

Odessa Disturbance Follow-Up

NERC Inverter-Based Resource Performance Working Group (IRPWG)

White Paper – October 2021

This brief white paper was developed by the NERC Inverter-Based Resource Performance Working Group (IRPWG) as a follow-up to the Odessa Disturbance Report published by NERC in October 2021.¹ That report contained a set of key findings and recommendations. The IRPWG discussed each of the key findings and recommendations in detail and is providing a brief technical discussion and technical basis for each recommendation. Where appropriate, follow-up action items are identified. Table 1 shows the recommendations and actions needed from Chapter 3 of the NERC disturbance report on the left-hand column and the IRPWG follow-up and recommendations for each item in the right-hand column.

The following are the recommended actions from the IRPWG review:

1. FERC and NERC should collaboratively modernize the interconnection study process and applicable NERC Reliability Standards to ensure that 1) the recommendations outlined in the reliability guidelines are effectively and consistently converted to performance requirements for inverter-based resources. These requirements should not be overly burdensome nor discriminatory, yet should be clear, detailed, and effective in ensuring that developers, equipment manufacturers, and GOs understand the performance requirements needed to ensure reliable operation of the BPS moving forward.
2. IRPWG will develop standard authorization requests (SARs) related to a number of existing standards and possibly the addition of new standards to address the issues described below.
3. IRPWG will conduct a comprehensive assessment, taking into consideration the guidelines and reference documents developed thus far, to determine any performance gaps not addressed by the NERC Reliability Standards and will provide recommendation for additional SARs, where applicable. This assessment will also specifically evaluate the need for any inverter-specific performance requirements language.

¹ https://www.nerc.com/pa/rrm/ea/Documents/Odessa_Disturbance_Report.pdf

4. IRPWG will continue to develop guidelines, technical reference documents, and white papers to support industry advancements in the reliable integration of BPS-connected inverter-based resources. IRPWG will also support any other activities needed to advance industry efforts and help modernize and improve the process in which these resources are interconnected, modeled, studied, analyzed, and operated.

Table 1: Review of Disturbance Report Findings and Recommendations

#	Recommendation	IRPWG Follow-Up
Improved Requirements and Processes		
1	<p>Adoption of Reliability Guidelines: While the IRPWG reliability guidelines are some of the most downloaded guidelines produced and most widely used across the industry, it is clear that industry is not adopting the recommendations contained within NERC reliability guidelines. GOs, GOPs, developers, and equipment manufacturers should adopt the performance recommendations provided in the NERC reliability guidelines. All TOs should establish (or improve) clear and consistent interconnection requirements for BPS-connected inverter-based resources to support the implementation of the NERC FAC-001-3 standard.</p>	<p>IRPWG has put a significant amount of time, effort, and expertise into developing clear recommended practices for industry in the areas of inverter-based resource performance, modeling, and studies. It is reassuring that industry is well-aware of the guidelines and that they are having a positive impact on industry efforts to-date. However, it is clear that the guidelines are not being adopted comprehensively due to numerous challenges related to the development of connection requirements, modifications to TOs’ transmission tariffs, and other factors.</p> <p>Clear, consistent, and comprehensive performance requirements that are fair, just, and reasonable are strongly needed. Unclear requirements (lack of specificity and detail) have led to significant confusion by the industry as they continue interconnecting new technologies, which have led to many different reliability issues across the multiple NERC disturbance reports published. In most cases, the causes for solar PV reduction have been previously documented in reliability guidelines seeking improvements to correct the performance issues; however, the issues continue to occur (and new ones are being identified) because the guidelines are not being widely implemented. This needs to be addressed by a regulatory framework change.</p>
2	<p>Improvements to Interconnection Process: As stated, the NERC reliability guidelines are not being widely adopted in a comprehensive manner, leaving gaps in reliable interconnection of BPS-connected inverter-based resources. Significant improvements are needed to the FERC Generator Interconnection Process (GIP) and Generator Interconnection Agreement (GIA) that include comprehensive requirements that must be met during the interconnection process. These requirements should be clear, consistent, and ensure reliable operation of these resources prior to commercial operation of the facility. Presently, plants are being interconnected in an unreliable manner with inadequate studies to appropriately identify these issues ahead of commercial operation. These issues need to be addressed in the GIP and GIA, and they should not be left up to individual interconnecting TOs to address using only the NERC FAC-001-3 requirements.</p>	<p>IRPWG supports a modernization and revamping of the performance requirements for inverter-based resources (and all generating resources) to ensure clarity, consistency, and minimal compliance burden. Either or both updates to the NERC reliability standards or improvements to the FERC generator interconnection process are needed to facilitate this modernization.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG has not identified a specific follow-up action item for this recommendation; however, IRPWG is willing to support advancements in</p>

