

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard is adopted by the NERC Board of Trustees (Board).

Description of Current Draft

Completed Actions	Date
Standards Committee accepted revised Standard Authorization Request (SAR) for posting	April 19, 2023
Standards Committee approved waivers to the Standards Process Manual	December 13, 2023

Anticipated Actions	Date
25-day formal comment period with initial ballot	March 27 - April 22, 2024
15-day formal comment period and additional ballot	May 20 - June 4, 2024
15-day formal comment period and additional ballot	July 1 - 16, 2024
Final Ballot	July 18 - 24, 2024
Board adoption	August 14, 2024

New or Modified Term(s) Used in NERC Reliability Standards

This section includes all new or modified terms used in the proposed standard that will be included in the *Glossary of Terms Used in NERC Reliability Standards* upon applicable regulatory approval. Terms used in the proposed standard that are already defined and are not being modified can be found in the *Glossary of Terms Used in NERC Reliability Standards*. The new or revised terms listed below will be presented for approval with the proposed standard. Upon Board adoption, this section will be removed.

Term(s):

Continuous Operating Region – The range of voltages, measured at the high-side of the main power transformer, that are ≥ 0.9 per unit and ≤ 1.1 per unit.

Mandatory Operating Region – The range of voltages, measured at the high-side of the main power transformer, that are > 0.1 per unit and < 0.9 per unit – or – > 1.1 and ≤ 1.2 per unit.

Permissive Operating Region – The range of voltages, measured at the high-side of the main power transformer, that is ≤ 0.1 per unit.

A. Introduction

1. **Title:** Frequency and Voltage Ride-through Requirements for Inverter-Based Generating Resources
2. **Number:** PRC-029-1
3. **Purpose:** To ensure that Inverter-Based Resources (IBRs) remain connected and perform operationally as expected to support of the Bulk Power System (BPS) during and after defined frequency and voltage excursions.
4. **Applicability:**
 - 4.1 **Functional Entities:**
 - 4.1.1. Generator Owner
 - 4.1.2. Transmission Owner¹
 - 4.2 **Facilities: For purposes of this standard, the term “applicable Inverter-Based Resource” or “applicable Inverter-Based Resources” refers to the following:**
 - 4.2.1. BPS IBRs
 - 4.2.2. IBR Registration Criteria
5. **Effective Date:** See Implementation Plan for Project 2020-02 – PRC-029-1

¹ For owners of Voltage Source Converter – High-voltage Direct Current (VSC-HVDC) transmission facilities that are dedicated connections for IBR to the BPS

B. Requirements and Measures

- R1.** Each Generator Owner or Transmission Owner of an applicable IBR shall ensure that each IBR remains electrically connected and continues to exchange current in accordance with the no-trip zones and operation regions as specified in **Attachment 1** unless needed to clear a fault or a documented equipment limitation exists in accordance with **Requirement R6**. *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*
- M1.** Each Generator Owner and Transmission Owner shall have evidence of actual recorded data or other evidence for each applicable IBR demonstrating adherence to ride-through requirements, as specified in **Requirement R1**.
- R2.** Each Generator Owner or Transmission Owner of an applicable IBR shall ensure that during a System disturbance, each IBR’s voltage performance adheres to the following, unless a documented equipment limitation exists in accordance with **Requirement R6**. *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*
 - 2.1.** While the voltage at the high-side of the main power transformer remains within the Continuous Operation Region as specified in **Attachment 1**, each IBR shall:
 - 2.1.1** Continue to deliver the pre-disturbance level of active power or available active power, whichever is less, and continue to deliver active power and reactive power up to its apparent power limit.
 - 2.1.2** If the IBR cannot deliver both active and reactive power due to a current or apparent power limit, when the applicable voltage is below 95% and still within the Continuous Operation Region, then preference shall be given to active or reactive power according to requirements specified by the Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator.
 - 2.2.** While voltage at the high-side of the main power transformer is within the Mandatory Operation Region as specified in **Attachment 1**, each IBR shall:
 - 2.2.1** Exchange current, up to the maximum capability while maintaining automatic voltage regulation, on the affected phases during both symmetrical and asymmetrical voltage disturbances.
 - 2.2.2** Adjust reactive current injection at the high-side of the main power transformer so that the magnitude of the reactive current responds to changes in voltage at the high-side of the main power transformer in accordance with default reactive prioritization unless the Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator specifies a certain magnitude of reactive power response to voltage changes or specifies active power priority instead of reactive power priority.
 - 2.3.** The IBR shall not itself cause voltage at the high-side of the main power transformer to exceed the applicable **Attachment 1** Table 1 or Table 2 no-trip

zone voltage thresholds and time durations in its response from Mandatory or Permissive Operation Regions to the Continuous Operating Region.

