

IRPTF Review of NERC Reliability Standards

NERC Inverter-Based Resource Performance Task Force (IRPTF)

White Paper - March 2020

Executive Summary

The electric industry is still experiencing unprecedented growth in the use of inverters as part of the bulk power system and growth is possibly creating new circumstances where current standards may not be sufficiently addressing those needs. As a result, the NERC Planning Committee (PC) and Operating Committee (OC) assigned the task of evaluating today's current standards and requirements to the Inverter-Based Performance Task Force (IRPTF). This white paper details the findings of the IRPTF as a result of this activity and makes recommendations on actions that should be taken to address the issues identified.

Recommendations

The IRPTF identified potential gaps and areas for improvements in the following standards, and makes the following recommendations:

1. **FAC-001-3 and FAC-002-2** should be revised to: (a) clarify which entity is responsible for determining which facility changes are materially modifying, and therefore require study, (b) clarify that a Generator Owner should notify the affected entities before making a change that is considered materially modifying, and (c) revise the term "materially modifying" so as to not cause confusion between the FAC standards and the FERC interconnection process;
2. **MOD-026-1 and MOD-027-1** should either be revised or a new model verification standard should be developed for inverter-based resources (IBRs) since these standards stipulate verification methods and practices which do not provide model verification for the majority of the parameters within an inverter-based resource. For example, the test currently used to comply with MOD-026-1 does not verify the model parameters associated with voltage control behavior during large disturbance conditions;
3. **PRC-002-2** should be revised to require disturbance monitoring equipment in areas not currently contemplated by the existing requirements, specifically in areas with potential inverter-based resource behavior monitoring benefits;
4. Clarifications should be made to **TPL-001-4** to address terminology throughout the standard that is unclear with regards to inverter-based resources the next time the standard is revised. This terminology was not changed in the recently FERC-approved **TPL-001-5** version of the standard; and
5. **VAR-002-4.1** should be revised to clarify that the reporting of a status change of a voltage controlling device per Requirement R3 is not applicable for an individual generating unit of a dispersed power producing resource, similar to the exemption for Requirement R4.

The IRPTF did not identify issues with the existing standard language in the BAL, CIP, COM, EOP, INT, IRO, NUC, PER, or TOP NERC Reliability Standards.

The IRPTF recommends that a Standards Authorization Request (SAR)s be developed to address each of the issues identified. IRPTF recommends that this be made a priority by the NERC Standards Committee, due to the continued growth of BPS-connected inverter-based resources.

Background

The IRPTF was formed in 2017 following several grid disturbances involving IBRs. In 2018, the PC and OC approved an IRPTF-developed white paper¹ on identified gaps in PRC-024-2 based on IRPTF's findings following investigations of the grid disturbances. Subsequently, a SAR to modify PRC-024-2 based on the white paper was endorsed by the PC and OC and approved by the NERC Standards Committee. This led to the formation of a Standards Drafting Team (SDT) to modify PRC-024-2.

In 2019, the IRPTF undertook an effort to perform a comprehensive review of all NERC Reliability Standards to determine if there are any further potential gaps or improvements beyond what was identified for PRC-024-2, based on the work and findings of the IRPTF. To accomplish this activity, IRPTF volunteers reviewed all of the current and future enforceable reliability standards, identified potential gaps or improvements, and presented findings to the entire IRPTF. The IRPTF reviewed these findings and finalized a set of recommendations.

The IRPTF acknowledges that the findings in this whitepaper are limited by the knowledge of its members and other issues may be discovered as industry and technology continues to evolve and grow. Any such issues may be addressed through the NERC technical committee or Standards Committee processes. In particular, the IRPTF acknowledges that it did not have subject matter experts in regards to the CIP, COM, NUC, and PER standards. Nevertheless, the IRPTF performed a cursory review of these standards and did not identify any potential gaps or improvements related to IBRs.

A similar review was also conducted as part of NERC Project 2014-01 for dispersed power producing resources.² However, industry knowledge of IBR technology and experience with NERC Reliability Standards implementation has evolved since that project was completed. For example, the Project 2014-01 efforts led to revisions of PRC-024-1, but those efforts did not capture the issues IRPTF identified in the PRC-024-2 Gaps Whitepaper.

FAC Standards Issues

The IRPTF identified issues with FAC-001-3 and FAC-002-2 that should be addressed. The IRPTF did not identify any issues with any other FAC standards.