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		this area moving forward (see rows below). IRPWG is willing to serve as a body of subject matter experts to support FERC in any revisions to the GIA/GIP.
NERC Standards Updates Needed to Address Performance Gaps in Inverter-Based Resources		
	<p>Significant NERC Standards Updates Needed Related to Performance: The systemic nature of these events across multiple interconnections and a wide range of facilities, many of which are recently energized, warrants significant enhancements to the NERC Reliability Standards to address gaps in BES inverter-based resources. As reported in this disturbance report (and building on past reports published by NERC), the following recommendations are provided. The NERC RSTC should facilitate and ensure the development of SARS to address each of the following issues:</p>	See rows below.
3	<ul style="list-style-type: none"> • Performance Validation Standard Needed: TOPs, RCs, BAs (in coordination with the TP and PC) should have the capability to seek corrective actions to plants that are not performing adequately based on the requirements imposed on them at the time of interconnection. Any abnormal performance identified in real-time should be compared against the models provided during time of interconnection (or any material modification to the facility) as well as based on a comparison of any applicable interconnection requirements in place. Abnormalities in plant performance should be reported to NERC and the Regional Entity and should be corrected by the GO in a timely manner. Persistent deviations of performance from expectations are not acceptable. 	<p>IRPWG has repeatedly highlighted the criticality of TOs improving their interconnection requirements per FAC-001-3. IRPWG published NERC Reliability Guideline: Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources, which strongly recommends all TOs adopt the detailed recommendations laid out in their interconnection requirements. As industry continues to make improvements to their requirements, they need a clear and consistent means of ensuring that the requirements are adhered to and that corrective actions are taken if any abnormal performance is identified. In essence, a closed loop feedback is needed to ensure that those corrective actions are taken when abnormalities are identified.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will develop a SAR regarding revisions to FAC-001-3 and FAC-002-2 to ensure that: 1) TOPs, RCs, and BAs that identify abnormal performance issues can work with the GO to seek corrective actions for resources not meeting their established interconnection requirements, 2) seek improvements to the requirements developed by the TO, TP, or PC (per FAC-001-3 or FAC-002-2) if gaps are identified, and 3) that those abnormal performance issues are reported to NERC for continued risk assessment. The standard will need to consider how to handle legacy equipment that has equipment limitations and cannot be modified; however, the standard should seek to ensure effective feedback loops for improvements are developed.</p>

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4	<ul style="list-style-type: none"> Ride-Through Standard to Replace PRC-024-3: The original intent of the PRC-024 standard was to ensure that plants remain connected to the BPS during frequency and voltage excursions. This was approved only as a protective relaying standard, but then caused significant confusion for inverter-based resource controls and protection within the individual inverters. Additionally, the events analyzed by NERC regarding fault-induced reductions in solar PV output and wind output have identified issues with controls and protections unrelated to voltage and frequency. For example, PLL loss of synchronism, sub-cycle ac overvoltage protection, dc reverse current, and wind converter crowbar failure are all examples of widespread tripping that are not addressed by PRC-024-3. Furthermore, industry continues to misinterpret PRC-024-3 and continues to set seemingly unnecessary voltage and frequency protection within facilities “for compliance reasons” even though the standard was updated to address this confusion. The growing evidence leads NERC to recommend that a ride-through standard focusing specifically on generator ride-through performance should be developed and implemented on an expedited timeline. 	<p>IRPWG submitted a SAR seeking improvements to PRC-024-2 (resulting in PRC-024-3); however, it is clear from the Odessa disturbance and other disturbances that resources are tripping for issues outside the scope of PRC-024-3 and that further action is needed to address a reliability gap in resource performance. The Odessa Disturbance Report outlines the challenges and misinterpretation with the existing standard. IRPWG has observed similar issues over the years and supports the enhancement of PRC-024-3 to a generator² protection and control ride-through standard. The standard may not need to include generator auxiliary bus protection; protection and controls on the generator and collection system (GSU, collector system, etc.) should be the primary focus as they present the greatest risks as observed in multiple large-scale disturbances. The standard should be written in a performance-based manner, and not focus specifically on documentation. Resources failing to ride through normal grid disturbances should be identified and corrective actions should be implemented. IEEE P2800 activities can serve as a useful reference but should not be considered a replacement for this standard.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will develop a SAR regarding revisions to PRC-024-3 to the effect described above, focusing specifically on all forms of protection and controls of the generator and collection systems associated with the resource (not protection of auxiliary systems). The SAR will ensure that PRC-024 revisions focus on a performance-based approach to resource ride-through for the plant rather than on only focusing on the protection system documentation alone.</p>
5	<ul style="list-style-type: none"> Analysis and Reporting for Abnormal Inverter Operations: Inverter-based resource power reductions of more than 75 MW in aggregate per facility should be analyzed and reported. While this may not be the present intent of the PRC-004 standard, the standard scope should be extended (or another standard introduced) to ensure that abnormal power reductions are analyzed, reported, and corrected in a timely manner. Ongoing, persistent tripping or reductions in 	<p>As identified in multiple NERC disturbance reports, generator owners of solar PV facilities are often unaware of abnormal performance of the resource; however, when many resources are systemically performing abnormally, the BA, TOP, or RC will identify an event and report it to NERC if it meets the Category 1i criteria (or other applicable criteria). This approach does not ensure proactive mitigation of abnormal inverter-based resource performance issues before they elevate to a large disturbance. Therefore, IRPWG supports the extension of analysis and reporting of resource performance issues identified by the TOP, RC, or BA in an effort to seek better performance from inverter-based resources moving forward. This would</p>