- 2.4.** Each IBR shall restore active power output to the pre-disturbance or available level within 1.0 second when the voltage at the high-side of the main power transformer returns to the Continuous Operation Region from the Mandatory Operation Region or Permissive Operation Region (including operation in current block mode) as specified in **Attachment 1**, unless the Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator specifies a lower post-disturbance active power level requirement or specifies a different post-disturbance active power restoration time.
- 2.5.** Each IBR shall only trip to prevent equipment damage, when the voltage at the high-side of the main power transformer is outside of the no-trip zone as specified in **Attachment 1**.
- M2.** Each Generator Owner and Transmission Owner shall have evidence of actual recorded data or other evidence for each applicable IBR demonstrating adherence to performance requirements, as specified in **Requirement R2**, during each System disturbance which has occurred within the associated Planning Coordinator(s) area(s).
- R3.** Each Generator Owner or Transmission Owner of an applicable IBR shall ensure that during a transient overvoltage as a result of a switching event whereby instantaneous voltage at the high-side of the main power transformer exceeds 1.2 per unit, each IBR shall either: *[Violation Risk Factor: Lower] [Time Horizon: Operations Assessment]*
- Remain electrically connected and continue to exchange current in accordance with instantaneous transient overvoltage levels and durations specified in **Attachment 2**; or
 - Remain electrically connected in current block mode in accordance with instantaneous transient overvoltage levels and durations specified in **Attachment 2**, and restart current exchange within 5 cycles of the instantaneous voltage falling below (and remaining below) 1.2 per unit.
- M3.** Each Generator Owner and Transmission Owner shall have evidence of actual recorded data or other evidence for each applicable IBR demonstrating adherence to performance requirements, as specified in Requirement R3, during each transient overvoltage period which has occurred within the associated Planning Coordinator(s) area(s).
- R4.** Each Generator Owner or Transmission Owner of an applicable IBR shall ensure each IBR remains electrically connected and continues to exchange current during a frequency excursion event whereby the frequency remains within the “no trip zone” according to **Attachment 3** and the absolute rate of change of frequency (ROCOF)²

² Rate of change of frequency (ROCOF) is calculated as the average rate of change for multiple calculated system frequencies for a time period of greater than or equal to 0.1 second. ROCOF is not calculated during the fault occurrence and clearance.

magnitude is less than or equal to 5 Hz/second. *[Violation Risk Factor: Lower] [Time Horizon: Operations Assessment]*

