

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
Initial 25-day formal comment period and additional ballot	March 27 – April 21, 2024

Anticipated Actions	Date
15-day formal comment period and additional ballot	June 18 – July 8, 2024
Final Ballot	July 16 - 20, 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):

Ride-through: Remaining connected, synchronized with the Transmission System, and continuing to operate in response to System conditions through the time-frame of a System Disturbance.

A. Introduction

1. **Title:** Frequency and Voltage Ride-through Requirements for Inverter-Based Resources
2. **Number:** PRC-029-1
3. **Purpose:** To ensure that Inverter-Based Resources (IBRs) adhere to Ride-through requirements as expected to support 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:**
 - 4.2.1. BES inverter-based resources²
 - 4.2.2. IBR Registration Criteria

Effective Date: See Implementation Plan for Project 2020-02 – PRC-029-1

Standard-Only Definition: None

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

² For the purpose of this standard, “inverter-based resources” refers to a collection of individual solar photovoltaic (PV), Type 3 and Type 4 wind turbines, battery energy storage system (BESS), or fuel cells that operate as a single plant/resource. In case of offshore wind plants connecting via a dedicated VSC-HVDC, the inverter-based resource includes the VSC-HVDC system.

B. Requirements and Measures

- R1.** Each Generator Owner or Transmission Owner shall ensure the design and operation is such that each facility adheres to Ride-through requirements, in accordance with the “must Ride-through³ zone” as specified in Attachment 1, except for the following: *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*
- The facility needed to electrically disconnect in order to clear a fault;
 - A documented equipment limitation exists in accordance with Requirement R4; or
 - 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; or
 - The Volts per Hz (V/Hz) at the high-side of the main power transformer exceed 1.1 per unit for longer than 45 seconds or exceed 1.18 per unit for longer than 2 seconds.
- M1.** Each Generator Owner and Transmission Owner have evidence of dynamic simulations, studies, or other evidence to demonstrate the design of each facility will adhere to Ride-through requirements, as specified in Requirement R1. Each Generator Owner and Transmission Owner have evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) to demonstrate that the operation of each facility did adhere to Ride-through requirements, as specified in Requirement R1. If the Generator Owner and Transmission Owner choose to utilize Ride-through exemptions that occur within the “must Ride-through zone” and are caused by non-fault initiated phase jumps of greater than 25 electrical degrees, then each Generator Owner and Transmission Owner also have evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) data to demonstrate that the facility failed to Ride-through during a phase jump of greater than or equal to 25 electrical degrees, and documentation from their Transmission Planner, Reliability Coordinator, Planning Coordinator, or Transmission Operator that a non-fault initiated switching event occurred.
- R2.** Each Generator Owner or Transmission Owner shall ensure the design and operation is such that the voltage performance for each facility adheres to the following during a voltage excursion, unless a documented equipment limitation exists in accordance with Requirement R4. *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*

³ Includes no tripping associated with phase lock loop loss of synchronism

- 2.1.** While the voltage at the high-side of the main power transformer⁴ remains within the continuous operation region as specified in Attachment 1, each facility shall:
- 2.1.1** Continue to deliver the pre-disturbance level of active power or available active power, whichever is less.⁵
 - 2.1.2** Continue to deliver reactive power up to its reactive power limit and according to its controller settings.
 - 2.1.3** If the facility cannot deliver both active and reactive power due to a current limit or reactive power limit, when the voltage is below 95 per unit and still within the continuous operation region, then preference shall be given to active or reactive power according to requirements if required 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 exchange current, up to the maximum capability to provide voltage support, on the affected phases during both symmetrical and asymmetrical voltage disturbances, either under⁶:
- Reactive power priority by default; or
 - Active power priority if required by the Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator.
- 2.3.** While voltage at the high-side of the main power transformer is within the permissive operation region, as specified in Attachment 1, each facility may operate in current block mode if necessary to avoid tripping. Otherwise, each facility shall follow the requirements for the mandatory operation region in Requirement R2.2.
- 2.3.1** If a facility enters current block mode, it shall restart current exchange in less than or equal to five cycles of positive sequence voltage returning to a continuous operation region or mandatory operation region.
- 2.4.** Each facility shall not itself cause voltage at the high-side of the main power transformer to exceed the applicable high voltage thresholds and time

⁴ For the purpose of this standard, the main power transformer is the power transformer that steps up voltage from the collection system voltage to the nominal transmission/interconnecting system voltage for inverter-based resources. In case of offshore wind plants connecting via a dedicated VSC-HVDC, the main power transformer is the onshore main power transformer.