² This includes generator-specific protection and controls such as on machines and on inverters, and also includes plant-level protection and controls on the feeder/collector lines and at the plant-level controller.

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	<p>inverter-based resources is the present situation and should not be considered acceptable.</p>	<p>include extending the focus solely on protection systems to both protection within control systems and controls that cause abnormal reductions in output.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will develop a SAR regarding either revisions to PRC-004 or a new standard that focuses specifically on analyzing, reporting, and correcting the abnormal performance of BES generating resources. These revisions may link with those identified above regarding the performance validation standard. Both topics may be accomplished with a singular SAR.</p>
6	<ul style="list-style-type: none"> • Monitoring Data: NERC should ensure that recording at all BES inverter-based resources includes plant-level high resolution oscillography data, plant SCADA data with a resolution of 1-second, sequence of events recording for all inverters that include all fault codes, and at least one inverter on each collector system configured to capture high resolution oscillography data within the inverter. These are standard features for modern inverters that should be enabled within all facilities to better understand their response to grid events and improve overall fleet performance. The Project 2021-04 Standard Drafting Team should consider whether these recommendations are within scope and adopt as possible. Otherwise, a future standards project should address this issue. 	<p>IRPWG has published reliability guidelines seeking these same monitoring capabilities from all newly connecting BPS-connected inverter-based resources. IRPWG submitted a SAR for PRC-002-2 seeking improvements to ensure sufficient monitoring capability is available.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will engage the Project 2021-04 Standard Drafting Team leadership to determine if any of the recommendations are within scope of their project. IRPWG will develop a follow-on SAR if any recommendations outlined in the Odessa report are not being adopted by the SDT presently.</p>
7	<ul style="list-style-type: none"> • Inverter-Specific Performance Requirements: The NERC IRPWG conducted an assessment of existing NERC Reliability Standards that should be updated to ensure clarity and consistency for inverter-based resources; however, the assessment did not comprehensively consider performance characteristics specific to inverter-based resources that should be addressed by a NERC Reliability Standard. This assessment should be conducted by the NERC IRPWG and any necessary SARs should be produced through the RSTC: <ul style="list-style-type: none"> ○ As one example, the absence of return to service timing requirements established consistently by 	<p>The IRPWG published an inverter-based resource performance guideline in 2018 which was one of the drivers for the IEEE P2800 efforts presently underway. IRPWG has supported the advancement in standardization of resource performance from inverter-based resources as they become a prominent component of the generation mix. Improving levels of standardization, and clear and consistent performance requirements for these resources (where needed) will help ensure reliable operation of the BPS moving forward.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will conduct a comprehensive assessment, considering all guidelines and technical reference documents developed thus far, including IEEE P2800, to determine any performance gaps not addressed by the NERC Reliability Standards and will provide recommendation for additional SARs, where applicable.</p>