- M4.** Each Generator Owner and Transmission Owner shall have evidence of actual recorded data or other evidence for each applicable IBR demonstrating adherence to ride-through requirements, as specified in Requirement R4, during each frequency excursion event which has occurred within the associated Planning Coordinator(s) area(s).
- R5.** Each Generator Owner or Transmission Owner of an applicable IBR shall ensure each IBR remains electrically connected and continues to exchange current during instantaneous positive sequence voltage phase angle changes that are initiated by non-fault switching events on the transmission system and are changes of less than 25 electrical degrees at the high-side of the main power transformer. *[Violation Risk Factor: Lower] [Time Horizon: Operations Assessment]*
 - 5.1.** When the instantaneous positive sequence voltage phase angle change is more than 25 electrical degrees at the high-side of the main power transformer and is initiated by a non-fault switching event on the transmission system, the IBR may trip, but shall only trip to prevent equipment damage.
- M5.** Each Generator Owner and Transmission Owner shall have evidence of actual recorded data or other evidence for each applicable IBR demonstrating adherence to ride-through requirements, as specified in Requirement R5, during instantaneous positive sequence voltage phase angle changes that are changes of less than 25 electrical degrees at the high-side of the main power transformer and that such changes are not initiated by non-fault switching events.
- R6.** Each Generator Owner and Transmission Owner with a documented equipment limitation that would prevent an applicable IBR that is in-service by the effective date of this standard from meeting voltage ride-through requirements as detailed in Requirements R1 and R2 shall communicate each equipment limitation to the associated Planning Coordinator(s), Transmission Planner(s), and Reliability Coordinator(s). *[Violation Risk Factor: Lower] [Time Horizon: Long-term Planning]*
 - 6.1.** Each Generator Owner and Transmission Owner shall include in its documentation:
 - 6.1.1** Identifying information of the IBR (name, facility #, other)
 - 6.1.2** Which aspects of voltage ride-through requirements that the IBR would be unable to meet
 - 6.1.3** Identify the specific piece(s) of equipment causing the limitation
 - 6.1.4** Information regarding any plans to repair or replace the limiting equipment that would remove the limitation (such as estimated date of repair/replacement)
 - 6.2.** Each Generator Owner and Transmission Owner with a previously communicated equipment limitation that repairs or replaces the equipment causing the limitation shall document and communicate such equipment

change to the associated Planning Coordinator(s), Transmission Planner(s), and Reliability Coordinator(s) within 30 days of the equipment change.

- M6.** Each Generator Owner and Transmission Owner shall have evidence of equipment limitations, as specified in Requirement R6, documented prior to the effective date of PRC-029-1. Each Generator Owner and Transmission Owner with changes to equipment shall have evidence of communication to each associated Planning Coordinator, Transmission Planner, and Reliability Coordinator. Acceptable types of evidence may include, but are not limited to, meeting minutes, agreements, copies of procedures or protocols in effect between entities or between departments of a vertically integrated system, or email correspondence.

C. Compliance

1. Compliance Monitoring Process

1.1. Compliance Enforcement Authority: “Compliance Enforcement Authority” means NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2. Evidence Retention: The following evidence retention period(s) identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full-time period since the last audit.

The applicable entity shall keep data or evidence to show compliance as identified below unless directed by its Compliance Enforcement Authority to retain specific evidence for a longer period of time as part of an investigation.

- Each Generator Owner and Transmission Owner shall retain evidence with each requirement in this standard for five calendar years.

1.3. Compliance Monitoring and Enforcement Program: As defined in the NERC Rules of Procedure, “Compliance Monitoring and Enforcement Program” refers to the identification of the processes that will be used to evaluate data or information for the purpose of assessing performance or outcomes with the associated Reliability Standard.

Violation Severity Levels

R #	Violation Severity Levels			
	Lower VSL	Moderate VSL	High VSL	Severe VSL
R1.	N/A	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable IBR remains electrically connected and continued to exchange current in accordance with Attachment 1, unless needed to clear a fault, in accordance with Requirement R1.
R2.	N/A	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable IBR adhered to performance requirements during each System disturbance, as specified in Requirement R2.
R3.	N/A	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable IBR adhered to performance requirements during each transient overvoltage period as specified in Requirement R3.

R #	Violation Severity Levels			
	Lower VSL	Moderate VSL	High VSL	Severe VSL
R4.	N/A	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable IBR adhered to performance requirements during each frequency excursion event, as specified in Requirement R4.
R5.	N/A	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable IBR adhered to performance requirements during each instantaneous positive sequence voltage phase angle change of less than 25 electrical degrees, as specified in Requirement R5.
R6.	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator, Transmission Planner, and Reliability	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator, Transmission Planner, and Reliability	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator, Transmission Planner, and Reliability	The Generator Owner or Transmission Owner failed to document evidence of equipment limitations consistent with Requirement R6 and prior to the effective date of PRC-029-1 Requirement R6. OR

R #	Violation Severity Levels			
	Lower VSL	Moderate VSL	High VSL	Severe VSL
	Coordinator more than 30 calendar days but less than or equal to 60 calendar days after the change to the equipment.	Coordinator more than 60 calendar days but less than or equal to 90 calendar days after the change to the equipment.	Coordinator more than 90 calendar days but less than or equal to 120 calendar days after the change to the equipment.	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator, Transmission Planner, and Reliability Coordinator more than 120 calendar days after the change to the equipment.