⁵ Except if this would occur during a frequency excursion. The active power response should recover in accordance with the primary frequency controller.

⁶ In either case and if required, the magnitude of active power and reactive current shall be as specified by the Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator.

durations in its response as voltage recovers from the mandatory or permissive operation regions to the continuous operation region.

- 2.5.** Each facility shall restore active power output to the pre-disturbance or available level (whichever is lesser) within 1.0 second when the voltage at the high-side of the main power transformer returns from the mandatory operation region or permissive operation region (including operating in current block mode), as specified in Attachment 1, unless the Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator requires a lower post-disturbance active power level requirement or requires a different post-disturbance active power restoration time.⁷
- M2.** Each Generator Owner and Transmission Owner have evidence of dynamic simulations, studies, or other evidence to demonstrate the design of each facility will adhere to requirements, as specified in Requirement R2. Each Generator Owner and Transmission Owner also have evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) data to demonstrating that the operation of each facility did adhere to performance requirements, as specified in Requirement R2, during each voltage excursion measured at the high-side of the main power transformer. The Generator Owner or Transmission Owner have evidence of receiving such performance requirements, (e.g. email exchange, contract information) if the Transmission Planner, Transmission Operator, Reliability Coordinator, or Planning Coordinator has required the Generator Owner or Transmission Owner to follow performance requirements other than those in Requirement R2 (e.g. ramp rates, reactive power prioritization).
- R3.** Each Generator Owner or Transmission Owner shall ensure the design and operation is such that each facility adheres to Ride-through requirements during a frequency excursion event whereby the System frequency remains within the “must Ride-through zone” according to Attachment 2 and the absolute rate of change of frequency (RoCoF)⁸ magnitude is less than or equal to 5 Hz/second. [*Violation Risk Factor: High*] [*Time Horizon: Operations Assessment*]
- M3.** Each Generator Owner and Transmission Owner have evidence of dynamic simulations, studies, or other evidence to demonstrate the design of each facility will adhere to Ride-through requirements, as specified in Requirement R3. Each Generator Owner and Transmission Owner also have evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) data to demonstrate the operation of each facility did adhere to Ride-through requirements, as specified in Requirement R3, during each frequency excursion event measured at the high-side of the main power transformer.
- R4.** Each Generator Owner and Transmission Owner identifying a facility that is in-service by the effective date of PRC-029-1, has known hardware limitations that prevent the

⁷ Except if this would occur during a frequency excursion. The active power response should recover in accordance with the primary frequency controller.

⁸ 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.

facility from meeting voltage Ride-through criteria as detailed in Requirements R1 and R2, and requires an exemption from specific voltage Ride-through criteria shall:⁹
Lower] [Time Horizon: Long-term Planning]

