Welcome to the Reliable IBR Integration and Milestone 3 of FERC Order 901 NERC Industry Engagement Workshop – Day 2

Wi-Fi: Renaissance_conference
Passcode: NERC2025

Safety Briefing

Wi-Fi: Renaissance_conference
Passcode: NERC2025

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NERC Antitrust Compliance Guidelines and Commission Staff Disclaimer

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NERC Recommended Modeling Practices

JP Skeath, Manager of Engineering and Security Integration
NERC Industry Engagement Workshop
January 16, 2025

Day 1 Recap

Why did NERC Provide Dynamic Model Recommendations

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- Standardized Parameters
- Standardized models for Interconnection-wide cases
- Vetted by System Analysis Modeling Subcommittee, now disbanded

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NERC Libraries of Standardized Powerflow Parameters and Standardized Dynamics Models
Version 1 – October 15, 2015

Introduction
There is a growing need for accurate interconnection-wide powerflow and dynamics simulations that analyze phenomena such as:

- Frequency response,
- inter-area oscillations, and
- interactions between the growing numbers of wide-area control and protection systems.

	A
1	**NERC LIST OF ACCEPTABLE MODELS FOR INTERCONNECTION-WIDE MODELING**
2	
3	**Purpose**
4	The purpose of this list of acceptable models is to develop and maintain a repository of models deemed acceptable by the ERO and industry stakeholders for use in developing interconnection-wide models developed by the MOD-032 Designee. The NERC System Analysis and Modeling Subcommittee (SAMS) initially developed this list and is maintained and updated by NERC Advanced Systems Analytics and Modeling.
5	This list seeks to bring together multiple sources of data to ensure uniformity in the use of models across interconnections. While models may be deemed 'obsolete' or 'deprecated' due to known issues, those models are not removed from the software vendor libraries for various reasons. However, those models should not be used for developing interconnection-wide models.
6	
7	**Table Legend**
8	Yellow: Use of this model is not recommended. Other models may be more appropriate for use. While existing models in the cases may still use these models, their future use is discouraged. Resubmission of models as per MOD-026-1 and MOD-027-1 for existing resources should convert the existing model to a more representative model.
9	Orange: Use of this model for new resources or resources re-certifying their models as per MOD-026-1 and MOD-027-1 should be prohibited, unless specifically acceptable by the Modeling Designee for interconnection-wide base case creation. Known modeling issues, errors, or deficiencies exist with this model. Modeling Designees should consider proactive actions to move towards more representative and accurate models.
10	Blue: These models are industry-accepted (e.g., IEEE standard models) that have not yet been implemented by the software vendors. Therefore they are listed on the list of acceptable models for tracking purposes using this color and will be updated accordingly once implemented by the software vendors. This is intended to provide direction to software vendors on which models industry recommends being implemented with higher priority.

Dynamic Model Recommendations

- Standardized parameters largely the same
- Corrected Dynamic modeling process concerns
- Refocused to address misuse of Acceptable Model List
    - Model Practices
    - Positive Sequence Standard Library
    - User Defined Models
    - EMT Models
    - GMD Models
    - Interconnection-wide model
    - List of Unacceptable Models

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Dynamic Modeling Recommendations

Recommended Modeling Practices and List of Unacceptable Models

Primary Interest Groups

This document applies to Transmission Planners (TP), Planning Coordinators (PC), and MOD-032 designees. The recommendations are also relevant to Generator Owners (GO), original equipment manufacturers (OEM), consultants, and any other organization performing bulk power system (BPS) reliability studies.

Scope and Intended Use

This document replaces the NERC Acceptable Model List, which has historically been used to establish requirements and criteria for the creation of Interconnection-wide base cases by MOD-032 designees. The intent of this paper is to provide clear and more comprehensive recommendations regarding the use of dynamic models for different types of reliability studies. This paper particularly focuses on models used for dynamic stability analyses but does incorporate recommendations for other types of studies as well. MOD-032 designees shall incorporate the recommendations contained herein for their Interconnection-wide case creation processes; TPs and PCs are strongly encouraged to review and incorporate these recommendations in their modeling and study processes.

Dynamic Model Recommendations

Planning Models

- Long-term Horizon to Short-Term Horizon
- Powerflow
- Stability
- Short Circuit

Operational Models

- Seasonal to real-time
- Operational Planning Analysis
- Real-Time Assessment

185 FERC ¶ 61,042
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 40

[Docket No. RM22-12-000; Order No. 901]

Reliability Standards to Address Inverter-Based Resources

(Issued October 19, 2023)

AGENCY: Federal Energy Regulatory Commission

ACTION: Final rule

Differences exist. recommendations focus on planning, but harmonize to operational models

Model Practices

- All models should be detailed and accurate representations of expected or as-built facilities on the BPS, including during interconnection studies and throughout the lifecycle of a project.
- TP/PC’s responsibility to establish and update project modeling requirements and model quality needs
- GO/developer responsibility to check and meet NERC standard and local TP/PC’s model requirements
- GO’s responsibility to maintain accurate model throughout the lifecycle of the project.
- GO’s duty to notify TP/PC of any expected change/updates for the equipment and the corresponding models updated

Model Practices

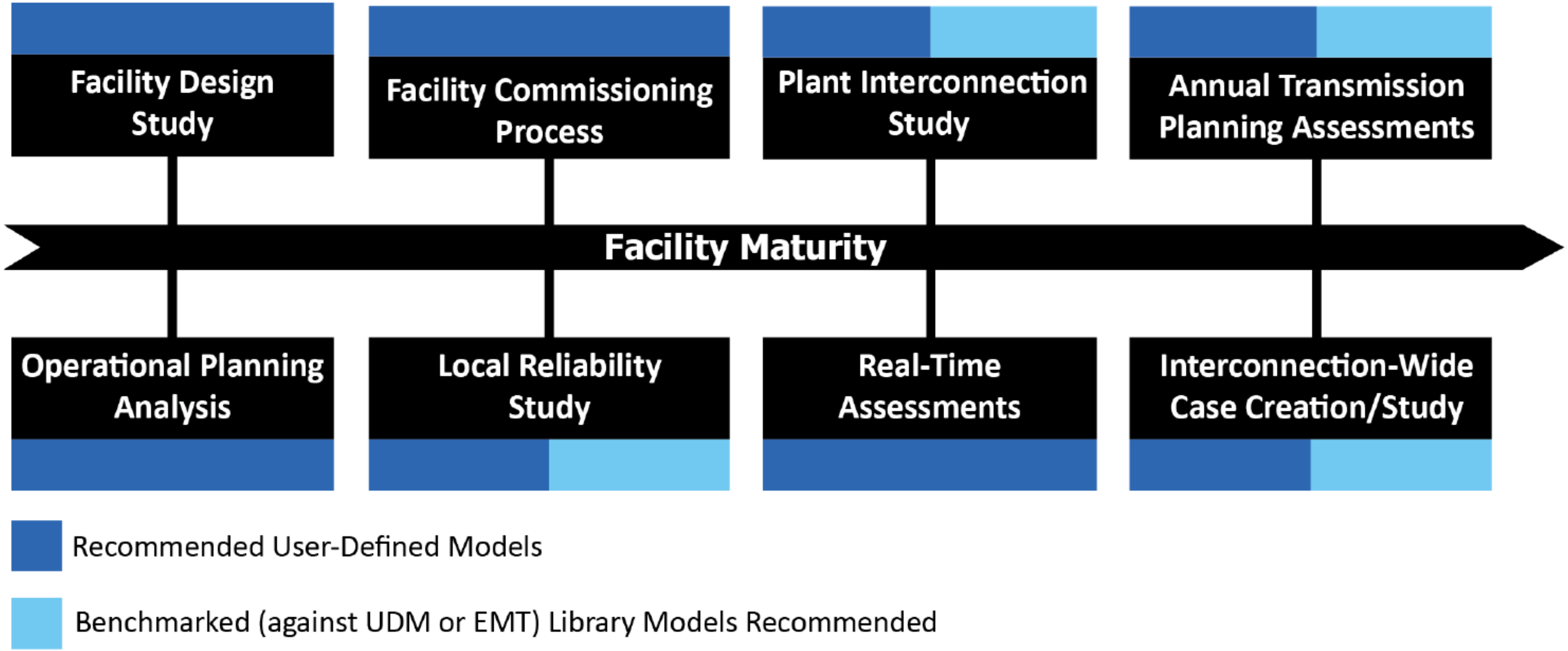

Figure 1: Recommended Dynamic Modeling Practices[6]

Model Practices

Standard Library

- Generic
- Easily shared
- Less accurate

Recommend benchmarking of library model to User Defined

User Defined

- Equipment-specific
- Compilation required
- More accurate

Positive Sequence User Defined Models

- Historically, planners had difficulty with user-defined models
  - Version control
  - Numerical instability
- User Defined Models are acceptable if:
  - Model validation report against equipment performance
  - Model benchmarking report across model domains
  - Compiled files, no additional compiling required by end-user
  - Documentation to integrate into network cases, understand modes and functions, understand ratings and capabilities, initialize models appropriately in reliability studies

EMT Models

- Positive sequence models is inadequate for identifying reliability risks in certain system conditions
  - EMT models are needed to accurately identify reliability
  - EMT models should be accurate representation of site-specific controls & protections (different from the example model in EMT library)
- TPs should establish EMT model quality requirements and acceptance criteria
  - Include a complete, full, and accurate representation of the inverter-based resource
  - Represent all pertinent controls and protections
  - Include attestations that the model matches site-specific equipment, controls, and protection
  - Validation reports on unit/plant EMT model, benchmarking against corresponding positive sequence model
  - Model Documentation for end-user integration

EMT Models

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- User Defined Models are acceptable if:
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  - Model benchmarking report across model domains
  - Compiled files, no additional compiling required by end-user
  - Documentation to integrate into network cases, understand modes and functions, understand ratings and capabilities, initialize models appropriately in reliability studies