D. Regional Variances

None.

E. Associated Documents

Implementation Plan .

Version History

Version	Date	Action	Change Tracking
Initial Draft	3/27/24	DRAFT	

Attachment 1: Voltage Ride-Through Criteria

Table 1: Voltage Ride-Through Requirements for AC-Connected Wind IBR

Voltage (per unit)	Minimum Ride-Through Time (sec)
≥1.200	N/A
≥1.1	1.0
≥1.05	1800
< 0.90	3.00
< 0.70	2.50
< 0.50	1.20
< 0.25	0.16
< 0.10	0.16

Table 2: Voltage Ride-Through Requirements for All Other IBR

Voltage (per unit)	Minimum Ride-Through Time (sec)
≥1.200	N/A
≥1.1	1.0
≥1.05	1800
< 0.90	6.00
< 0.70	3.00
< 0.50	1.20
< 0.25	0.32
< 0.10	0.32

1. Table 1 applies to applicable wind IBR unless connected via a dedicated VSC-HVDC transmission facility.
2. Table 2 applies to all other IBR types not covered in Table 1; including, but not limited to, the following IBR:
 - a. Isolated IBR, regardless of their energy resource, interconnecting via a dedicated VSC-HVDC transmission facility.
 - b. Other IBR plants or hybrid plants consisting of photovoltaic (PV) and ESS.

3. In the case of hybrid IBR consisting of wind and various other IBR technologies, the applicable table shall be based on direction by the Transmission Planner.
4. The voltage base for per unit calculation is the nominal phase-to-ground or phase-to-phase transmission system voltage unless otherwise defined by the Planning Coordinator or Transmission Planner.
5. The applicable voltage for Tables 1 and 2 is identified as the voltage max/min of phase to neutral or phase to phase fundamental root mean square (RMS) voltage at the high side of the MPT.
6. Tables 1 and 2 are only applicable when the frequency is within the no trip zone as specified in Table 3 of Attachment 3.
7. At any given voltage value, each IBR shall not trip until the time duration at that voltage exceeds the specified minimum ride-through time duration. If the voltage is continuously varying over time, it is necessary to add the duration within each band of Tables 1 and 2 over the 10-second time period to determine compliance.
8. The specified duration of the Mandatory Operation Regions and the Permissive Operation Regions in Tables 1 and 2 is cumulative over one or more disturbances within a 10 second time period.
9. The IBR may trip for more than four deviations of the applicable voltage at the high-side of the main power transformer outside of the Continuous Operation Region within any 10 second time period.
10. If the positive sequence voltage at the high-side of the main power transformer enters the Permissive Operation Region, an IBR may operate in current block mode if necessary to protect the equipment.

