NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Standard Authorization Request (SAR)

Complete and please email this form, with attachment(s) to: sarcomm@nerc.net

The North American Electric Reliability Corporation (NERC) welcomes suggestions to improve the reliability of the bulk power system through improved Reliability Standards.

Requested information			
SAR Title:	PRC-024-2 Generator Frequency and Voltage Protective Relay Settings		
Date Submitted:	11/27/2018		
SAR Requester			
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Organization:	Lloyd – Western Area Power Administration (NERC Operating Committee) Brian – Utility Services, Inc. (NERC Planning Committee)		
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SAR Type (Check as many as apply)			
☐ New Standard ☒ Revision to Existing Standard ☐ Add, Modify or Retire a Glossary Term ☐ Withdraw/retire an Existing Standard		☐ Imminent Action/ Confidential Issue (SPM Section 10) ☐ Variance development or revision ☐ Other (Please specify)	
Justification for this proposed standard development project (Check all that apply to help NERC prioritize development)			
☐ Regulatory Initiation ☒ Emerging Risk (Reliability Issues Steering Committee) Identified ☐ Reliability Standard Development Plan		☒ NERC Standing Committee Identified ☐ Enhanced Periodic Review Initiated ☒ Industry Stakeholder Identified	
Industry Need (What Bulk Electric System (BES) reliability benefit does the proposed project provide?):			
The NERC Integration of Variable Generation Task Force (IVGTF) was convened many years ago and developed a technical report that highlighted a number of topics and issues related to variable generation that would need to be addressed. The NERC IVGTF specifically highlighted that potential changes would need to be made to NERC Standards, including PRC-024-2, to ensure consistency and clarity for inverter-based resources. In 2017, NERC convened the Inverter-Based Resource Performance Task Force (IRPTF) shortly after it became clear that inverter-based generation was dropping off-line during normally cleared BPS line faults. The NERC IRPTF supported NERC and WECC Staff in the analysis of the Blue Cut Fire and Canyon 2 Fire disturbances in southern California.[1] From the key findings and recommendations of those reports,			

[1] An ad-hoc task force supported the development of the Blue Cut Fire disturbance report, which subsequently developed into the NERC IRPTF.

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the NERC IRPTF as a stakeholder group of industry experts developed recommended performance characteristics from inverter-based resources connected to the BPS. The recommended performance is documented in the NERC Reliability Guideline: BPS-Connected Inverter-Based Resource Performance, published September 2018. During the disturbance analyses and development of the Reliability Guideline, the NERC IRPTF identified a number of technical issues with PRC-024-2 that require clarification and correction to ensure inverter-based generator owners, operators, developers, and equipment manufacturers clearly understand the intent of the standard so their plants respond to grid disturbances in a manner that contributes to the reliable operation of the bulk power system.

These issues include:

a. Modifying the region outside the "No Trip" zone of the ride through curves so that registered entities do not interpret this area as a must trip zone.

b. Clarifying the "Off Nominal Frequency Capability Curve" and the "Curve Data Point" tables on pages 8 and 9 of PRC-024-2 to reconcile the apparent 0.1 sec time delay in the frequency capability curve with the curve data point table that allows instantaneous (i.e., no deliberate time delay) operation. Calculation of frequency over a window or time period should also be clarified.

c. Clarifying the language in point #5 of the Curve Details found in the Voltage Ride-Through Curve Clarifications (page 11 of PRC-024-2) to eliminate confusion as to whether the curves pertain to RMS (Root Mean Square) or crest values. If RMS, clarify that the RMS signal pertains to the fundamental frequency RMS signal rather than the true RMS signal.

d. Removing inconsistency regarding per unit voltage and nominal operating voltage by correcting point #1 of the Curve Details found in the Voltage Ride-Through Curve Clarifications (page 11 of PRC-024-2).

e. Clarifying the implied functionality of cumulative time (point #3 of the Curve Details in the Voltage Ride-Through Curve Clarifications – Page 11 of PRC-024-2) by explicitly specifying the conditions for when cumulative values for low and high voltage curves start, stop, and reset.

f. Clarifying whether the voltage and frequency protection functions within the inverter that can trip the inverter are subject to the standard requirements, and clarify any confusion related to footnote 1.

g. Clarifying the definition and whether the use of momentary cessation for inverter-based resources within the "No Trip" zone of PRC-024-2 is acceptable. If the use of momentary cessation within the "No Trip" zone of PRC-024-2 should be disallowed, then its use should be reported as an equipment limitation per Requirement R3 if used. The Standard Drafting Team (SDT) should further consider the acceptability of using of momentary cessation for very low voltages within the "No Trip" zone of PRC-024-2.