Process looks different for EMT models, but follows same fundamentals

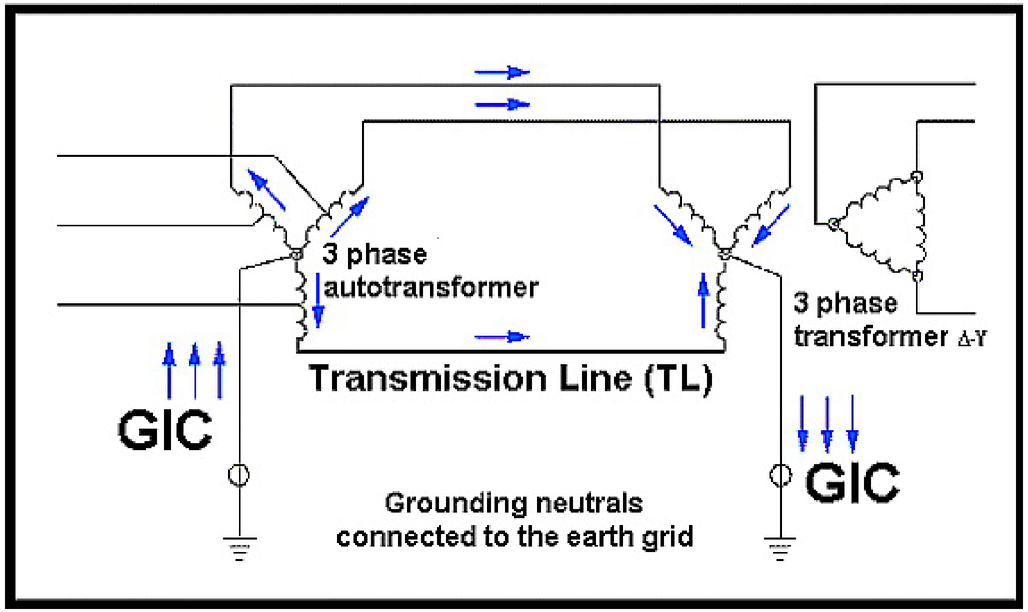
GMD Models

- NERC TPL-007 establish requirements for transmission system planned performance during geomagnetic disturbance (GMD) events.
  - R2 requires TP to maintain models for GDM Vulnerability Assessments
  - TPs and PCs should leverage MOD-032 Attachment 1

TPL-007-4 – Transmission System Planned Performance for Geomagnetic Disturbance Events

A. Introduction

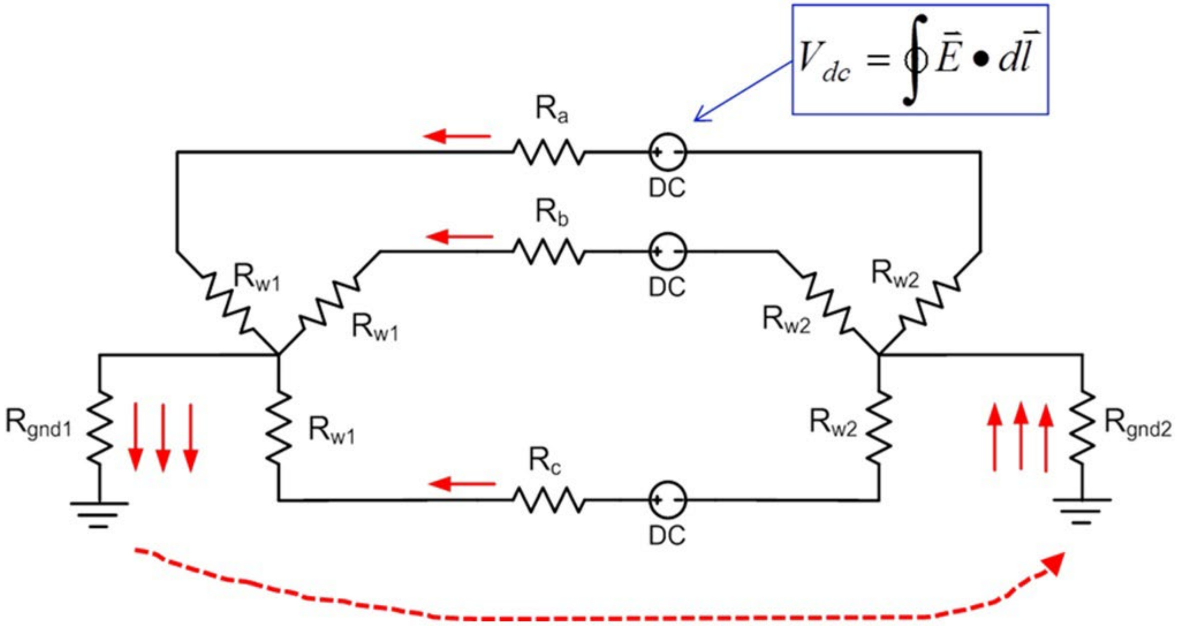
1. **Title:** Transmission System Planned Performance for Geomagnetic Disturbance Events
2. **Number:** TPL-007-4
3. **Purpose:** Establish requirements for Transmission system planned performance during geomagnetic disturbance (GMD) events.



https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2006SW000282

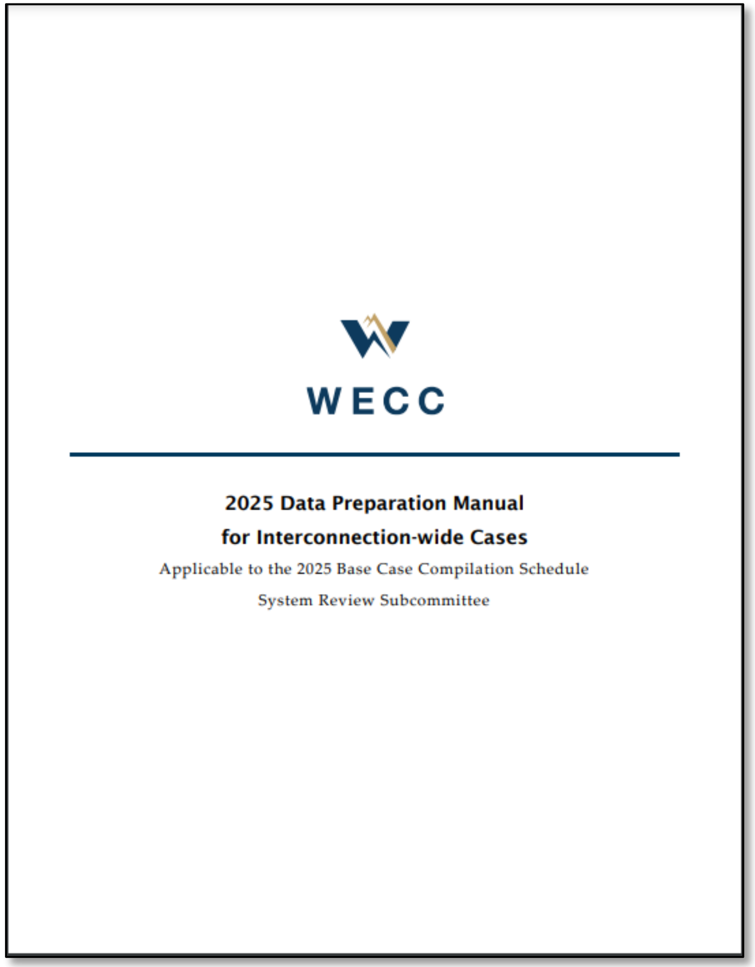
GMD Models

- Practices should include, but are not limited to:
  - Winding and Phase configuration
  - Terminal Voltages
  - DC model equivalent
  - Thermal and electrical limits of transformer winding
  - Earth conductivity (known or supplemental) for grounded transformers
  - Substation grounding



