Essential Actions to Industry

Inverter-Based Resource Performance and Modeling

Initial Distribution: May 20, 2025

NERC is issuing this *Level 3 Alert: Essential Actions for Inverter-Based Resource (IBR)[1] Performance and Modeling* to Transmission Owners (TO), Transmission Planners (TP), Planning Coordinators (PC), and currently registered Generator Owners (GO) to enhance technical minimum requirements and study processes to mitigate risks posed by IBR performance during system disturbances.

Since 2016, NERC has analyzed numerous major events totaling more than 15,000 MW of unexpected generation reduction. These major events were not predicted through current planning processes. Furthermore, NERC studies were not able to replicate the system and resource behavior that occurred during the events, indicating systemic deficiencies in industry's ability to accurately represent the performance of IBRs and study the effects of IBR on the bulk power system (BPS).

In response to these disturbances, NERC has issued 10 major event reports and four Level 2 Alerts. The *Level 2 Alert: IBR Performance Issues*[2] findings report contains the following critical findings:

- **(i) The voluntary recommendations set forth in NERC guidelines and other publications are not being implemented by GOs.**
- **(ii) Many GOs indicated that they did not have the requested facility data readily available.**
  - **a. The information requested in the worksheet is fundamental equipment information that NERC expects would be retained and easily accessible with some assistance from equipment manufacturers, if necessary.**

Assessment of the data received and feedback from entities during the *Level 2 Alert: IBR Model Quality Deficiencies*[3] provided additional evidence of the critical findings above. NERC issued its second-ever deadline extension for this alert due to numerous questions and comments received that indicated the requested data was still not readily available, resulting in another extremely low data submission worksheet submittal rate.

The information provided in response to this alert will also be of use to the potential Standards Drafting Team (SDT) working on the Reliability Standard FAC-001 and FAC-002 Standard Authorization Request sent by the Reliability and Security Technical Committee (RSTC) to the Standards Committee (SC). NERC anticipates that the data obtained will support effective and efficient review of the modeling issues by any SDT.

[1] Inverter-Based Resource (IBR): A plant/facility consisting of individual devices that are capable of exporting Real Power through power electronic interface(s), such as an inverter or converter, and that are operated together as a single resource at a common point of interconnection to the electric system. Examples include, but are not limited to, plants/facilities with solar photovoltaic (PV), Type 3 and Type 4 wind, battery energy storage system (BESS), and fuel cell devices.

[2] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Inverter-Based_Resource_Performance_Issues_Public_Report_2023.pdf

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

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Status:	**Acknowledgement Required by Midnight Eastern on May 27, 2025** **Reporting Required by Midnight Eastern on August 18, 2025**
	**PUBLIC:** No Restrictions [More on handling >>]
Instructions:	Essential Actions are specific actions that NERC has determined to be essential for certain segments of owners, operators, or users of the BPS to undertake to ensure the Reliable Operation of the BPS. Pursuant to Rule 810 of NERC's Rules of Procedure (ROP),[4] NERC registered entities shall (1) acknowledge receipt of these Essential Actions within the NERC Alert System, and (2) report to NERC on the status of their activities in relation to these Essential Actions (as provided below). For entities in the United States, NERC will aggregate the responses and provide an anonymized report to Federal Energy Regulatory Commission (FERC). This Level 3 NERC alert is not the same as a Reliability Standard. Your organization will not be subject to penalties under Section 215 of the Federal Power Act for failure to implement the Essential Actions. Further issuance of these Essential Actions does not alter the requirements of any approved Reliability Standard, nor would it excuse the failure to follow the practices discussed in these Essential Actions if such failure constitutes a violation of a Reliability Standard. Registered entities must continue to comply with applicable Reliability Standards.
Distribution:	**Initial Distribution:** Generator Owner (GO), Transmission Planner (TP), Transmission Owner (TO), Planning Coordinator (PC) [Who else will get this alert? >>]
Primary Interest Groups:	Generation Engineering, Generation Operations, System Operations – Transmission Engineering, System Operators, Transmission Planning
Essential Actions:	Identifies actions deemed to be essential to BPS reliability and requires NERC Board of Trustees' approval prior to issuance. Like Recommendations, Essential Actions also require recipients to respond as defined in this alert. These Essential Actions to Industry do the following: • Require registered entities to acknowledge receipt of these Essential Actions within the NERC Alert System.

[4] NERC Rules of Procedure

- Require registered entities to respond to the questions.
- Urge registered entities to take the Essential Actions below.

To the extent that Canadian jurisdictions have implemented laws or requirements that vary from Section 810 of the ROP, NERC requests that entities in such jurisdictions voluntarily participate in acknowledgment and reporting pursuant to this alert.