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~~h. Clarifying how situations of partial tripping (i.e., tripping of some but not all inverters in a dispersed power producing resource) or partial momentary cessation would be treated with respect to PRC-024-2 compliance.~~ This SAR proposes to address these technical issues.
Purpose or Goal (How does this proposed project provide the reliability-related benefit described above?):
This SAR proposes to revise PRC-024-2 to address ambiguities, inconsistencies, and technical errors within the existing standard. The goal is to add clarity, eliminate inconsistency and address ambiguity in the existing requirements.
Project Scope (Define the parameters of the proposed project):
The proposed scope of this project is as follows: a. Update the PRC-024~~-2~~ ride-through curves to ~~specify~~ clarify that the area outside the ~~-~~"No Trip" zone ~~is a "May Trip" zone,[2] so that it~~ is not erroneously interpreted as ~~a "Must Trip" zone~~requiring resources to trip. b. Clarify inconsistencies between the Curve Data Point tables and the Off Nominal Frequency Capability Curves (pages 8 & 9)~~, and~~ to ensure that instantaneously calculated frequency is not permissible to define the trip parameters. c. Clarify the language in points #1, #3, and #5 of the Curve Details section of the "Voltage Ride-Through Curve Clarifications" on page 11. d. ~~Reinforce~~ Consider whether the SDT should address manners in which to reinforce that the requirements pertain to the Point of Interconnection.~~, and clarify further that the Generator Owner needs to consider this when developing the voltage settings for individual generating units (this pertains to both synchronous and inverter-based resources). If possible, provide either Implementation Guidance or example calculations within the standard for dispersed power producing (inverter-based) resources.~~ e. Clarify if the voltage and frequency protective functions within an inverter control system that trip the inverter are subject to the requirements of PRC-024]~~-2.~~.~~[3]~~ f. Clarify that plant auxiliary equipment protection systems are not subject to the requirements of PRC-024. ~~e.~~g.~~Specify~~ Clarify ~~that~~ whether the use of momentary cessation (a control function) within the "No Trip" zone of PRC-024~~-2~~ does not comply with the standard. The SDT should consider the use of momentary cessation for very low voltages within the "No Trip" zone of PRC-024~~-2.~~. ~~The SDT~~

~~[2] Another option is to refer to this as "Prefer No Trip". The SDT can determine the best language; however, it should be clear that resources do not necessarily have to trip outside the curve yet are permitted to in order to protect facilities and personnel.~~

~~[3] This clarification could also further strengthen that station service voltage settings or tripping are not considered in scope of the standard. The standard pertains to the voltage and frequency related tripping directly applied to the individual generating unit(s).~~

