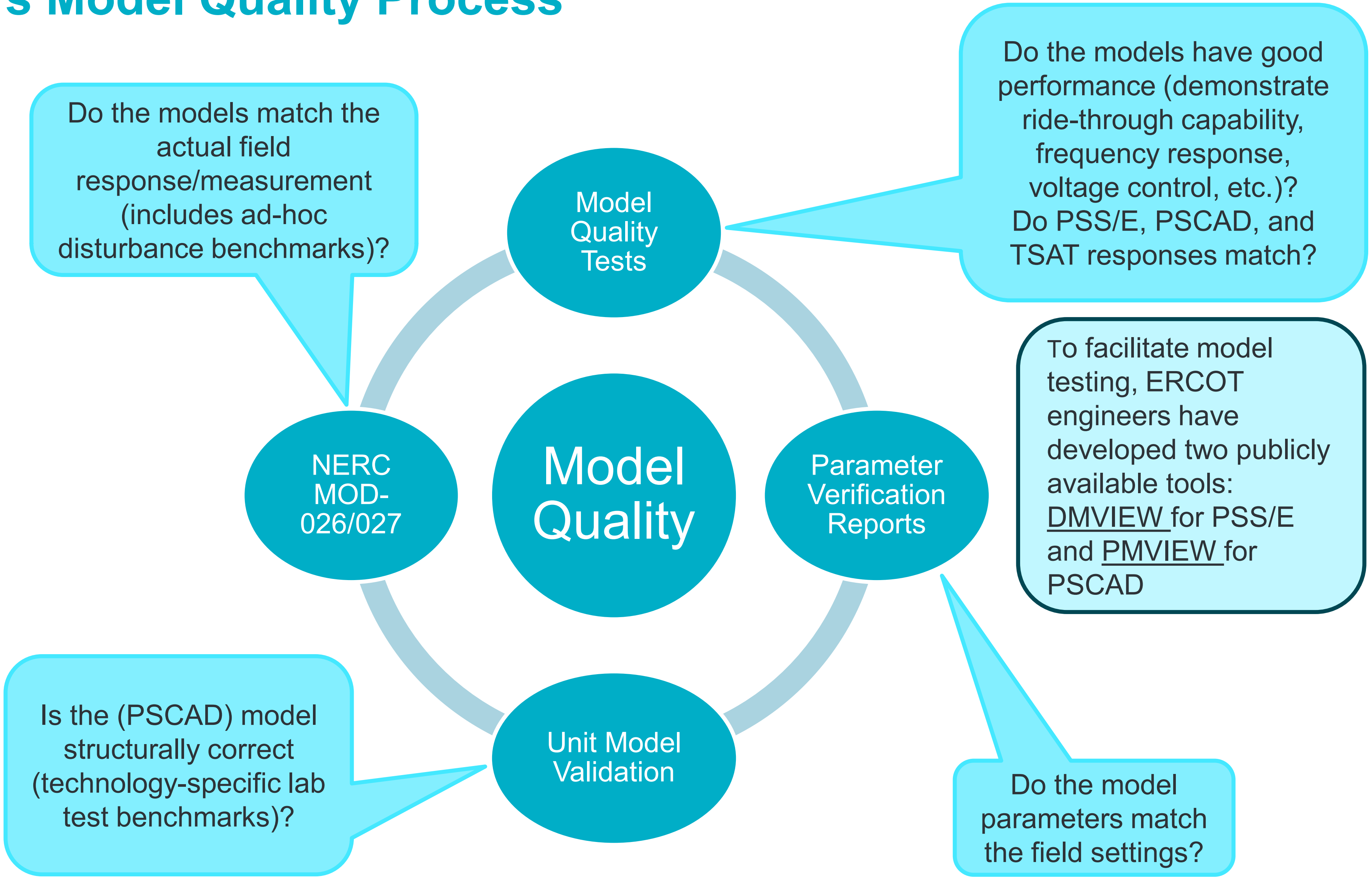
June 3-5, 2025

Panel Discussion: System and IBR Model Validation and ERO Criteria for Acceptable Models

Model Acceptability

John Schmall
ERCOT Grid Planning

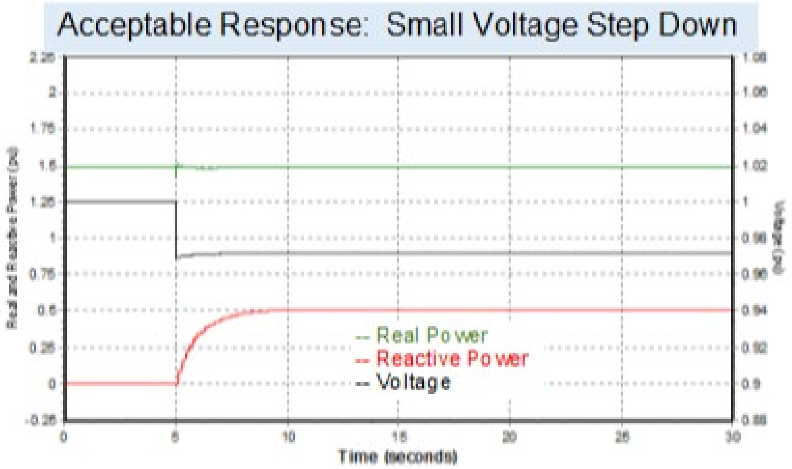
ERCOT's Model Quality Process



To facilitate model testing, ERCOT engineers have developed two publicly available tools: DMVIEW for PSS/E and PMVIEW for PSCAD

Model Quality Tests (MQT)

- 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 consistency across software platforms
- Performance guidance published in Dynamics Working Group (DWG) Procedure Manual



Model Documentation and Functionality

- Important for user-defined models (UDM), including EMT models
  - Are UDM held to a higher standard than generic/library models?
- Crafting effective compliance obligations is particularly challenging for a task that, at its core, requires engineering judgment

ERCOT PSCAD Model Submittal Guidelines

ERCOT requests you submit this completed checklist along with your PSCAD model. Please include this completed sheet in the same zip file when submitting your PSCAD model to your RARF form or RIOO system.

1. Introduction

PSCAD models are a specialized type of model used in Electromagnetic Transient (EMT) studies. These models are more detailed than standard dynamic stability models (e.g. PSS/E models) and are necessary for modeling generators in weak grid studies and subsynchronous resonance studies, among others.

Not all PSCAD models are created equal. Some are unreasonably difficult to use and some contain certain modeling approximations. In order to provide better quality control, ERCOT with the help of the Dynamic Model Task Force created this check-sheet. When submitting a PSCAD model to ERCOT, please fill out this check sheet and attach it along with your model (zip the files together). This will facilitate ERCOT providing feedback, and ultimately reduce issues that may occur down the road.

It is expected that all PSCAD models adhere to these guidelines. Any deviations should be documented and explained and will be subject to review. **This form should only be completed by an SME knowledgeable with the inner-workings of the PSCAD black-box model, usually this implies OEM staff**

PSCAD submission checklist:

- ✓ Include a Model Quality Test (MQT) report overlaying the PSCAD and PSS/E model response. If utilizing a user-defined-model in PSS/E, then also include the TSAT model response in the overlay.
- ✓ PSCAD model inserted into the ERCOT PSCAD Template, available in the "Dynamic Model Templates" package posted at: https://www.ercot.com/services/rq/re
- ✓ Include this completed checksheet (check off the items in the below tables)

ERCOT User Defined Model Submittal Guideline

Please provide this Guideline to your manufacturer when requesting PSSE/TSAT dynamic stability model for your plant. This information will help your manufacturer provide functional models.

1. Introduction

To adequately simulate dynamic and transient events in the ERCOT System, it is necessary to establish and maintain dynamics data and simulation-ready study cases representing the dynamic capability and frequency characteristics of machines and equipment connected to the ERCOT System. ERCOT Dynamics Working Group (DWG) uses the PSS/E and TSAT software programs. Standard library models, including the so called "WECC Generic Models" are preferred provided the model accuracy is good, as these models are simpler to use and maintain. Often, however, generators especially IRRs and batteries will require use of User-Defined Models (UDM). UDM models utilize compiled model code provided by the manufacturer (.dll file) to expand the capability of the simulation program. To improve compatibility, ERCOT requests that all UDM models adhere to these guidelines.