Please note that all Essential Actions urged herein should be implemented in agreement with NERC Reliability Standards, as appropriate for the Applicable Entity. Such Reliability Standards could include those being developed in accordance with NERC's work in response to FERC Order No. 901. Further, as noted above, NERC anticipates that the data gathered through this alert will be of use in any project following the Reliability Standard FAC-001 and FAC-002 SAR sent by the RSTC to the SC in September 2024. Please see NERC's Reliability Standards Under Development page[5] for more details regarding this effort and NERC's Reliability Standards One-Stop-Shop[6] for links to standards, implementation plans, project pages, Reliability Standards Audit Worksheets, FERC Orders, and compliance guidance. Last, nothing herein should be interpreted to conflict with FERC or state requirements.

Essential Actions for TOs, TPs, and PCs:

Essential Action #1: Each TO and TP, in coordination with their PC, should enhance the existing criteria and policies in their generator interconnection and planning activities, respectively, with additional technical details and IBR-specific performance criteria. These performance-based factors should be publicly available in an open and transparent manner (e.g., Open Access Same-Time Information System (OASIS)) and help ensure uniform[7] IBR performance both in normal and post-disturbance operations to address the following:

- Expected reactive power control[8] modes and parameters with considerations given to:
  - The type of automatic voltage or reactive power control required for the IBR.

[5] https://www.nerc.com/pa/Stand/Pages/Standards-Under-Development.aspx
[6] One-Stop Shop (Compliance Monitoring & Enforcement Program) (nerc.com)
[7] Some areas of the BPS may need location-specific variances to any uniform set of requirements. These additional or varied requirements are not in conflict with expectations of uniform performance from standardized requirement. For example, standardized voltage control modes may need local alterations to reach expected rise and settling time requirements.
[8] Automatic voltage control, fixed reactive power control, and power factor control, etc.

  - Specific value ranges for parameters like voltage control deadbands, voltage slopes or droops, and reactive power limits, and point of measurement and control for the IBR.

- Expected frequency response control modes and parameters with considerations given to:
  - The expected frequency control behavior.[9]
    - Performance expectation for staged tests, such as those conducted during commissioning, should be differentiated from real-time operational performance expectations. Such real-time expectations include, but are not limited to, performance during frequency events.
  - Specific value ranges for parameters like frequency control deadbands, droops, ramp rate limits, and other settings that may impact the frequency response performance.
- Expected ride-through behaviors[10] during system disturbances with considerations given to:
  - System disturbances and event thresholds for which BPS-connected IBR should ride through.
  - Maximization of ride-through capabilities up to equipment capability.
  - Use of measurement filtering or time delays to prevent erroneous instantaneous trips.
  - Positive and negative sequence current injections and their priority under different ride-through modes.
- Post-disturbance performance requirements, inclusive of settling time requirements, with considerations given to:
  - Active power recovery speed and magnitude.
  - Reactive power injection speed and magnitude.
  - Voltage recovery speed and magnitude.
  - Active/reactive current priority when current limits are reached.
- Reactive power capability requirements within the continuous operation range of system voltage.

[9] This includes frequency control modes (e.g., primary frequency response and fast frequency response, etc.), coordination between frequency response and dispatch commands. See NERC Lesson Learned on frequency response and dispatch commands.
[10] This includes voltage and frequency ride through as well as any other causes of tripping or active power reduction like phase angle jump or direct current (DC) bus protections. See NERC major event reports.

- The requirements should emphasize the full use of reactive power capability.

Essential Action #2: Each TP and PC should enhance their modeling and study practices to ensure sufficient study work and model quality verification are performed and documented to reflect models that are representative of installed, or to-be installed, equipment with the following considerations:

- Model quality and accuracy criteria to ensure models used are accurate representations of the equipment being studied.
  - Request and review IBR unit model validation reports[11] from the GO, who can collaborate with the original equipment manufacturers (OEM) that show the response of positive sequence phasor domain (PSPD) equipment-specific models, electromagnetic transient (EMT) models, and PSPD standard library models against actual measured product responses.
  - Request and review parameter verification reports that show mapping between models and products used. This is necessary to ensure that model configuration reflects how the equipment is configured on-site and that changes made in either the product or model can be accurately translated between the two.
  - Request and review model quality attestations like those detailed in the *NERC EMT Modeling Reliability Guideline.*[12]
- Performance tests and conformity criteria to be used by the GO to show the modeled representation of the IBR meets performance expectations published by the TP and PC and the field performance.
  - Performance testing processes should include sufficient tests necessary to show conformity with published performance expectations without adding undue study burden.
  - Performance tests and expected performance should be publicly posted and readily available to interconnection customers so that more of the design work can be completed before the interconnection process begins.
  - Performance testing process should ensure that model parameters reflect as-built field settings and that model performance matches field performance *before* reaching full commercial operations.

