

To: NERC Board of Trustees and Stakeholders

From: NERC Staff and Representatives from the Standards Committee

Re: Summary of Issues and Alternatives Considered, Proposed Reliability Standard PRC-029-1
(Frequency and Voltage Ride-through Requirements for Inverter-based Resources)

Date: September 24, 2024

In Order No. 901, the Federal Energy Regulatory Commission (“FERC”) directed the development of new or revised Reliability Standards to address certain reliability issues related to inverter-based resources (“IBRs”), including IBR ride-through performance.¹ To address the IBR ride-through directives, Project 2020-02 Modifications to PRC-024-4 initiated development of proposed Reliability Standard PRC-029-1 (Frequency and Voltage Ride-through Requirements for Inverter-based Resources). However, proposed Reliability Standard PRC-029-1 has failed to pass ballot through the usual standard development process.

Section 321 of the NERC Rules of Procedure allows the NERC Board of Trustees to take special actions when a ballot pool has failed to approve a proposed Reliability Standard that contains a provision to adequately address a specific matter identified in a directive issued by an Applicable Governmental Authority. The NERC Board of Trustees took such action for the proposed PRC-029-1 standard at its August 2024 meeting.²

Consistent with Section 321.2 of the NERC Rules of Procedure, the Standards Committee and NERC staff convened a technical conference from September 4-5, 2024 to discuss the issues surrounding the FERC Order No. 901 directives, including whether or not the proposed Reliability Standard PRC-029-1 is just, reasonable, not unduly discriminatory or preferential, in the public interest, helpful to reliability, practical, technically sound, technically feasible, and cost-justified. This memorandum discusses the issues, an analysis of alternatives considered, and other appropriate matters.

Background

On October 19, 2023, the Commission issued Order No. 901 directing the development of new or revised Reliability Standards to address reliability issues associated with the growth of IBRs on the Bulk-Power

¹ *Reliability Standards to Address Inverter-Based Resources*, Order No. 901, 185 FERC ¶ 61,042, Docket No. RM22-12-000 (Oct. 19, 2023) [hereinafter Order No. 901]. Available [here](#).

² NERC Board of Trustees, Minutes of the August 15, 2024, available [here](#).

System.³ The Commission directed NERC to develop new or revised Reliability Standards addressing IBR reliability issues as follows:

- 1) IBR disturbance monitoring data sharing and post-event performance validation⁴ and ride-through performance requirements⁵ by November 4, 2024;
- 2) IBR data and model validation⁶ by November 4, 2025; and
- 3) planning and operational studies⁷ for IBRs by November 4, 2026.

The Commission also directed NERC to develop and submit a work plan to develop new and revised Reliability Standards to address these issues in accordance with the specified timeframe.⁸

On January 17, 2024, NERC submitted its Order No. 901 Work Plan,⁹ which consists of key milestones to meet the Commission's directives by the filing deadlines mentioned above. **Milestone 2**, in progress, focuses on the development of Reliability Standards to address disturbance monitoring, performance-based ride-through requirements and post-event performance validation for registered IBRs by November 4, 2024.

The Reliability Standards being proposed to address **Milestone 2** of FERC Order 901 are being developed through the following projects:

- [Project 2020-02 Modifications to PRC-024 \(Generator Ride-through\)](#),
- [Project 2021-04 Modifications to PRC-002](#),
- [Project 2023-02 Analysis and Mitigation of BES Inverter-Based Resource Performance Issues](#)

As of this writing, Projects 2021-04 and 2023-02 are on track for timely completion through the usual NERC standard development process. Project 2020-02, addressing generator ride-through directives from Order No. 901, is the subject of special Board action under Section 321.

Specifically, proposed Reliability Standard PRC-029-1 (Frequency and Voltage Ride-through Requirements for Inverter-based Resources) is a draft standard designed to establish capability-based and performance-based ride-through requirements for IBRs during grid disturbances, to address the Commission directives from Order No. 901. The draft standard failed to achieve consensus from the Registered Ballot Body over

³ See Order No. 901, *supra*, at PP 229.

⁴ See *id.* at PP 66-109 (discussing directives related to data sharing requirements).