https://www.powerworld.com/products/simulator/add-ons-2/simulator-gic

Interconnection-wide Models



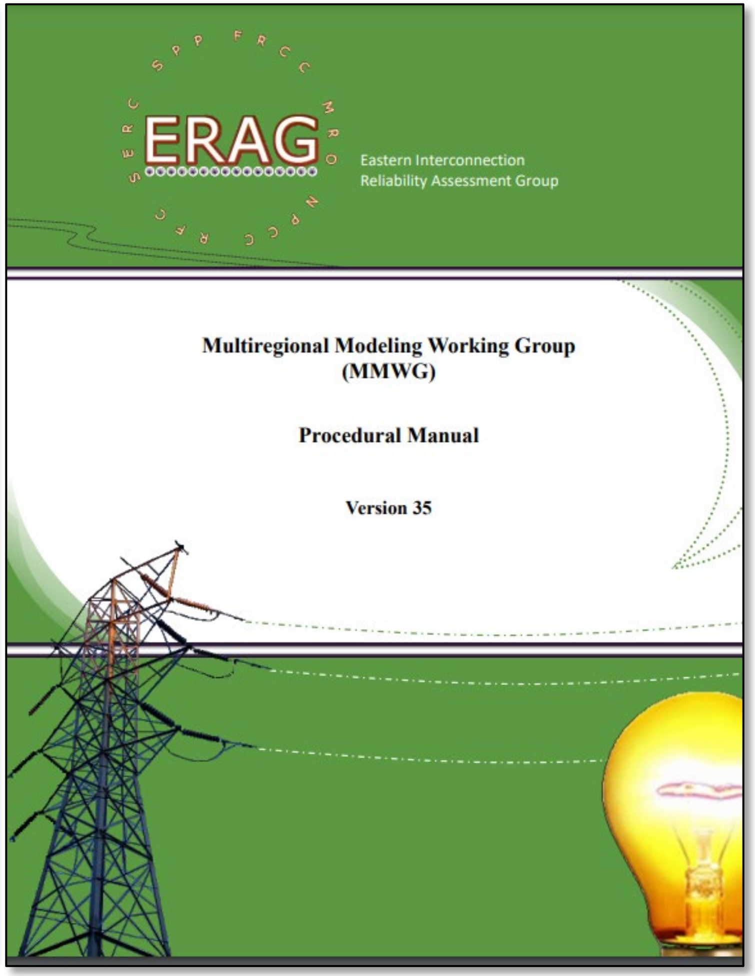
WECC

2025 Data Preparation Manual

for Interconnection-wide Cases

Applicable to the 2025 Base Case Compilation Schedule

System Review Subcommittee



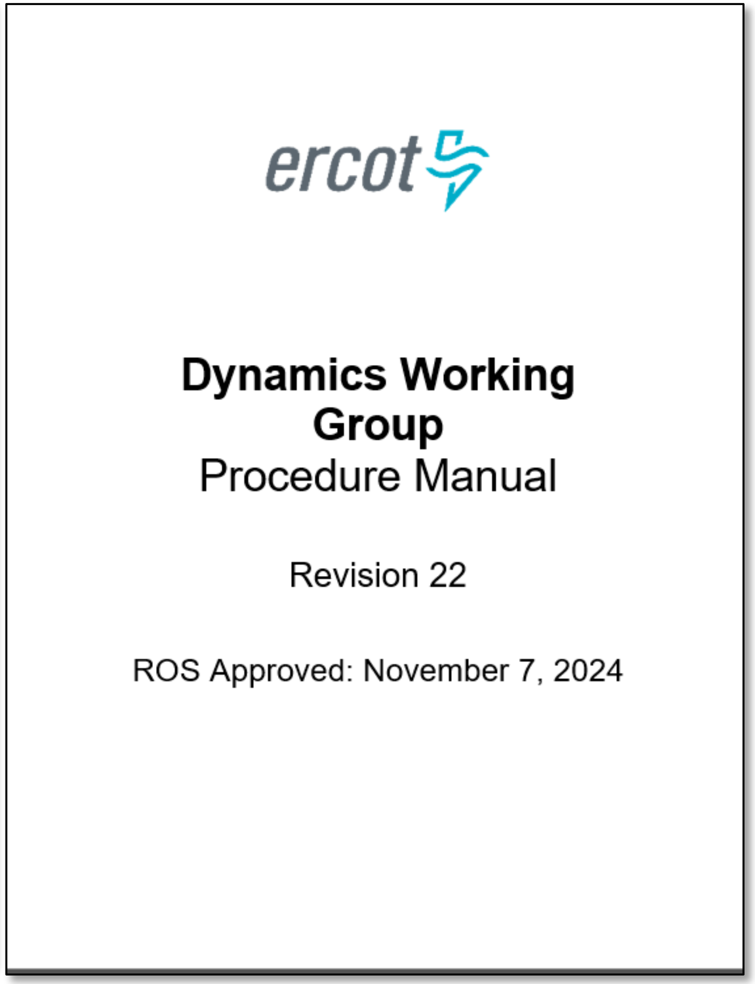
ERAG

Eastern Interconnection
Reliability Assessment Group

Multiregional Modeling Working Group
(MMWG)

Procedural Manual

Version 35



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Dynamics Working Group

Procedure Manual

Revision 22

ROS Approved: November 7, 2024

Interconnection-wide Models

- The MOD-032 R4 Designees are responsible for:
  - Establishing model requirements for the Interconnection-wide base case
  - Accounting for and incorporating the NERC unacceptable models list to the model requirements
  - Defining/maintaining acceptable and recommended models
  - Determining (work with TP/PC) whether UDM will be deemed acceptable in the base cases

MOD-032-1 — Data for Power System Modeling and Analysis

A. Introduction

1. **Title: Data for Power System Modeling and Analysis**
2. **Number: MOD-032-1**
3. **Purpose:** To establish consistent modeling data requirements and reporting procedures for development of planning horizon cases necessary to support analysis of the reliability of the interconnected transmission system.

MOD-032-1 — Data for Power System Modeling and Analysis

R4. Each Planning Coordinator shall make available models for its planning area reflecting data provided to it under Requirement R2 to the Electric Reliability Organization (ERO) or its designee to support creation of the Interconnection-wide case(s) that includes the Planning Coordinator's planning area. *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

Unacceptable Model List

- Modeling errors, numerical issues, incomplete documentation, etc.
  - Same as before in Acceptable Model List
  - Updates only when model is confirmed unacceptable

Table A.1: Unacceptable Model List

Known Unacceptable Model Name	Model Description
Renewable Energy Models	
WT3G1,WT3G2, wt3g	Generic Type 3 WTG Generator/Converter Model - Doubly-fed induction generator
WT4G1,WT4G2, wt4g	Generic Type 4 WTG Generator/Converter Model - Variable speed generator with full converter
WT3E1, wt3e	Generic Type 3 WTG Electrical Control Model
WT4E1,WT4E2, wt4e	Generic Type 4 WTG Electrical Control Model
WT3T1, wt3t	Generic Type 3 WTG Turbine Model
WT3P1, wt3p	Generic Type 3 WTG Pitch Control Model
WT12A1, wt1p,wt2p	Generic Type 1 and 2 WTG Pitch Control Model
WT4E1, wt4t	Generic Type 4 WTG Power Converter Model
wt4p	Generic Type 4 Pitch Control Model
REECB1,REECBU1, reec_b	Generic Phase 2 PV Electrical Controls Model
genwri	Vestas Model of Wound-Rotor Induction Generator (with Variable External Rotor Resistance)
exwtg1	Vestas Model of Rotor Resistance Control for Wound-Rotor Induction WTG
wndtge	GE Wind Turbine Control Model - Doubly Fed Induction Generator (DFIG) and Full Converter (FC) Models
gewtg	GE Wind Turbine Generator/Converter - DFAG and FC Models
exwtge	GE Wind Turbine Excitation (converter) Control Model for DFAG Generators
wndvar	GE Wind Turbine Plant-Level Supervisory Voltage/VAR Control
Machine Models	
GENSAL, gensal	Salient Pole Generator Model (IEEE Std 1110 §5.3.1 Model 2.1)
GENCLS, gencls	Classical Generator Model (IEEE Std 1110 §5.4.2)
GENTRA	Transient Level Generator Model

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Modeling Notification

Recommended Practices for Modeling Momentary Cessation
Initial Distribution: February 2018

This Modeling Notification provides Generator Owners who own inverter-based resources, particularly solar photovoltaic (PV) resources, with recommendations for accurately modeling momentary cessation for existing resources that are not able to eliminate its use. Specific modeling requirements and steps to accurately model this behavior in the second-generation positive sequence generic renewable energy system models are provided in the notification.

Primary Interest Groups

Generator Owners (GOs), Generation Operators (GOPs), Transmission Planners (TPs), Planning Coordinators (PCs), Reliability Coordinators (RCs), MOD-032 Designees

https://www.nerc.com/comm/pc/nercmodelingnotifications/modeling_notification_-_modeling_momentary_cessation_-_2018-02-27.pdf

Questions and Answers

SLIDO

- Option 1
  - Navigate in browser to www.slido.com
  - Enter Event Code: NERC901
  - Email address requested on entry
    – so we can respond to all questions!

- Option 2:
  - You may also scan this QR code
    to be auto-directed to the event

FERC Order 901 & Standards Development

Jamie Calderon, Director of Standards Development, NERC
NERC Industry Engagement Workshop
January 16, 2025

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

NERC Files Proposed Revisions to its Rules of Procedures

- March 19, 2024 – NERC filed its proposed revisions with FERC
- Category 2 Generator Owner and Generator Operator
- Register entities that own and/or operate:
  - Non-BES Inverter Based Resources (IBRs) with aggregate nameplate capacity >= 20 MVA connected at a voltage >= 60 kV
- These changes ensure 97.5% of impactful IBRs become subject to Reliability Standards

NERC is currently in **Phase 2** of the registration milestones identified in the FERC-approved work plan.

Phase 1: May 2023–May 2024

- Complete Rules of Procedure revisions and approvals
- Commence Category 2 GO and GOP candidate outreach and education (e.g., through trade organizations)

Phase 2: May 2024–May 2025

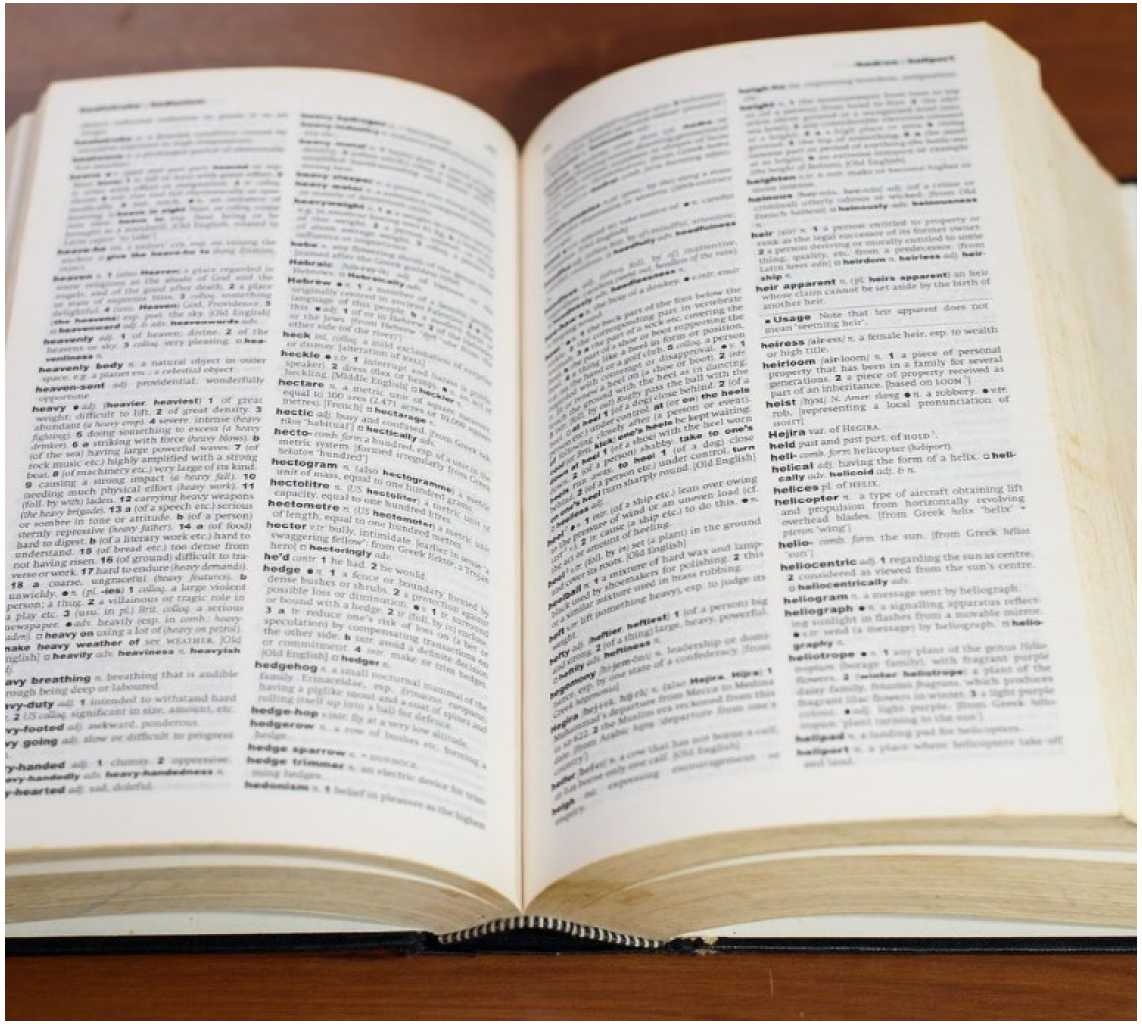
- Complete identification of Category 2 GO and GOP candidates
- Continue Category 2 GO and GOP candidate outreach and education (e.g., quarterly updates, webinars, workshops, etc.)