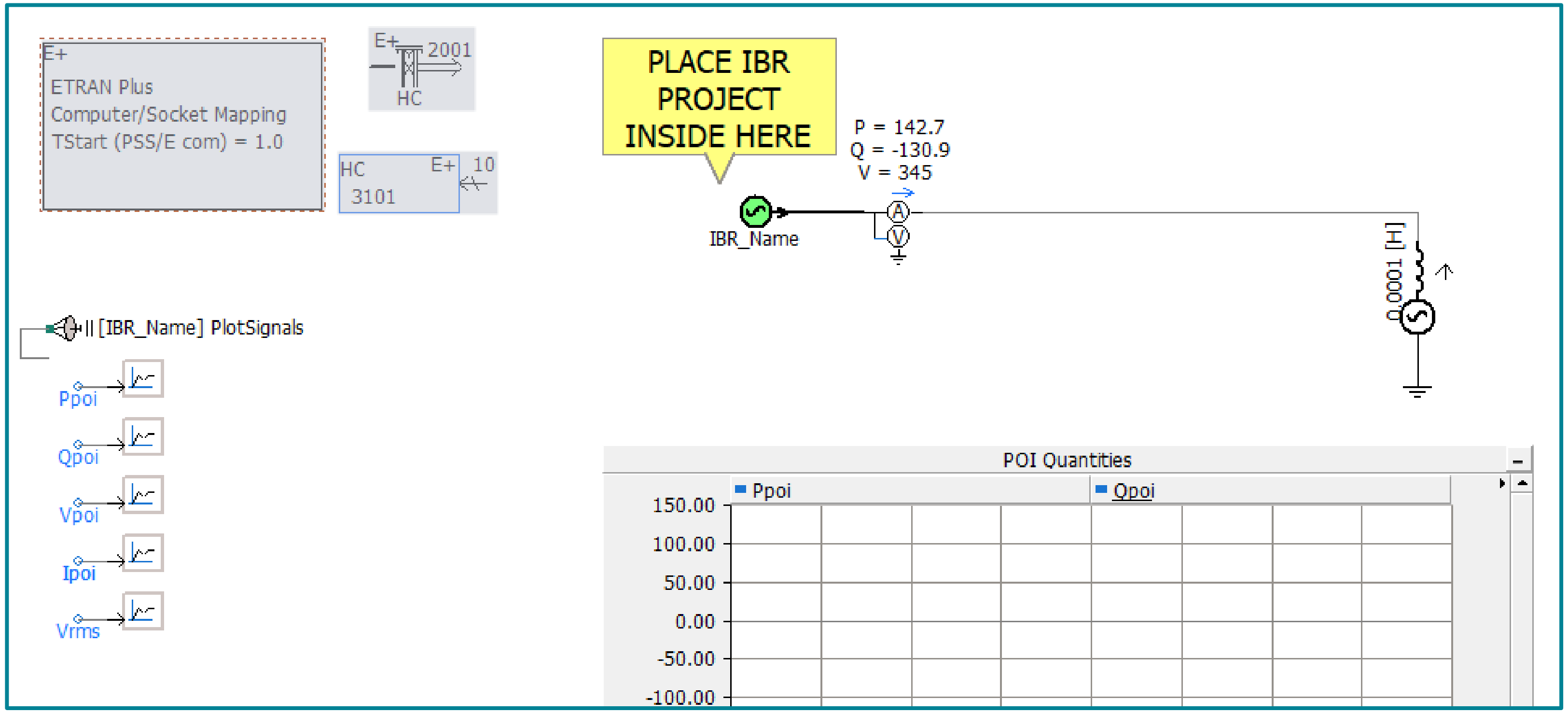
2. UDM Guidance

Some UDMs lack features or have certain limitations that have been observed to create challenges in preparing DWG simulation-ready study cases and are often difficult or impossible to use in large scale grid studies. The following list of items provides discussion and recommendations regarding UDM characteristics based on user experience.

- **Detailed Model Manual shall be provided:**
  The model manual should contain all the information needed to set up the dynamic model and understand its overall behavior. In particular,
  - Manual should describe how the poweflow generator model should be set up, including values for Rsource, Xsource, MBase, Qmin, Qmax, and whether the model is considered a "Wind Machine" in PSSE.
  - Manual should list and describe the major tunable control parameters.
  - Manual should provide a high level control block diagram illustrating major control functions and how the tunable control parameters are utilized.

Data Format

- Common data formats are essential for efficient model processing
  - PSS/E templates ensure consistent model submission format
  - PSCAD templates organize facility models into a single block – facilitates incorporation into a larger study case



Elements of Model Acceptability

- Format [MOD-032]
- Documentation/Functionality [MOD-032]
- Quality [MOD-032/MOD-026]
- Verification [MOD-026]
- Validation [MOD-026]

Evaluation of model acceptability involves a degree of engineering judgment, making it difficult to establish mandatory compliance obligations that are objective and efficient.

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
  - Includes the PSCAD model template and associated guidance
- 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

Questions

?

WECC

System and IBR Model Validation and ERO Criteria for Acceptable Models

Enoch Davies

Manager, Reliability Modeling

Electric Reliability
& Security for the West

June 5, 2025

WECC Interconnection-wide Model Case Builders Needs

WECC Generator Unit Model Validation Guideline

- Generator Owner Responsibilities
  - Review, verify, and update the Generating Facility data:
    - No later than 180 days after commercial operation
    - No later than 180 days after commercial operation with modified equipment, control settings, or software that influences the behavior
    - At least once every five years
- Transmission Planner Responsibilities
  - The Transmission Planner should maintain a current list of all Generating Facilities
  - Disturbance data recorded either at the generator or at the point of interconnection can be used for model data validation

WECC Generator Unit Model Validation Guideline

WECC Responsibilities

WECC should:

- Maintain a master data file with the current validated models
- Review and accept the generator testing and model validation reports
- Verify that the models are stable and the modeled system responses reasonably match power system performance

Master Dynamics File

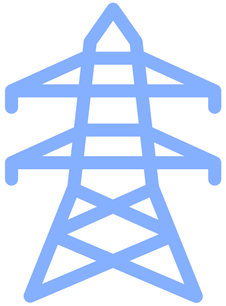
- Includes all the dynamic models that are included in the interconnection-wide base cases
  - Generators
  - DC Lines
  - Protection
    - UFLS
    - UVLS
    - Other relays
  - Load

Opportunities

Generator Owners/Operators

Use the models

Increase expectations on the third parties testing generators



Transmission Planners/Planning Coordinators

Initialize your area for each data submission

- Correct obvious errors identified by the software
- Adjust output to address messages limit exceeded

Issues Specific to Inverter-based Resources

- Getting updated data after new issues identified
    - Momentary cessation
- The right level to represent in interconnection-wide cases
    - WECC's data requirement documents require generators to be explicitly modeled:
        - 10 MVA, and
        - Connected to 60 kV or higher

WECC-specific Items

- WECC posts interconnection-wide cases in software programs
  - GE PSLF
  - Siemens PTI
  - PowerWorld Simulator
- WECC MVS Approved Models
  - Standard library models developed through open process
  - Models approved after implemented and benchmarked in other software programs