⁵ See *id.* at PP 178-211 (discussing directives related to performance requirements).

⁶ See *id.* at PP 110-161 (discussing directives related to data and model validation requirements).

⁷ See *id.* at PP 162-177 (discussing directives related to planning and operational studies requirements).

⁸ See *id.* at P 222.

⁹ Informational Filing of the North American Electric Reliability Corporation Regarding the Development of Reliability Standards Responsive to Order No. 901, (Docket No. RM22-12-000) (2024) [hereinafter Order No. 901 Work Plan].

multiple ballots, the latest of which occurred between August 2, 2024 to August 12, 2024. This called into question whether development would be completed by FERC's filing deadline of November 4, 2024.

As a result, the NERC Board of Trustees initiated the use of Section 321 at its August 15, 2024 meeting. Under this special authority, the Board directed the Standards Committee to work with NERC Staff to convene a technical conference to gather input from industry to address the outstanding issues and revise PRC-029-1. This memorandum describes the issues that led to the technical conference convening and the alternative solutions that were considered. The proposed PRC-029-1 standard has been revised using input from the technical conference and is submitted for stakeholder ballot. This process must be completed within 45 days of being initiated, which is September 30, 2024. If the re-balloted proposed Reliability Standard achieves at least an affirmative 60% majority vote of the weighted Segment votes cast, then the Board may consider it for adoption under Section 321.

Order No. 901 Directives for Ride-through

In Order No. 901, the Commission cites to multiple event reports as the reason that IBRs should have Reliability Standards for ride-through frequency and voltage system disturbances and that permit IBR tripping only to protect the IBR equipment in scenarios similar to when synchronous generation resources use tripping as protection from internal faults.¹⁰ Below you will find the Commission's specific directives on how IBRs should ride-through disturbances and how exceptions should be applied to certain IBRs. Finding consensus around these directives were a part of the main issues addressed during the technical conference.

“Pursuant to section 215(d)(5) of the FPA, we adopt the NOPR proposal and direct NERC to develop new or modified Reliability Standards that require registered IBR generator owners and operators to use appropriate settings (i.e., inverter, plant controller, and protection) to ride through frequency and voltage system disturbances and that permit IBR tripping only to protect the IBR equipment in scenarios similar to when synchronous generation resources use tripping as protection from internal faults. The new or modified Reliability Standards must require registered IBRs to continue to inject current and perform frequency support during a Bulk-Power System disturbance. Any new or modified Reliability Standard must also require registered IBR generator owners and operators to prohibit momentary cessation in the no-trip zone during disturbances. NERC must submit new or modified Reliability Standards that establish IBR performance requirements, including requirements addressing frequency and voltage ride through, post-disturbance ramp rates, phase lock loop synchronization, and other known causes of IBR tripping or momentary cessation.”¹¹

“Therefore, we direct NERC through its standard development process to determine whether the new or modified Reliability Standards should provide for a limited and documented exemption for certain registered IBRs from voltage ride-through performance requirements. Any such exemption should be only for voltage ride-through performance for those existing IBRs that are unable to

¹⁰ See Order No. 901 at PP 190.

¹¹ See *id.*

modify their coordinated protection and control settings to meet the requirements without physical modification of the IBRs' equipment."¹²

Summary of Issues and Alternatives Considered

The technical conference took place on September 4-5, 2024, and focused on unresolved issues raised by stakeholders raised during the PRC-029-1 comment periods. Specifically, the technical conference focused on: (1) the proposed definition of "Ride-through"; (2) the proposed criteria for frequency ride-through performance; and (3) the feasibility of allowing hardware-based exemptions from the frequency ride-through requirements, similar to the voltage ride-through exemption FERC directed NERC to consider in Order No. 901.¹³ These issues, and the alternatives considered, are discussed below.