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	<p>BAs has introduced unexpected and anomalous behavior from inverter-based resources when returning from “minor faults” that trip the facility off-line. Furthermore, the lack of specifications around return-to-service could introduce challenges and complexity for RCs and TOPs in the event of a widespread outage conditions during blackstart recovery. Industry is not adhering to the recommendations in the NERC guideline and this should be addressed in a standard or within the FERC GIA.</p> <ul style="list-style-type: none"> ○ Having inverter-specific requirements or standards has been considered by the SAR Drafting Teams focused on revisions to MOD-025, PRC-019, MOD-026, and MOD-027 given there are differences and unique characteristics of inverter-based resources that do not directly relate to synchronous generation. 	<p>Any modifications will seek to ensure the same outcome across resource types and ensure a similar intent is met with the language used in each standard requirement.</p>
NERC Standards Updates Needed to Address Modeling and Studies Gaps for Inverter-Based Resources		
8	<p>Requirements for Accurate EMT Models at Time of Interconnection: The existing NERC FAC-001 and NERC FAC-002 standards provide too much leverage and have led to inconsistency in how TPs and PCs are gathering modeling information and conducting interconnection studies. As the penetration of inverter-based resources is growing across North America, all TPs and PCs should have clear requirements to gather EMT models at the time of interconnection and execute EMT studies to ensure proper ride-through performance for BPS fault events. Presently, the approaches taken by industry are leading to modeling and study gaps and consequently unreliable performance of inverter-based resources once interconnected. The FAC-001 and FAC-002 standards more clearly align with the FERC GIP and GIA to clearly specify the models required and the studies to be conducted at the time of interconnection.</p>	<p>IRPWG has talked in depth about the need for improved EMT modeling capabilities and included detailed recommendations for improvements to interconnection requirements to gather accurate EMT models during the time of interconnection. IRPWG supports updates to interconnection requirements to ensure accurate EMT models are provided during the interconnection process. Further, EMT models are increasingly being required during the interconnection process; however, there is insufficient time with the pro forma GIP timelines to conduct adequate EMT studies. This has led to significant complications in the study process in areas of high penetrations of inverter-based resources.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will develop a SAR to incorporate EMT modeling (and model validation) requirements and EMT study requirements for the interconnection study process. FAC-002-2 will be reviewed to determine the best strategy for incorporating these types of requirements. IRPWG will also develop a white paper specifically aimed at policy makers to clarify EMT modeling considerations and trade-offs as planning groups begin to adopt EMT into their planning processes.</p>

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9	<p>Update to NERC MOD-032 to Include EMT: The NERC MOD-032 standard is used by TPs and PCs to ensure appropriate models for performing system studies are provided by equipment and data owners. Presently, it is unclear how EMT models are treated in this standard and this lack of clarity needs to be addressed with a standard revision. EMT models should be made available by GOs to ensure system studies are conducted in the planning horizon for growing levels of inverter-based resources, not just for newly interconnecting facilities. Larger-scale EMT studies will likely be needed in the future as penetration levels continue to rise.</p>	<p>Industry has had significant challenges with the implementation of MOD-032, particularly around how to use models being validated under MOD-025, MOD-026, and MOD-027. IRPWG submitted SARs seeking improvements to those standards but did not address issues with MOD-032. Presently, MOD-032 is silent with respect to the collection of EMT models for any large-scale studies. Further, MOD-032 can be improved to ensure that the appropriate models are provided during the annual case creation processes. While EMT modeling is still relatively new to many entities, it is becoming widely used and needed in many areas with high penetrations of inverter-based resources. To prepare for a future with significantly more inverter-based resources on the BPS, IRPWG support efforts towards ensuring that the modeling efforts and case creation processes provide clarity on how to handle EMT models. In situations where the TP or PC need the ability to develop a large-scale EMT model, they need to have the authority and capability to do so for reliability study purposes. The recommendation by NERC for ERCOT to conduct a system-wide model validation using EMT models (see ERCOT-specific recommendations in the Disturbance Report) is an excellent example of the need for collecting these models.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will develop a SAR to ensure that EMT modeling is included in the MOD-032 efforts and that MOD-032 is clear on using accurate and validated models.</p>
10	<p>Updates to Ensure Model Quality Checks and Model Improvements: GOs need to provide accurate models to the TPs and PCs based on existing requirements. A feedback loop to ensure model accuracy (for any type of model) is only an optional specification in the existing MOD-032 standard. Model quality checks should be conducted by all TPs and PCs, and any modeling errors should be addressed by the equipment owner (i.e., the GO) in a timely manner. Model quality reviews should include more than just model usability—they should check for model parameterization issues or inconsistencies against plant performance to real events.</p>	<p>These issues also stem from complexities during the interconnection study process and the need for more transparent modeling practices and model quality checks conducted by the TP and PC. Without conducting model quality checks, TPs and PCs are running studies with models (positive sequence dynamic models and EMT models) fraught with errors, which has led to resources operating in an unreliable manner (as observed in the Odessa disturbance). These issues need to be corrected, and TPs and PCs should be conducting detailed model quality and model performance checks during the interconnection study process and during annual planning assessments. Any model errors identified should be corrected.</p> <p>Recommended Action from IRPWG Follow-Up: IRPWG will develop a SAR to ensure that model quality and model performance checks are conducted during the interconnection study process (FAC-002-2) and annual case creation process (MOD-032), and that model improvements are made by the generator owner. Those checks should clearly include model parameter validation to ensure that the models actually reflect the as-built equipment in the</p>

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		field. This applies to both positive sequence dynamic models and EMT models for existing in-service facilities (and newly interconnecting resources).
ERCOT Recommended Actions		
IRPWG did not review the ERCOT-specific recommendations.		