WECC

WWW.WECC.ORG | (801) 582-0353

155 N 400 W, Salt Lake City, UT 84103, USA

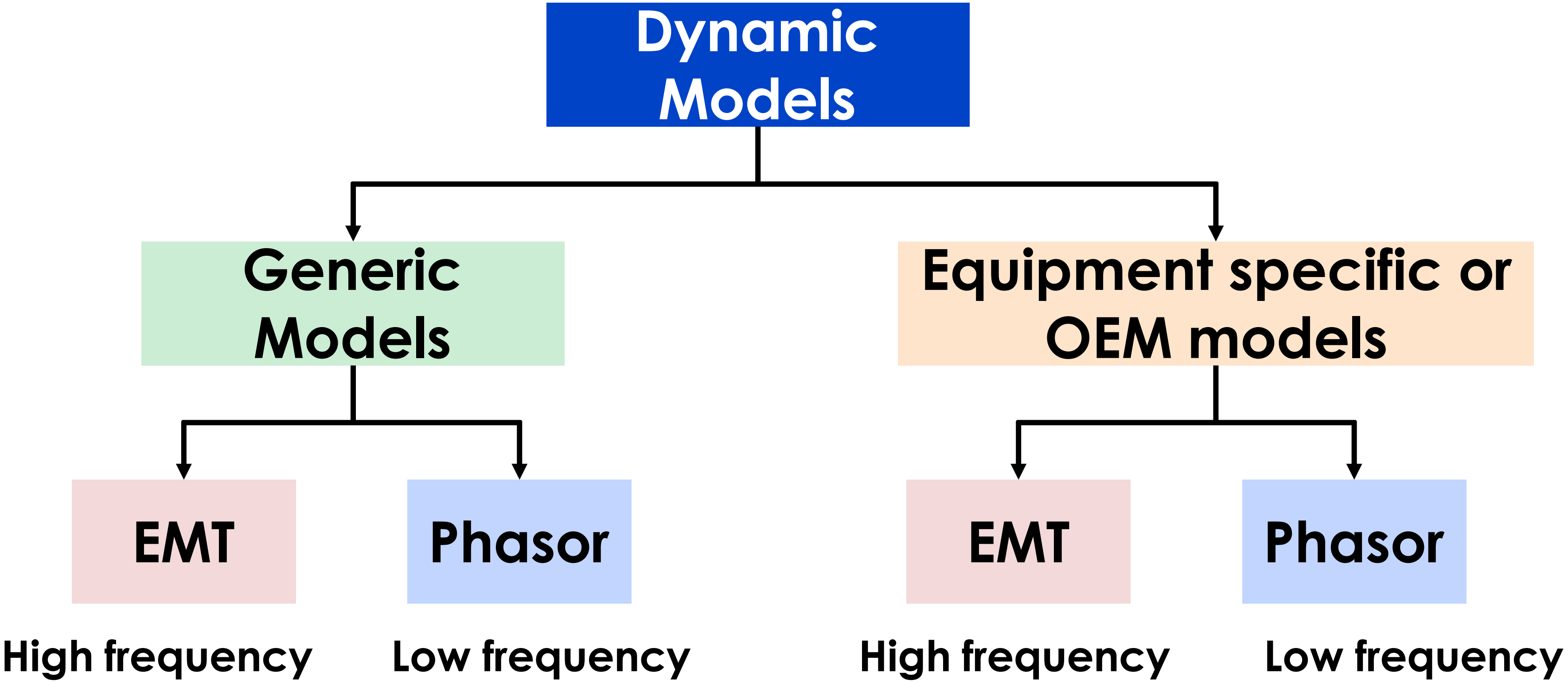
Emerging concepts in model validation

Panel: System and IBR Model Validation and ERO Criteria for Acceptable Models

Deepak Ramasubramanian
dramasubramanian@epri.com

3rd June 2025
NERC Industry Engagement Workshop

Dynamic Model Nomenclature



Few objectives model validation process aims to address

Model quality across software

- Does the model show similar performance?

Applicability of a model

- Is it ok to use a +SEQ/RMS model for a study?

Advanced Grid Support Behavior

- Does the model represent advanced grid support property?

Generic model performance

- Is a generic model appropriately parameterized to represent the trend of behavior?

Performance against requirements of a standard

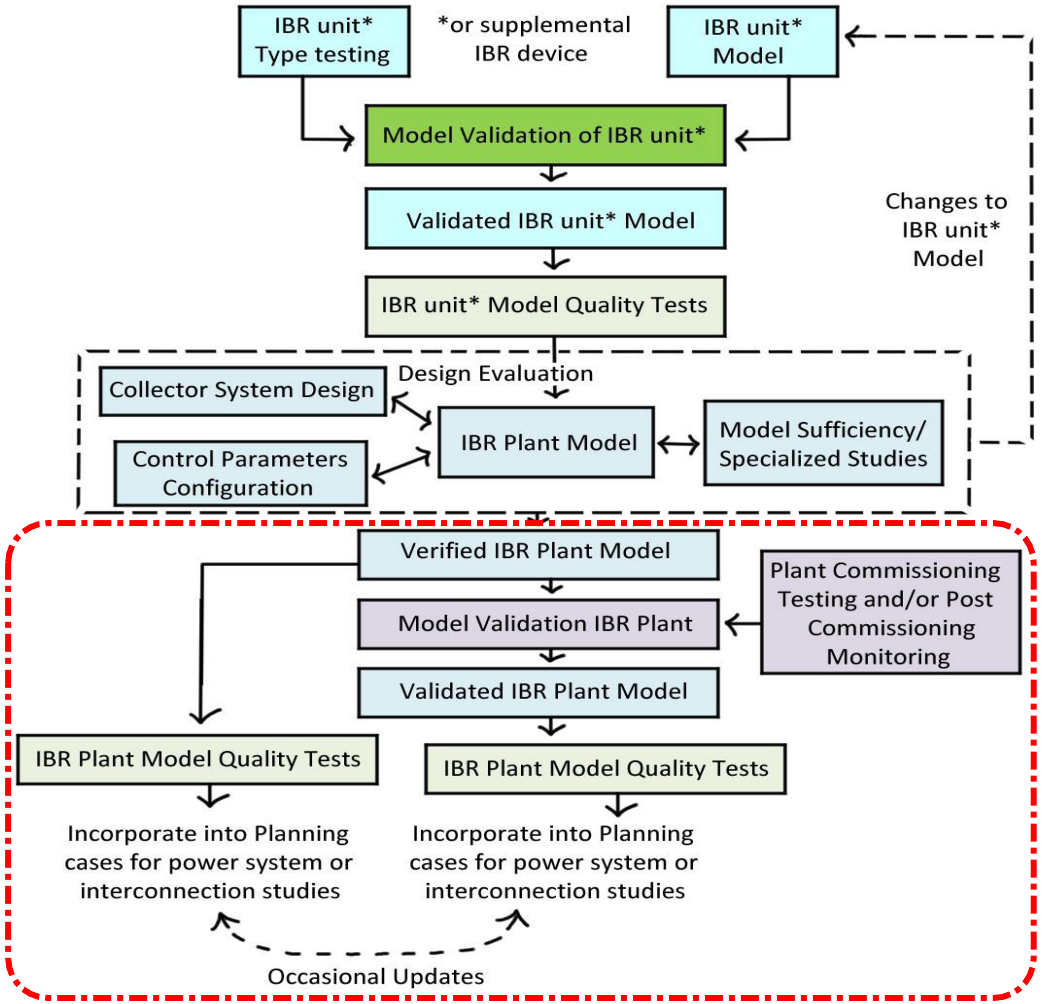
- Does the model conform to what is asked from a standard?

Model robustness

- Is the model robust across various system scenarios and conditions?