Ride-Through Definition

The most recent Standard Authorization Request for Project 2020-02 included direction to the drafting team to define the term "ride-through" as necessary. During the development of **Milestone 2** projects, a definition for "ride-through" was considered by the drafting teams of both PRC-029 and PRC-030 as both Reliability Standards leverage the term to refer to acceptable performance criteria outlined in PRC-029. Per the Standards Process Manual (NERC Rules of Procedure Appendix 3A), definitions themselves may not include statements of performance requirements. As such, the specific performance requirements and measures to demonstrate ride-through are to be found within the Requirements and Attachments of PRC-029-1. References to "Ride-through criteria" in PRC-030-1, allow for those additional analytics to include further evaluations with PRC-029-1 Ride-through performance requirements as appropriate while preventing duplication of those performance requirements in different Reliability Standards.

Comments from Draft 3 of PRC-029-1 concerning the proposed definition of "Ride-through" were reviewed. In the previously proposed definition, many stakeholders argued that the proposed definition was too broad and ambiguous, particularly with the inclusion of phrases like "entire" and "in its entirety." Those stakeholders recommended revisions to clarify the definition and ensure it aligns better with IEEE Std 2800™, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems.¹⁴ The Draft 3 proposed definition of "Ride-through" was discussed at the technical conference and presented on by a member of the original drafting team.¹⁵ The Draft 3 definition was presented as follows: "The entire plant/facility remaining connected to the Bulk Power System and continuing in its entirety to operate through System Disturbances."

As part of the presentation, ten (10) alternative definitions were presented as proposed by commenters during the previous rounds of ballot and formal comment. After the presentation, four (4) of the most

¹² See Order No 901 at PP 193.

¹³ See Order No 901 at PP 199.

¹⁴ Hereinafter referred to as "IEEE 2800-2022".

¹⁵ See "Outlining Objectives of a Ride-through Definition" of posted [Standards Committee and NERC Ride-through Technical Conference material](#); page 94/129.

distinct definitions were opened to technical conference attendees as a straw poll to gauge overall industry preference. When asked “Which of the following proposed definitions for Ride-through do you think is most correct?”:

- 68% voted in favor of the “Ability to withstand voltage or frequency disturbances inside defined limits and to continue operating as specified.”;
- 16% voted in favor of “The plant/facility remaining connected to the Bulk Power System and continuing to operate through System Disturbances as defined in applicable reliability standards.”;
- 12% voted in favor of “The entire plant/facility remaining connected to the Bulk Power System and continuing in its entirety to operate through System Disturbances.”; and
- 4% voted in favor of “The plant/facility shall remain connected and in service, maintaining the pre-disturbance equipment configuration in operation, throughout the entirety of the system disturbance and recovery.”

Following the technical conference, NERC staff, Standards Committee representatives, some members of the drafting team, and FERC staff met to discuss the results of the straw poll as well as previously reviewed material. Based on that discussion, language in the preferred definition such as “ability to withstand”, “defined limits” and “as specified” were unclear and were inherently challenging for use in a definition that must be leveraged by multiple Reliability Standards. It was determined that the final draft would proceed with the 2nd most preferred definition, with slight modifications to remove usage of other defined terms that had an embedded usage of the Bulk Electric System defined term. The final definition as proposed in Draft 4 of PRC-029-1 is as follows: “The plant/facility remains connected and continues to operate through voltage or frequency system disturbances.”

Proposed Criteria for Frequency Ride-Through Performance

As described in the Project 2020-02 Standard Authorization Request and assigned directives from Order No. 901, the drafting team was tasked with developing new or modified Reliability Standards to assure a performance-based approach to generator ride-through. This scope included requirements that generating resources shall ride-through grid disturbances and include quantitative measures on expectations for ride-through that address all possible causes of tripping and power reductions from generating resources (particularly generator, turbine, inverter, and all plant-level protection and controls).

The proposed new Reliability Standard PRC-029-1 requires generator owners of IBR to both design and operate their IBR plants to ride-through voltage and frequency system disturbances. Requirement R3 and Attachment 2 of PRC-029-1 define the quantitative frequency ride-through criteria by use of measured frequency magnitude and time duration of sustaining that magnitude for all conditions. As discussed during the development of PRC-029-1, many stakeholders commented in previous ballots a preference to leverage those quantitative values as currently established in IEEE 2800-2022.