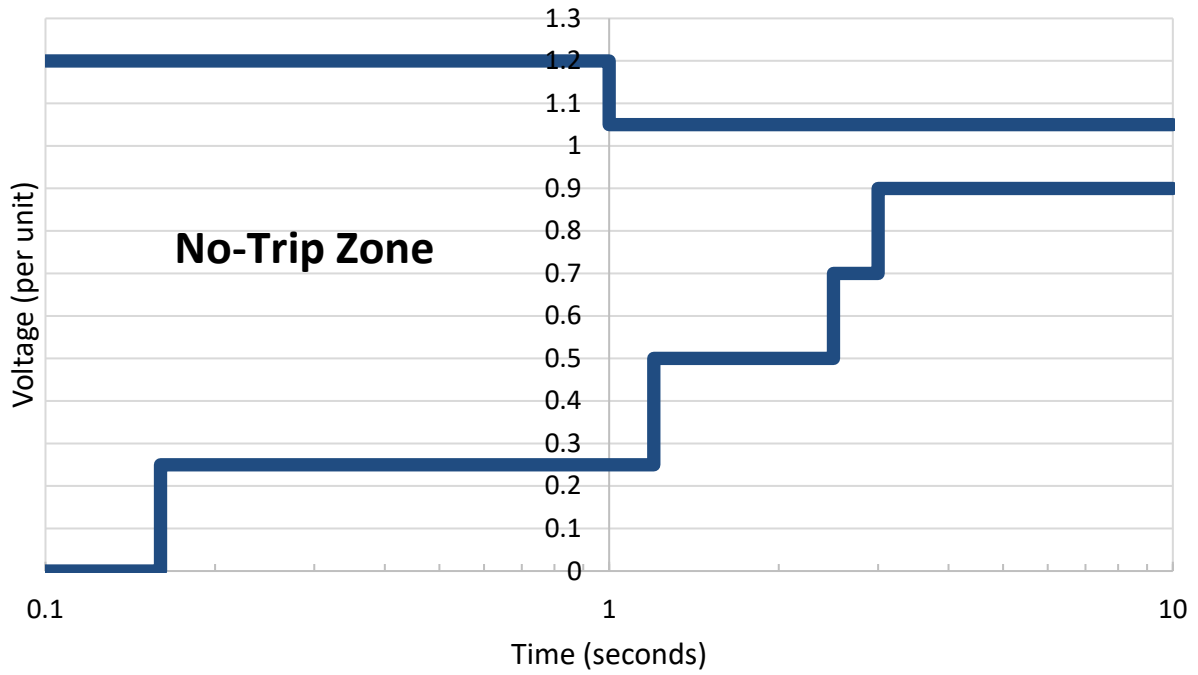


Figure 1: Voltage Ride-Through Requirements for AC-Connected Wind IBR

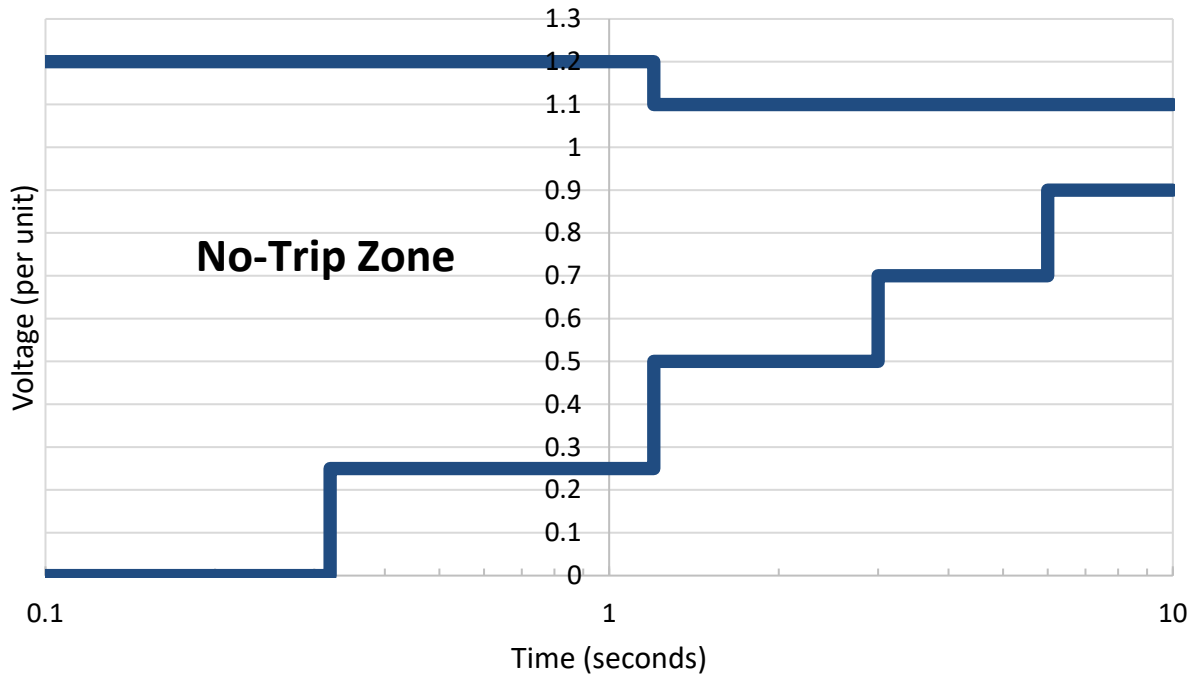


Figure 2: Voltage Ride-Through Requirements for All Other IBR

Attachment 2: Transient Overvoltage Ride-Through Criteria

Table 3: Transient Overvoltage Ride-Through Criteria

Voltage (per unit) at the high side of the MPT	Minimum Ride-Through Time (millisec)
> 1.8	May trip
> 1.7	0.2
> 1.6	1.0
> 1.4	3.0
> 1.2	15.0

