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IBR Modeling Through the Lifecycle of a Project

Reliability Perspectives

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ESIG Webinar – December 2023

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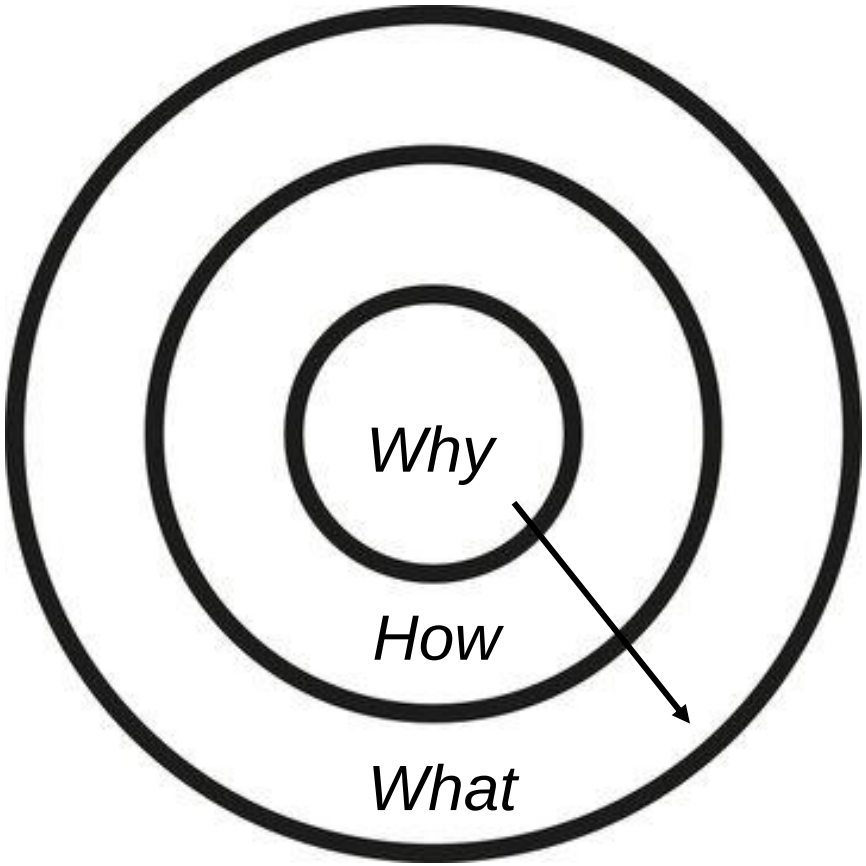
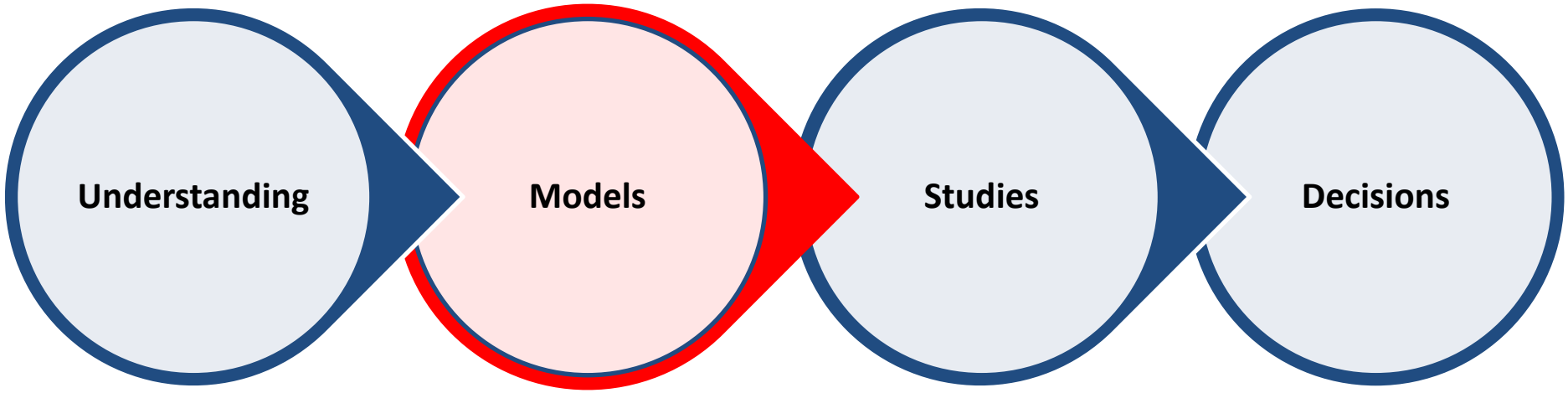
"Start with Why" – Simon Sinek



