

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.

Performing dynamic simulations of the BPS allows Transmission Planners (TP), in cooperation with Generator Owners (GO), to mitigate reliability risks before they occur. Accurate dynamic models of resources are critical to this analysis and to BPS reliability. Several of NERC's published disturbance reports included analyses of the models for the affected facilities, which revealed systemic dynamic model inaccuracies. These analyses also revealed that the models provided for conducting generator interconnection studies or other system studies failed to accurately reflect the dynamic performance of the plants. Accurate modeling of IBR facilities is critical in performing system studies to assess the reliable operation of the BPS.

This alert is being distributed to all GOs of Bulk Electric System (BES)-connected IBRs as modeling deficiencies, best practices, and recommendations are applicable across all IBR technologies. NERC encourages owners and operators of non-BES and BPS-connected IBRs to review this alert as well.

The significantly higher complexity and software-based nature of IBR modeling when compared to synchronous machine modeling necessitates an improvement in the fundamental principles of dynamic modeling to accurately capture the performance of IBR plants. This alert is also being distributed to TPs and Planning Coordinators (PC) to provide recommendations that can be implemented to strengthen current modeling practices. TPs and PCs are required to answer a set of questions in the alert system; however, only GOs of IBRs will need to complete the Data Submission Worksheet.

This alert will gather dynamic modeling information from BES-connected IBR GOs, TPs, and PCs to understand the extent of condition of dynamic modeling for IBR, which will inform what additional actions are necessary to mitigate observed deficiencies. These GOs are strongly encouraged to coordinate with their inverter- and plant-level controller manufacturers and third-party consultants to review the parameters and controls installed in the field, review and mitigate modeling deficiencies, and implement the recommendations described in this alert. The information gathered throughout this alert should also be shared and reviewed with the associated GOPs as applicable.

For more information, see the [NERC Major Event Analysis Reports web page](#).¹ All recipients are strongly encouraged to read the findings from these reports, as well as NERC’s Dynamic Modeling Recommendations.²

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Status: **Acknowledgement Required³ by Midnight Eastern on June 11, 2024
Reporting Required by Midnight Eastern on September 2, 2024**



PUBLIC: No Restrictions

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Instructions: This Level 2 Industry Recommendation provides specific actions that registered entities should consider for responding to a particular issue. Pursuant to Rule 810 of NERC’s Rules of Procedure (ROP), NERC registered entities shall 1) acknowledge receipt of this Industry Recommendation within the NERC Alert System, and 2) report to NERC on the status of their activities in relation to this recommendation as provided below. For U.S. entities, NERC will compile the responses and report the results to FERC.

This recommendation is not the same as a Reliability Standard, and your organization will not be subject to penalties for a failure to implement. Issuance of this recommendation does not replace or modify the requirements of any approved Reliability Standard or excuse the prior failure to follow the practices discussed in the recommendation if such failure constitutes a violation of a Reliability Standard.

Distribution: Generator Owner (GO), Transmission Planner (TP), and Planning Coordinator (PC)

[Who else will get this alert? >>](#)

Primary Interest Groups: Generation Engineering, Generation Operations, Transmission Planning

Recommendation: The recommendations in this alert should be implemented by all industry stakeholders to help mitigate systemic modeling deficiencies. Recommendations 1–3 of this alert are general in nature and are intended to provide recommendations for general modeling best practices and should be implemented by all stakeholders using models that perform studies that assess BPS reliability.

¹ <https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx>

² <https://www.nerc.com/pa/RAPA/ModelAssessment/Documents/Dynamic%20Modeling%20Recommendations.pdf>

³ To the extent that Canadian jurisdictions have implemented laws or requirements that vary from Section 810 of the ROP, NERC requests entities in such jurisdictions voluntarily participate in response to this Alert.