Frequency ride-through criteria was a prominent discussion of the technical conference. Members of the drafting team presented on the decisions made during the development of these criteria during the technical conference.¹⁶ The presentation explained that the voltage and frequency ride-through zones

¹⁶ See “Review of Voltage and Frequency Ride-through Criteria in PRC-029-1” of posted [Standards Committee and NERC Ride-through Technical Conference material](#); page 47/129.

proposed in Draft 3 of the standard were based on the IEEE 2800-2022 no-trip zones and were established in view of drafting team member experience with frequency excursions in planning and operations. The drafting team also stated the proposed frequency criteria were reasonable and were practical limits of IBR frequency tolerances, inclusive of adequate margins for worst-case conditions.

Following the presentation by the drafting team, NERC staff presented on voltage and frequency Ride-through evaluations taken from recent NERC disturbance reports and the report results from the March 2023 Level 2 Alert.¹⁷ The NERC presentation stressed balancing Bulk Power System needs with reasonable criteria that account for technical capabilities of currently designed equipment. NERC also highlighted a continued need to coordinate messaging during the design and interconnection phases of new IBR to have protection and controller equipment set in accordance with the hardware capability of the IBR rather than only in relation to minimum values established in NERC Reliability Standards.

Two panels regarding frequency criteria were held during the technical conference. The first panel included representatives of various IBR original equipment manufacturers, and the second panel included other members of industry.¹⁸ Discussions from both panels highlighted the following key issues:¹⁹

- Many IBR designed before 2014 would be unable to meet frequency Ride-through magnitude and duration criteria proposed in Attachment 2 of Draft 3. It was estimated by one panelist that approximately 20 GW of installed capacity would not be able to meet the criteria, indicating significant challenges for legacy IBR without substantial hardware replacement and redesign.
- Many IBR had not been designed to meet a rate of change of frequency (RoCoF) of 5 Hz per second. Of concern from the panelist was the technical basis for determining the need for a 5 Hz RoCoF did not include a study or more thorough evaluation of potential system strength benefits and that different parts of the Bulk Power System have not been demonstrated to require it.
- Recent event reports presented by NERC were all related to voltage excursions, potentially indicating that frequency-based disturbances were less likely to occur. Some panelists contended that this potential lower likelihood of experiencing a frequency event did not align with the expansion of frequency criteria beyond those currently established in IEEE 2800-2022.

After the panels of this topic, two straw polls were opened for attendees of the Ride-through technical conference to provide their feedback for consideration regarding “legacy” IBR and future IBR.

When attendees were asked “Based on the conversation you heard today from our panels, for legacy assets, what should PRC-029 voltage and frequency criteria follow that assures reliability and is reasonable for industry?”:

- 64% voted in favor of “Maintain PRC-024 criteria for IBR”;

¹⁷ See “Review of Voltage and Frequency Ride-through” of posted [Standards Committee and NERC Ride-through Technical Conference material](#); page 67/129.

¹⁸ See “Panel Discussion: Original Equipment Manufacturer Perspectives on Voltage and Frequency Ride-through Criteria” of posted [Standards Committee and NERC Ride-through Technical Conference material](#); pages 85/129 and 86/129.

¹⁹ See Day 1 Recording and Transcript of the Standards Committee & NERC Ride-through Technical Conference; [Project 2020-02 Modifications to PRC-024 \(Generator Ride-through\) Related Files](#); posted September 18, 2024.

- 29% voted in favor of “Adopt voltage and frequency bands proposed in IEEE 2800-2022”; and
- 6% voted in favor of “Retain currently proposed PRC-029 criteria”.

When attendees were asked “Based on the conversation you heard today from our panels, for assets being brought online in the future, what should PRC-029 voltage & frequency criteria follow that assures reliability and is reasonable for industry?”:

- 90% voted in favor of “Adopt voltage and frequency bands proposed in IEEE 2800-2022”; and
- 10% voted in favor of “Retain currently proposed PRC-029 criteria”.