[11] GOs responding to requests for unit model validation reports should obtain these reports from their OEM for the specific technology and product (plant controller and inverter-level) versions as is used or intended to be used at the IBR. These reports typically include benchmarking between model (root mean squared (RMS) and point on-wave quantities) response and actual product response for a variety of small and large signal disturbances. If the manufacturer is no longer in business or the IBR is not supported any longer, validation of a standard library PSPD or EMT model against IBR performance data is recommended.

[12] *NERC EMT Modeling Reliability Guideline*

- Procedures that allow and promote a transparent feedback loop between GOs and applicable entities such that changes to proposed IBR design are captured in the model(s).
  - Changes made to modeled representations should also be tracked and translated into real-world parameters through these procedures.
- Once performance and study enhancements are completed per the above, TOs, TPs, or PCs, where applicable, should:
  - Enhance the existing criteria used throughout generator interconnection through implementing these urged measures.
  - Apply these factors to their local reliability planning processes.

Essential Action #3: TOs, TPs, or PCs, where applicable, should perform a detailed review of currently operating IBRs on their system to understand the extent of condition of both real-world performance and accuracy of their models.

- This can be completed through verifying the performance of existing IBRs and their models, comparing the field performance to model performance against previous criteria or requirements, and making note of opportunities to address and correct identified issues.[13]
  - Confirm any changes made to correct identified issues.
  - Update IBR models to reflect new performance, if there is any change in the field.
  - Communicate any model changes to all affected parties.

Essential Action for GOs:

Essential Action #4: Each GO should create and implement processes to help ensure the models used for the evaluation of their design and submitted to TPs and PCs for use in generator interconnection and planning processes are—to the extent possible based on the available information—accurate and high-fidelity representations of their IBR. This should be accomplished through the following:

- GOs should request unit model validation and model benchmark reports from both their inverter and power plant controller manufacturers that show the following:
  - EMT model performance against measured performance during type testing, including technical explanations for any mismatch.

[13] This Essential Action would require operational data and collaboration between TO, TOP, GO, and equipment manufacturers.

  - EMT model performance against PSPD equipment-specific and PSPD standard library models, including technical explanations for any mismatch.

- GOs should leverage publicly posted performance requirements for their interconnecting area and finalize the control design to minimize changes made throughout the generator interconnection study process.
- GOs should perform a conformity assessment for what is installed and commissioned so that it matches what has been designed and studied. The acceptance criteria of this assessment by GOs should be stricter than the criteria used by TO or PC for measuring performance.
  - Frequency response performance stipulated in operational performance requirements and measured during frequency events should not be used as acceptable criteria when assessing IBR Primary Frequency Response (PFR) performance from staged tests. The applicable criteria should be the performance expectation set by TO, TP and PC for testing PFR during commissioning, as mentioned in Essential Action #1.
- GOs should use models that allow for parameters in the model space to be easily translated into actual product parameters. This makes it easier to track IBR equipment and corresponding IBR models.
- GOs should enhance change management processes to ensure any changes, including firmware changes, made to the actual IBR or the IBR model are reflected in both the equipment and the model representing the equipment. GOs should communicate such changes to TPs and PCs. Representative models are critical for BPS reliability as all study work relies on accurate inputs. GOs should perform this verification *before* they implement the changes in the field.
- GOs should enhance change management processes to track any firmware changes within the IBR and ensure unintended changes, such as control parameters being reset to factory default values, do not occur following firmware changes.
- GOs should organize and retain critical IBR information, so that it is readily available. This information should be periodically reviewed for accuracy. This information should be kept up to date, as part of enhanced change management processes. Critical IBR information is, at a minimum, the list of information requested in the Level 2 Alert[14] regarding IBR Model Deficiencies, which are summarized below:
  - Inverter or turbine make, model, and firmware versions.

[14] *Industry Recommendation: Inverter-Based Resource Model Quality Deficiencies*

  - Inverter or turbine active and reactive power capabilities.
  - Inverter or turbine voltage and frequency ride-through capabilities.
  - Inverter or turbine voltage and frequency protection settings.
  - Plant controller make, model, and firmware versions.
  - Plant-level active and reactive power capabilities.
  - Plant-level voltage and frequency protection settings.
  - Plant-level control modes and associated parameters.
  - Plant- and inverter-level control descriptions.[15]
- GOs should consider adding these model requirements and model support throughout the lifecycle of the facility to their agreements with the equipment manufacturers and entities involved in the creation of the IBR model.