FAC-001-3 and FAC-002-2

¹ PRC-024-2 Gaps White Paper, <https://www.nerc.com/pa/Stand/Project%20201804%20Modifications%20to%20PRC0242/NERC%20IRPTF%20PRC-024-2%20Gaps%20Whitepaper.pdf>

² Project 2014-01 Whitepaper, https://www.nerc.com/pa/Stand/Prjct201401StdndsAppDispGenRes/DGR_White_Paper_v17_clean_01_13_2016_Final_rev1.pdf

The purpose of FAC-001-3 is to ensure that Facility interconnection requirements exist for Transmission Owners and Generator Owners (GO)s when connecting new or materially modified facilities. The purpose of FAC-002-2 is to ensure studies are performed to analyze the impact of interconnecting new or materially modified facilities on the Bulk Electric System (BES). An ambiguity exists in these standards for both synchronous resources and IBRs, but it may be amplified for IBRs that are comprised of many smaller individual units connected through a network of collection feeder circuits.

Both standards imply that the term “materially modified” should be used to distinguish between facility changes that are required to be studied and those that need not be studied. However, there is not a requirement for any entity to determine what changes are to be considered materially modifying and GOs are not required to notify potentially affected entities of the changes. This has led to confusion and potential reliability issues within industry. For example, a Transmission Planner (TP) may consider an IBR control system software change to be materially modifying, but if the GO does not consider such a change to be materially modifying they will not notify the TP of the change.

Additionally, the frequency of change of components could be higher for IBRs and the magnitude of such changes could vary. For example, due to a rapid change in wind turbine generator (WTG) technology, it is a common practice to re-power an existing wind power plant with bigger blades while keeping the same electrical generator and converter systems (for both Type 3 and Type 4 WTGs). This may be considered a material modification since a new set of bigger blades (e.g., 93 m to 208 m) can produce more power at a lower wind speed. However, the nameplate rating of the plant will remain unchanged. From an interconnection requirements’ perspective, it is the electrical generator and converter system that impacts the majority of the steady-state, short-circuit, and dynamic characteristics and therefore will be mostly unchanged. Therefore, the question remains if these sort of repowering projects should be studied under FAC-002-2 R1 and which entity should make that determination. Therefore, the IRPTF recommends these standards be modified to specify which entity is responsible for determining what facility changes should be considered materially modifying and requiring that Generator Owners notify the appropriate affected entities before they make such a change.

The IRPTF further notes that if the plant owner makes a change in electrical generator, power electronic converter, or any control systems (including change of OEMs for partial individual units), it should be considered as “materially modifying”. On the other hand, due to the advanced nature of control systems in the power electronic converters, it is not uncommon to have firmware updates (similar to the updates on a personal computer) occasionally that may have no impact on the functionalities of the WTGs or plant-level controls in any way. Therefore, such firmware updates that do not affect the electrical performance of the plant should not be considered as “materially modifying”.

Additionally, in FERC-jurisdictional areas, the term “Materially Modification” refers to a new generation project’s impact on other generators in the interconnection queue. This has led to widespread confusion across the industry regarding the correct application of these terms related to the FERC Open Access Transmission Tariff (OATT) implementation and the NERC Reliability Standards requirements. The application of these terms is different between the FERC process and the NERC Reliability Standards (specifically FAC-001-3 and FAC-002-2). For example, if a GO changes out the inverters on an existing solar

PV resource, the change may have no impact on other generators in the interconnection queue, and thus would not be considered a material modification under the FERC OATT rules. But such a change could have reliability impacts on the system that should be studied in accordance with FAC-002-2. Any revision to these standards should consider changing the term to avoid this confusion. FAC-001-3 and FAC-002-2 should be modified to clarify the use of “materially modifying”, particularly as it relates to compliance with the standards.

MOD Standards Issues

The IRPTF identified issues with MOD-026-1 and MOD-027-1 that should be addressed. The IRPTF did not identify any issues with any other MOD standards that are not already being addressed in other forums.

MOD-026-1 and MOD-027-1

MOD-026-1 and MOD-027-1 require, among other things, GOs to provide verified dynamic models to their TP for the purposes of power system planning studies. Both standards contain language that is specific to synchronous generators and is not applicable to IBRs. For example, sub-requirement 2.1.3 in MOD-026-1 states that each verification shall include “model structure and data including, but not limited to reactance, time constants, saturation factors, total rotational inertia” The standards should be revised to clarify the applicable requirements for synchronous generators and IBRs. For example, total rotational inertia should not be required for IBRs, while voltage ride-through control settings should only be required of IBRs and not synchronous generators.

To some degree, all dynamic model parameters affect the response of a represented resource in dynamic simulations performed by power engineers. Accurate model response is required for the engineers to adequately study system conditions. Hence, it is crucial that all parameters in a model be verified in some way. However, a significant number of parameters in the models are not verified in the typical verification tests used to comply with MOD-026-1 and MOD-027-1. For example, the test currently used to comply with MOD-026-1 does not verify the model parameters associated with voltage control behavior during large disturbance conditions.