"People don't buy what you do, they buy why you do it." – Simon Sinek

https://www.youtube.com/watch?v=2Ss78LfY3nE

Why Modeling Is So Critical

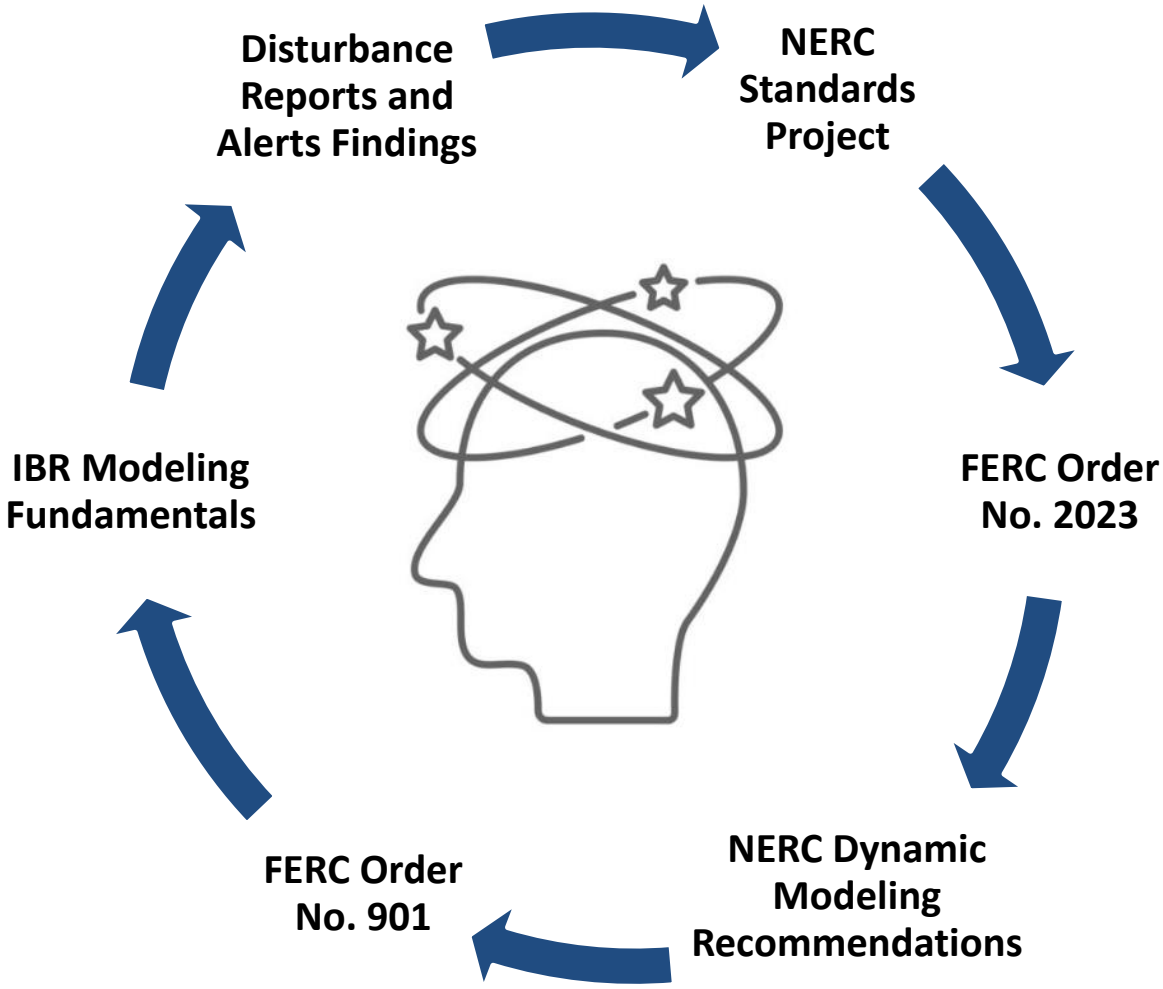


The Modeling Problem, Simplified

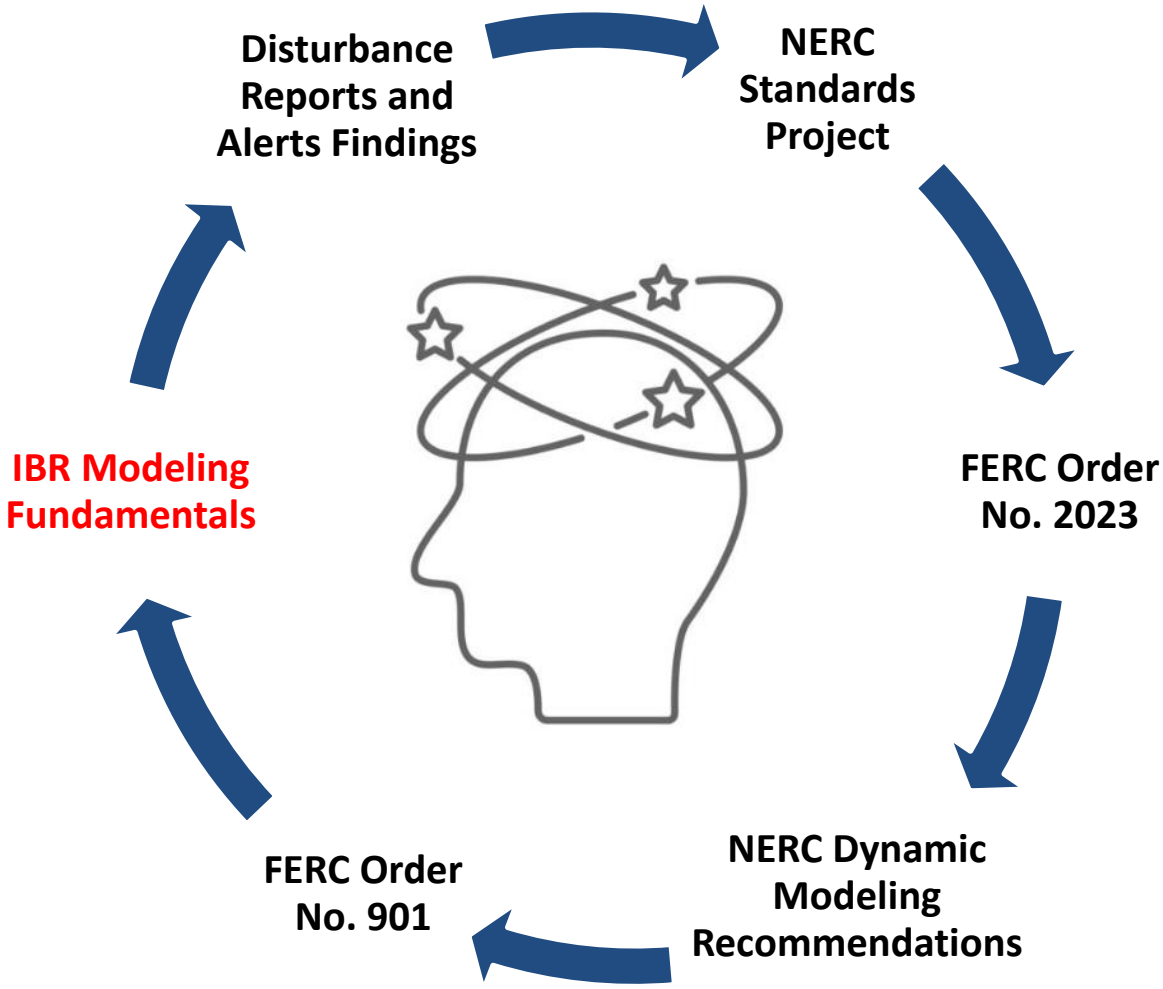
What was studied

What was installed

The Modeling Conundrum



The Modeling Conundrum



Types of Models

Standard Library Model

- Simplified representation of control modes
- Fully transparent model given simplicity
- Often inability to represent actual OEM control strategies
- No or very limited ability to represent protection

User-Defined Model

- More detailed representation of OEM control strategies
- “Black box” model given detailed controls
- Can represent some or most of the OEM controls
- May represent some protections
- Still limited by software platform

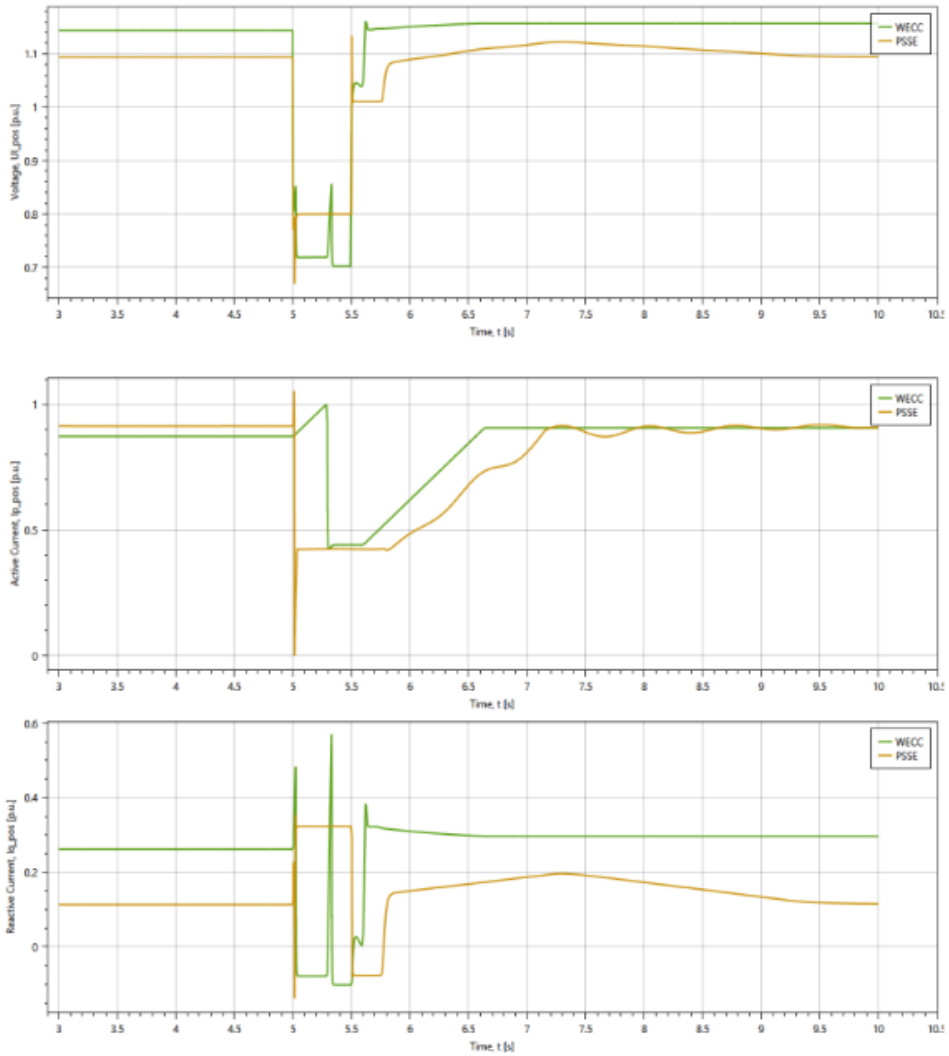
EMT Model

- Most detailed representation of IBR
- Still generally an aggregated plant representation
- Includes inner control loops (very fast time step)
- Phase-based (not positive sequence)
- Can identify ride-through issues and interactions
- Minimal software limitations
- Data confidentiality issues