- 4.1.** Document information supporting the identified hardware limitation no later than 12 months following the effective date of PRC-029-1. This documentation shall include:
 - 4.1.1** Identifying information of the IBR (name, facility #, other);
 - 4.1.2** Which aspects of voltage ride-through requirements that the IBR would be unable to meet and the capability of the equipment due to the limitation;
 - 4.1.3** Identify the specific piece(s) of equipment causing the limitation;
 - 4.1.4** Supporting technical documentation verifying the limitation is due to hardware that needs to be physically replaced or that the limitation cannot be removed by software updates or setting changes, and;
 - 4.1.5** Information regarding any plans to remedy the equipment limitation (such as an estimated date).
 - 4.2.** Provide a copy of the information detailed in Requirement R4.1 to the applicable Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and to the Regional Entity no later than 12 months following the effective date of PRC-029-1.
 - 4.2.1** Any response to additional information requested by the applicable Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and to the Regional Entity shall be provided back to the requestor within 90 days of the request.
 - 4.3.** Each Generator Owner and Transmission Owner with a previously submitted request for exemption that replace the equipment causing the limitation shall document and communicate such an equipment change to the associated Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), and Reliability Coordinator(s) within 90 days of the equipment change.
 - 4.3.1** When existing equipment is replaced, the exemption for that Ride-through criteria no longer applies.
- M4.** Each Generator Owner and Transmission Owner seeking an exemption for facilities that are in-service by the effective date of PRC-029-1 have evidence of submission to the Regional Entity consistent with the information listed in Requirement R4.1. Each Generator Owner and Transmission Owner have evidence of communicated copies of each submission in accordance with Requirement R4.2 and to the applicable entities described in Requirement R4.2. Acceptable type of evidence for submittals include but

⁹ The exemption requests for a non-US Registered Entity should be implemented in a manner that is consistent with, or under the direction of, the applicable governmental authority or its agency in the non-US jurisdiction

are not limited to, meeting minutes, agreements, copies of procedures or protocols in effect, or email correspondence. Acceptable types of evidence for an equipment limitation may include but is not limited to, documentation that contains study results, experience from an actual event, or manufacturer’s advice. Each Generator Owner and Transmission Owner that replace equipment at a facility that is directly associated with an approved exemption and that equipment is the cause for the limitation, have evidence of communicating the equipment change to the applicable entities described in Requirement R4.3 within 30 calendar days of the equipment replacement.

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 Requirements R1, R2, and R3 in this standard for 36 calendar months.
- Each Generator Owner and Transmission Owner shall retain evidence with Requirement R4 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.	The Generator Owner or Transmission Owner failed to demonstrate the capability of each applicable facility to Ride-through in accordance with Attachment 1, except for those conditions identified in Requirement R1.	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable facility adhered to Ride-through requirements in accordance with Attachment 1, except for those conditions identified in Requirement R1.
R2.	The Generator Owner or Transmission Owner failed to demonstrate the capability of each applicable facility to adhere to performance requirements during voltage excursions, as specified in Requirement R2.	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable facility adhered to performance requirements during voltage excursions, as specified in Requirement R2.
R3.	The Generator Owner or Transmission Owner failed to demonstrate the capability of each applicable facility to Ride-through in accordance with Attachment 2.	N/A	N/A	The Generator Owner or Transmission Owner failed to demonstrate each applicable facility adhered to Ride-through requirements in accordance with Attachment 2.
R4.	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that	The Generator Owner or Transmission Owner with a previously communicated equipment limitation that	The Generator Owner or Transmission Owner failed to document complete information for facilities

R #	Violation Severity Levels			
	Lower VSL	Moderate VSL	High VSL	Severe VSL
	<p>repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and Regional Entity more than 30 calendar days but less than or equal to 60 calendar days after the change to the equipment.</p> <p>OR</p> <p>The Generator Owner or Transmission Owner provided a copy to the applicable entities as detailed in R4.2 more than 12 months but less than or equal to 15 months after the effective date of R4.</p>	<p>repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator(s), Transmission Planner(s), Reliability Coordinator(s), Transmission Operator(s), and Regional Entity more than 60 calendar days but less than or equal to 90 calendar days after the change to the equipment.</p>	<p>repairs or replaces the documented limiting equipment but failed to document and communicate the change to its Planning Coordinator(s), Transmission Planner(s), Reliability Coordinator(s), Transmission Operator(s), and Regional Entity more than 90 calendar days but less than or equal to 120 calendar days after the change to the equipment.</p>	<p>identified with known hardware limitations that prevent the facility from meeting voltage Ride-through criteria as detailed in Requirements R1 or R2.</p> <p>OR</p> <p>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(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and Regional Entity more than 120 calendar days after the change to the equipment.</p> <p>OR</p> <p>The Generator Owner or Transmission Owner failed to provide a copy to the applicable entities as detailed in R4.2 within 24 months after the effective date of R4.</p>

D. Regional Variances

None.