This issue is one of the predominant reasons why ride-through operation modes such as momentary cessation were able to persist and promulgate in IBRs without the knowledge of planners and system operators until the Blue Cut Fire and Canyon 2 Fire events exposed them. The dynamic models did not accurately represent this large disturbance behavior due to the model deficiency and because certain key parameters that govern large disturbance response were incorrectly parameterized. However, many of the same plants that entered momentary cessation mode during these events were able to provide verification reports that demonstrated that the small disturbance behavior driven mainly by plant-level control settings reasonably matched modeled performance in compliance with these standards.

This reliability gap exists for both synchronous generators and IBRs. However, it is potentially more severe for IBRs since their behavior is based more on programmable control functions than for synchronous generators which have behavior that is based more on the physical characteristics of the machine. Both MOD-026-1 and MOD-027-1 should be reviewed and potentially revised to provide sufficient clarification for verification of generating resource model parameters, or a new standard should be developed to meet

the reliability objective. Additionally, the IRPTF notes that it is not feasible to stage large disturbances for verification purposes, so other methods for verification of model performance under large disturbance conditions may need to be developed.

PRC Standards Issues

The IRPTF identified issues with PRC-002-2 that should be addressed. The IRPTF did not identify any issues with any other PRC standards that are not already being addressed in other forums.

PRC-002-2

The purpose of the NERC standard PRC-002-2 is to have adequate data available to facilitate analysis of BES disturbances. Requirements R1 and R5 provide guidance on selecting BES elements where data monitoring is required, which is summarized briefly below.

1. Per Requirement R1 (which uses criteria outlined in Attachment 1), Sequence of Event Recording (SER) and Fault Recording (FR) devices are required at BES buses with high short circuit MVA values. The methodology identifies the top 20 percent of BES buses with highest short circuit MVA values and requires a subset of these buses to be monitored for SER and FR data.
2. Requirement R5, identifies BES locations based on a size criteria for generating resources and other critical elements such as HVDC, IROs and elements of UVLS program, for which Dynamic Disturbance Recording (DDR) data is required. In regard to generation resources, it includes requirements for monitoring at sites with either gross individual nameplate rating of greater than or equal to 500 MVA or gross individual nameplate rating greater than or equal to 300 MVA where gross plant/facility aggregate nameplate rating is greater than or equal to 1000 MVA.

Requirements R1 and R5 are written with a focus on synchronous machine dominated systems. The BES elements with short circuit MVA in the top 20% are typically elements at baseload generating plants with multiple generating units or BES elements within a heavily meshed transmission network usually close to large load centers. IBRs do not contribute much fault current and are usually interconnected in remote parts of the system. As such, the short circuit MVA for the point of interconnection (POI) bus and nearby BES buses is not expected to be in the top 20%. Hence, BES buses near these resources are more likely to be omitted from requiring SER and FR data monitoring. In addition, most IBRs do not meet the nameplate rating criteria outlined in Requirement R5. With increasing penetration of IBRs, it is important that some of these resources and nearby BES elements are monitored with DDR and SER/FR devices, respectively.

Recent disturbance analyses of events involving IBRs including the Blue Cut Fire and Canyon 2 Fire have demonstrated the lack of disturbance monitoring data available from these facilities and nearby BES buses to adequately determine the causes and effects of their behavior. None of the IBRs involved in these two events met the size criteria stated in PRC-002-2 to be required to have disturbance monitoring. Additionally, none of the buses near the IBRs met the criteria in Requirement R1 for being required to have SER and FR devices since the IBRs inherently produce very little fault current. This led to difficulty in adequately assessing the events.

With the changing resource mix and increasing penetration of IBRs, PRC-002-2 does not serve its intended purpose adequately. To the extent that the standard is already requiring monitoring devices, the location requirements need to be revised. These revisions are necessary so that required data is available for the purposes of post-mortem event analysis and identifying root causes of large system disturbances.

TPL Standards Issues

The IRPTF did not identify any requirements that may need to be changed in TPL-007-3, Transmission System Performance for Geomagnetic Disturbance Events, or the upcoming revisions to the standard. The IRPTF did identify several clarifications that may be helpful in the requirements of TPL-001-4, Transmission System Planning Performance Requirements. However, these clarifications are minor in nature and do not warrant changing the standard at this time. These clarifications should be considered by a subsequent SDT if the standard is revised in the future.