Model Accuracy

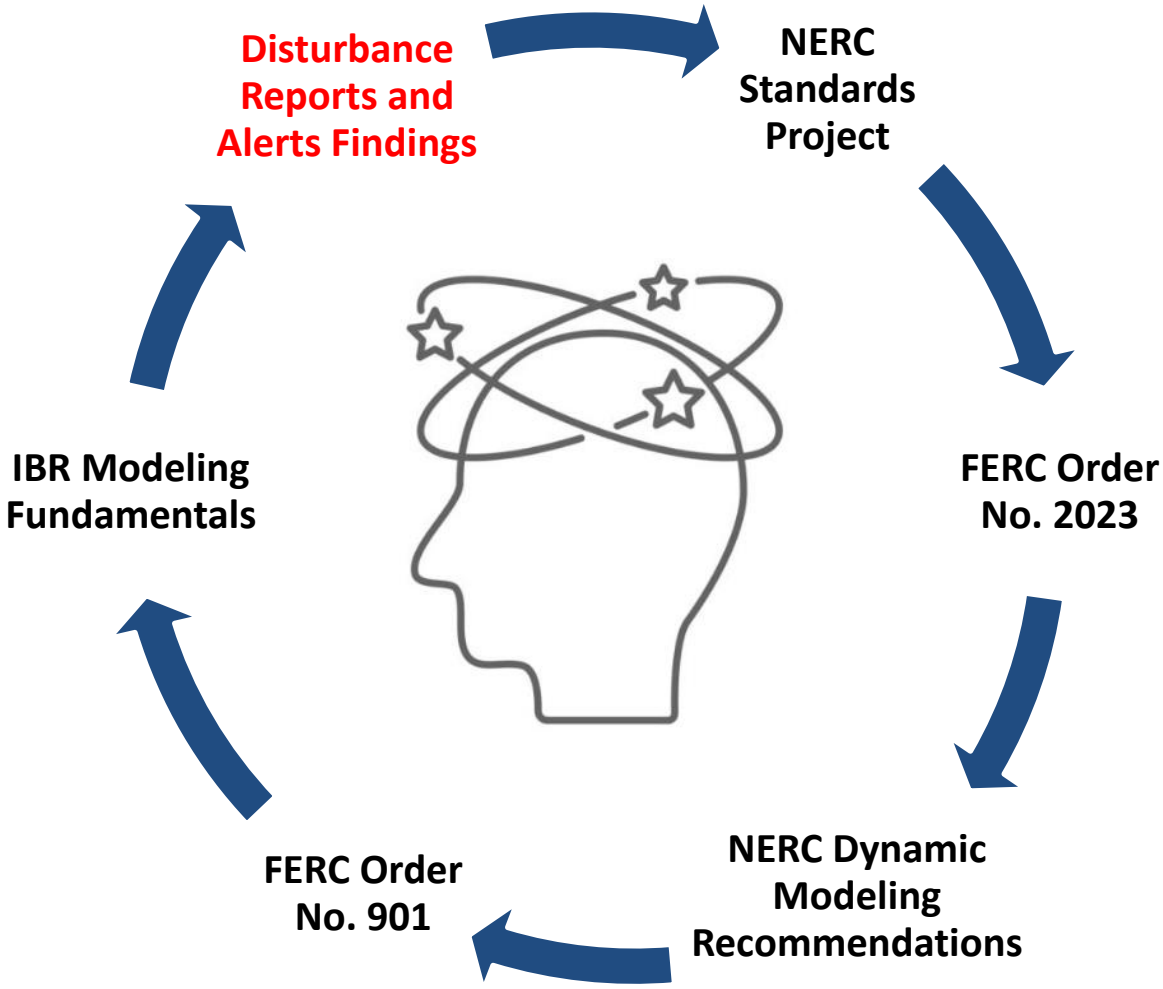
- Accurate models are *absolutely* ***critical*** for reliable operation of the bulk power system
  - Used in long-term planning, operations planning, and real-time operations
- Model inaccuracy leads to reliability issues ***AND*** possibly to delays in the interconnection process
- Process improvements around modeling and study challenges can bring clarity to both transmission and generation sides
- Model accuracy is not just usability (definition of the past)
- Model accuracy refers to matching the as-built facility, models with sufficient fidelity (ability to represent controls/protections), usability, etc.

The (Very Significant) Challenge Illustrated…

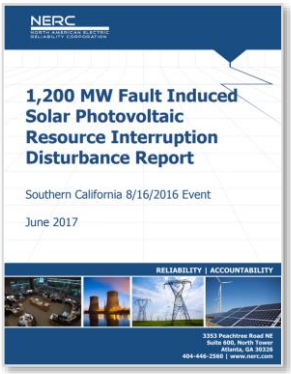


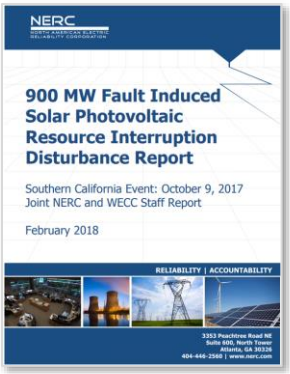
- OEM-supplied info = proof
- Standard library model is a BAD match to actual product
  - Steady-state differences
  - Dynamic response differences
  - Higher fidelity in UDM
  - More stability-related dynamics present in UDM

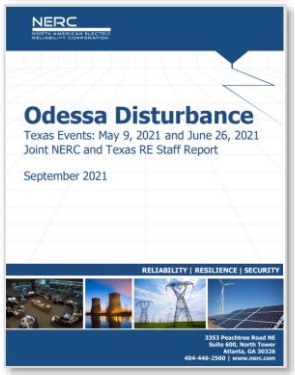
The Modeling Conundrum

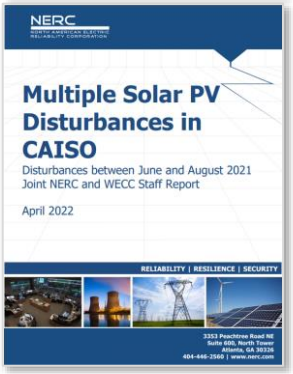


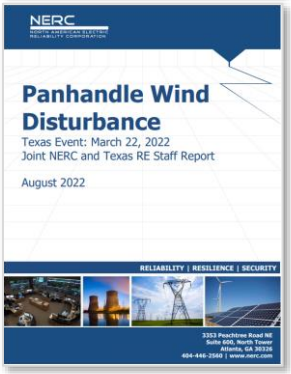
NERC Disturbance Reports and Alerts

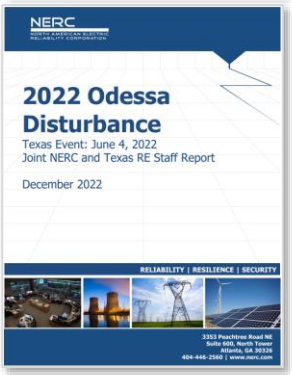


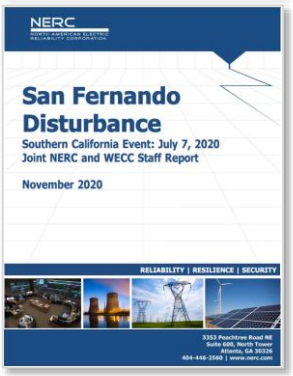


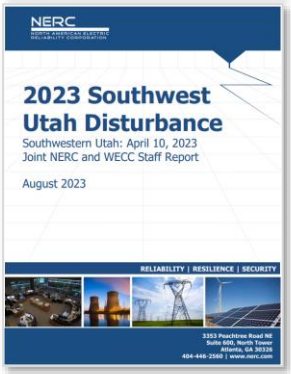


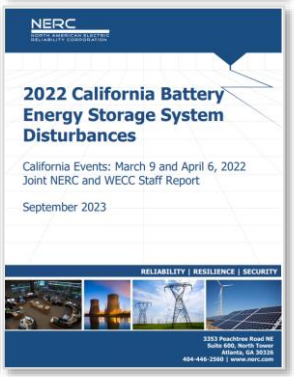












https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx

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Odessa Report Finding: Positive Sequence vs. EMT