E. Associated Documents

Implementation Plan .

Version History

Version	Date	Action	Change Tracking
Initial Draft	3/27/24	DRAFT	
DRAFT 2	6/4/24	Revised follow initial comment review	

Attachment 1: Voltage Ride-Through Criteria

Table 1: Voltage Ride-Through Requirements for AC-Connected Wind Facility¹⁰

Voltage (per unit) ¹¹	Operation Region	Minimum Ride-Through Time (sec)
> 1.20	N/A ¹²	N/A
≤ 1.20 and ≥ 1.1	Mandatory Operation Region	1.0
≤ 1.10 and > 1.05	Continuous Operation Region	1800
≤ 1.05 and ≥ 0.90	Continuous Operation Region	Continuous
< 0.90 and ≥ 0.70	Mandatory Operation Region	3.00
< 0.70 and ≥ 0.50	Mandatory Operation Region	2.50
< 0.50 and ≥ 0.25	Mandatory Operation Region	1.20
< 0.25 and ≥ 0.10	Mandatory Operation Region	0.16
< 0.10	Permissive Operation Region	0.16

Table 2: Voltage Ride-Through Requirements for All Other Inverter-based Resource Facilities

Voltage (per unit) ¹³	Operation Region	Minimum Ride-Through Time (sec)
>1.20	N/A ¹⁴	N/A
≤ 1.20 and > 1.1	Mandatory Operation Region	1.0
≤ 1.10 and > 1.05	Continuous Operation Region	1800
≤ 1.05 and ≥ 0.90	Continuous Operation Region	Continuous
< 0.90 and ≥ 0.70	Mandatory Operation Region	6.00
< 0.70 and ≥ 0.50	Mandatory Operation Region	3.00
< 0.50 and ≥ 0.25	Mandatory Operation Region	1.20
< 0.25 and ≥ 0.10	Mandatory Operation Region	0.32
< 0.10	Permissive Operation Region	0.32

¹⁰ Type 3 and type 4 wind resources directly connected to the AC Transmission System

¹¹ Refer to bullet #5 below.

¹² These conditions are referred to as the “may Ride-through zone”.

¹³ Refer to bullet #5 below.

¹⁴ These conditions are referred to as the “may Ride-through zone”.

1. Table 1 applies to type 3 and type 4 wind facilities unless connected via a dedicated VSC-HVDC transmission facility.
2. Table 2 applies to all other inverter-based resource facility types not covered in Table 1; including, but not limited to, the following facilities:
 - a. Inverter-based resources, regardless of their energy resource, interconnecting via a dedicated VSC-HVDC transmission facility.
 - b. Other inverter-based resource plants or hybrid plants consisting of photovoltaic (PV) and BESS.
3. The applicable voltage for Voltage Source Converter High Voltage Direct Current (VSC HVDC) system with a dedicated connection to an inverter-based resource is on the AC side of the transformer(s) that is (are) used to connect the VSC HVDC system to the interconnected transmission system
4. Table 1 applies to hybrid facilities consisting of wind (type 3 or type 4) and various other IBR technologies. Otherwise, Table 2 applies to hybrid facilities with no wind (type 3 or type 4).
5. 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.
6. 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 main power transformer.
7. Tables 1 and 2 are only applicable when the frequency is within the “must Ride-through zone” as specified in Table 3 of Attachment 2.
8. At any given voltage value, each facility shall Ride-through unless the time duration at that voltage has exceeded 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 any 10 second time period.
9. 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 any 10 second time period.
10. The facility 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.
11. Instantaneous trip settings based on instantaneously calculated voltage measurements with less than filtering lengths of one cycle (16.6 msec) are not permissible.
12. The “must Ride-through zone” is the combined area of the mandatory operating regions, the continuous operating regions, and the permissive operating region. All

area outside of these operating regions is referred to as the “may Ride-through zone”.