Recommendation 1: All models should be detailed and accurate representations of expected or as-built facilities across all expected operational conditions. Changes to any model parameters, including plant controller parameters that change the performance of the IBR plant, should be studied to ensure BPS reliability before implementation.

- a. Models should be validated at the individual inverter level and plant level to ensure that the performance of the plant model matches the expected performance of the in-service IBR plant.
- b. Models should be updated throughout the lifecycle of the plant to capture any proposed changes that could alter a plant’s performance (e.g., hardware, firmware, control settings, or any qualified changes).⁴ Proof of model accuracy⁵ should be documented and retained by the GO and supplied to all affected stakeholders any time a model update is performed. Updated models should be used to perform studies to confirm whether or not the proposed changes affect BPS reliability prior to implementation of those proposed changes at the in-service plant.
- c. Preferably, models should be verified by the equipment manufacturer to be accurately and appropriately parameterized⁶ to represent site- and equipment-specific capabilities, site-specific⁷ controls, settings, and protections with supporting documentation and attestations. They should also be validated against actual product performance according to NERC Reliability Standards and local TP and PC requirements.⁸

Recommendation 2: Industry-approved standard library⁹ positive sequence phasor domain (PSPD) models are sufficient for use in Interconnection-wide base-case creation.

- a. Generally, standard library models that have not been verified by the equipment manufacturer should not be used for local reliability studies or generation interconnection studies, particularly in and near the study area due to a lack of sufficient model accuracy and fidelity to represent the actual equipment controls and protections.

⁴ Qualified changes are defined by Planning Coordinators (PC) in accordance with [NERC FAC-002-4](#).

⁵ Proof of model accuracy can include but is not limited to equipment manufacturer attestations, parameter verification reports, and model benchmarking reports.

⁶ The default parameters listed in the library model software manuals are provided only as a starting point to prevent model initialization issues. Those parameters are not suitable replacements for site-specific parameters. Documentation showing how the library model was parameterized and compared to inverter and plant-level controller settings should be provided.

⁷ While finalized plant settings are not available at this stage of the interconnection process, the models should be parameterized with control modes and parameters that are as reflective of the intended final design as possible. Model submitters should leverage publicly available regional performance requirements and ensure appropriate parameters are reflected in the model to the best of their ability.

⁸ “Model validation” involves comparing the simulated response against actual product performance; “model verification” refers to ensuring that model settings and parameters match the actual equipment installed in the field.

⁹ Also referred to as “WECC Generic Models,” “Generation 2 generic models,” and “standard library model” throughout this document for uniformity.

- b. While it is not required in the FERC Large¹⁰ and Small¹¹ Generator Interconnection Procedures (LGIP and SGIP) for standard library models to be validated models, validation could provide additional information on model accuracy or technical limitations.
- c. If model validation is performed, standard library models should be validated by the equipment manufacturer through benchmarking against the equipment performance, equipment-specific electromagnetic transient (EMT)¹² model or equipment-specific¹³ PSPD model that has been verified by the equipment manufacturer and parameterized with the as-left or to-be-commissioned settings at the plant. Written documentation for the equipment-specific model should be supplied explaining the dynamic performance characteristics and performance comparison to the standard library models used.

Recommendation 3: Equipment-specific models should be used for detailed reliability studies (e.g., during generation interconnection studies and local reliability studies). These equipment-specific models should be considered acceptable by a TP or PC if the following usability requirements are met:

- a. A unit model validation¹⁴ report should be produced by the equipment manufacturer that compares the actual equipment performance against the performance of the EMT model, equipment-specific positive sequence model, and positive sequence standard library model is provided.¹⁵ The GO should request this benchmarking report from the equipment manufacturer(s) for each inverter type for each IBR plant.
- b. The equipment-specific model includes compiled .dll files such that no additional compilation is required by the end user.
- c. The equipment-specific model is accompanied by sufficient documentation¹⁶ for the TP and PC to:
 - a. Properly integrate the plant model(s) into a network model.