Model validation using field measurement

- Use of field measurements cannot be the go-to step for model validation
  - It should only be the fine tuning step
- There can be a distinct difference between model validation using play-in data vs entire system level validation
  - Representation of dynamic behavior across various elements
- IBR plant model validation at a system level should also consider accuracy of models of other elements
  - Load and transmission devices

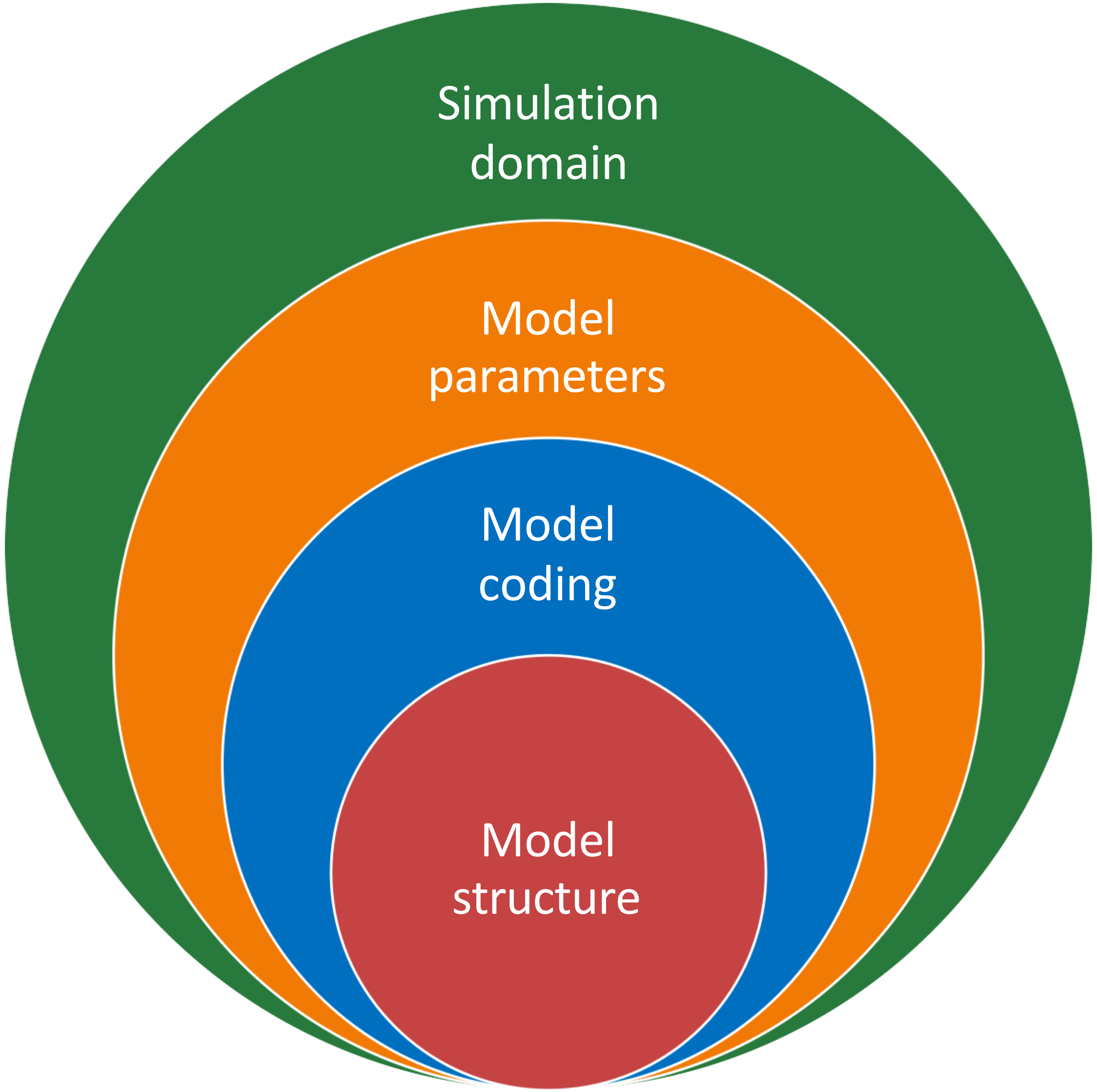


D. Ramasubramanian *et al.*, "Techniques and Methods for Validation of Inverter-Based Resource Unit and Plant Simulation Models Across Multiple Simulation Domains: An Engineering Judgment-Based Approach," in *IEEE Power and Energy Magazine*, vol. 22, no. 2, pp. 55-65, March-April 2024

Concepts of Model Quality Testing for Inverter Based Resources. EPRI, Palo Alto, CA: 2023. 3002027506

Positive sequence model not working?

- Four major reasons/limitations as to why a positive sequence model can show either a false positive/negative result
- Be cautious about jumping to an assumption that every reason for failure is due to inadequacy of simulation domain

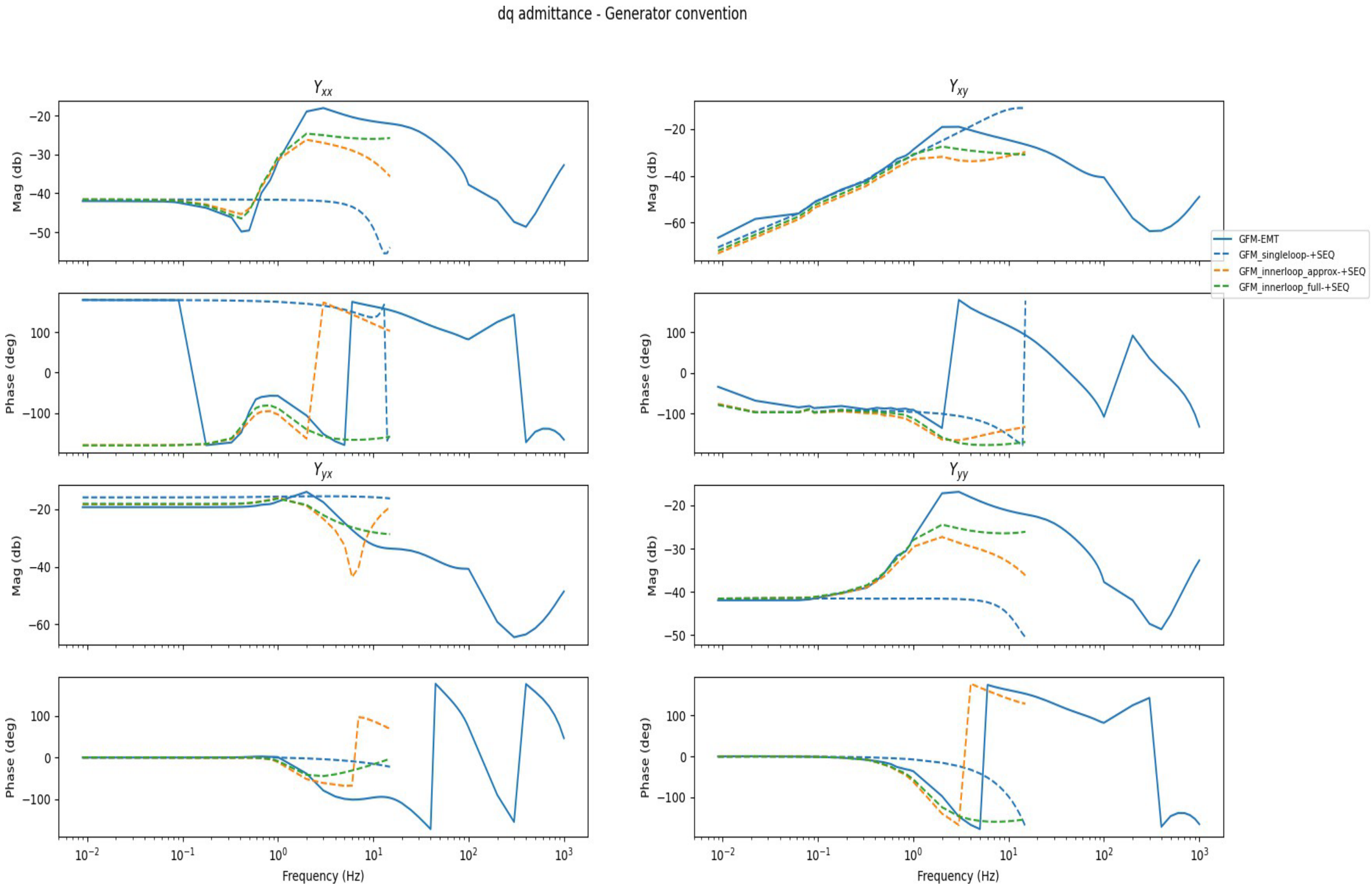


Reasons for limitations in positive sequence models with inverters

Deepak Ramasubramanian and Andrew Isaacs, ``Bad Model," NERC Inverter-Based Resource Performance Subcommittee (IRPS), Virtual Meeting, May 2022

Move beyond time domain for model validation

- Frequency domain model validation can show aspects and nuances that go beyond time domain
  - Reduces time spent testing models across various scenarios.
  - Improves efficiency in verifying use of models



Determining which positive sequence model is to be used to represent a given inverter