Phase 3: May 2025–May 2026

- Complete registration of Category 2 GO and GOP candidates thereafter subject to applicable NERC Reliability Standards
- Conduct specific Category 2 GO and GOP outreach and education (e.g., quarterly updates, webinars, workshops, etc.)

Relevant Projects

- GO/GOP Definitions Project (2024-01)
  - Revising GO and GOP definitions
  - Developing Implementation Plan for new definitions
  - Proposing Initial Ballot of revised definitions Q1-2025
- Milestone 2 Projects
  - Non-BES IBR have phased-in compliance later than BES IBR



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Break

9:30 – 9:45 a.m. Mountain

Panel Discussion: IBR Modeling Requirements and Importance of Model Verification

Moderator: Enoch Davies, WECC
Andy Hoke – National Renewable Energy Lab

- Brad Marszalkowski – ISO New England
- Bo Gong – Salt River Project
- JP Skeath – NERC
- John Schmall – ERCOT
- Mohamed ElNozahy – IESO

Perspectives on Raising the Bar for IBR Models

Andy Hoke, Ph.D., P.E.

Panel: **IBR Modeling Requirements and Importance of Model Verification**

NERC Industry Engagement Workshop: Reliable IBR Integration and Milestone 3 of FERC Order No. 901

January 16, 2025

Background

- *Since at least 2016, NERC and industry have been working towards raising the bar for IBR models*
- *Milestone 3 of FERC Order 901 establishes a deadline to finish some key modeling standards*
- *A key question is, how **high and how fast do we raise the bar**?*
  - *We clearly need improved models, including **validation against hardware tests***
  - *We know models are never perfect*
  - *Our task as an industry is to find the right compromise in improving model requirements to safeguard system reliability without imposing a burden so high that interconnection times and costs become unreasonable*
- *IEEE P2800.2 proposes a framework and procedures for **IBR plant standards conformity assessment** in which modeling plays a key role*
  - *Includes near-final draft procedures for **model validation** at IBR unit level and plant level**, model verification**, etc.*
  - *Expected to start ballot in spring 2025*
  - *We welcome coordination with NERC drafting teams*

Some potentially useful model-related definitions

First two are aligned with definitions in Project 2020-06 (MOD-026-2):

1. ***Model validation**: The process of **comparing measurements with simulation results** for the assessment of whether a model response sufficiently matches the measured response*
2. ***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*
3. ***Model benchmarking**: The process of **comparing simulation results from two models** for the assessment whether a response from one model sufficiently matches the response from the other model for the same disturbance and external power system conditions*
4. ***Model quality assessment (MQA):** The process of evaluating the **plausibility, usability, and numeric stability** of a model based on a review of model documentation, data, and simulations*

Role of **models** in IEEE P2800.2 conformity assessment framework

Type Tests

Lab or field tests of individual IBR unit and PPC for model validation

IBR Unit and PPC Model Validation

Based on type test data

√ Individual inverter, turbine, and PPC models validated against hardware tests

IBR Plant Model Development

Based on validated IBR unit model(s) and balance of plant

√ Plant model built from validated device models

IBR Plant Design Evaluation

IBR plant simulations and document review to assess plant conformity to IEEE 2800

√ Simulations of plant model show plant will meet 2800

Plant construction complete

As-built Installation Evaluation

Verification of installed plant

Commissioning Tests

Partial field assessment of plant performance

Post-Commissioning Model Validation

Based on commissioning test data. (Limited to tests feasible during commissioning)

√ Plant model validated against field data (limited tests)

Post-commissioning Monitoring

Monitoring of plant performance during grid events and model validation against field measurements

√ Plant model validated against field data (as available)

Periodic Tests and Verifications

Why do we need models *before* commissioning?

Once plant is built, major changes are costly

Standards conformity assessment should occur ***before commissioning***

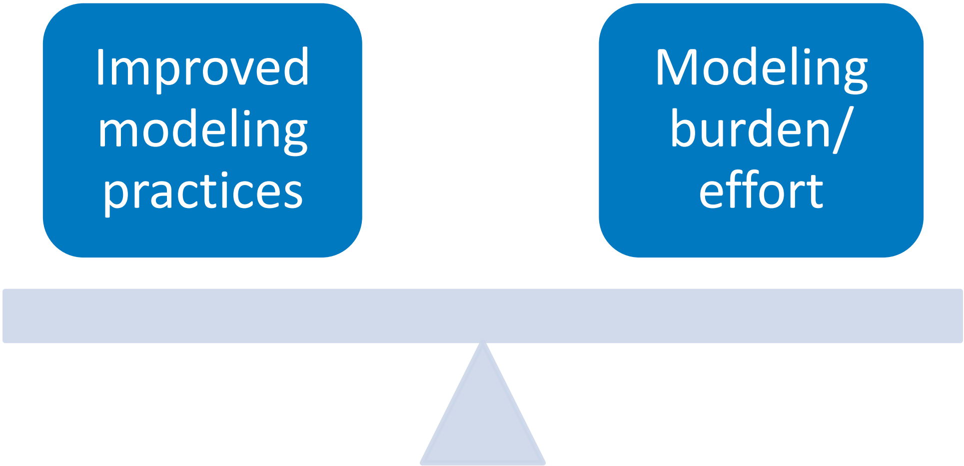
BPS IBR plant performance is too complex to assess based on type tests alone

An accurate ***plant model is essential*** *to conformity assessment*

High quality, accurate IBR plant model is needed before commissioning

Final points and summary

- *P2800.2 requires both **positive sequence** ("RMS") and **EMT** models*
- *P2800.2 failed to find consensus on **quantitative** model validation criteria.*
    - *Instead, we have **qualitative** criteria and a framework for quantitative evaluation*
- *NERC standards should probably not include the level of detail in P2800.2, but could consider leveraging some key pieces*
    - *P2800.2 does avoid saying which entity does what; focuses on technical solutions*
- *Modeling expertise in industry is still maturing. Standards need to balance improving modeling practices against the effort/burden of model requirements*



Thank you!

www.nrel.gov

Andy Hoke (Andy.Hoke@nrel.gov)
Power Systems Engineering Center
National Renewable Energy Laboratory

Funded by U.S. DOE Solar Energy Technologies Office

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NREL
Transforming ENERGY

PHOENIX, AZ | JANUARY 16, 2025

IBR Verification & Validation During Interconnection Process

NERC Industry Engagement Workshop –Reliable IBR Integration and Milestone 3 of FERC Order 901

-Panel Discussion: IBR Modeling Requirements and Importance of Model Verification

Brad Marszalkowski

SUPERVISOR, RESOURCE INTEGRATION

SYSTEM PLANNING

Verification and Validation of Models During Interconnection Process

- ISOs/RTOs need accurate, **OEM developed** models of IBR units, HVDC, PPC's and other related equipment, to predict system behavior during interconnection studies
  - Need to be benchmarked against measured responses (Type Testing, HIL, etc)
- Models submitted to the ISO/RTO must be **project specific**
  - Developers should be working with OEMs from the beginning
- ISO-NE requires attestations to ensure that we are receiving models that **best represent** the planned equipment

ISO-NE EMT Model Attestation Forms

Appendix C-1A

Equipment Model Quality Attestation (e-MQA) Form

Respective OEM must complete the follow equipment Model Quality Attestation (e-MQA) form

Equipment Model Quality Attestation	
Interconnection Request ID	
Point of Interconnection	
Technology type (Wind, Solar, BESS, Fuel Cell etc)	
Equipment Type[15]	
Equipment OEM	
OEM Attester (Name)	
Equipment Model	
Equipment Software version	
Date of Attestation (mm/dd/yyyy)	
Attestation Revision Number	

Please provide any additional comments here including list of changes since last revision.

Attester Signature

I hereby certify that, to the best of my knowledge, the equipment-level Electromagnetic Transient (EMT) model provided in support of Interconnection Request ____________ has been parametrized to be site specific and meets the requirements listed in Appendix C.

Appendix C-1B

Plant-level Model Quality Attestation (p-MQA) Form

The Interconnection Customer (IC) must complete the following plant-level Model Quality Attestation (p-MQA) form

Plant-level Model Quality Attestation	
Interconnection Request ID	
Technology type (Wind, Solar, BESS, Fuel Cell etc)	
Point of Interconnection (POI)	
SCR at POI[16]	
IC Attester (Name)	
Date of Attestation (mm/dd/yyyy)	
Attestation Revision Number	

Equipment OEMs	Equipment Type[17]	Equipment Model	Hardware Firmware version

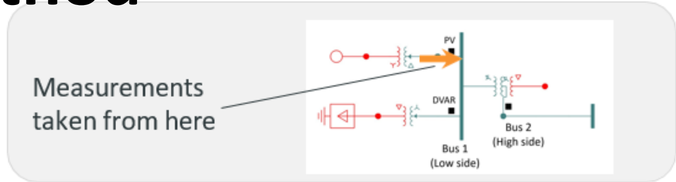
Please provide any additional comments here including list of changes since last revision.