Table 3.1: Solar PV Tripping and Modeling Capabilities and Practices		
Cause of Reduction	**Can Be Accurately Modeled in Positive Sequence Simulations?**	**Can Be Accurately Modeled in EMT Simulations?**
Inverter Instantaneous AC Overcurrent	No	Yes
Passive Anti-Islanding (Phase Jump)	Yes[a]	Yes
Inverter Instantaneous AC Overvoltage	No	Yes
Inverter DC Bus Voltage Unbalance	No	Yes
Feeder Underfrequency	No[b]	No[c]
Incorrect Ride-Through Configuration	Yes	Yes
Plant Controller Interactions	Yes[d]	Yes[e]
Momentary Cessation	Yes	Yes
Inverter Overfrequency	No[b]	Yes
PLL Loss of Synchronism	No	Yes
Feeder AC Overvoltage	Yes[f]	Yes
Inverter Underfrequency	No[b]	Yes

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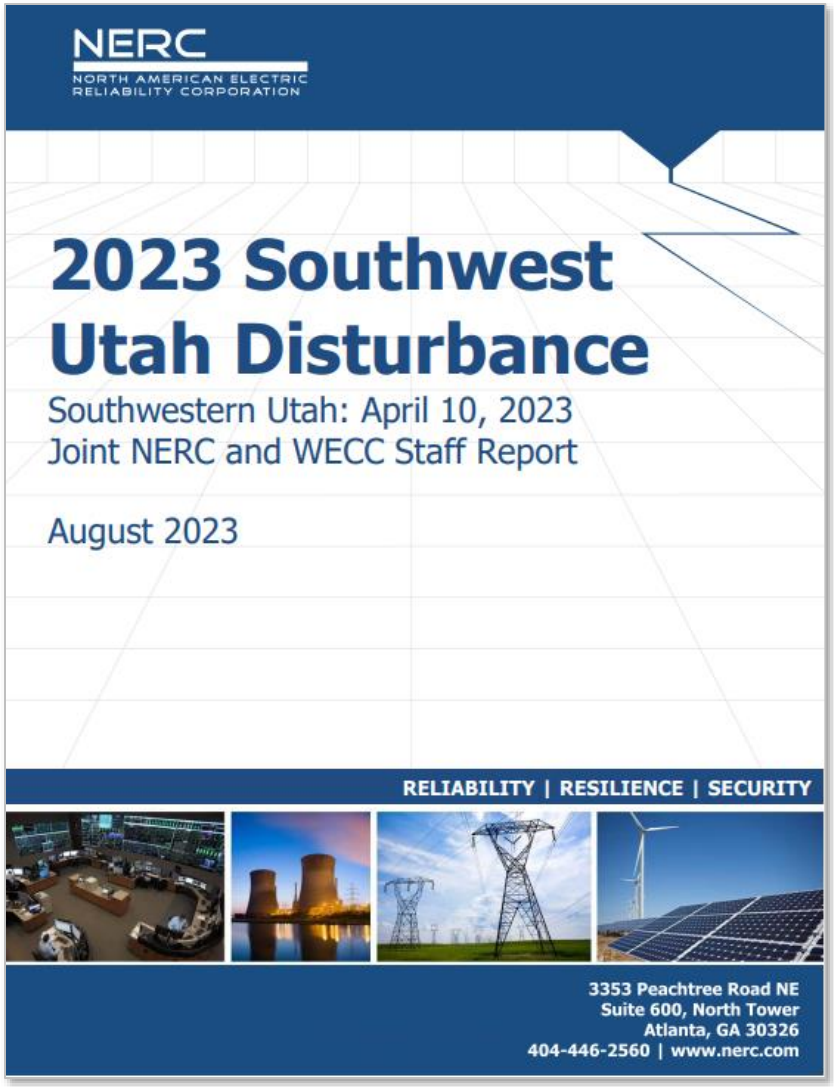
Odessa Report Finding: Do the Models Recreate the Cause?

Table 3.4: Review of Solar PV Facilities				
Facility ID	Reduction [MW]	Cause of Reduction	Positive Sequence Model Capable?	EMT Model Capable?
Plant B	133	Inverter phase jump (passive anti-islanding) tripping.	Unknown*	Unknown
Plant C	56	Inverter phase jump (passive anti-islanding) tripping.	Unknown	Unknown
Plant E	159	Inverter ac overvoltage tripping.	Unknown*	Unknown
Plant U	136	Inverter ac overvoltage tripping; feeder underfrequency tripping.	Unknown	Unknown
Plant F	46	Unknown.	Unknown	Unknown
Plant I	196	Inverter phase jump (passive anti-islanding) tripping.	Unknown	Unknown
Plant J	106	Inverter dc voltage imbalance tripping.	Unknown	Unknown
Plants K + L	130	Momentary cessation/inverter power supply failure.	Unknown	Unknown
Plant M	146	Inverter dc voltage imbalance tripping; incorrect inverter ride through configuration.	Unknown	Unknown
Plant N	35	Unknown.	Unknown	Unknown
Plant O	15	Unknown.	Unknown	Unknown
Plant P	10	Inverter ac overcurrent tripping.	Unknown*	Unknown
Plant Q	12	Inverter ac overcurrent tripping.	Unknown	Unknown
Plant R	261	Inverter ac overcurrent tripping.	Unknown*	Unknown
Plant S	94	Inverter dc voltage imbalance tripping.	Unknown*	Unknown
Plant T	176	Inverter ac overcurrent tripping; feeder underfrequency tripping.	Unknown*	Unknown

ERCOT's answer…

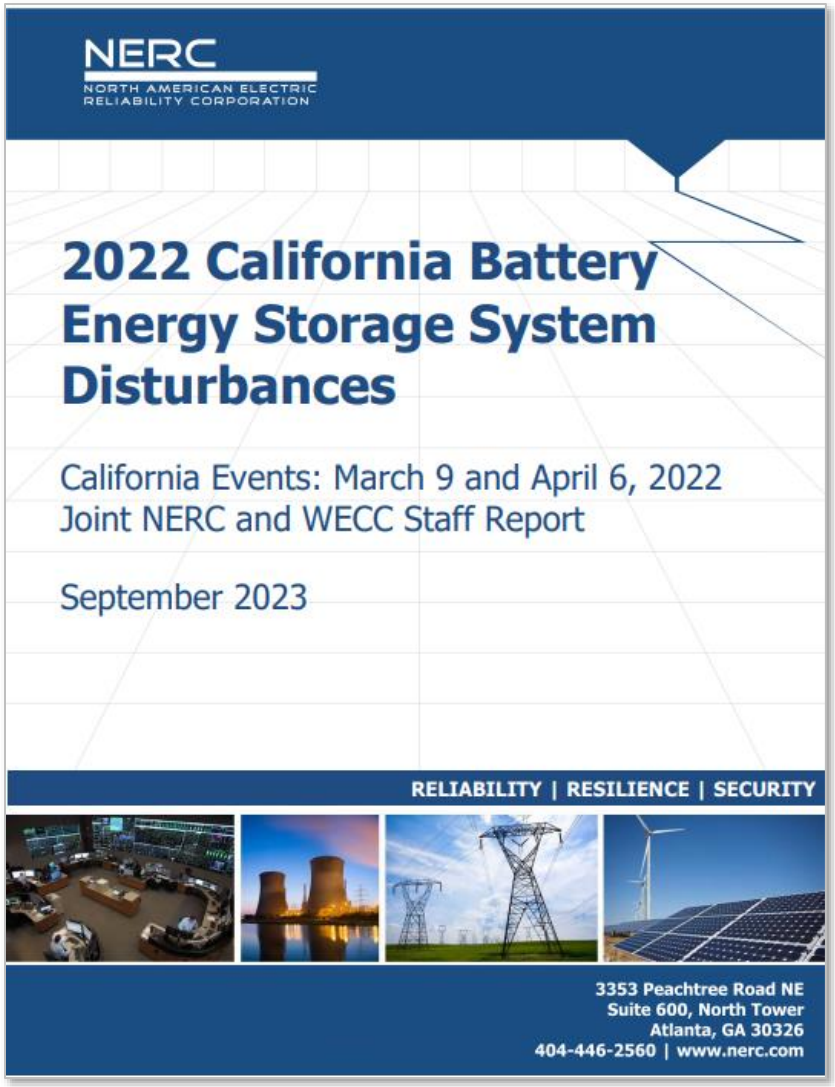
(Circa 2022)