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~~may need to define momentary cessation, and provide guidance on the performance of inverter control systems during a voltage disturbance within the "No Trip" zone of PRC-024-2.~~ ~~f. Clarify how situations of partial tripping or partial momentary cessation would be treated with respect to PRC-024-2 compliance.~~ h. The SDT should consider whether Interconnection-specific modification(s) or Regional Variance(s) are necessary for the voltage ride-through time duration curve(s) in Attachment 2. Other topics not addressed here will be considered in future activities of the NERC IRPTF as well as the IEEE p2800 project.
Detailed Description (Describe the proposed deliverable(s) with sufficient detail for a drafting team to execute the project. If you propose a new or substantially revised Reliability Standard or definition, provide: (1) a technical justification[4] which includes a discussion of the reliability-related benefits of developing a new or revised Reliability Standard or definition, and (2) a technical foundation document (e.g., research paper) to guide development of the Standard or definition):
The Standards Drafting Team should address the following technical issues within PRC-024-2: 1. Update the PRC-024 ride-through curves to clarify that the area outside the "No Trip" zone is not erroneously interpreted as requiring resources to trip. ~~The region outside the "No Trip" zone of the PRC-024-2 ride-through curves should be clearly marked as a "May Trip" zone so this region is not incorrectly interpreted as a "Must Trip" zone.~~ Many newly interconnecting resources (including inverter-based resources) on the BPS are setting voltage and protective functions based solely on these curves, since the area outside the no trip region is incorrectly interpreted as a must trip zone. This practice does not consider the actual capability of the resource to ride through transmission line faults that create conditions outside of the "No Trip" zone. Clarification will help to ensure correct interpretation industry-wide. ~~This will enhance reliability since the generator owner, operator, developer, and equipment manufacturer will understand that the inverter protective trip settings should be based on equipment capability if it exceeds the curves in the standard, minimizing undesired tripping of inverter-based generation that may not be necessary.~~ 2. The "Off Nominal Frequency Capability Curve" (page 8 of PRC-024-2) is a logarithmic graph that starts at time t=0.1 seconds. However, the tables in the "Curve Data Point" section (pages 8 and 9 of PRC-024-2) allow for "instantaneous trip". Frequency cannot and should not be measured or calculated using an instantaneously sampled value. Frequency calculation methods use various types of time windows and filtering methods in order to accurately calculate grid frequency. Typically, these methods use a window on the order of 100 milliseconds (6 cycles). Thus, a delay of 100 milliseconds would occur even if the protective relay algorithm has no intentional time delay. This delay should be reflected in the standard. Also, the IRPTF identified that erroneous tripping due to frequency calculation errors was a significant factor in the Blue Cut Fire

[4] The NERC Rules of Procedure require a technical justification for new or substantially revised Reliability Standards. Please attach pertinent information to this form before submittal to NERC.

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disturbance. Eliminating instantaneous tripping for frequency disturbances reduces the probability of incorrect tripping due to spurious noise in the measure voltage, for example during the period of fault clearing.

3. Point #5 in the Curve Details section of the "Voltage Ride-Through Curve Clarifications" (page 11 of PRC-024-2) states, "voltages in the curve assume minimum fundamental frequency phase to ground or phase to phase voltage for the low duration curve and the greater of maximum RMS (Root Mean Square) or crest phase to phase voltage for the high voltage duration curve." There are a number of ways this can be interpreted, and issues that need to be addressed.
4. To minimize the probability of incorrect tripping (as noted in point 2 above), any voltage compared with the PRC-024-2 voltage ride through curves should be a well-filtered, fundamental frequency component of the voltage waveform. This will filter out spurious voltage spikes caused by switching action on the BPS. Voltage protective relays should not operate at the voltage levels specified in the voltage ride-through curve using instantaneously sampled values. The clarification should focus on using the RMS value of the voltage, and that the voltage signal should be adequately filtered to obtain this fundamental component.
5. The overvoltage component of the clarification states, "the greater of maximum RMS or crest phase to phase voltage". The crest value is greater than the RMS value of a periodic waveform, so there is ambiguity regarding which value to apply. Without clarification, inverter based resources may trip based on different criteria. Failure to address this may lead to reliability issues, as identified in the Canyon 2 Fire disturbance analysis report.
6. Only phase to phase voltage is used for the high voltage component of the PRC-024-2 curve. However, inverter-based resource transient overvoltage protection may be based on phase to ground voltage as well. Use of phase to ground voltage for overvoltage protection needs to be considered.
7. Point #1 of the Curve Details section of the "Voltage Ride-Through Curve Clarifications" on page 11 of PRC-024-2 states, "the per unit voltage base for these curves is the nominal operating voltage specified by the Transmission Planner in the analysis of the reliability of the Interconnected Transmission Systems at the point of interconnection to the Bulk Electric System (BES)." Firstly, the Transmission Planner does not specify nominal operating voltage. Regardless, the per unit base for the curves should be based on the nominal voltage level that the generator is connected to at its Point of Interconnection. This is a static value and can be provided by the Transmission Planner.
8. Point #3 of the Curve Details section of the "Voltage Ride-Through Curve Clarifications" on page 11 of PRC-024-2 states, "The envelope within the curves represents the cumulative voltage duration at the point of interconnection with the BES." The ride-through curves end at four seconds, and the curves imply a requirement for cumulative time duration for the "No Trip" zone. Protective relays and inverter protective functions within their control systems must be set to accommodate the cumulative nature of ride through curves. Under the current version of PRC-024-2, it is not explicitly clear at what point the cumulative values for the low and high