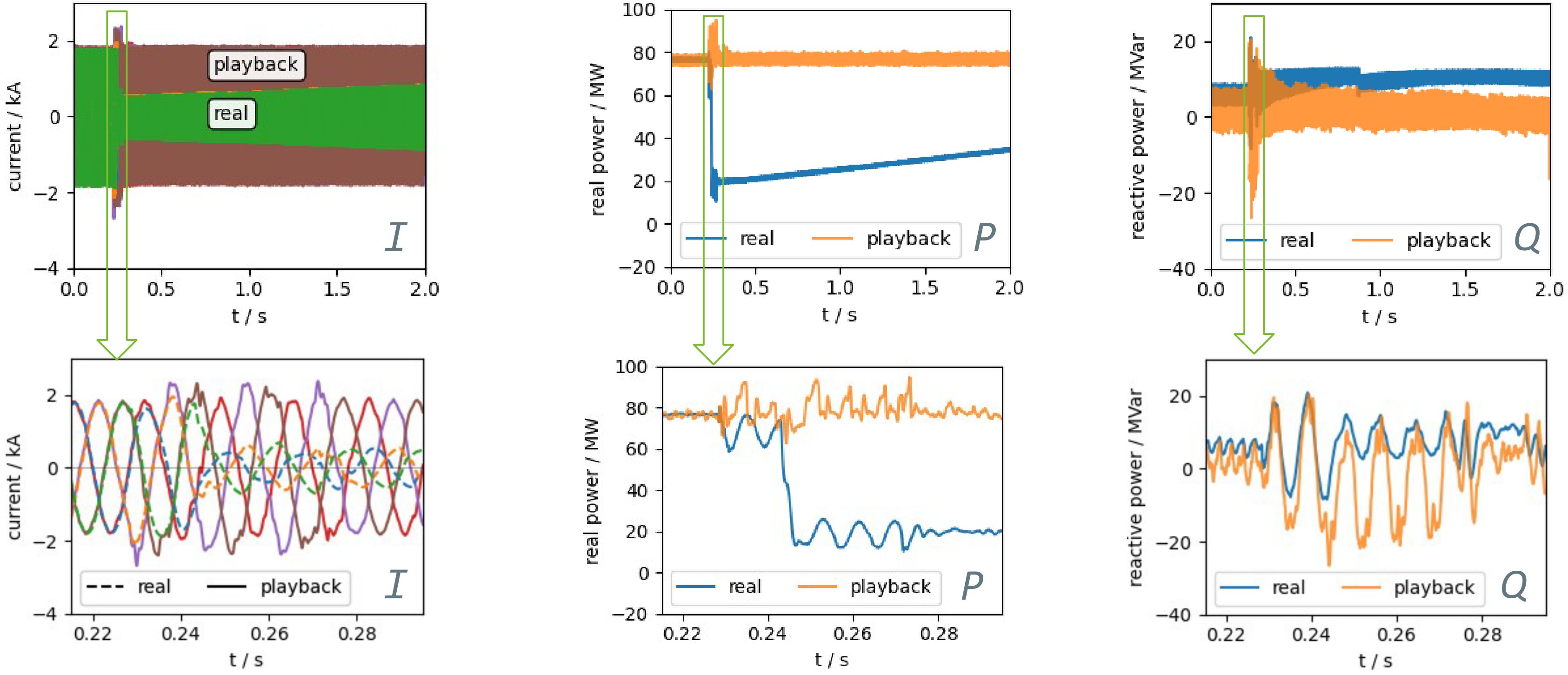
Attester Signature

I hereby certify that, to the best of my knowledge, the plant-level Electromagnetic Transient (EMT) model provided in support of Interconnection Request ____________ has been parametrized to be site specific and meets the requirements listed in Appendix C.

[*Planning Procedure 5-6 Appendix C-1*]

EMT Model Verification – Comparison of EMT model to measured DFR Data – Playback Method





ISO-NE PUBLIC

Questions

BMarszalkowski@iso-ne.com

IBR Modeling Requirements and Model Verification: Positive Sequence Model Aspect

Bo Gong, PhD

Senior Principal Engineer, SRP

NERC Industry Engagement Workshop

Phoenix, Jan 16, 2025

SRP's recent efforts on IBR modeling/ verification

- 1,300 MW IBR (8 projects) recently commissioned
  - Pre-commissioning effort includes field tests/measurements, control setting verification, PSLF/PSCAD modeling, simulation, model validation, etc.
  - Each project lasts for more than 6 months, working side by side with developers and OEMs, verifying in-depth of IBR settings, performance, and modeling accuracy
  - Typically, 5~6 iterations of setting adjustments in the pre-commissioning stage, all with impacts to the models and performance.
  - Model verification and validation shows large discrepancy between measured performance and PSLF/PSCAD models. Different operating conditions need a different set of PSLF generic model parameters.

Guidance from NERC needs further clarification…

NERC level 2 alert "Inverter-Based Resource Model Quality Deficiencies"

Recommendation 1: All models should be detailed and accurate … across all expected operational conditions	**Recommendation 3:** Equipment-specific models should be used for detailed reliability studies	**Recommendation 7:** Maintain an accurate and representative model throughout the lifecycle of the project

Then

Recommendation 2: Industry-approved standard library … models are sufficient (???) for use in Interconnection-wide (???) base-case creation(???)

Delivering water and power™

Observations 1: Positive sequence models are still needed

- NERC message creates a loophole for people to game the process
  - For example, WECC uses “approved model list” to mandate all western utilities to only provide generic models for base case creation, using this message to prohibit utilities from submitting equipment specific models. Reliability risk in the planning base cases.
- Ask TP/PC to maintaining 2 sets of positive sequence models is not practical and meant to introduce errors
  - Standard library model shouldn’t be given precedence over equipment specific models.
- A clear description of restrictions of standard library model is needed. Just saying it is ok for base case creation is not rigorous and accurate

Observation 2: Develop a uniform modeling framework is not simple, can we rely on a voluntary WECC group?

What we learn from this voluntary effort on creating generic models	• Insufficient stakeholder input, particularly from OEMs • Flaws identified in models, no responsibility • Insufficient rigor testing (i.e., silent approval)
OEM's participation is critical, can NERC help?	• More OEM engagement and transparency needed • OEMs don't typically endorse standard library models – why force it? • OEMs prefer UDMs, when allowed • IBR control structures do not match WECC models
Model benchmarking & validation is not the silver bullet to solve all modeling issues	• Benchmarking should not be a curve fitting exercise • Model structural matching across platforms is critical for reliability decisions

Questions ?

bo.gong@srpnet.com

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC Recommended Modeling Practices

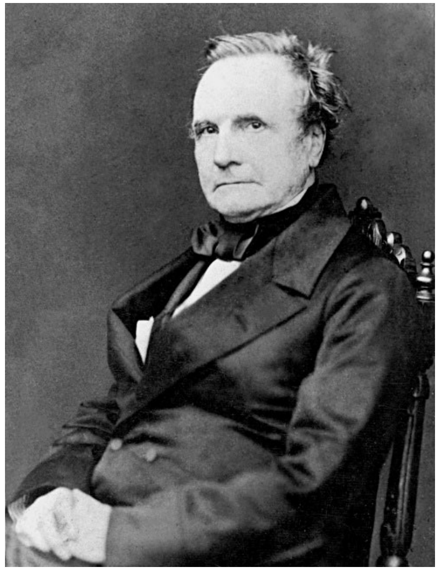
JP Skeath, Manager, Engineering
January Technical Conference
January 16, 2025

Recommended Modeling Practices – First Principles

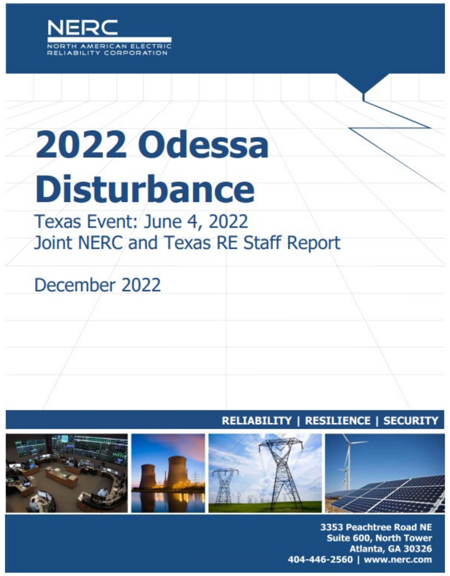
- All models should be detailed and accurate representations of expected or as-built facilities on the BPS
- All models should be accompanied by sufficient documentation to explain the parameters, states, and usability of the model
- All models for studies should be sufficient for the study purpose or objective.

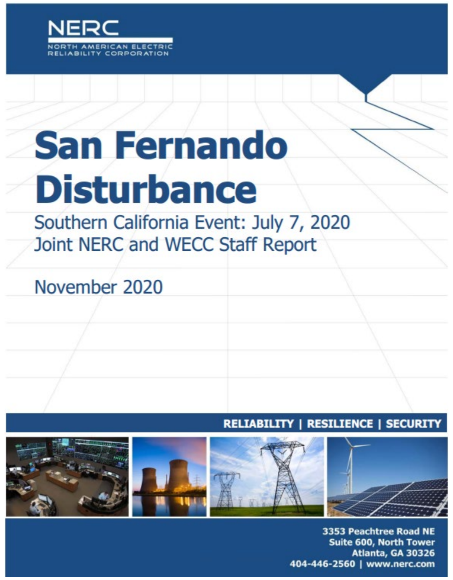
These principles hold and build the NERC recommendations to improve model practices.

The errors which arise from the absence of facts are far more numerous and more durable than those which result from unsound reasoning respecting true data.



Past NERC Observations on Model Quality





In summary, these all say very similar things. Models reviewed did not predict or represent facility behavior during Disturbance.

https://www.nerc.com/pa/RAPA/ModelAssessment/Pages/default.aspx
https://www.nerc.com/pa/rrm/ea/pages/major-event-reports.aspx

NERC Level 2 Alert - Summary

1. All models should be detailed and accurate representations of expected or as-built facilities across all expected operational conditions.
2. Industry-approved standard library positive sequence phasor domain (PSPD) models are sufficient for use in Interconnection-wide base-case creation.
3. Equipment-specific models should be used for detailed reliability studies.
8. All applicable recommendations in this alert should be implemented such that an updated set of dynamic models is available to be included in the next applicable TP and PC annual model updates.

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Industry Recommendation

Inverter-Based Resource Model Quality Deficiencies

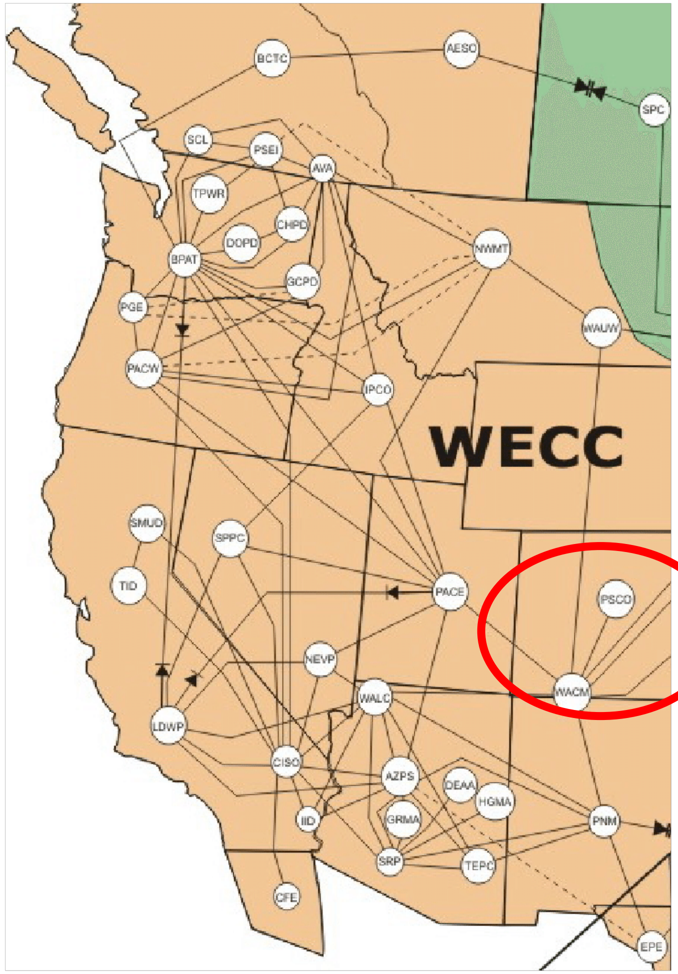
Initial Distribution: June 4, 2024

NERC has analyzed 10 large-scale disturbances on the bulk power system (BPS) that involved the widespread and unexpected reduction in output of inverter-based resources (IBR) since 2016. These 10 disturbances totaled nearly 15,000 MW of unexpected IBR output reduction with approximately 10,000 MW occurring between 2020 and 2024. The increase of IBR-related events coincides with an increase in IBR penetration across the BPS. Two contributing causes to these events are poor modeling and study practices to assess the performance of these resources.