Talk to me offline to know more about how to generate these curves

Aspects to consider for model validation across simulation domain

- Impact of initialization from power flow (+SEQ) vs starting from true zero (most EMT)
  - Values taken by reference quantities in control loop
  - Deadbands
  - Triggers, thresholds, mode switches in IBR control loop (especially for FRT)
  - Pre-disturbance steady state frequency
- Load dynamic characteristics
- Reactive power consumed by along transformer magnetization path
- Simulation algorithms
  - Integration time step
  - Integration algorithm
  - Numerical precision

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Questions and Answers

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Closing Remarks and Adjournment

Welcome to the Milestone 3 of FERC Order 901 NERC Industry Engagement Workshop Day 2

Network Name: RitzCarlton_CONFERENCE
Password: NERC2025

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

FERC Order 901 and Standards Development

Jamie Calderon, Director of Standards Development, NERC
Milestone 3 of FERC Order 901 NERC Industry Engagement Workshop
June 4, 2025

Slido Q&A

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Standards Development - General

- NERC facilitates the Standards Development process
- The Drafting Team develops specifics
- A strong Reliability Standard:
  - Identifies responsible entity(ies) - WHO
  - Specifies objectives – WHAT
  - Specifies a periodicity – WHEN
- A strong Reliability Standard does not specify the HOW
  - Entity facts & circumstances must be considered
  - Entities have flexibility in meeting objectives

Order 901 Summary

- FERC Order 901
  - October 2023
  - 4 Milestones through November 2026
  - IBR related performance issues
  - Leverage existing guidance where possible

Order 901 Summary

IBR REGISTRATION INITIATIVE

STANDARDS MILESTONES: ORDER 901

1 — COMPLETED JANUARY 2024

Order No. 901 Work Plan submission

2 — DUE NOVEMBER 4, 2024

Standards development and filing to address performance requirements and post-performance validations for Registered IBRs

3 — DUE NOVEMBER 4, 2025

Development and filing of Reliability Standards to address data sharing and model validation for all IBRs

4 — DUE NOVEMBER 4, 2026

Development and filing of Reliability Standards to address use of performance data in Operational and Planning studies

Milestone 2 Summary

Disturbance monitoring and data sharing

- PRC-002 updated with IBR definition and applicability
- PRC-028 created for IBR disturbance monitoring

Use this data for Model Validation (Milestone 3 requirements)

IBR ride-through criteria

- PRC-024 updated to include Type 1 and Type 2 Wind
- PRC-029 created for IBR ride-through

Perform post-event analytics

- PRC-030 created to analyze unexpected IBR excursions

Milestone 3 Summary

Model Verification and Model Validation

MOD-026 updated with requirements for providing Model Verification and Model Validation documentation to planners that include IBRs

This project defined terms "Model Verification" and "Model Validation"

Modeling and analysis data

MOD-032 updated with requirements for ensuring consistent data for Model Validation in accordance with ERO criteria

Perform Model Validation

MOD-033 updated with requirements for Model Validation with dynamic event data

Milestone 3 and 4 Next Steps

Milestone 3

- Project 2021-01 and Project 2022-02 initial ballots complete.
- Project 2020-06 ballot opens on June 6.
- Drafting teams to provide next drafts for ballot around July/August timeframe.
- Milestone 3 Standards to be complete by November 2025.

Milestone 4

- Milestone 4 SARs to be published around August timeframe.
- Call for nominations for Milestone 4 Drafting Teams!
- Looking for individuals from utilities, Regions, and vendors with expertise in planning and operational studies with IBRs.

Operational Studies Potential Updates:

- Revise definitions (Real-time Assessment, Operational Planning Analysis, Balancing Contingency Event) to include IBR performance and sudden IBR output reduction.
- TOP Standards:
  - Require entities to utilize IBR performance as captured via updated modeling standards. IBR performance to inform generation-load-interchanges as well as Operating Plans.
- IRO, FAC, PRC Standards:
  - Require Reliability Coordinators to utilize IBR performance information to identify Operating Limit exceedances as well as Transmission and Generation outages.
  - Require Reliability Coordinators to utilize IBR performance information to determine stability limits, Contingency events, and responses to Remedial Action Schemes

Planning Studies Potential Updates:

- Revise TPL-001 Standard or create new Standard to update Planning Models. These updated Planning Models will include IBRs as required in updated Standards from Milestone 3.
- Ensure grid stress performance conditions are updated where necessary.
- Planning assessments to capture IBR performance under these conditions, and to include ride-through performance.

Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P0 No Contingency	Normal System	None	N/A	EHV, HV	No	No
…cy	Normal System	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single Pole of a DC line	SLG			
…cy	Normal System	1. Opening of a line section w/o a fault [7]	N/A	EHV, HV	No[9]	No[12]
		2. Bus Section Fault	SLG	EHV	No[9]	No
				HV	Yes	Yes
		3. Internal Breaker Fault[8] (non-Bus-tie Breaker)	SLG	EHV	No[9]	No
				HV	Yes	Yes
		4. Internal Breaker Fault (Bus-tie Breaker)[8]	SLG	EHV, HV	Yes	Yes

Table 1 – Steady State & Stability Performance Planning Events

Steady State & Stability:

a. The System shall remain stable. Cascading and uncontrolled islanding shall not occur.

b. Consequential Load Loss as well as generation loss is acceptable as a consequence of any event excluding P0.

c. Simulate the removal of all elements that Protection Systems and other controls are expected to automatically disconnect for each event.

d. Simulate Normal Clearing unless otherwise specified.

e. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

Questions and Answers

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Panel Discussion: Project 2022-02

Moderator: Howard Gugel– NERC

Panelists: John Schmall – ERCOT (Chair of DT), Jonathan Hayes– SPP (VC of DT), Hayden Maples – Evergy (DT Member)

Q&A

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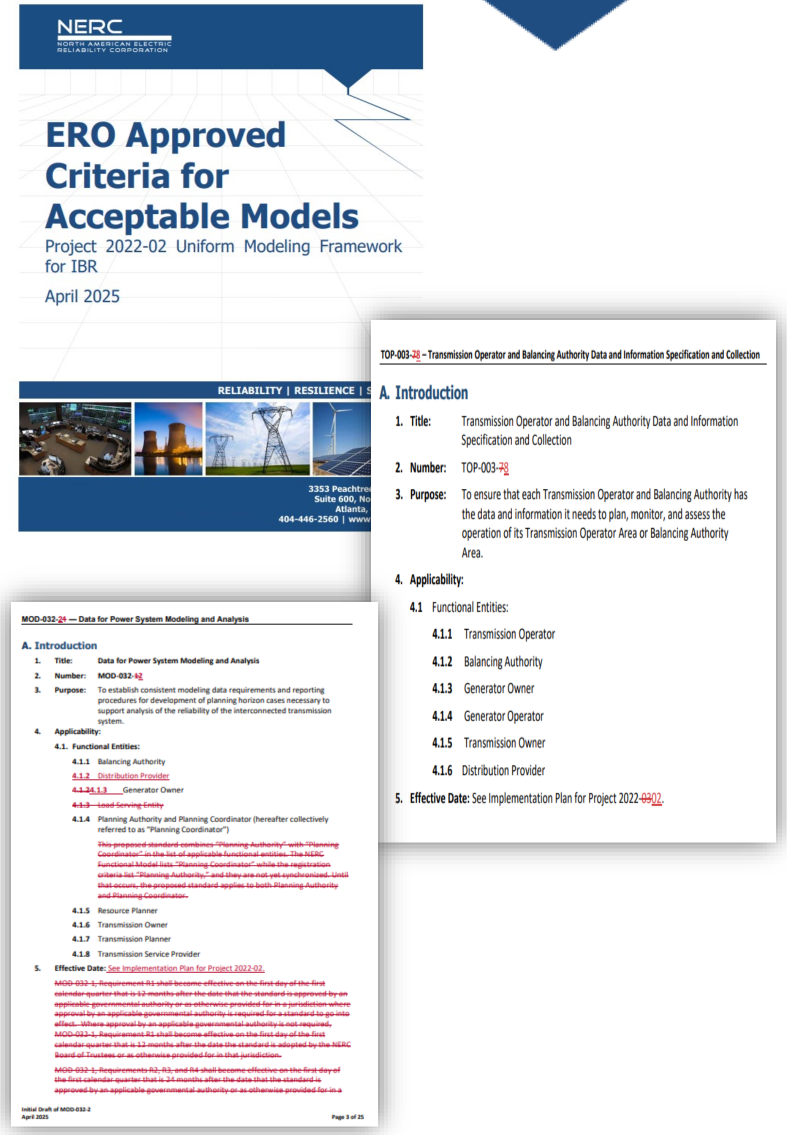
Initial Ballot and Non-Binding Poll