1. The voltage base for per unit calculation is the nominal instantaneous phase-to-ground or phase-to-phase voltage at the high side of the MPT unless otherwise defined by the Planning Coordinator or Transmission Planner.
2. If surge protection devices are installed within the plant, the per unit voltage refers to the residual voltage with the surge arresters applied.
3. Each IBR shall not trip unless the cumulative time of one or more instances over a 1-minute time window in which the instantaneous voltage exceeds the respective voltage threshold and the minimum ride-through time.

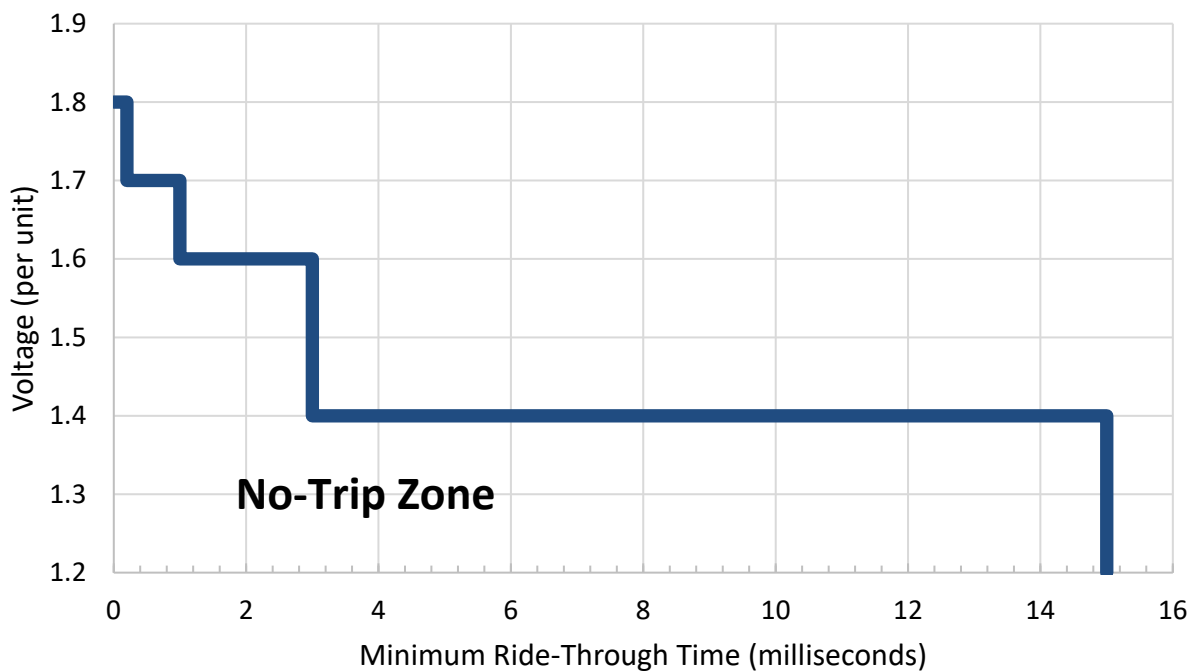


Figure 3: Transient Overvoltage Ride-Through Criteria

Attachment 3: Frequency Ride-Through Criteria

Table 4: Frequency Ride-Through Capability Requirements

Averaged System Frequency (Hz)	Minimum Ride-Through Time (sec)
≥64	May trip
≥61.8	6
> 61.5	299
> 61.2	660
< 58.8	660
< 58.5	299
< 57.0	6
< 56	May trip

1. Measurements are taken at the high-side of the main power transformer for each phase (phase to neutral).
2. Measurements are averaged over a set time period (such as 3-6 cycles) to calculate averaged system frequency at the high-side of the main power transformer.
3. Instantaneous or single points of measurement may not be used in the determination of control settings.
4. At any given frequency values, each IBR shall not trip until the time duration at that frequency exceeds the specified minimum ride-through time duration.
5. The specified durations of Table 4 are cumulative over one or more disturbances within a 15-minute time period.