Following the technical conference, NERC staff, Standards Committee representatives, some members of the drafting team, and FERC staff met to discuss the results of the straw polls as well as previously reviewed material. The team discussed that the term “legacy assets”, as used during the technical conference, aligned with the date for seeking potential exemption within PRC-029-1; meaning those IBR that were “in-service” by the effective date of PRC-029-1. While respondents at the technical conference did vote more favorably to retaining existing PRC-024 criteria for legacy assets, other information submitted by commenters and highlighted during the panel of original equipment manufacturers, indicated that a significant majority of IBR have been designed to meet IEEE 2800-2022 values.^{20, 21}

Additional information provided during the NERC staff presentation²² identified that many IBR were still being designed and installed without setting their protection and controls in accordance with their physical capabilities. Due to a concern of lowering the bar of performance by requiring that IBR perform less than what the significant majority of IBR are being designed and manufactured to, it was determined that the proposed standard should not align with previous PRC-024-3 criteria.

Based on the more clearly understood hardware-based capability limitation established due to manufacture design for a significant amount of installed IBR, there was a reliability concern to proceed with Draft 3 PRC-029-1 frequency criteria as that same amount of IBR could necessitate disconnection and retrofitting in order to comply. It was also identified that the potential disconnection of a large amount of installed IBR capacity did not substantially outweigh unstudied reliability benefits potentially resulting from setting frequency ride-through bands wider than those established in IEEE 2800-2022 and overwhelmingly identified by manufacturers during our comment review when designing IBR throughout the past decade. Due to these reliability concerns, the frequency criteria in Attachment 2 of the draft has been adjusted to align with those values in IEEE 2800-2022.

Feasibility of Hardware-Based Exemptions from Frequency Ride-Through Requirements

Potential hardware-based exemptions were discussed during each formal comment period of PRC-029-1, with a significant majority of commenters supporting some exemptions from frequency ride-through

²⁰ See Industry Submitted Comments for the Standards Committee & NERC Ride-through Technical Conference; [Project 2020-02 Modifications to PRC-024 \(Generator Ride-through\) Related Files](#); posted September 2024.

²¹ See Day 1 Recording and Transcript of the Standards Committee & NERC Ride-through Technical Conference; [Project 2020-02 Modifications to PRC-024 \(Generator Ride-through\) Related Files](#); posted September 18, 2024.

²² See “Review of Voltage and Frequency Ride-through” of posted [Standards Committee and NERC Ride-through Technical Conference material](#); page 67/129.

criteria for legacy IBR. The drafting team and industry were advised that Order No. 901 only included and only allowed for exemptions of voltage ride-through performance requirements, based on the following discussion of allowable exemptions within the order:

“Therefore, we direct NERC through its standard development process to determine whether the new or modified Reliability Standards should provide for a limited and documented exemption for certain registered IBRs from voltage ride through performance requirements.”²³

“Further, we direct NERC to ensure that any such exemption would be applicable for only existing equipment that is unable to meet voltage ride-through performance. When such existing equipment is replaced, the exemption would no longer apply, and the new equipment must comply with the appropriate IBR performance requirements specified in the Reliability Standards (e.g., voltage and frequency ride through, phase lock loop, ramp rates, etc.).”²⁴

While the order spoke only to exemptions from voltage ride-through requirements and was silent regarding any exemptions for frequency ride-through criteria, industry continued to identify that there was a need to include such exemptions in PRC-029-1. It was determined that the details shared leading up to and during the technical conference provided clarity as well as a more substantiated basis for why hardware-based exemptions of frequency ride-through criteria was needed.

Prior to the technical conference, NERC solicited comments from industry as well as original equipment manufacturers.²⁵ In particular, any information on hardware-based limitations that would prevent IBR from meeting the proposed frequency criteria within PRC-029-1 was requested. 21 individual comments were received including six (6) from different original equipment manufacturers of IBR. NERC and representatives from the Standards Committee reviewed the submitted material and confirmed that IBR are being designed by original equipment manufacturers to be able to meet those voltage and frequency ride-through curves established in IEEE 2800-2022. As Draft 3 of PRC-029-1 proposed frequency criteria were beyond those established in IEEE 2800-2022, there was a concern that IBR would not be able to meet those proposed frequency criteria as IBR capability limits were hardware-based and inherent to a manufacturer’s design.