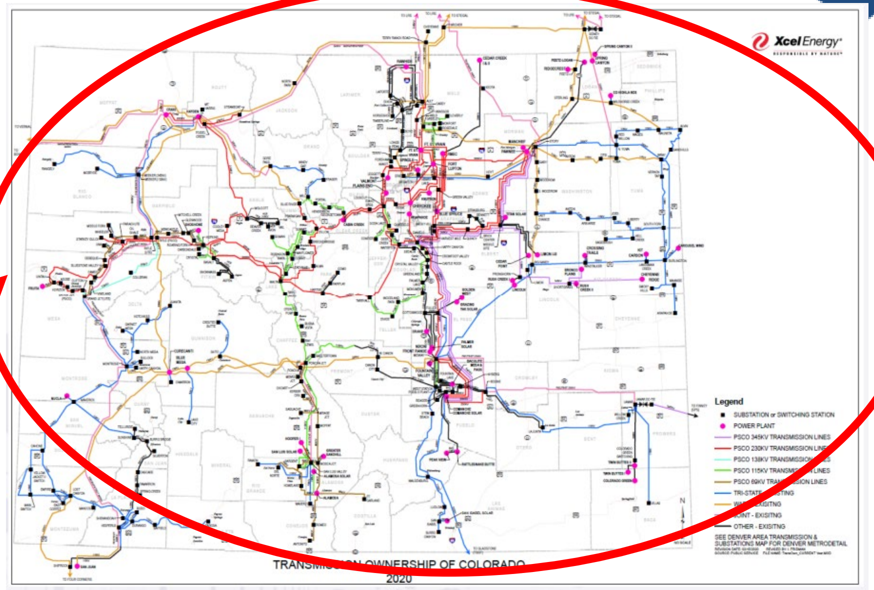
https://www.nerc.com/pa/rrm/bpsa/Alerts%20DL/NERC%20Alert%20Level%202%20-%20Inverter-Based%20Resource%20Model%20Quality%20Deficiencies.pdf

Sufficient =/= Best
Sufficient == Minimum

Example



Focus on Transfers and Flows



PC and TP cut-in for detailed results.

- Includes “distribution” lines (44.5 and 69kV)

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JANUARY 16, 2025

Overcoming the Barriers to EMT Modeling Adoption: A Case Study of the IESO

Mohamed ElNozahy, Ph.D., P.Eng., PMP, Sr.M.I.E.E.E
Engineering Manager, EMT Studies

Connecting Today. Powering Tomorrow.

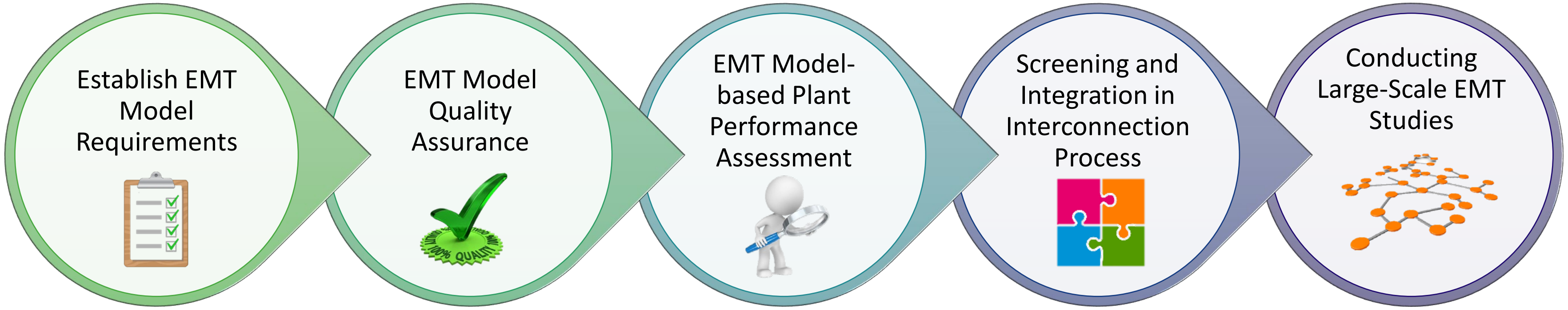
Industry Survey Results on EMT Modeling Adoption

- Low Adoption Rate:
  - Minimal use of EMT modeling in interconnection and planning studies.
  - Lack of rigorous model verification practices.
- Widespread Recognition:
  - PCs and TPs acknowledge the need for increased EMT modeling.
- Key Challenges:
  - Limited in-house expertise.
  - Over-reliance on external resources.

IESO's EMT Adoption Process - A Case Study

- Adopting NERC's Roadmap:
  - Started in January 2023 with a single FTE.
  - Adopted NERC's 5-stage EMT adoption roadmap.
- Achievements:
  - Established EMT model requirements and automated verification procedures (MQT).
  - Completed EMT model verification/performance validation for over 2 GW of IBRs.
- Current Status:
  - Dedicated EMT studies team with 4 FTEs (and growing).
  - Collaborating with MHI to develop a large-scale EMT model by Q1 2025.

Where to Start ? … IESO EMT Roadmap



- *Industry best practices*

- *2500 MW of storage projects validated*

- *Automated tool (684 Tests)*
- *IESO's MRs and P2800*
- *Highlighted several issues with facilities*

- *SSCI: AFL Tool*
- *SSR: Topology Scan*

- *Develop Large-scale EMT basecase (WIP with MHI)*
- *Conduct large-scale EMT studies*

* Adopted from the NERC EMT Modeling Adoption Roadmap

Connecting Today. Powering Tomorrow.

Key Takeaways and Recommendations: Immediate Action

- The largest challenge the industry faces is the representation of legacy equipment without EMT models
  - The more you wait, the more this problem compounds
- Begin EMT roadmap development leveraging in-house expertise, leveraging consultant's support (if needed).
  - NERC's Roadmap is practical starting point for EMT adoption.
- Adopt an agile approach. Avoid waiting for a "perfect" plan.

Key Takeaways and Recommendations: Start Simple

- Adopt or adapt NERC's EMT Model Requirements (published in 2022 Guideline)
  - Implement model verification/quality testing early to ensure accuracy.
- EMT modeling is not the same as "Large-scale EMT modeling"
  - Single-resource infinite bus (SRIB) validation is a good and inexpensive way to catch many problems
    - Protection settings failing ride-through requirements.
    - Aggressive gains causing oscillations.
    - Poor performance in weak grid conditions.

Questions ?

Mohamed.elnozahy@ieso.ca

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Lunch
11:45 – 12:45 p.m. Mountain

Panel Discussion: Interconnection-Wide Cases – Model Fidelity and Use Cases

Moderator: JP Skeath, NERC
Mark Henry – Texas RE
Enoch Davies – WECC
Shayan Rizvi – NPCC
Christian Danielson – ERCOT

TEXAS RE

NERC Industry Engagement Workshop

Mark Henry

Chief Engineer &

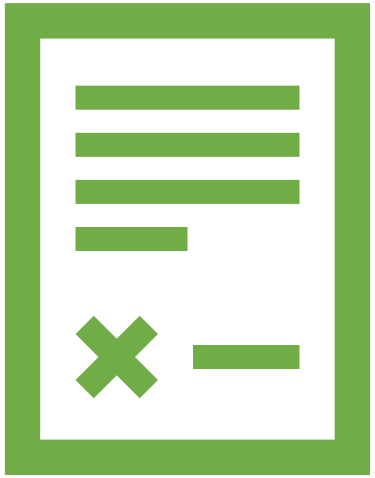
Director, Reliability Outreach

January 16, 2025

NERC MOD-032 Designee Agreement

MOD-032 Designees

- Western Interconnection – WECC
- Eastern Interconnection – MRO, NPCC, RF, and SERC
- Texas Interconnection – Texas RE
  - ERCOT is the only Planning Coordinator



Responsibilities

- Create and provide Interconnection-wide cases to NERC
- Identify and vet qualified users of the cases
- Create cases that represent system events
- Ensure that all Planning Coordinators in their Interconnection and all system elements defined in the Planning Coordinator's modeling procedures is included in the data collection process
- Develop and maintain a case creation manual for the Interconnection, including the process by which the designated cases must be assembled, tested for quality, and tested for case fidelity
- Maintain a list of acceptable dynamics models for representing equipment in the base cases
  - NERC's list of unacceptable models
- Address any case quality issues identified by NERC's annual case quality assessment
  - Shall collaborate with NERC to address

Texas RE Designee Requirements

ERCOT Protocols

- Process for identifying and vetting of qualified users of the cases

ERCOT Steady State and Dynamic Working Group (SSWG and DWG) Manuals

- Process for creating for cases that represent system events
- Common method of collecting data and model
- Process by which the designated cases must be assembled, tested for quality, and tested for case fidelity
- List of acceptable dynamics models for representing equipment in the base cases NERC's list of unacceptable models

Texas RE Extranet

- Process to provide cases to NERC upon request
- Annually for NERC assessment

Texas RE/ERCOT/DWG

- Process to address any case quality issues identified by NERC's annual case quality assessment

Questions?

ERAG Eastern Interconnection Reliability Assessment Group

...to further augment the reliability of the bulk-power system...