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voltage curves start, stop, and reset for multiple ride-through events. There are multiple ways to implement this cumulative effect, which result in different performance, for example during multiple, successive low voltage events. The correct methods for implementing the cumulative time duration should be clarified in PRC-024-2.[5] 9. The IRPTF identified that it is ambiguous and unclear as to whether the requirements of PRC-024-2 apply to the individual inverters. Footnote 1 does state that "protective functions within control systems that directly trip or provide tripping signals to the generator based on frequency or voltage inputs" are considered as part of the standard. Yet, the group acknowledged that the vagueness of the footnote as well as the synchronous generator-centric language in the requirements makes this confusing. There may exist multiple types of voltage and frequency protection, including relaying or individual inverter protective functions within their control systems that need to be considered in PRC-024-2. This should be clarified and strengthened throughout the standard. 10. Momentary cessation is a form of operation that some inverters have historically used during "ride-through" operation where voltage is outside the continuous operating range of the inverter. Momentary cessation is when zero current is injected into the grid by the inverter. This occurs because the power electronic firing commands are blocked so that the inverter does not produce current. Thus active and reactive current (and subsequently power) go to zero at the inverter terminals. The NERC IRPTF performed stability studies, particularly in the Western Interconnection, and demonstrated that the propagation and widespread use of momentary cessation, particularly at voltages within the PRC-024-2 voltage ride-through curve, could cause potential situations of instability. Both NERC Alerts following the Blue Cut Fire and Canyon 2 Fire gathered data related to the use of momentary cessation, and the latter NERC Alert explicitly recommended mitigating the use of momentary cessation to the best extent possible for existing and future resources. Clarifying PRC-024-2 relative to the use of momentary cessation within the "No Trip" zone of PRC-024-2 aligns with all these efforts. Momentary cessation within the "No Trip" zone of PRC-024-2 could be reported as an equipment limitation per Requirement R3.
Cost Impact Assessment, if known (Provide a paragraph describing the potential cost impacts associated with the proposed project):
This SAR proposes to clarify some issues and correct others. The cost impact is unknown, but in many cases is expected to be minimal (i.e., will only require changes to existing inverter control software and setting).
Please describe any unique characteristics of the BES facilities that may be impacted by this proposed standard development project (*e.g.* Dispersed Generation Resources):
Inverter-based resources including asynchronous ties may be impacted by this proposed standard development as Generator Owners, Transmission Owners and Original Equipment Manufacturers may

[5] Example: One implementation considers one cumulative window timer for both low voltage and high voltage curves, and it starts when the voltage goes outside the continuous operating bounds. Another implementation considers separate cumulative timers and the HV timer starts when the voltage is greater than this curve and the LV timer starts when the voltage is less than that curve.