Reporting Instructions:	Initial acknowledgment of receipt is required by May 27, 2025, Midnight Eastern via the NERC Alert System. Responses to the questions below are required to be submitted via the NERC Alert System by August 18, 2025, Midnight Eastern. To ensure a valid response in the NERC Alert System the submitting entity must: • Acknowledge the Alert • Submit a Response • Approve the Response Being Submitted 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, TO, and PC functional groups are required to acknowledge receipt of this alert and respond, as applicable. ***All registered entities covered by this Essential Action are required to provide an approved response as defined above to the following questions.***

[15] e.g., plant-level controls hierarchy, voltage control strategy, theory of operation

TO Questions

1) Do you have publicly posted generator interconnection requirements or other policies, criteria, protocols, or guidance in alignment with Essential Action #1?
   A. Yes
   B. No
   C. Not Applicable: This entity is not registered as a TO.
2) If "No" to Question 1, when do you plan to implement these enhancements to align with Essential Action #1?
   A. 2025
   B. 2026
   C. 2027
   D. No Plans to Update
   E. Not Applicable: This entity is not registered as a TO.
3) In the free text box below, please summarize any additional details or narratives that may clarify your answers. Please note that a response to this question is NOT REQUIRED, but strongly encouraged to help inform future assessment and mitigation efforts. Please enter "NA" if no further information is provided or you are not registered as a TO.

TP and PC Questions

4) Do you have publicly posted planning requirements or other policies, criteria, protocols, or guidance in alignment with Essential Action #1?
   A. Yes
   B. No
   C. Not Applicable: This entity is not registered as a TP or a PC.
5) If "No" to Question 4, when do you plan to implement these changes to align with Essential Action #1?
   A. 2025
   B. 2026
   C. 2027
   D. No Plans to Update
   E. Not Applicable: This entity is not registered as a TP or a PC.
6) Do you have modeling practices and study processes in alignment with Essential Action #2?

A. Yes

B. No

C. Not Applicable: This entity is not registered as a TP or a PC.

7) If "No" to Question 6, when do you plan to make the recommended enhancements to align with Essential Action #2?

A. 2025

B. 2026

C. 2027

D. No Plans to Update

E. Not Applicable: This entity is not registered as a TP or a PC.

8) In the free text box below, please summarize any additional details or narratives that may clarify your answers. Please note that a response to this question is NOT REQUIRED, but strongly encouraged to help inform future assessment and mitigation efforts. Please enter "NA" if no further information is provided or you are not registered as a TP or PC.

GO Questions

9) Do you currently have internal processes that align with the details in Essential Action #4?

A. Yes

B. No

C. I do not own any IBR or am not registered as a GO.

10) If "No" to Question 9, when do you plan to implement these changes to align with the details in Essential Action #4?

A. 2025

B. 2026

C. 2027

D. No Plans to Update

E. I do not own any IBR or am not registered as a GO.

11) Do you have internal processes to accurately confirm the actual dynamic performance of the plant following events on the system compared to the IBR model?

A. Yes

B. No

C. I do not own any IBR or am not registered as a GO

12) Do you have internal processes to update and inform applicable transmission entities when changes are made to the IBR that can alter the IBR's performance?

A. Yes

B. No

C. I do not own any IBR or am not registered as a GO

13) In the free text box below, please summarize any additional details or narratives that may clarify your answers. Please note that a response to this question is NOT REQUIRED, but strongly encouraged to help inform future assessment and mitigation efforts. Please enter "NA" if no further information is provided or you are not registered as a GO.

Additional Information:

On the North American BPS, both the frequency and magnitude of major, IBR-related disturbances have been increasing significantly since 2016. These major disturbances have been observed in areas with large penetrations of IBR. NERC expects that if the systemic deficiencies with IBR performance and modeling are not mitigated, this trend will continue to grow in proportion with IBR penetration.

The following links provide additional information on previous major events, NERC IBR activities, and best practices:

- *Level 2 Industry Recommendation: Inverter-Based Resource Performance Issues*
- *Inverter-Based Resource Performance Issues Public Report*
- *Level 2 Industry Recommendation: Inverter-Based Resource Model Quality Deficiencies*
- *Inverter-Based Resource Model Quality Deficiencies Public Report*
- *Blue Cut Fire Disturbance Report*
- *Canyon II Fire Disturbance Report*
- *Angeles Forest and Palmdale Roost Disturbance Report*
- *San Fernando Disturbance Report*
- *Odessa 2021 Disturbance Report*
- *Victorville, Tumbleweed, Windhub, and Lytle Creek Fire Disturbance Report*
- *Texas Panhandle Wind Disturbance Report*

- *Odessa 2022 Disturbance Report*
- *Southwest Utah Disturbance Report*
- *California Battery Energy Storage System Disturbances Report*
- *NERC Dynamic Modeling Recommendations*
- *NERC IBR Strategy*
- *NERC EMT Modeling Guideline*

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