Interconnection-Wide Cases: Model Fidelity and Use Cases Panel

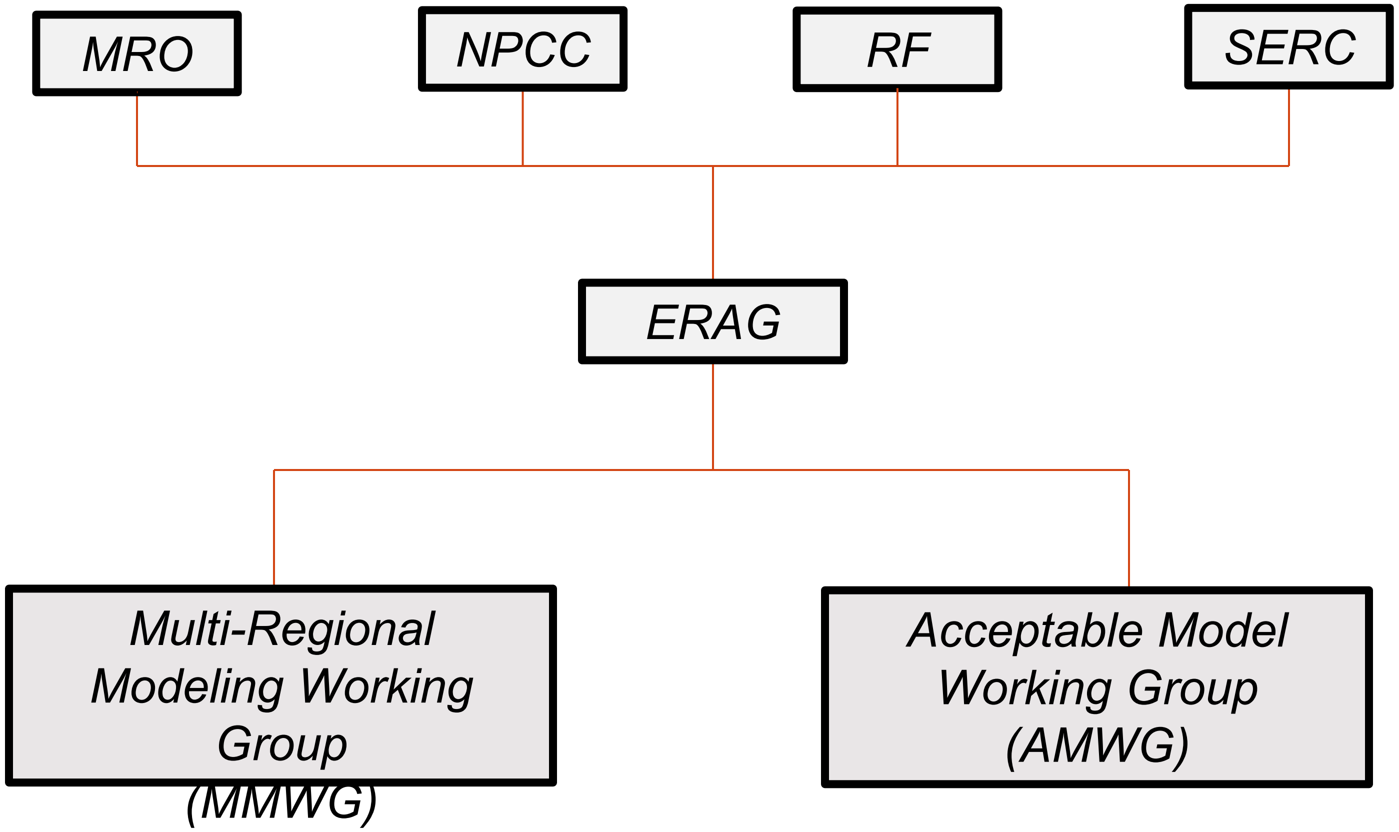
Multi-Regional Model and Acceptable Model Working Group Overviews

Shayan Rizvi, Senior RAPA Engineer, NPCC

NERC Industry Engagement Workshop: Reliable IBR Integration & FERC Order 901 Milestone 3

January 16, 2025

ERAG Reporting Structure



Multi-Regional Model Working Group (MMWG)

- *Working Group under ERAG*
- *Develops power flow and dynamics base cases for the Eastern Interconnection*
- *Functions in a coordinated fashion among regional data submitters (PC's/Group of PC's)*
- *Guided by a Procedure Manual, which outlines:*
  - *MMWG process and guidelines*
  - *Regionally specific base case information – bus numbers, area numbers, owner & zone numbers*
  - *Recommendations on building power flow and dynamics base cases along with modeling requirements*
  - *Outlines case quality checks for power flow and dynamics cases*

Acceptable Model Working Group (AMWG)

- *Working Group under ERAG*
- *Established to maintain an Eastern Interconnection acceptable model list & support maintenance of NERC dynamic modeling recommendations*
- *Membership open to EI regions, regional data submitters, software vendors, GO's, OEM's, NERC, and ERO*
- *Eastern Interconnection dynamic models are to be reviewed, developed, and validated through:*
  - *AMWG dynamic model list*
  - *Model validation testing criteria and procedure*
  - *Model usage guidance*
  - *Dynamic model tracker*

Questions/Comments

Shayan Rizvi

srizvi@npcc.org

ERAG/MMWG/AMWG Webpage

[ERAG | Eastern Interconnection | MMWG | Reliability Assessment]

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Break

2:00 – 2:10 p.m. Mountain

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Presentations : NERC Standards Drafting Teams

FERC Order No. 901 - Milestone 3 Projects

2022-02 Uniform Modeling Framework for IBR

2020-06 Verifications of Models and Data for Generators

2021-01 System Model Validation with IBRs

NERC Order No.901 Projects

FERC Order 901 Milestone 3 Projects

Project 2020-06 – Verifications of Models and Data for Generators: *Addressing the verification and validation of models for registered inverter-based resources (IBR), unregistered and aggregated IBR, and aggregated distributed energy resources.*

Additional Focus:

- Define terms, such as Model Verification and Model Validation
- Develop process for post-interconnection model validation based on performance data
- Set validation expectations using performance data

Standards Include: MOD-026, MOD-027, FAC-00

Project 2021-01 – System Model Validation with IBRs: *Addressing system-level model verification and validation against actual system operational behavior during disturbances as well as aligning steady state and dynamic representation, where appropriate.*

Additional Focus:

- Develop criteria for performing validation
- Determine minimum study conditions for conducting validation studies
- Develop process to communicate system interconnection-wide model defects to Transmission Planners and other associated entities

Standards Include: MOD-033

Project 2022-02 – Uniform Framework Model Framework for IBR: *Addressing development of a NERC-maintained library consisting of generic IBR model types.*

Additional Focus:

- Establish a uniform framework for data sharing and model development
- Ensure other standards use performance data and library using this framework

Standards Include: MOD-032, TOP-003, IRO-010

Project 2022-04 – Electromagnetic Transient (EMT) Modeling (expected to be added December 2024): *Addressing establishment of EMT studies, as appropriate, during the interconnection process.*

Additional Focus:

- Assure alignment with other modeling requirements developed by Milestone 3 project teams to ensure a streamlined model validation and data sharing process

Standards Include: MOD-032, FAC-001, FAC-002

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Project 2022-02

Uniform Modeling Framework for IBR

John Schmall (Chair), ERCOT
Jonathan Hayes (Vice Chair), SPP
Jordan Mallory (Developer), NERC

Project 2022-02
Drafting Team (DT) Members

Name	Company
John Schmall (chair)*	Electric Reliability Council of Texas, Inc.
Jonathan Hayes (vice-chair)*	Southwest Power Pool
Josie Daggett	Western Area Power Administration
Hassan Baklou	SDG&E
Zach Mansell	Tennessee Valley Authority
Qiushi (Cho) Wang	The AES Corporation
Patrick Dalton	Midcontinent Independent System Operator (MISO)
Alexander Stewart	Bonneville Power Administration
Joshua Pierce	Southern Company Services
Mohit Singh	Exelon
Andrea Pinceti	Dominion Energy
Hayden Maples	Evergy
Ejovi Ovhori	Duke Energy Carolinas
Steve Wendling	American Transmission Company, LLC

Project 2022-02 Overview

Project 2022-02 Standard Authorization Request

- SC Accepted November 13, 2024

Uniform Modeling Framework for IBR

- **Phase One (November 4, 2025, Regulatory Deadline)**
  - Provide industry with a uniform framework for each Interconnection that includes a minimum modeling criteria consistent with NERC's Dynamic Modeling Recommendations, a registered modeling designee, and necessary data exchange requirements.
- **Phase Two (Medium or low priority)**
  - Provide clarity, or in some cases, expand the scope of requirements when considering the performance of DERs to ensure the accuracy of Transmission System Planning Assessments.

FERC Order 901

- 24 Regulatory Directives

Standards Impacted – Phase One

- MOD-032
- TOP-003
- IRO-010

FERC Directives Overview

Uniform framework for each interconnection

↓

NERC Approved Model Library

↓

Data specification and coordination

↓

Implementation Plan Alignment

Next Steps

Goal Date (2025)	Latest Dates Possible (2025)	Action
January 15 – 16		Industry Engagement Workshop
March 1	April 1	Initial Draft Standards Completed
April – May	June 14 – July 14	Initial Ballot and Comment Period
May 29 – June 18	July 30 – August 18	Additional Comment and Ballot Period
June 10 – June 19	September 9 - September 20	Final Ballot
August 1	October 1	Submit to NERC Board for Adoption
November 4	November 4	File with FERC

Resources

- Project 2022-02 Standard Authorization Request (link)
- Dynamic Modeling Recommendations (link)
- 2022-02 Uniform Framework NERC Project Page (link)
- FERC Order 901 (link)

Questions and Answers

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Project 2020-06

Verifications of Models and Data for Generators

Brad Marszalkowski (Chair), ISO- NE
Katie Iversen (Vice- Chair), S-Power
Josh Blume (NERC Standards Developer)

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Project 2020-06 Drafting Team (DT) Members

Name	Company
Brad Marszalkowski (chair)*	ISO-New England
Katie Iversen (vice-chair)*	S Power
Andrew Arana	Florida Power & Light
Jonathan Rose	ERCOT
Biju Gopi	California ISO
Jason MacDowell*	GE Energy Consulting
Sam Li	BC Hydro
Michael (Bing) Xia	Powertech Labs
Robert J. O’Keefe*	American Electric Power
David Marshal	Southern Company
Emily Greene	AES
Husam Al Haddadi	Manitoba Hydro
Mohamed ElNozahy	IESO
Mohamed El Khatib	Invenergy

History of 2020-06

- Previous Efforts:
  - Main purpose of the original SAR was adding IBRs into Reliability Standard MOD-026 for validation of IBRs.
    - Consideration of frequency responsiveness of reactive power responsiveness.
    - Introduce EMT model validation in MOD-026 as a means of validating positive sequence modeling.
  - Three drafts of MOD-026-2 were posted for comment and ballot (5/20/22 – 7/21/23)
  - Created the Inverter-Based Resource (IBR) Definition (9/18/23 – 9/12/24)

Project 2020-06 Overview

Project 2020-06 Standard Authorization Request

- SC Accepted November 13, 2024

Verifications of Models and Data for Generators

- **SAR Objectives (November 4, 2025, Regulatory Deadline)**
  - **Defining the terms in the NERC Glossary “Model Validation” and “Model Verification”**
  - **Provide industry with a complete process for validation and verification**
  - **A complete set of validation expectations from performance data**
  - Dynamic Behaviors to a defined level of fidelity for planning and operational studies
  - Post interconnection validation not solely based on stage testing
  - A set of duties, roles, and responsibilities for registered entities for registered IBR, unregistered IBR, and DERs in the aggregate to coordinate (with TO and DP respectively), verify, and keep up to date models of such resources.