Key Modeling Messages



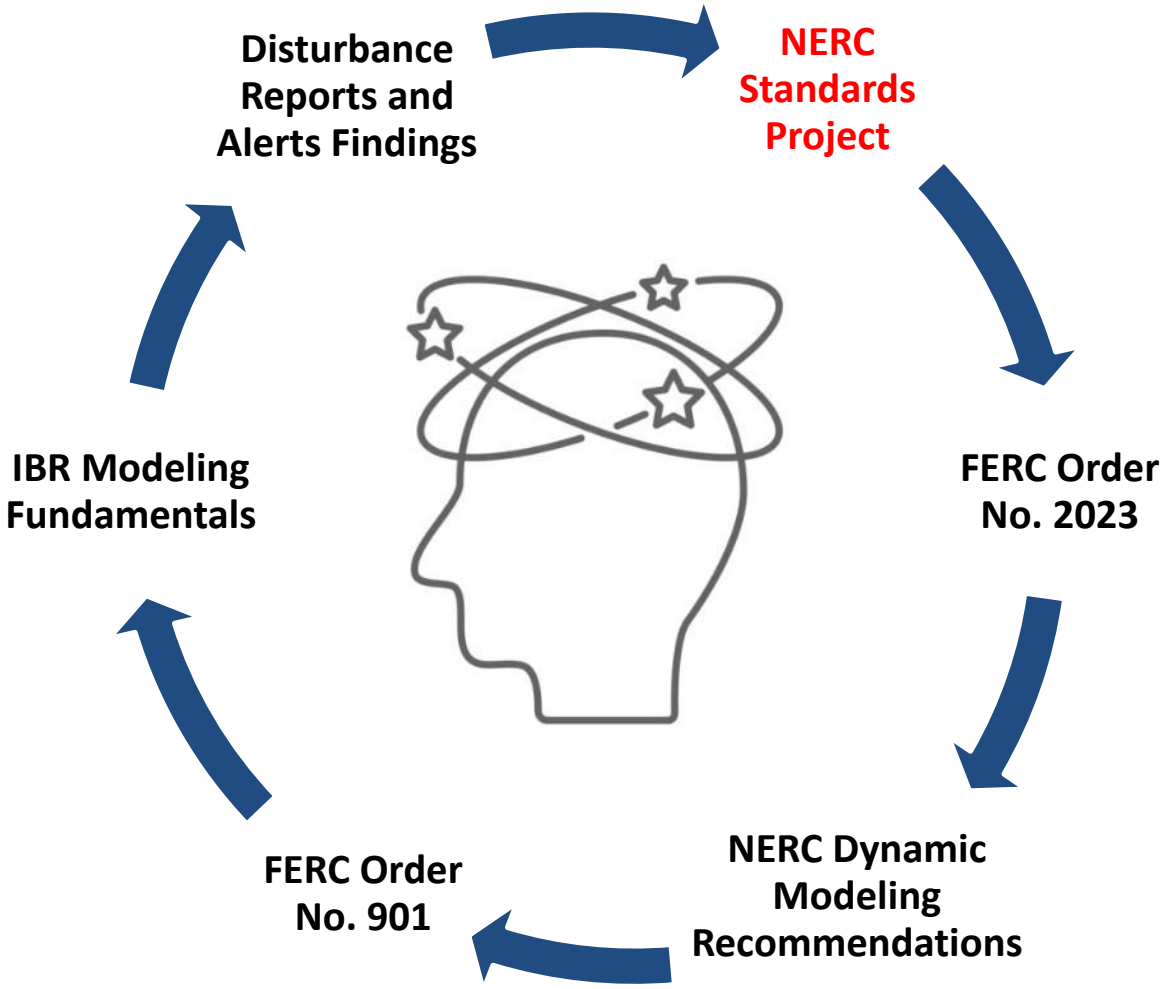
- Older “legacy” resources
- 920 MW loss across 9 facilities
- Systemic inverter tripping issues
- No action taken by industry based on guidelines and reports published by NERC
- Latent BPS risks that threaten BPS reliability
- Inadequate modeling and studies (older plants)

Recent Disturbance Reports: California BESS



- Same story, different resource type
- Systemic inverter tripping issues
- Inadequate ride-through assessments conducted
- Poor commissioning practices
- Bad data, lost data, etc.
- Questionable modeling practices
- Relatively new facilities