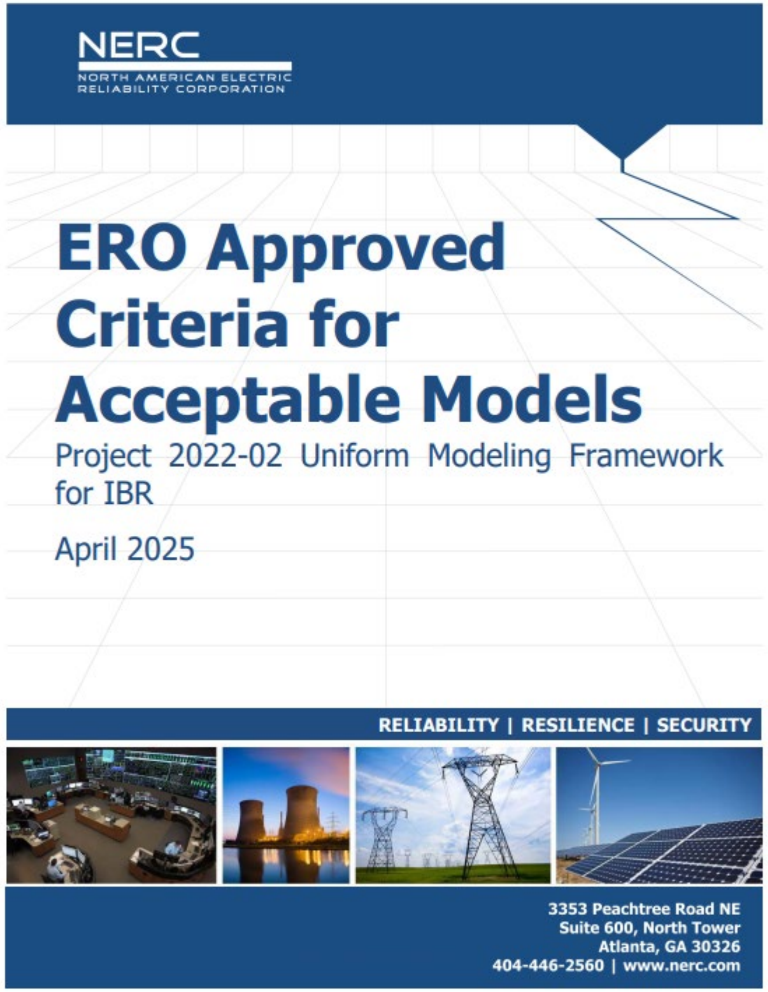
	Ballot
Standard	Quorum / Approval
MOD-032-2 (246 Votes)	87.86% / 39.05%
IRO-010-6 (246 Votes)	87.54% / 41.62%
TOP-003-8 (247 Votes)	87.90% / 34.70%
Implementation Plan (242 Votes)	88.00% / 39.46%

Standalone Standard(s)

- Some commenters do not agree that enforceable Reliability Standards should be reliant on external documents such as the document titled “ERO Approved Criteria for Acceptable Models” (FERC Order 901, P 125) for the establishment of enforceable and auditable compliance requirements.
- Some commenters do not agree with the revisions to IRO-010-5 and TOP-003-8. Specifically, the standards are no longer self-contained and require entities to reference external information, developed and updated outside of the standards balloting process and not contained within the standard, to determine the required level of performance.
- IRO-010, MOD-032, TOP-003, and ERO Approved Criteria for Acceptable Models.



ERO Approved Criteria for Acceptable Models



ERO Approved Criteria for Acceptable Models Concern:

- Some commenters point out that “Order 901 P141 directs NERC to mandate that generator owners of registered IBRs and transmission owners with unregistered IBRs on their system provide Bulk-Power System planners and operators with dynamic models that accurately represent the dynamic performance of both registered and unregistered IBRs.

Requirement R2 Part 2.1 Estimation Concern

- This is asking for data that would not be relevant for models if it is not accurate data and could call for ambiguity between regions on the amount of data required.
- Unregistered entities do not fall under the purview of this standard or NERC requirements.
- R2.1 asks entities that can't gather IBR/DER data to estimate the data. The model data that will be gathered with this provision is likely of low value and will potentially lead to more inaccurate models or models that have different issues.

2.1. If the responsible entity, as identified in Requirement R1 Part 1.1, is unable to gather unregistered Inverter-based Resource (IBR)[1] data or aggregate Distributed data and parameters and include an explanation of the limitations of the availability of data, an explanation of the limitations of any data provided, and the method used for estimation.

MOD-032-2 Attachment 1

steady-state *(Items marked with an asterisk indicate data that vary with system operating state or conditions. Those items may have different data provided for different modeling scenarios)*	**dynamics**	**short circuit**
1. Each bus [TO] a. nominal voltage b. area, zone and owner 2. Aggregate Demand[3] [DP] a. real and reactive power* b. in-service status* 3. Generating and storage units[4] [GO, TO[5], RP (for future planned resources only)] a. real power capabilities - gross maximum and minimum values b. reactive power capabilities - maximum and minimum values at real power capabilities in 3a above c. station service auxiliary load for normal plant configuration (provide data in the same manner as that required for aggregate Demand under item 2, above).	1. Generator [GO, RP (for future planned resources only)] 2. Excitation System [GO, RP (for future planned resources only)] 3. Governor [GO, RP (for future planned resources only)] 4. Power System Stabilizer [GO, RP (for future planned resources only)] 5. Aggregate Demand[3] [DP] 6. Wind plant model (for plants with type 1 and type 2 wind turbines) [GO] 7. Inverter-Based Resource [GO, TO[5]] a. IBR capabilities related to momentary cessation, tripping, Ride-through, and frequency control 8. Static Var Systems and FACTS [GO, TO, DP] 9. DC system models [TO]	1. Provide for all applicable elements in column "steady-state" [GO, RP, TO, DP] a. Positive Sequence Data b. Negative Sequence Data c. Zero Sequence Data 2. Mutual Line Impedance Data [TO] 3. Other information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes. [BA, GO, DP, TO, TSP]