¹⁰ [Pro forma LGIP | Federal Energy Regulatory Commission \(ferc.gov\)](#)

¹¹ [Pro Forma SGIP | Federal Energy Regulatory Commission \(ferc.gov\)](#)

¹² [Reliability Guideline - Electromagnetic Transient Modeling for BPS-Connected Inverter-Based Resources— Recommended Model Requirements and Verification Practices](#)

¹³ Also referred to “user-written model,” “user-defined model (UDM),” or “equipment-specific model (ESM)” throughout this document for uniformity.

¹⁴ This validation should be performed with detailed testing on both the inverter and power plant controller as parameterized by the equipment manufacturer to demonstrate model accuracy. This is not expected to be performed with as left, or issued for construction parameters and is intended to show only unit model accuracy and not the accuracy of the plant as parameterized.

¹⁵ Performance differences between real equipment, user-defined EMT, and user-defined positive sequence models should be minimized as manufacturer-verified models, and these models should provide the highest accuracy and fidelity. Performance differences between the manufacturer-verified models and the library models display the limitations of the library models.

¹⁶ Model validation test reports, user manuals, capability curves, etc. may also be supplemented with block diagrams; however, block diagrams may be proprietary and may not be applicable to real-code integrated user-defined models.

- b. Understand control functions and associated parameters.
- c. Understand the plant and equipment ratings and capabilities.
- d. Initialize models appropriately in reliability studies.

TPs and PCs who are receiving this Industry Recommendation are strongly encouraged to implement the following recommendations:

Recommendation 4: Establish clear, consistent, sufficiently detailed, and comprehensive modeling requirements that include standard library, PSPD, and EMT¹⁷ models, are aligned with the recommendations in this alert, aligned with the FERC LGIP and SGIP, include model quality checks,¹⁸ and are updated when necessary (e.g., after an event where model quality is noted as an issue.) Requirement categories should include the following:

- a. Detailed list of model quality check tests and pass/fail criteria across a reasonable range of expected operational conditions such as, but not limited to, different levels of voltage dip/rise, fault-clearing duration, and system strength.
- b. Detailed processes for requesting model verification data to be submitted by the GO and verification of the submitted data's accuracy to ensure that the most recently updated model representation of the IBR used in generator interconnection studies is representative of the commissioned IBR plant.
 - i. Verified data could include but should not be limited to critical control modes, protection parameters, and any parameters that can affect the performance of the IBR.
 - ii. Using manufacturer-verified, equipment-specific models throughout the interconnection process can provide a detailed reference to be used for parameterizing the IBR during the commissioning process.
 - iii. Mechanisms for "modeling true-up" to promote collaboration between GOs, TPs, and PCs to mitigate model inaccuracies within interconnection process timeline.

Recommendation 5: TPs and PCs should require all of the following for each generator currently connected to the BPS to ensure that sufficient models and supporting documentation are provided. TPs or PCs should provide models and model updates to the Reliability Coordinator (RC), Transmission Operator

¹⁷ EMT models should be required only if the TP performs an EMT study as part of the interconnection study process.

¹⁸ See [Reliability Guideline: Electromagnetic Transient Modeling for BPS Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices](#). Although the guideline is written for EMT modeling, the principles around establishing, verifying, and documenting model quality, including accuracy, are applicable to positive sequence models.

(TOP), Balancing Authority (BA), and any affected stakeholders. For generating resources seeking interconnection to the BPS, model submission requirements should align with the FERC LGIP and SGIP:

- a. A positive sequence library model that is not on the list of unacceptable models found in Appendix A of the NERC Dynamic Modeling Guidance.¹⁹
- b. An equipment-specific PSPD model.
- c. An equipment-specific EMT model if the TP intends to perform EMT analysis during generation interconnection study processes.
- d. A model benchmarking report should be required to be provided by GOs that compares all the aforementioned models against each other and against the actual product. The report should document any discrepancies across the models, including those due to software platform limitations. The benchmark reports should be available among neighboring TPs and PCs.