The Modeling Conundrum



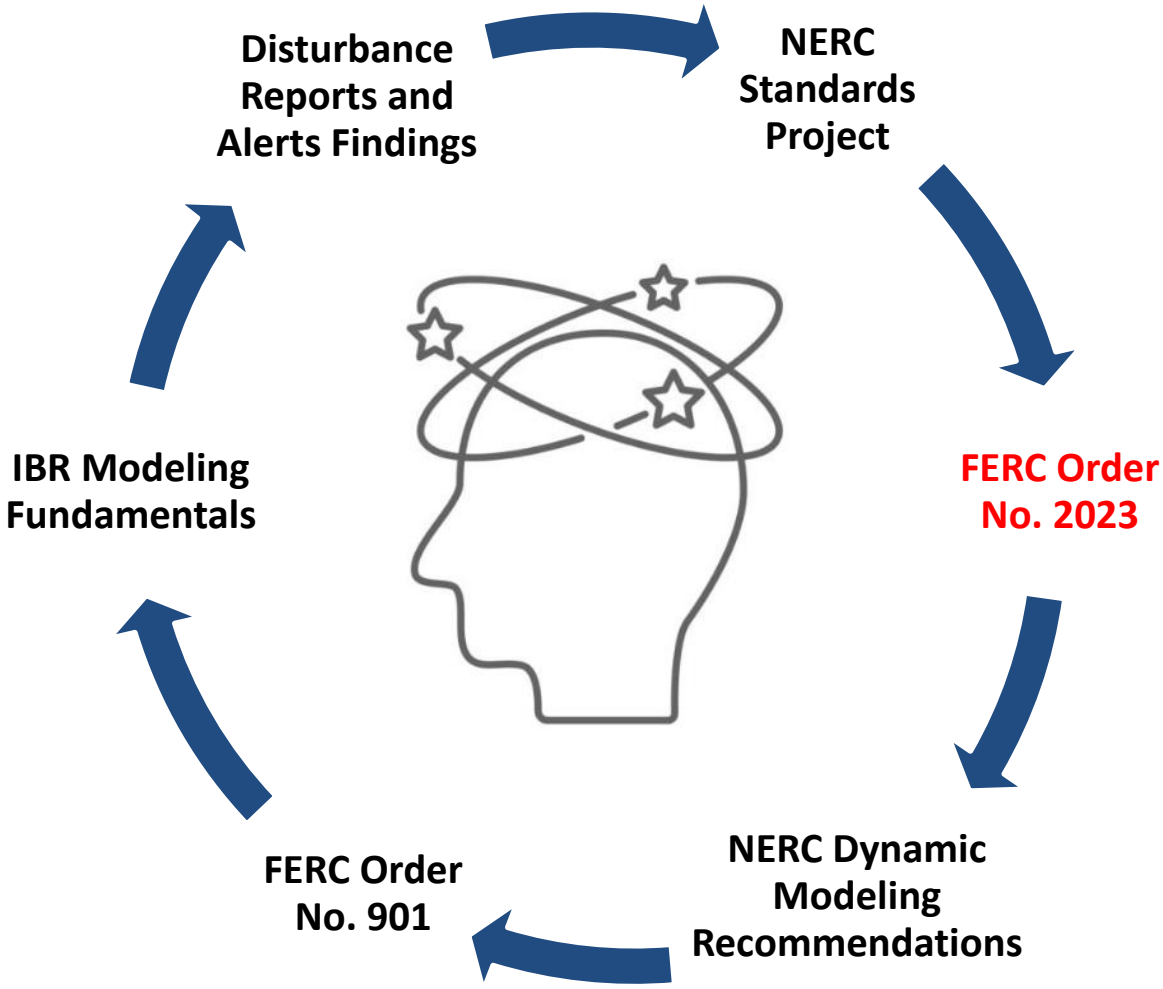
NERC IBR Registration Activities

- FERC IBR Registration Order in November 2022 (Docket No. RD22-4)
  - FERC approved NERC's Work Plan in May 2023
- ERO Enterprise coordinating with stakeholders on draft Rules of Procedure changes in June – August 2023
- ROP Revisions posted in September – October
  - Revisions to ROP Appendix 2, 5A, and 5B
- Proposes new "GO-IBR" and "GOP-IBR" functions
  - "…if the entity owns, maintains, or operates non-BES inverter-based generating resources that have an aggregate nameplate capacity of greater than or equal to 20 MVA, delivering such capacity to a common point of connection at a voltage greater than or equal to 60 kV."[9]

Modeling-Related IBR NERC Standards Projects Underway

- Project 2020-02: PRC-024 Generator Ride-Through
- Project 2020-06: Verifications of Models and Data for Generators
- Project 2021-01: Modifications to MOD-025 and PRC-019
- Project 2021-04: Modifications to PRC-002-2
- Project 2022-02: Modifications to TPL-001-5.1 and MOD-032-1
- Project 2022-04: EMT Modeling
- Likely more on the horizon… (FERC Order No. 901)

The Modeling Conundrum



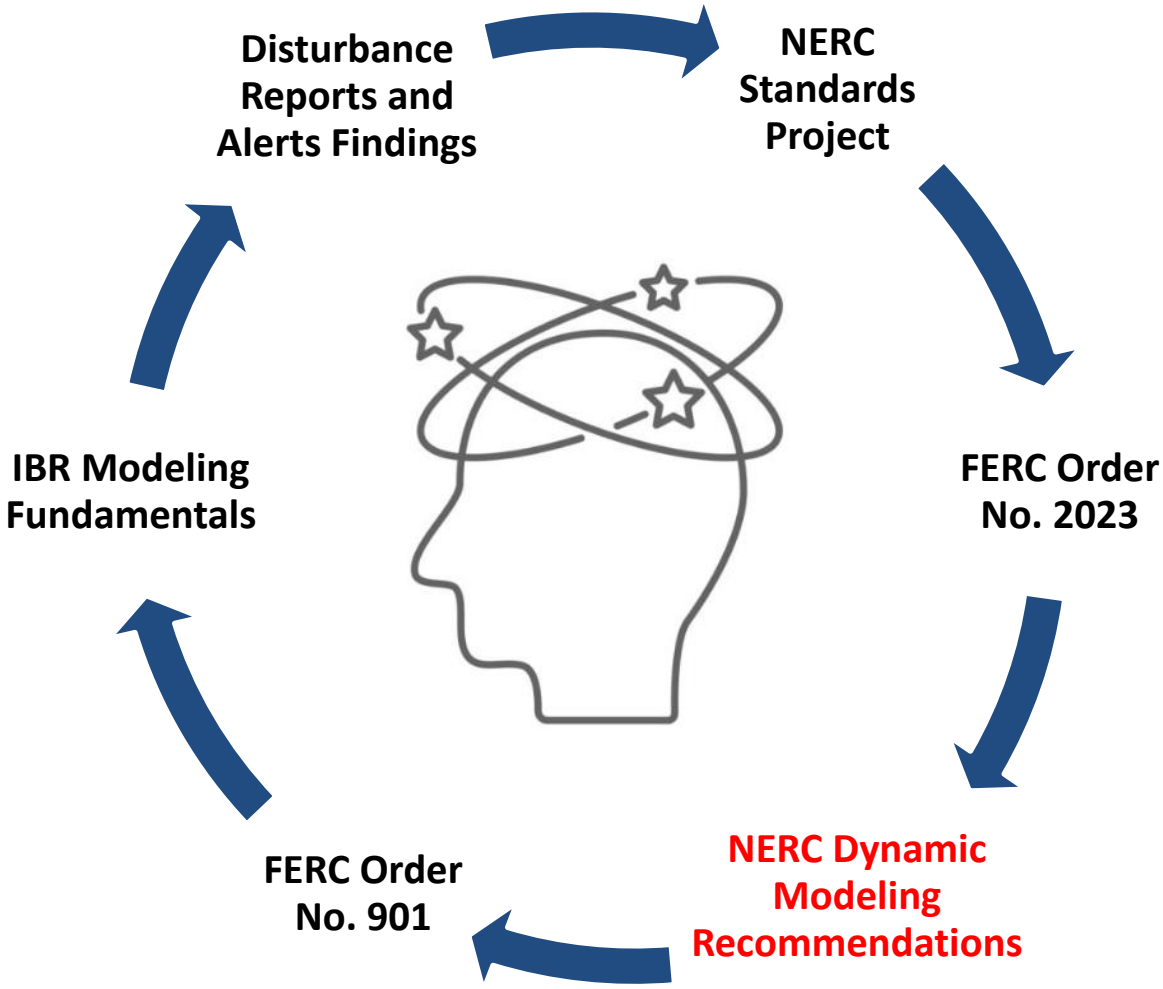
Modeling-Related Revisions to *Pro Forma* LGIP and SGIP

- Require each interconnection customer of non-synchronous (IBR) generating facility to submit to transmission provider:
  - Validated user-defined RMS positive sequence dynamic model
  - Appropriately parameterized standard library RMS positive sequence dynamic model
    - Include model block diagram of inverter control system and plant control system
    - New table of "acceptable models" in procedures, or model approved by WECC
  - Validated EMT model if transmission provider performs EMT study as part of interconnection study process
- Defines "user-defined model" as:
  - "[A]ny set of programming code created by [OEMs] or developers that captures the latest features of controllers that are mainly software-based and represent the entities' control strategies but does not necessarily correspond to any particular generic library model…"