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need to change the control programming to enhance capabilities. Other generation resources may be impacted if the clarifications cause them to correct relay settings.
To assist the NERC Standards Committee in appointing a drafting team with the appropriate members, please indicate to which Functional Entities the proposed standard(s) should apply (*e.g.* Transmission Operator, Reliability Coordinator, etc. See the most recent version of the NERC Functional Model for definitions):
Generator Owners
Do you know of any consensus building activities[6] in connection with this SAR? If so, please provide any recommendations or findings resulting from the consensus building activity.
Many of these proposals were developed by the NERC IRPTF, are outlined in the NERC Reliability Guideline: BPS-Connected Inverter-Based Resource Performance, and also captured in a white paper on potential standards gaps related to PRC-024-2. There were also similar proposals developed by the NERC IVGTF in 2015.
Are there any related standards or SARs that should be assessed for impact as a result of this proposed project? If so which standard(s) or project number(s)?
Are there alternatives (e.g. guidelines, white paper, alerts, etc.) that have been considered or could meet the objectives? If so, please list the alternatives.
The following materials have been developed by the NERC IRPTF, NERC Staff, and WECC Staff as part of the event analyses of inverter-based resources during BPS disturbances. However, these activities do not address the inconsistencies and technical issues of PRC-024-2 that have been highlighted in all these activities. • Reliability Guideline: BPS-Connected Inverter-Based Resource Performance: https://www.nerc.com/comm/OC_Reliability_Guidelines_DL/Inverter-Based_Resource_Performance_Guideline.pdf. • Blue Cut Fire Disturbance Report: http://www.nerc.com/pa/rrm/ea/Pages/1200-MW-Fault-Induced-Solar-Photovoltaic-Resource-Interruption-Disturbance-Report.aspx. • Canyon 2 Fire Disturbance Report: https://www.nerc.com/pa/rrm/ea/October%209%202017%20Canyon%202%20Fire%20Disturbance%20Report/900%20MW%20Solar%20Photovoltaic%20Resource%20Interruption%20Disturbance%20Report.pdf. • NERC Alert I: Loss of Solar Resources during Transmission Disturbances due to Inverter Settings: https://www.nerc.com/pa/rrm/bpsa/Pages/Alerts.aspx. • NERC Alert II: Loss of Solar Resources during Transmission Disturbances due to Inverter Settings: https://www.nerc.com/pa/rrm/bpsa/Pages/Alerts.aspx. • "NERC IVGTF Summary and Recommendation Report", published in June 2015. Relevant to PRC-024-02 are task 1-3 and 1-7: https://www.nerc.com/comm/PC/Integration%20of%20Variable%20Generation%20Task%20Force%20I1/IVGTF%20Summary%20and%20Recommendation%20Report_Final.pdf.

[6] Consensus building activities are occasionally conducted by NERC and/or project review teams. They typically are conducted to obtain industry inputs prior to proposing any standard development project to revise, or develop a standard or definition.

Reliability Principles	
Does this proposed standard development project support at least one of the following Reliability Principles (Reliability Interface Principles)? Please check all those that apply.	
☒	1. Interconnected bulk power systems shall be planned and operated in a coordinated manner to perform reliably under normal and abnormal conditions as defined in the NERC Standards.
☒	2. The frequency and voltage of interconnected bulk power systems shall be controlled within defined limits through the balancing of real and reactive power supply and demand.
☐	3. Information necessary for the planning and operation of interconnected bulk power systems shall be made available to those entities responsible for planning and operating the systems reliably.
☐	4. Plans for emergency operation and system restoration of interconnected bulk power systems shall be developed, coordinated, maintained and implemented.
☐	5. Facilities for communication, monitoring and control shall be provided, used and maintained for the reliability of interconnected bulk power systems.
☐	6. Personnel responsible for planning and operating interconnected bulk power systems shall be trained, qualified, and have the responsibility and authority to implement actions.
☐	7. The security of the interconnected bulk power systems shall be assessed, monitored and maintained on a wide area basis.
☐	8. Bulk power systems shall be protected from malicious physical or cyber attacks.

Market Interface Principles	
Does the proposed standard development project comply with all of the following Market Interface Principles?	Enter (yes/no)
1. A reliability standard shall not give any market participant an unfair competitive advantage.	Yes
2. A reliability standard shall neither mandate nor prohibit any specific market structure.	Yes
3. A reliability standard shall not preclude market solutions to achieving compliance with that standard.	Yes
4. A reliability standard shall not require the public disclosure of commercially sensitive information. All market participants shall have equal opportunity to access commercially non-sensitive information that is required for compliance with reliability standards.	Yes

Identified Existing or Potential Regional or Interconnection Variances	
Region(s)/ Interconnection	Explanation
None	None

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SAR Status Tracking (Check off as appropriate)	
☐ Draft SAR reviewed by NERC Staff ☐ Draft SAR presented to SC for acceptance ☐ DRAFT SAR approved for posting by the SC	☐ Final SAR endorsed by the SC ☐ SAR assigned a Standards Project by NERC ☐ SAR denied or proposed as Guidance document

Version History

Version	Date	Owner	Change Tracking
1	June 3, 2013		Revised
1	August 29, 2014	Standards Information Staff	Updated template
2	January 18, 2017	Standards Information Staff	Revised
2	June 28, 2017	Standards Information Staff	Updated template