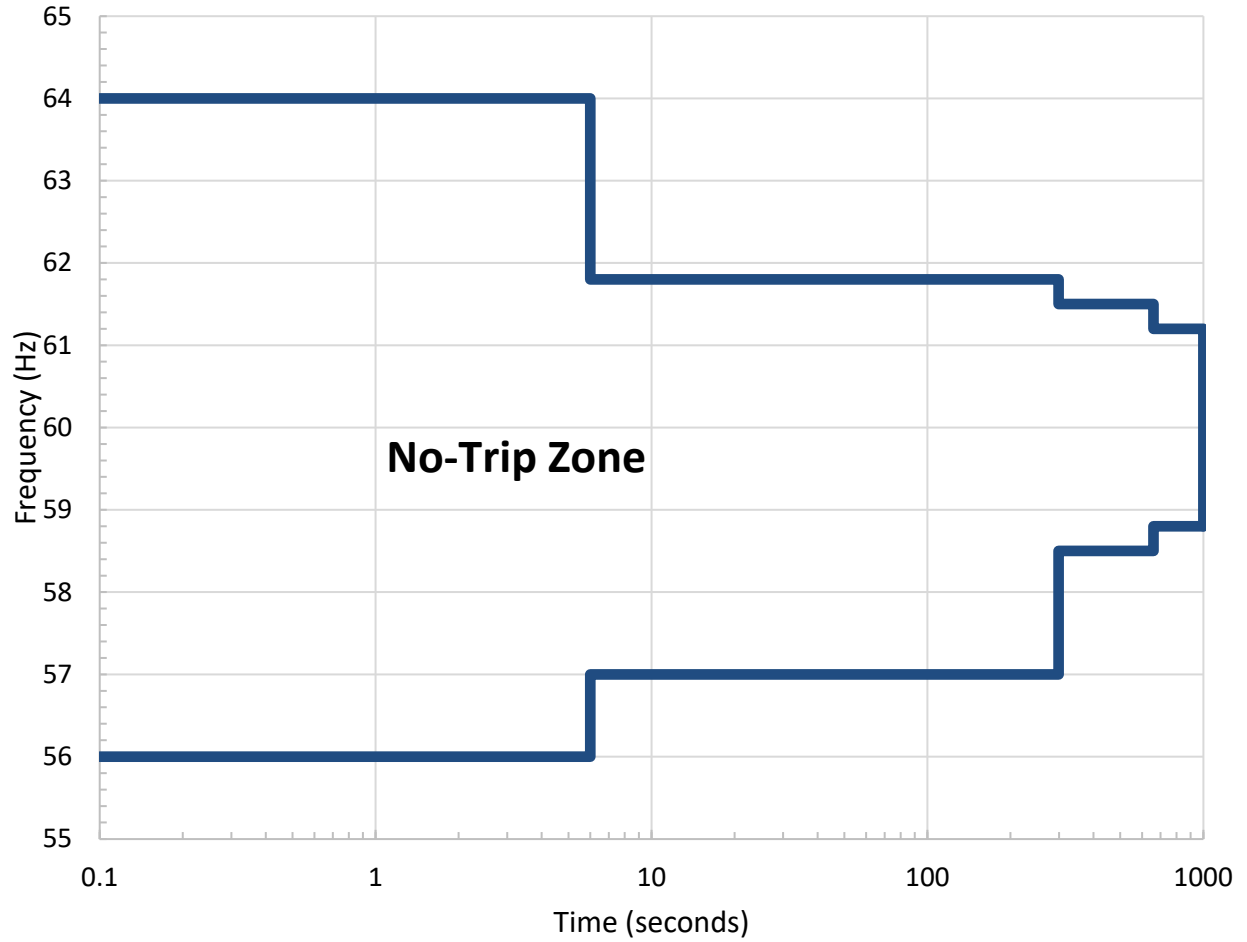


Figure 4: PRC-029 Frequency Envelopes