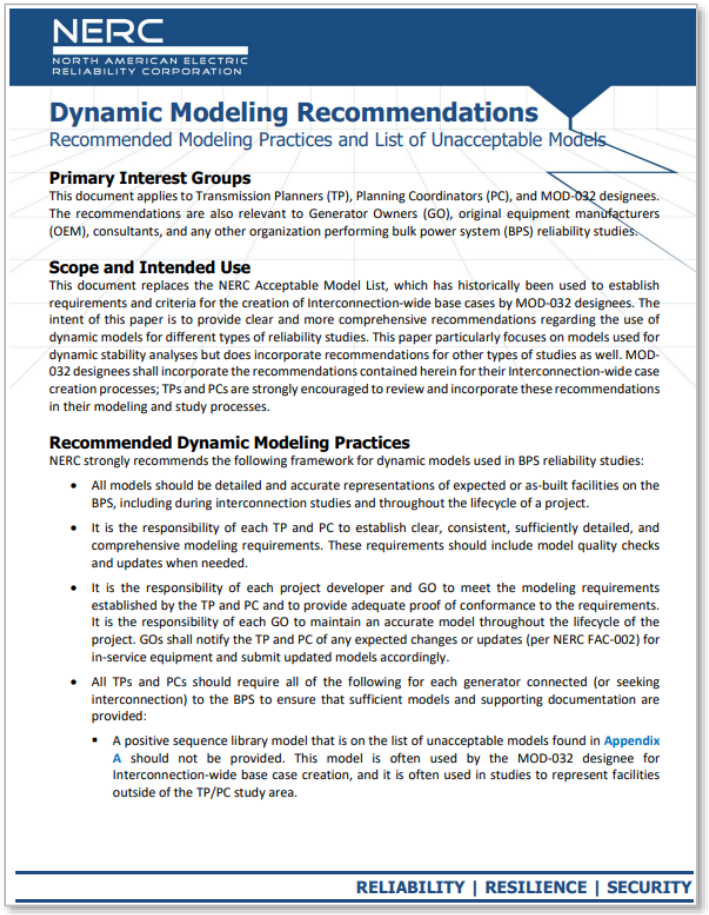
Key Modeling-Related Directives

- Requires any proposed modification to interconnection request be accompanied by updated models of proposed facility
- Cure period for model deficiencies; failures to meet requirements considered “incomplete” and “invalid”
- “Definition of a validated model (i.e., confirmation that the equipment behavior is consistent with the modeled behavior) is sufficiently flexible to enable interconnection customers to provide such a model with their interconnection requests.”
  - “...attestation that the models accurately reflect the…facility…based [on] best understanding at the time…[provides] further flexibility…to change the equipment or control systems of the proposed generating facility…”

The Modeling Conundrum



NERC Dynamic Modeling Recommendations



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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.

Recommended Dynamic Modeling Practices

NERC strongly recommends the following framework for dynamic models used in BPS reliability studies:

- 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.
- It is the responsibility of each TP and PC to establish clear, consistent, sufficiently detailed, and comprehensive modeling requirements. These requirements should include model quality checks and updates when needed.
- It is the responsibility of each project developer and GO to meet the modeling requirements established by the TP and PC and to provide adequate proof of conformance to the requirements. It is the responsibility of each GO to maintain an accurate model throughout the lifecycle of the project. GOs shall notify the TP and PC of any expected changes or updates (per NERC FAC-002) for in-service equipment and submit updated models accordingly.
- All TPs and PCs should require all of the following for each generator connected (or seeking interconnection) to the BPS to ensure that sufficient models and supporting documentation are provided:
  - A positive sequence library model that is on the list of unacceptable models found in Appendix A should not be provided. This model is often used by the MOD-032 designee for Interconnection-wide base case creation, and it is often used in studies to represent facilities outside of the TP/PC study area.

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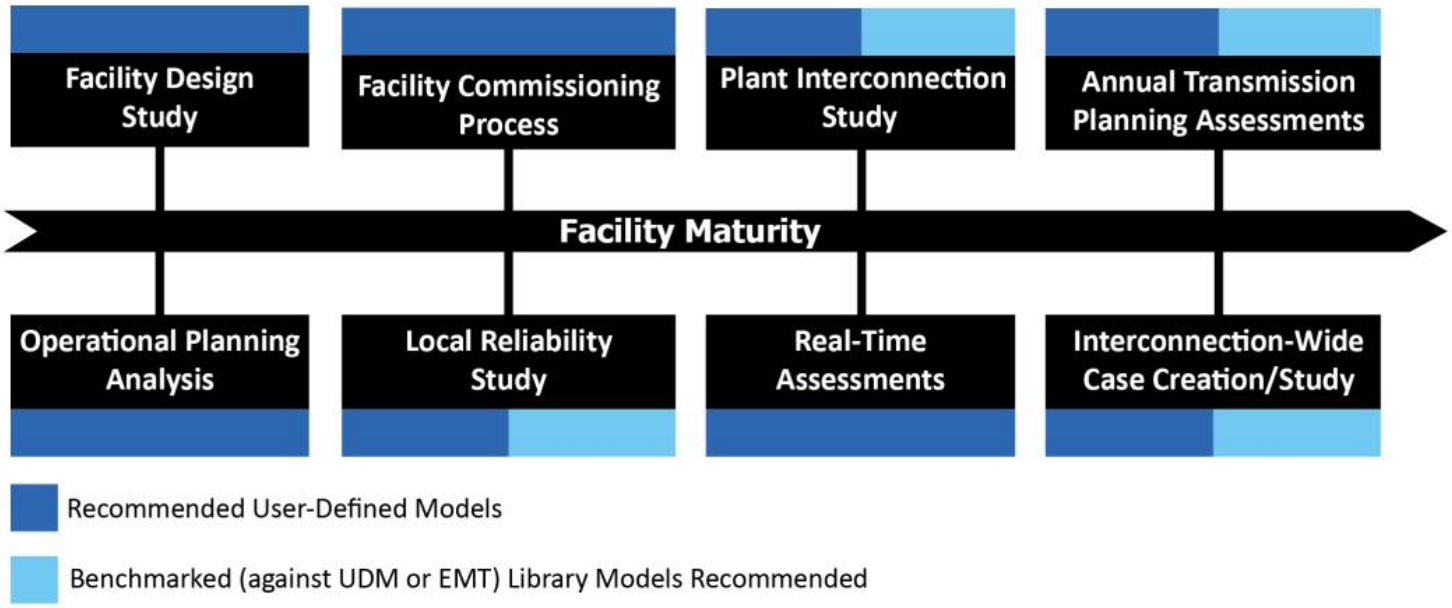
Dynamic Modeling Recommendations (nerc.com)

- Dynamic Modeling Recommendations
  - Recommended dynamic modeling practices
    - Positive sequence library models
    - Positive sequence user-defined models (UDM)
    - Electromagnetic transient (EMT) models
    - Geomagnetic disturbance (GMD) models
    - Applicability to MOD-032
  - Guidance on which models to use for different types of reliability studies
  - Focus on ensuring model quality – accuracy, usability, fidelity, etc.
- Acceptable/Unacceptable Model List
  - Retired “NERC Acceptable Model List” – often misinterpreted and needed a rewrite
  - This Dynamic Modeling Recommendations document replaces that list
- Relation to FERC Order 901

Key Recommendations



- Dynamic models are used in reliability studies throughout the life cycle of a project.
- The recommended use of dynamic models across these studies varies based on the type of study being conducted
- For all studies, EMT models should be used if positive sequence simulation platforms or models are insufficient, or if high accuracy is desired

Key Recommendations

- 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.
- Each TP and PC should establish clear, consistent, sufficiently detailed, and comprehensive modeling requirements.
  - Should include model quality checks and updates when needed.
- Project developers and GOs should meet the modeling requirements established by the TP and PC and provide adequate proof of conformance to the requirements.
  - Maintain an accurate model throughout the lifecycle of the project
  - Notify TP and PC of any expected changes or updates per NERC FAC-002 for in-service equipment; submit updated models accordingly