GOs of all BPS-connected IBR (including those which could fall within the scope of NERC’s proposed Category 2 GO Registry Criteria pending at FERC)²⁰ who are receiving this Industry Recommendation are strongly encouraged to implement the following recommendations:

Recommendation 6: Coordinate with inverter manufacturers,²¹ plant controller manufacturers, TPs, and PCs to meet all modeling requirements that are established by the TP and PC and provide adequate proof of conformance to the requirements.

Recommendation 7: Maintain an accurate and representative model throughout the lifecycle of the project, including:

- a. Notifying TP and PC of any expected changes or updates for in-service equipment or equipment undergoing interconnection analysis, including software updates that affect the performance of the IBR, and submitting updated models accordingly.
 - i. Changes that affect the performance of the IBR should be communicated to and subsequently studied by the TP and PC prior to those changes being made at an in-service plant.

¹⁹ <https://www.nerc.com/pa/RAPA/ModelAssessment/Documents/Dynamic%20Modeling%20Recommendations.pdf>

²⁰ IBR that falls within the scope of NERC’s proposed Category 2 GO Registry Criteria are encouraged to implement the recommendations in this alert but do not have any requirements to respond to this alert.

²¹ If the inverter manufacturer is no longer in business, a standard library model should be parameterized and validated to approximate the response of the IBR as closely as possible.

- b. Collaborating with equipment manufacturers, TPs, and PCs to advocate for the use of the most accurate model, regardless of model type, throughout the interconnection process and for local reliability studies.

Recommendation 8: All applicable recommendations in this alert should be implemented such that an updated set (e.g., standard library, equipment specific PSPD, and EMT) of dynamic models is available to be included in the next applicable TP and PC annual model updates.

**Reporting
Instructions:**

Initial acknowledgement of receipt is required by 12:00 a.m. Eastern on **June 11, 2024** via the NERC Alert System. Responses to the questions below are required to be submitted via the NERC Alert System by 12:00 a.m. Eastern on **September 2, 2024**.

The questions below seek data pursuant to Section 800 of the ROP to support NERC’s evaluation of actions taken in response to this alert and of risks to reliability presented by the identified issues.²² Plant and inverter information, for example, will enable NERC to track responses, including actions taken in response to this NERC Alert, and evaluate the extent of conditions associated with the identified issues.

A valid response in the NERC Alert System consists of the following three steps by the submitting entity:

- 1) Acknowledgement of Alert
- 2) Submission of Response
- 3) Approval of Response

The NERC Alert System contains menu options for each of the above commands that are available to authorized individuals upon login. **A response will not be considered valid until all three steps have been completed.**

All registered entities belonging to the GO, TP, and PC functional groups are required to acknowledge receipt of this alert and respond as applicable. For purposes of the NERC Alert System, the terms “Planning Coordinator” and “Planning Authority” are used interchangeably.

All GOs are required to respond to the following question:

²² See Section 810 of the ROP stating, “Members of NERC and Bulk Power System owners, operators, and users shall provide NERC with detailed and timely operating experience information and data.”; see also, Section 804 of the ROP stating, “To carry out the reviews and assessments of the overall reliability of the interconnected Bulk Power Systems, the Regional Entities and other entities shall provide sufficient data and other information requested by NERC in support of the annual long-term and seasonal assessments and any special reliability assessments.”

For GOs: Do you own any BPS-connected IBR generating facilities?²³ (Yes, No)

- **For GOs that answered “Yes” to the question above,** complete the attached Data Submission Worksheet and respond to the questions below.
- **For GOs that answered “No” to the question above,** there is no requirement to complete the attached Data Submission Worksheet or respond to the remaining questions in this alert. You must still Acknowledge, Submit, and Approve your response.