TPL-001-4

TPL-001-4 requires Planning Coordinators (PCs) and TPs to assess the reliability of their portion of the BES for various conditions across several specified future years and to plan Corrective Action Plans to address identified performance deficiencies. The requirements and sub-requirements include, among other things, certain simulation assumptions to be used by the planner and performance requirements.

Sub-requirements 3.3 and 4.3 describe simulation assumptions that the planner should use when performing contingency analysis for the steady-state and stability portion of the assessment, respectively. Sub-requirements 3.3.1.1 and 4.3.1.2 each require the planner to include the impact of the “tripping of generators where simulations show generator bus voltages or high side of the [GSU] voltages are less than known or assumed generator” low voltage ride-through capability.

The term GSU transformer can be confusing to GOs of IBR facilities because they will often refer to the transformer that steps the voltage up from the individual inverter (e.g., 600 V) to the collector system voltage (e.g., 34.5 kV). In this case, there is usually another transformer (i.e., the MPT) to step the voltage up from the collector system voltage to transmission system voltage. It was likely the intent of the TPL-001-2 SDT to be referring to transmission system voltages when drafting the language that refers to known or assumed generator low voltage ride-through capability at the high-side of the GSU. Therefore, the language in these sub-requirements should be modified to provide clarity for inverter-based resources.

Sub-requirements 4.1.1 and 4.1.2 provide stability performance criteria when a generator “pulls out of synchronism” in system simulations. Although an inverter-based resource does synchronize with the grid, the phrase “pulls out of synchronism” is typically applicable only to synchronous generators, referring to when a synchronous machine has an angular separation from the rest of the grid. Therefore, these sub-requirements could be clarified by clearly stating that this performance criteria is for synchronous generators.

Sub-requirement 4.3.2 specifies that stability studies must “simulate the expected automatic operation of existing and planned devices designed to provide dynamic control of electrical system quantities when such devices impact the study area.” It then contains a list of example devices that have dynamic behavior. Not

included in this list are power plant controllers and inverter controls, which often dominate the dynamic response of IBRs. While the sub-requirement does not preclude the simulation of plant-level controllers and inverter controls, it would add clarity if they were added to the list.

The suggested clarifications for sub-requirements 3.3, 4.3, 4.1.1, 4.1.2, and 4.3.2 should be considered by a future SDT when editing the standard. However, the IRPTF does not believe the clarifications by themselves warrant changing the standard at this time. It should be noted that the identified issues with TPL-001-4 also apply to the draft TPL-001-5 standard that is awaiting FERC approval as of the publication of this whitepaper.

VAR Standards Issues

The IRPTF identified issues with VAR-002-4.1 that should be addressed. The IRPTF did not identify any issues with any other VAR standards.

VAR-002-4.1

The purpose of VAR-002-4.1 is “to ensure generators provide reactive support and voltage control, within generating Facility capabilities, in order to protect equipment and maintain reliable operation of the Interconnection.” Requirement R3 requires each Generator Operator (GOP) to notify its Transmission Operator (TOP) of a status change on “the AVR, power system stabilizer, or alternative voltage controlling device within 30 minutes of the change.” Requirement R4 is similar in that it requires each GOP to notify its TOP of “a change in reactive capability due to factors other than a status change described in Requirement R3.”

For dispersed power producing resources, it is not clear if a GOP is required to notify the TOP for the status change of voltage control on an individual generating unit. For example, if an IBR consisting of one hundred inverters has one inverter trip out of service, is the GOP required to notify the TOP per Requirement R3? NERC Project 2014-01 revised VAR-002 Requirement R4 to clarify that it is not applicable to individual generating units of dispersed power producing resources. The IRPTF did not identify any reason why Requirement R3 should be treated differently than Requirement R4 in this respect and recommends VAR-002-4.1 be modified to make this same clarification to Requirement R3.

Conclusion and Recommendation

The IRPTF performed a comprehensive review of NERC Reliability Standards to determine if there were potential gaps for improvements based on the work and findings of the IRPTF. The outcome of this analysis includes the following recommendations:

1. **FAC-001-3 and FAC-002-2** should be revised to address the issues described herein;
2. **MOD-026-1 and MOD-027-1** should either be revised to address the issues described herein or a new model verification standard should be developed for IBRs
3. **PRC-002-2** should be revised to address the issues described herein;
4. Clarifications should be made to **TPL-001-4** to address the issues described herein the next time the standard is revised. This recommendation also applies to the draft **TPL-001-5**; and
5. **VAR-002-4.1** should be revised to address the issues described herein.

The IRPTF recommends that a SAR(s) be developed to address each of the issues identified. IRPTF recommends that this be made a priority by the NERC Standards Committee, due to the continued growth of BPS-connected inverter-based resources.