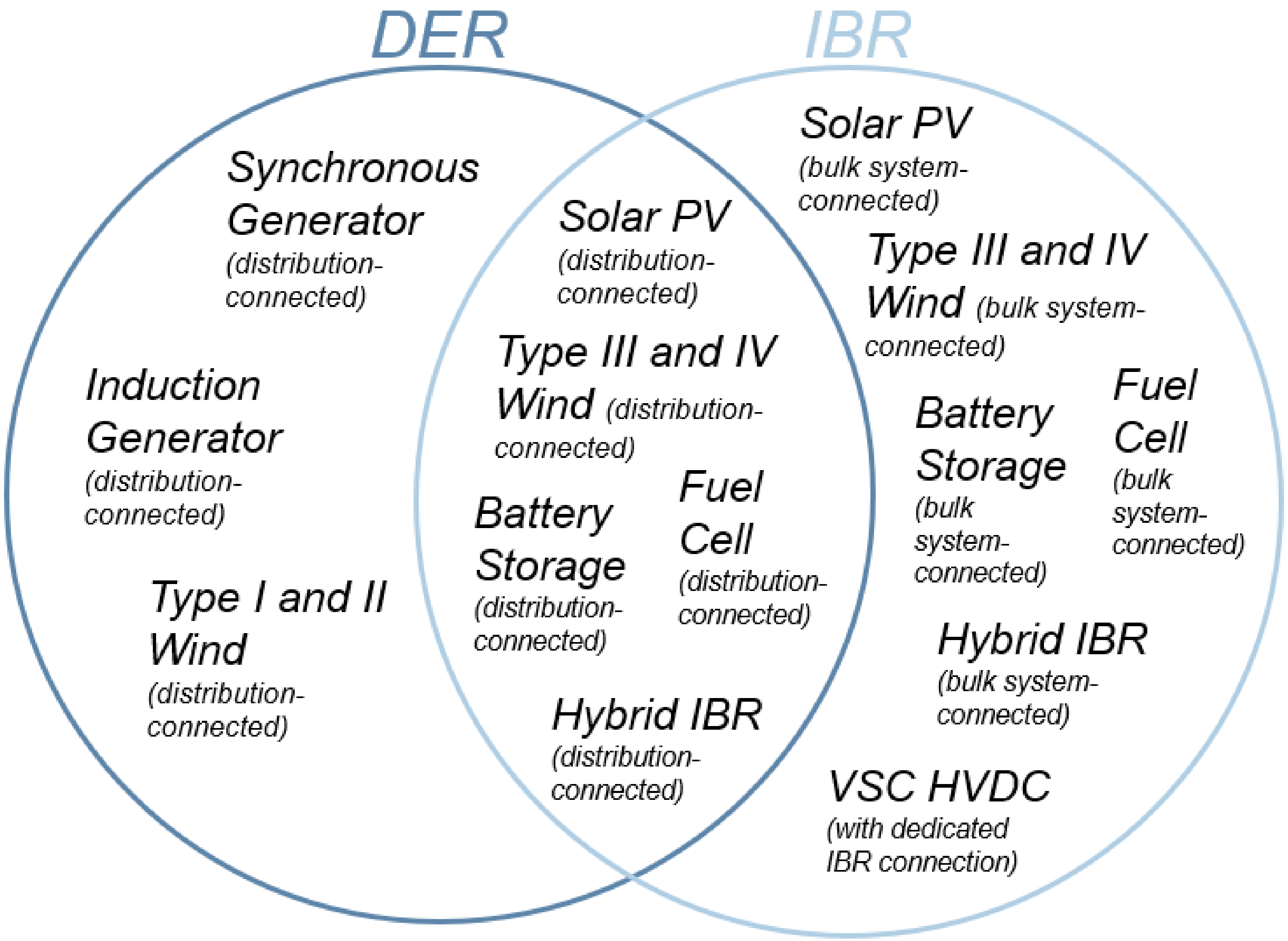
Definitions

- Proposed DER Definition
  - As a result of not defining this threshold, there is confusion as to what could be considered DER generation.
  - The definition of DER does not include any size requirements, such as voltage or MVA, that specifies when an individual DER or aggregate DER falls under the purview of the standard. TVA recommends adding size requirements to the definition or in Attachment 1.
- Unregistered IBR
  - Footnote 1 introduces the term "unregistered IBR" but does not adequately define it. Does the term "Unregistered IBR" only refer to IBRs that meet Category 2 criteria? This is not clear in the footnote as written.
- IBR-DER (See Diagram on next slide)

Distributed Energy Resources (DER): *Generators and energy storage technologies connected to a distribution system that are capable of providing Real Power in non-isolated parallel operation with the Bulk-Power System, including those connected behind the meter of an end-use customer that is supplied from a distribution system.*

Footnote 1: *As used in this standard, the phrase "unregistered IBR" refers to a Bulk-Power System connected IBR that does not meet the criteria that would require the owner to register with NERC for mandatory Reliability Standards compliance purposes.*

IBR-DER Diagram



Questions and Answers

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Senior Vice President and Chief Engineer

Panel Discussion: Project 2020-06

Moderator: Mark Lauby – Senior Vice President and Chief Engineer, NERC

Panelists: David Marshall – Southern Company (Vice Chair of DT), Rob O'Keefe – AEP (DT Member), Mohamed Elkhatib – Invenergy (DT Member)

Initial Ballot and Non-Binding Poll

	Ballot
Modeling Definitions (243 voters)	Quorum / Approval
Model Validation	89.01% / 71.75%
Model Verification	
Implementation Plan	88.28% / 73.08%

Slido Q&A

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Modeling Definition's Comment Theme

Modeling Definitions:

- What is the difference between Model Validation and Model Verification? To be explained by panelists.
- EEI and others do not agree that lower cased undefined "facility" rather the defined "Facility" term should be used in the Modeling definitions.
- The following slides show the similarities between IEEE draft definitions and the Project 2020-06 Modeling definitions.

NERC Glossary Definition:

Facility - A set of electrical equipment that operates as a single Bulk Electric System Element (e.g., a line, a generator, a shunt compensator, transformer, etc.)

Model Validation and Model Verification

2020-06 as successfully balloted with non-substantive revision

- **Model Validation**: The process of comparing simulation results with measurements to assess how closely a model's behavior matches the measured behavior.
- **Model Verification**: The process of confirming that model structure and parameter values are representative of the equipment or facility design and settings by reviewing equipment or facility design and settings documentation.

IEEE 2800.2 from unpublished unapproved draft, March 2025

- **Model Validation:** The process of comparing measurements with simulation results for the assessment of whether a model response sufficiently matches the measured response.
- **Model Verification:** The process of checking *IBR unit*, *supplemental IBR device*, or *IBR plant* documents, settings, and files, (e.g., controls & protection) and comparing them to model parameters or model structure.

Note IEEE definitions are drafts and subject to change.

MOD-026-2 Comments

Related to comments on the two definitions, some comments were centered around MOD-026-2 Footnote 4:

- Question on use of the term “ verified model” to indicate a model that has been both verified and validated according to the definitions (Model Verification and Model Validation) by the Generator Owner(s) or Transmission Owner(s).
- Would another term bring clarity and alleviate confusion?

> [4] The development of a “verified model” includes both Model Verification and Model Validation activities performed by the Generator Owner or Transmission Owner.

MOD-026-2 Requirement R1

During recent Project 2020-06 meetings, there was some discussion around deviation from a self-contained standard in referencing MOD-032 in MOD-026-2 Requirement R1.

- The Drafting team uses a broad reference to MOD-032.
- Believed needed to ensure that the two documents as required under MOD-032 and MOD-026-2 are in alignment but not overlapping.
- Is this reference to MOD-032 appropriate and helpful?

R1. Each Transmission Planner and its Planning Coordinator shall jointly develop dynamic model verification requirements and processes. The dynamic model verification requirements and processes shall be made available to Generator Owner(s) and Transmission Owner(s) by the Transmission Planner and shall include at a minimum the following: *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning and Long-term Planning]*

1.1. Positive sequence dynamic model specifications developed under MOD-032 for applicable facilities, specifically identified within the applicable table in Attachment 1:

1.1.1. Specify the limiting and protective functions listed within Table 1.1 that are required to be represented in the model;

Electromagnetic Transient (EMT) in MOD-026-2

The inclusion of EMT modeling included in MOD-026-2 has been a been the subject of several comments in former efforts of Project 2020-06.

- The inclusion of EMT Modeling in the most recent MOD-026-2 draft ensures Model Validation occurs, along with being essential with the evolving landscape of electric reliability.
- Is there an alternate means of validating the large disturbance behavior of IBRs that would be equally effective?

R3. For facilities identified under the Applicability sections 4.2.3.2, 4.2.4, 4.2.5, and 4.2.6, each Generator Owner or Transmission Owner shall provide a verified EMT model(s)[5] with associated parameters and accompanying information that represent the in-service equipment of the facility to its Transmission Planner according to the requirements and processes developed by its Transmission Planner and Planning Coordinator in Requirement R1 Part 1.2, within the timeframe specified in Attachment 2. The verified model(s) and accompanying information shall include at a minimum the following: *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

3.1. Test[6] result(s) demonstrating a comparison of the facility's response and the facility's EMT model response for large signal disturbances. For an IBR, the Generator Owner shall test and compare only the IBR unit.[7] If test results are not obtainable, the Generator Owner or Transmission Owner shall document the reason;

3.6. Documentation comparing large signal disturbance response of the facility positive sequence dynamic model(s) provided in Requirement R2 to the response of the facility EMT model.