While many comments received during the formal comment periods stressed a desire to align PRC-029-1 with IEEE 2800-2022, there was little differentiation between comments that sought to leverage other industry volunteer guidelines that have been significantly adopted with those comments that sought exemptions due to the fact that manufacturers are designing IBR capabilities to the IEEE 2800-2022 values. Moreover, comments submitted by manufacturers provided a better understanding and approximation of what percentage of the installed fleets of IBR would be unable to meet PRC-029-1 frequency criteria. While additional information regarding specific amounts of affected IBR is still sought by NERC, from the

²³ See *id.* at P 153.

²⁴ See *id.* at P 153.

²⁵ See Standards Committee and NERC Ride-through Technical Conference; Conference Details; publicly announced August 21, 2024; https://www.nerc.com/pa/Stand/Documents/SC_and_NERC%20Ride-through_Technical_Conference_Details_08212024.pdf

information provided, it appears that a significant percentage of IBR²⁶ – specifically Type 3 wind turbine facilities – would need to retrofit to avoid noncompliance with PRC-029-1 as proposed in Draft 3.

The technical conference included a panel discussion on frequency exemptions. Panelists discussed various challenges related to legacy IBR, such as difficulties obtaining more detailed information on equipment capabilities; specifically for manufacturers who are no longer in business and for IBR that are no longer supported by the manufacturer. In such instances, additional time and cost would be expected to conduct more detailed capability testing. Other concerns raised included the possibility that manufacturers would not be willing to provide design or hardware limitation documentation should they identify the information to be proprietary information. Other discussions substantiated information received during the solicitation of comments for the conference and provided more clarity as to the alignment of the IEEE 2800-2022 curves with inherent capability limitations.²⁷

Following the technical conference, NERC staff, Standards Committee representatives, some members of the drafting team, and FERC staff met to discuss the discussions during the conference as well as previously reviewed material. Based on the more clearly understood hardware-based capability limitation established due to manufacture design for a significant amount of installed IBR, there was a reliability concern to proceed with no potential for hardware-based limitations for frequency criteria, as that same amount of IBR could necessitate disconnection and retrofitting to comply.

It was determined that this potential disconnection of a large amount of installed IBR capacity overwhelmingly indicated a reliability need to allow for a documented and limited set of exemptions for IBR from voltage and frequency ride-through criteria. In light of this reliability concern, Requirement R4 of PRC-029-1 has been modified to allow for a documented, and limited set of exemptions for IBR from frequency criteria. Further modifications were made to allow Generator Owners to exclude information considered to be proprietary from submittals to anyone other than the Compliance Enforcement Authority, to facilitate the sharing of requisite information from manufacturers.

Conclusion

After following the process described in Section 321 of the NERC Rules of Procedure, as directed by the NERC Board of Trustees at the August 15, 2024 meeting, proposed Reliability Standard PRC-029-1 has been revised to: include revised definition for the new proposed term “Ride-through”, align frequency ride-through criteria with IEEE 2800-2022 values, allow for a limited documented set of exemptions for hardware-based limitations for frequency ride-through criteria, and to allow Generator Owners to only share information deemed by the original equipment manufacturer as proprietary with the Compliance Enforcement Authority..

These revisions in proposed Reliability Standard PRC-029-1 reflect a fulsome consideration of the technical, reliability, and implementation considerations raised in the underlying development proceeding and during

²⁶ Analysis of the data collected through NERC’s Level 2 Alert: Industry Recommendation for IBR Performance Issues showed that the number of resources that are not able to meet PRC-029 Draft 3 is approximately double when compared to those same resources ability to comply with the updated criteria in PRC-029 Draft 4 which align with IEEE 2800-2022. Information submitted through the comment period and the technical conference discussions indicated that this ratio would be higher for wind resources, specifically Type 3 wind.

²⁷ See Day 2 Recording and Transcript of the Standards Committee & NERC Ride-through Technical Conference; [Project 2020-02 Modifications to PRC-024 \(Generator Ride-through\) Related Files](#); posted September 18, 2024.

the technical conference, with the intent of addressing the Order No. 901 directives in a manner that is just, reasonable, not unduly discriminatory or preferential, in the public interest, helpful to reliability, practical, technically sound, technically feasible, and cost-justified.