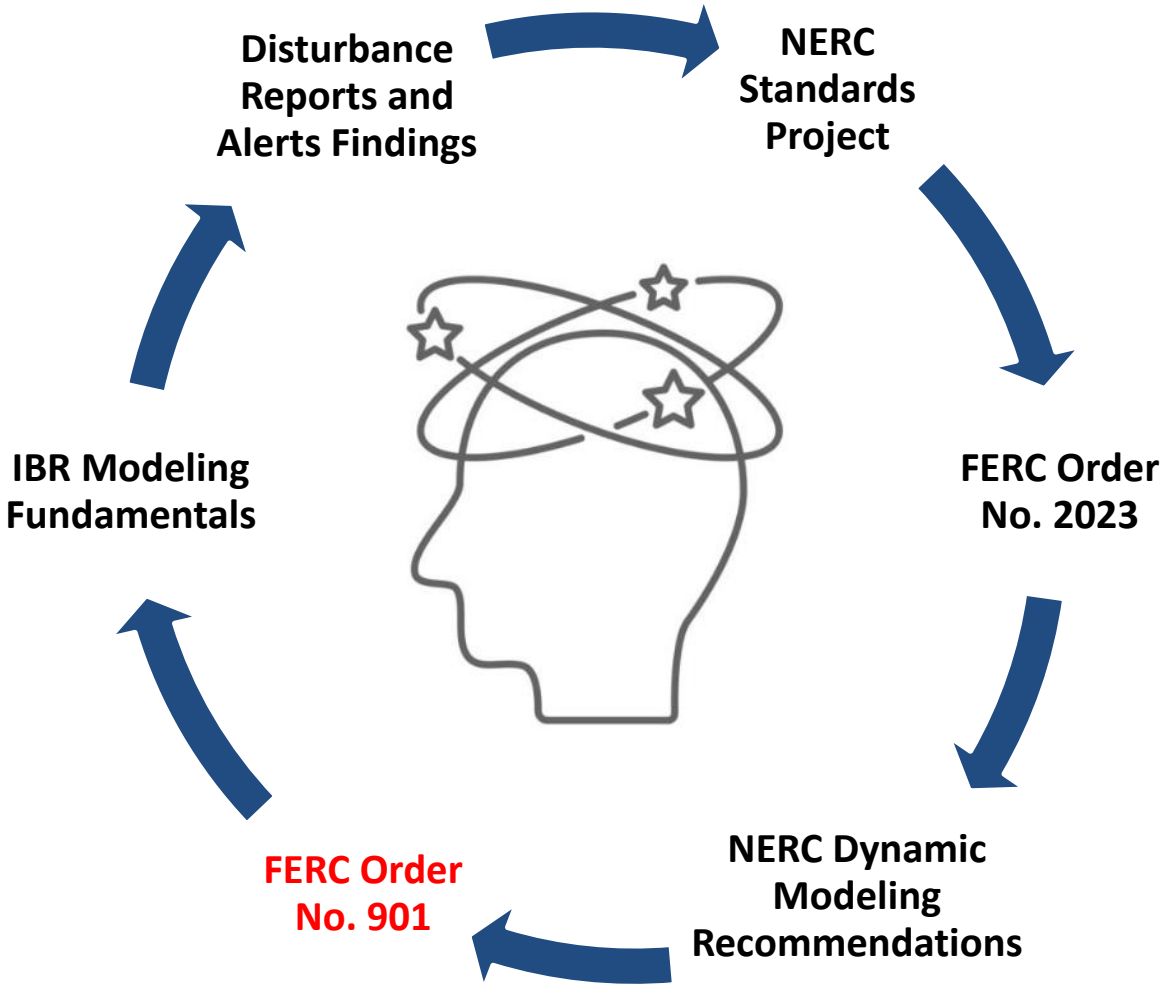
Key Recommendations

- Planners should require ***all*** the following for ***all*** BPS-connected generators:
  - Positive sequence standard library model
    - **Not** on the list of unacceptable models
    - Used for interconnection-wide cases to represent facilities outside study areas
  - Positive sequence user-defined model (UDM)
    - Used for system impact studies and local stability studies
  - Electromagnetic transient (EMT) model
    - Used for studying detailed BPS reliability risks increasingly prevalent and necessary for inverter-based resources
  - All models should be verified by OEM to be ***accurately parameterized*** to represent ***site-specific*** controls, settings, and protections with supporting documentation and attestations.
  - All submitted models should have an accompanying benchmarking report comparing models against each other (and discrepancies identified)

Key Recommendations

- MOD-032 designees have responsibility of creating interconnection-wide base cases used as starting point for TP and PC reliability studies
- Submitted models should meet all applicable requirements (including model acceptance criteria) and be accompanied by detailed documentation.
  - User manuals, OEM attestations, mapping between the model parameters, installed or to-be-installed facility settings, benchmark reports that show matching performance between the models
- Standard library models are sufficient for use in interconnection-wide base case creation but should be validated by the OEM and benchmarked against the OEM-verified EMT model or OEM-verified user-defined positive sequence model with the as-left or to-be-commissioned facility settings

The Modeling Conundrum



FERC Order No. 901

- Directs enhancements to NERC Reliability Standards related to:
  - Terms of “Registered IBRs,” “unregistered IBR,” and “IBR-DERs”
  - Data sharing – modeling data and disturbance monitoring
  - Data and model validation
    - Standard library models
      - Steady-state, short-circuit, and dynamics
    - DER_A model for IBR-DERs
    - Model accuracy
    - Provisions for inability to gather data
    - System model validation
  - Planning and operational studies
    - Expanded grid conditions to study (e.g., low inertia)
  - Performance requirements
    - Ride-through performance, current injection, minimal exemptions

Required Use of Standard Library Models

- Order No. 901 requires use of "approved industry generic library IBR models"
  - Steady state, short-circuit, and dynamics (no EMT, but did "encourage NERC and stakeholders to continue working in this area"
  - Planning, operations, and interconnection-wide models
  - Could reference NERC approved component model list
    - Per MOD-032-1, list defines models that may or may not be used in interconnection-wide base case creation
    - Includes IBR standard library models (i.e., "WECC models")
  - "We decline[d] to…allow NERC the discretion to include alternatives to approved industry generic library models…"
  - "…similarly decline[d] to…allow transmission providers the discretion to diverge from the approved nation-wide component model list."

Relation to Order No. 2023

- Order No. 2023 includes use of user-defined models for interconnection studies
- FERC expressed differences between interconnection studies and planning and operations studies; stated:
  - Interconnection study models “not typically shared or combined with models from neighboring systems”
  - Concerns with data sharing, model combination, model convergence, model transparency issues, etc.
  - Did not disallow TPs/PCs collecting UDMs but prohibited them for use in interconnection-wide base cases “so that [BPS] planners and operators can adequately predict behaviors and subsequent impacts to the reliable operation of the [BPS].”
- Highlighted entities that prefer or only allow standard library models: AEP, CAISO, ISO-NE, LADWP, PJM, NYSRC, etc.

Model Verification Directive

- FERC also directed NERC "to establish a standard uniform model verification process"
  - Models are complete and accurately represent the dynamic behavior of resources at a sufficient level of fidelity"
  - Highlighted consistency among processes for FAC-002, MOD-026, and MOD-027
- NERC Project 2020-06 is revamping the model verification process presently

Linking The Problem to The Interconnection Process

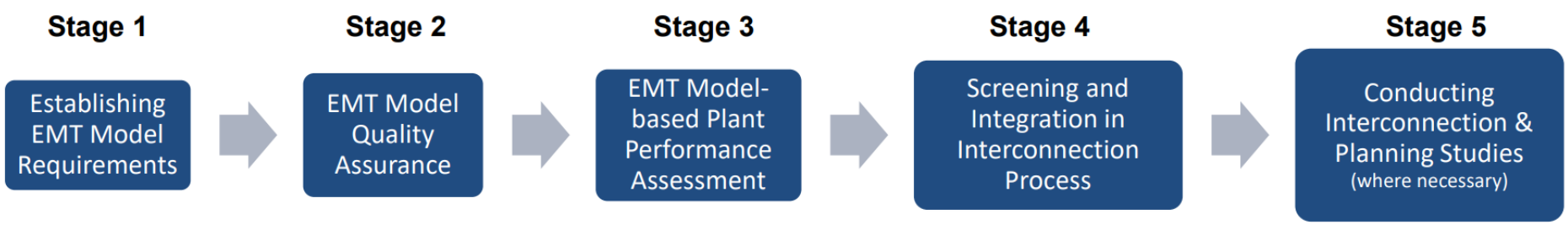
Without adequate modeling requirements, Transmission Planners cannot gather sufficient models from Interconnecting Customers. These requirements must be clear and consistent.

Just requiring models is not enough; those models must be checked for accuracy and sufficiency.

With an accurate model, the interconnecting facility can be tested to ensure it meets the performance requirements established.

Transmission Planners need to begin integrating EMT studies and rethinking positive sequence modeling and study processes.

Planning studies using EMT models will likely increase, other studies likely expand scenarios and sensitivities.



NERC EMT Task Force

**EMT = Electromagnetic Transient*

Questions and Answers

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