Questions and Answers

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Panel Discussion: Project 2021-01

Moderator: Jamie Calderon – NERC

Panelists: Trevor Schultz – Idaho Power, Shounak Abhyankar – (ISO New England, Inc.), Nazila Rajaei, PhD – (EPRI), Nadia Smith, PhD – (NERC)

Q&A

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Initial Ballot and Non-Binding Poll

	Ballot	**Non-binding Poll**
Standard	Quorum / Approval	Quorum / Supportive Opinions
MOD-033-3 (237 Votes)	86.81% / 57.06%	85.88% / 64.13%
Implementation Plan (232 Votes)	86.57% / 59.43%	N/A

"System" vs. "system"

- EEI and utilities deferring to EEI are concerned about toggling between "System" and "system". The concern relates to confusion on which grid portions must be modeled.
- System is a NERC-Glossary term. Therefore, the commenters believe that inconsistent capitalization could later be read as expanding applicability.
- They urge the DT to either clarify the rationale or update the text.
- DT proposes to correct all instances of "system" to "System".

R1. Each Planning Coordinator shall implement a documented ~~data validation~~Model Validation process for its portion of the existing system that includes the following attributes: *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

1.1. Comparison of the power flow simulation performance of the ~~Planning Coordinator's portion of the existing system in a planning power flow~~ steady state System model[1] to actual ~~s~~System behavior, represented by ~~a~~ state estimator case(s) or other Real-time data sources, at least once every 24 calendar months ~~through simulation;~~;

1.2. Comparison of the dynamic local event simulation performance of the ~~Planning Coordinator's portion of the existing system in a planning dynamic~~dynamic System model to actual ~~system response, through simulation of a dynamic local event,~~System behavior, represented by Real-time data sources such as Disturbance data recording(s), at least once every 24 calendar months (us~~e~~ing a dynamic local event that occurs within 24 calendar months of the last dynamic local event used in comparison~~,~~[2]) and complet~~e~~ing each comparison within 24 calendar months of the dynamic local event. ~~). If no dynamic local event occurs within the 24 calendar months, use the next dynamic local event that occurs;~~.

1.3. Guidelines ~~the Planning Coordinator will use~~ to determine unacceptable differences in performance under Parts 1.1 ~~or~~and 1.2; and

1.4. Guidelines to resolve the unacceptable differences in performance identified under Part 1.3.

M1. ~~Each Planning Coordinator shall provide~~Acceptable evidence ~~that it has~~may include, but is not limited to, a copy of the documented ~~validation~~Model Validation process ~~according to Requirement R1 as well as evidence~~and documentation that demonstrates ~~the~~its implementation ~~of the required components of the process~~in accordance with Requirement R1.

R2. Each Reliability Coordinator and Transmission Operator shall, within 30 calendar days of a written request, provide actual ~~s~~System behavior data (or a written response that it does not have the requested data) to any Planning Coordinator performing ~~validation under Requirement R1 within 30 calendar days of a written request, such as, but not limited to, state estimator case or other Real-time data (including disturbance data recordings) necessary for actual system response validation.~~Model

[1] System models include unregistered Inverter-Based Resources (IBRs) and aggregate Distributed Energy Resources (DERs) when present. The phrase "unregistered IBR" refers to a Bulk-Power System connected IBR that does not meet the criteria that would require the owner to register with NERC for mandatory Reliability Standards compliance purposes.

[2] If no dynamic local event occurs within this 24 calendar months period, use the next dynamic local event that occurs.

R1 edits to Model Validation:

- Commenter's view removing "planning power flow" and "planning dynamic model" adds ambiguity.
- They propose tying R1 directly to MOD-032 data.
- DT proposes to revert to previous language for planning models since this clarifies that planning models should be used. DT will consider updating language around model to use.

R1. Each Planning Coordinator shall implement a documented ~~data validation~~Model Validation process for its portion of the existing system that includes the following attributes: *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

1.1. Comparison of the power flow simulation performance of the ~~Planning Coordinator's portion of the existing system in a planning power flow~~ steady state System model[1] to actual ~~s~~System behavior, represented by ~~a~~ state estimator case(s) or other Real-time data sources, at least once every 24 calendar months ~~through simulation;~~ ;

1.2. Comparison of the dynamic local event simulation performance of the ~~Planning Coordinator's portion of the existing system in a planning dynamic~~dynamic System model to actual ~~system response, through simulation of a dynamic local event,~~System behavior, represented by Real-time data sources such as Disturbance data recording(s), at least once every 24 calendar months (us~~e~~ing a dynamic local event that occurs within 24 calendar months of the last dynamic local event used in comparison~~,~~[2]) and complet~~e~~ing each comparison within 24 calendar months of the dynamic local event. ~~). If no dynamic local event occurs within the 24 calendar months, use the next dynamic local event that occurs;~~.

1.3. Guidelines ~~the Planning Coordinator will use~~ to determine unacceptable differences in performance under Parts 1.1 ~~or~~and 1.2; and

1.4. Guidelines to resolve the unacceptable differences in performance identified under Part 1.3.

M1. ~~Each Planning Coordinator shall provide~~Acceptable evidence ~~that it has~~may include, but is not limited to, a copy of the documented ~~validation~~Model Validation process ~~according to Requirement R1 as well as evidence~~and documentation that demonstrates ~~the~~its implementation ~~of the required components of the process~~in accordance with Requirement R1.

Unregistered IBR (Footnote 1):

- Commenters propose the term “unregistered IBR” be defined in the NERC Glossary.
- There is confusion on consistent registration and enforcement for this term.
- Additionally, BPS connected IBRs as mentioned in the footnote is viewed as too vague.
- DT proposes that we use footnote that refers to MOD-032 as mentioned in comments.

[1] System models include unregistered Inverter-Based Resources (IBRs) and aggregate Distributed Energy Resources (DERs) when present. The phrase “unregistered IBR” refers to a Bulk-Power System connected IBR that does not meet the criteria that would require the owner to register with NERC for mandatory Reliability Standards compliance purposes.

[2] If no dynamic local event occurs within this 24 calendar months period, use the next dynamic local event that occurs.

Draft 1 of MOD-033-3
April 2025 **Page 4 of 15**

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Comment Theme

R1.2 edits to Model Validation:

- Commenters would like additional language around when the 24-month timer starts, and what happens if there is no qualifying event.
- There are proposals towards using fixed language.
- Please see Footnote 2 for clarification. DT considers adding this language back in.

R1. Each Planning Coordinator shall implement a documented ~~data validation~~Model Validation process for its portion of the existing system that includes the following attributes: *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

1.1. Comparison of the power flow simulation performance of the ~~Planning Coordinator's portion of the existing system in a planning power flow~~ steady state System model[1] to actual ~~s~~System behavior, represented by ~~a~~ state estimator case(s) or other Real-time data sources, at least once every 24 calendar months ~~through simulation;~~;

1.2. Comparison of the dynamic local event simulation performance of the ~~Planning Coordinator's portion of the existing system in a planning dynamic~~dynamic System model to actual ~~system response, through simulation of a dynamic local event,~~System behavior, represented by Real-time data sources such as Disturbance data recording(s), at least once every 24 calendar months (us~~e~~ing a dynamic local event that occurs within 24 calendar months of the last dynamic local event used in comparison~~,~~[2]) and complet~~e~~ing each comparison within 24 calendar months of the dynamic local event.~~). If no dynamic local event occurs within the 24 calendar months, use the next dynamic local event that occurs;~~.

1.3. Guidelines ~~the Planning Coordinator will use~~ to determine unacceptable differences in performance under Parts 1.1 ~~or~~and 1.2; and

1.4. Guidelines to resolve the unacceptable differences in performance identified under Part 1.3.

M1. ~~Each Planning Coordinator shall provide~~Acceptable evidence ~~that it has~~may include, but is not limited to, a copy of the documented ~~validation~~Model Validation process ~~according to Requirement R1 as well as evidence~~and documentation that demonstrates ~~the~~its implementation ~~of the required components of the process~~in accordance with Requirement R1.

Questions and Answers

Slido

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Closing Remarks and Adjournment