FERC Order 901

- 11 Regulatory Directives

Standards Impacted

- MOD-026
- MOD-027
- FAC-002

Milestone 3 Directives

1. **Require** Bulk Power System (BPS) planners and operators to validate IBR models using disturbance monitoring data installed by registered Generator Owners (GO) and their disturbance monitoring equipment.
3. Require GO of registered IBRs, Transmission Owners (TO) that have unregistered IBRs, and Distribution Providers (DP)s that have IBR-DER on their system to provide valid models that represent dynamic behavior to validate interconnection wide planning and operators comparable to synchronous resources.
5. To have a uniform model verification process that ensures all entities use the same set of minimum requirements to verify **all generation resource (Synchronous or Inverter Based generation) models** are complete.
7. To ensure reliability standards are consistent with Order 2023, making sure that similar model verification process timelines and modeling deadlines are consistent between to the two FERC Orders (2023 and 901).

Questions

- Questions:
  - How should legacy IBRs be handled in terms of model requirements, validation, and verification?
  - Should all models be verified by the OEM to ensure they are accurately parameterized to represent site-specific controls, settings, and protections, with supporting documentation?
  - Is an attestation on the equipment level possible, and can an OEM provide this?
  - How should performance data be used in comparison to staged testing for synchronous machines versus IBRs?
    - Is the focus on playback data or a specific playback method that entities would prefer to use?
  - What are the current OEM practices for model validation, and do they include any tolerance criteria?

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Resources

- Project 2020-06 Standard Authorization Request (link)
- Dynamic Modeling Recommendations (link)
- 2020-06 Verification of Models and Data for Generators NERC Project Page (link)
- FERC Order 901 (link)

Questions and Answers

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Project 2021-01

System Model Validation with IBRs

Hari Singh (Chair), Core Electric Cooperative
Trevor Schultz (Vice Chair), Idaho Power Company
Al McMeekin (Developer), NERC

Project 2021-01 Drafting Team

Name	Organization/ Company
Hari Singh (Chair)	CORE Electric Cooperative
Trevor Schultz (Vice Chair)	Idaho Power Company
Ruth Kloecker	ITC Holdings
David Schooley	Exelon (ComEd)
Nazila Rajaei	EPRI
Shounak Abhyankar	ISO New England
To Be Determined	

Project 2021-01 Relevant Directives

- FERC Order 901 Directives Assigned to this SAR:
  - Pursuant to section 215(d)(5) of the FPA, we adopt the NOPR proposal and **direct NERC to submit new or modified Reliability Standards that require Bulk-Power System planners and operators to validate, coordinate, and update in a timely manner the system models by comparing all generator owner, transmission owner, and distribution provider verified IBR models** (i.e., models of registered IBRs, unregistered IBRs, and IBR-DERs that in the aggregate have a material impact on the Bulk-Power System) **and resulting system models against actual system operational behavior**." (P 156)
  - **Specifically, we direct NERC to develop new or modified Reliability Standards that require** planning coordinators, transmission planners, reliability coordinators, transmission operators, and balancing authorities to establish for each interconnection a uniform framework with modeling criteria, a registered modeling designee, and necessary data exchange requirements both between themselves and with the generator owners, transmission owners, and distribution providers to coordinate the creation of transmission planning, operations, and interconnection-wide models (i.e., system models) and **the validation of each respective system model**. (P161)
  - **NERC may implement this directive by modifying Reliability Standard**s MOD-032-1 and **MOD-033-2 or by developing new Reliability Standards to** establish requirements mandating an annual process to **coordinate, validate, and keep up-to-date the transmission planning, operations, and interconnection-wide models.** (P161)

MOD-033-2, Requirement R1

R1. Each Planning Coordinator shall implement a documented data validation process that includes the following attributes:

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

1.2. Comparison of the performance of the Planning Coordinator’s portion of the existing system in a planning dynamic model to actual system response, through simulation of a dynamic local event, at least once every 24 calendar months (use a dynamic local event that occurs within 24 calendar months of the last dynamic local event used in comparison, and complete 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 Part 1.1 or 1.2; and

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

Is existing MOD-033 Adequate for System Model Validation with IBRs?

DT's Tentative Findings for Requirement R1

- Part 1.1 for steady-state (power flow) system model validation – *does not* need any substantive change to account for IBRs and/or aggregated IBR-DERs
- Part 1.2 for dynamic system model validation *may* need to be enhanced – likely with more detailed technical guidance for "dynamic local event" selection – to account for IBRs and/or aggregated IBR-DERs
- Part 1.3 for system model validation acceptance criteria/metrics *may* need to be enhanced – likely with more detailed technical guidance
- Part 1.4 for implementing corrections/updates to the component dynamic models *may* need to be enhanced – likely with more detailed technical guidance

MOD-033-2, Requirement R2

R2. Each Reliability Coordinator and Transmission Operator shall provide actual 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.

Is existing MOD-033 Adequate for System Model Validation with IBRs?

DT's Tentative Findings for Requirement R2

- Availability of real-time data for steady-state and dynamic system model validation <u>seems</u> to be adequately ensured – no significant inadequacy identified

DT's Preliminary Thoughts on Need to Develop New Requirement/Standard

- <u>Not Needed</u> – since implementing the MOD-033 enhancements would fully address the SAR objectives
  - Majority of SAR objectives pertain to judicious selection of "dynamic local event" suitable for validation of system models with high IBR penetration

Project 2021-01 SAR Objectives and Considerations for Industry Input

The Drafting Team shall address the following project objectives:

1. Either revise MOD-033 or create a new Reliability Standard to require system model validation against actual system operational behavior during Disturbances. As transient dynamics require an initial condition, these revisions should consider modification of steady-state procedure to align dynamic and steady-state representations where appropriate.
   This system model validation should consider:
   a. A complete set of validation expectations using system operational data. These expectations should be in concert with and not duplicative of IBR plant verification and validation procedures covered in Milestone 3, Part 2.
   b. A set of minimum criteria for performing validation (e.g., time, tolerance, impact). This set of criteria should allow for some entity flexibility to initiate system model validation.
      i. The SDT should consider region specific criteria to verify the expected transient dynamic behavior for IBRs.

{R1, part 1.2 enhancement?}

Project 2021-01 SAR Objectives and Considerations for Industry Input

The Drafting Team shall address the following project objectives:

1. … … … … This system model validation should consider:
   c. A set of minimum system conditions to study. For example, the SDT should consider requirements for system model validation under low or high IBR conditions as well as varying load levels and system conditions.

      {R1, part 1.2 enhancement?}

   d. A set of minimum disturbance types and data for those disturbances. For example, the SDT should consider requiring system model validation for balanced and unbalanced faults, generation loss, and disturbance report events as a starting point.

      {R1, part 1.2 enhancement?}

   e. A process to communicate system model deficiencies and incorporate associated updates into transmission planning, operations, and Interconnection-wide models (i.e., system models).

      {R1, part 1.4 enhancement?}

Order 901, P43 - Footnote 92

This final rule uses the term “system models” to refer collectively to planning and operations transmission area models and interconnection-wide models.

Is below a reasonable interpretation of the footnote’s intent/scope?

1. Since MOD-032, MOD-026/-027 and MOD-033 collectively pertain to assembly, verification and validation of *off-line system models* (aka planning models), the operations models noted in footnote 92 are intended to mean off-line system models used in operations horizon studies, not the EMS model used in real-time operations.
2. MOD-033 scope correctly excludes the validation of interconnection-wide models since their custodian is the ERO or its RE delegate, neither of which can be the applicable entity in a Reliability Standard.

Therefore, keeping the MOD-033 scope limited to the validation of off-line system model for each of the planning areas comprising an interconnection is aligned with the footnote’s intent/scope.

Order 901, P161

NERC may implement this directive by modifying Reliability Standards MOD-032-1 and MOD-033-2 or by developing new Reliability Standards to establish requirements mandating an annual[298] process to coordinate, validate, and keep up-to-date the transmission planning, operations, and interconnection-wide models.

298 *See* Reliability Standard MOD-032-1 at 15 (explaining that "presently, the Eastern/Quebec and Texas Interconnections build seasonal cases on an annual basis, while the Western Interconnection builds cases on a continuous basis throughout the year").

Is it reasonable to interpret that the "annual" periodicity specified in this directive is intended for the "coordinate" and "keep up-to-date" activities associated with the MOD-032 model building process, and not to the system model validation process in MOD-033?

Rationale: Footnote 298 appears to refer to the lack of a common "annual" cadence for the MOD-032 model building process across all Interconnections, which does not include system model validation.

Resources

- Project 2022-02 Standard Authorization Request (link)
- 2021-01 System Model Validation with IBRs Project Page (link)
- FERC Order 901 (link)

Questions

- Questions:
  - How should legacy IBRs be handled in terms of model requirements, validation, and verification?
  - All models should be verified by the OEM to ensure they are accurately parameterized to represent site-specific controls, settings, and protections, with supporting documentation.
  - Is an attestation on the equipment level possible, and can an OEM provide this?
  - How should performance data be used in comparison to staged testing for synchronous machines versus IBRs?
    - Is the focus on playback data or a specific playback method that entities would prefer to use?
  - What are the current OEM practices for model validation, and do they include any tolerance criteria?

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Closing Remarks

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