Use the “Add Additional Document” link on the NERC Alert System response web page to submit the completed worksheet(s). There should be one Data Submission Worksheet completed for each IBR plant.

All TPs and PCs are required to respond to the following questions:

- 1. Does your organization have publicly available model submission requirements?**
 - A. Yes
 - B. No
- 2. Does your organization have publicly available model quality requirements?**
 - A. Yes
 - B. No
- 3. If Yes to Question 1: Do you believe that your organization’s modeling requirements align with NERC’s Dynamic Modeling Recommendations?²⁴**
 - A. Yes
 - B. No
 - C. N/A, our answer to Question 1 was not “Yes”
- 4. Provide a link(s) to your organization’s publicly available model submission and model quality requirements.**
- 5. Does your organization *require* the submission of equipment-specific, user-written PSPD generator models for interconnection studies?**
 - A. Yes

²³ In the context of this report, IBR generating facilities include solar photovoltaic (PV), type 3 and type 4 wind, battery energy storage systems (BESS), and any hybrid facilities with an IBR component.

²⁴ <https://www.nerc.com/pa/RAPA/ModelAssessment/Documents/Dynamic%20Modeling%20Recommendations.pdf>

- B. No
6. Does your organization *allow* the submission of equipment-specific, user-written PSPD generator models for interconnection studies?
- A. Yes
- B. No
7. Does your organization require the submission of equipment- and site-specific EMT generator models during the interconnection process?
- A. Yes
- B. No
8. Does your organization perform EMT model verifications to determine if the model meets published requirements?
- A. Yes
- B. No
9. Does your organization integrate EMT models into studies performed for your organization's generator interconnection procedures?
- A. Yes
- B. No
10. Does your organization require generator model benchmarking reports that contain comparisons between all model types and actual equipment?
- A. Yes
- B. No
11. If Yes to Question 10: Does your organization have quantitative metrics to determine model accuracy?
- A. Yes
- B. No
- C. N/A, our answer to Question 10 was not "Yes"
12. If Yes to Question 11: Provide a copy or link to your organization's quantitative metrics used to determine model accuracy. Leave blank if your answer to Question 11 was not "Yes"
13. Does your organization have the tools and personnel to effectively perform EMT analysis?
- A. Yes

B. No

14. Does your organization have the tools and personnel to effectively perform analysis with equipment-specific, user-written models?

A. Yes

B. No

15. Submit one PSPD dynamic model (.dyd or .dyr) and associated load-flow model file (.epc or .sav) that are representative of your distribution, sub-transmission, and transmission systems and are used during Interconnection and Planning studies. (Use the “Add Additional Document” link)

Additional Information:

Primary concerns include the following:

- Modeling requirements, specifically for IBR, are insufficiently detailed or non-existent for many stakeholders across the NERC footprint. Existing modeling requirements are not uniform between TPs and PCs, which drives confusion during the interconnection processes.
- Many TPs and PCs do not allow the submission of PSPD equipment-specific models for use during interconnection studies, special studies, or planning studies. This creates an environment where models with known limitations must be used in lieu of manufacturer-verified, equipment-specific models.
- TPs and PCs do not have detailed PSPD equipment-specific model usability requirements.
- Model quality testing may not effectively test the quality across ranges of expected operational conditions, such as different levels of frequency and voltage dip/rise, fault-clearing duration, or system strength, that are commonly observed on the system.
- Earlier analysis indicates a lack of adoption of NERC recommendations in Reliability Guidelines and other technical reference materials pertaining to the reliable integration of IBRs as part of the BPS.

Contact:

For clarification or content-related questions, contact:

Alex Shattuck

Alex.Shattuck@nerc.net

For login/account/registration issues, contact:

Bulk Power System Awareness Group

nerc.alert@nerc.net

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North American Electric Reliability Corporation
3353 Peachtree Road NE
Suite 600 – North Tower
Atlanta, GA 30326
www.nerc.com