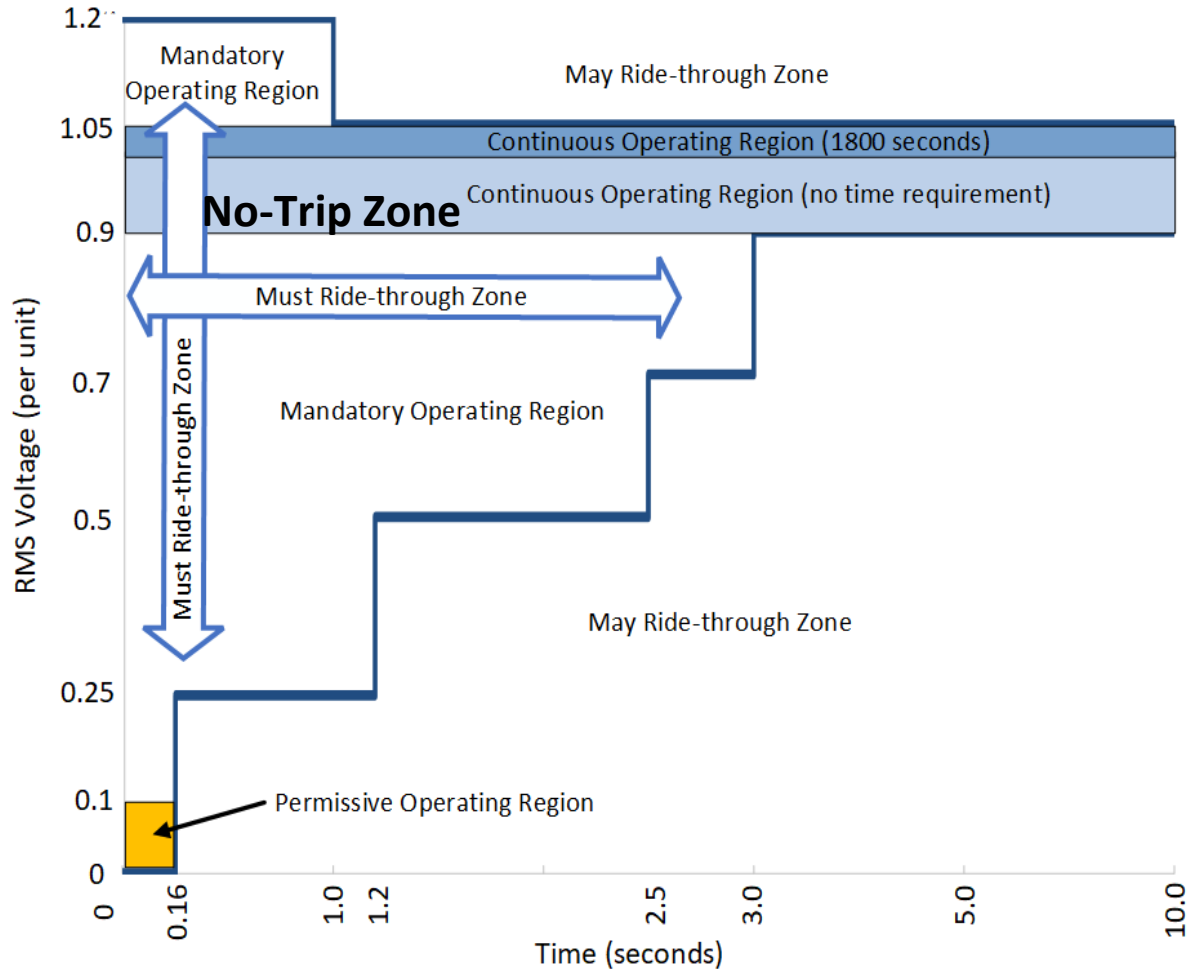


Figure 1: Voltage Ride-Through Requirements for AC-Connected Wind Facilities

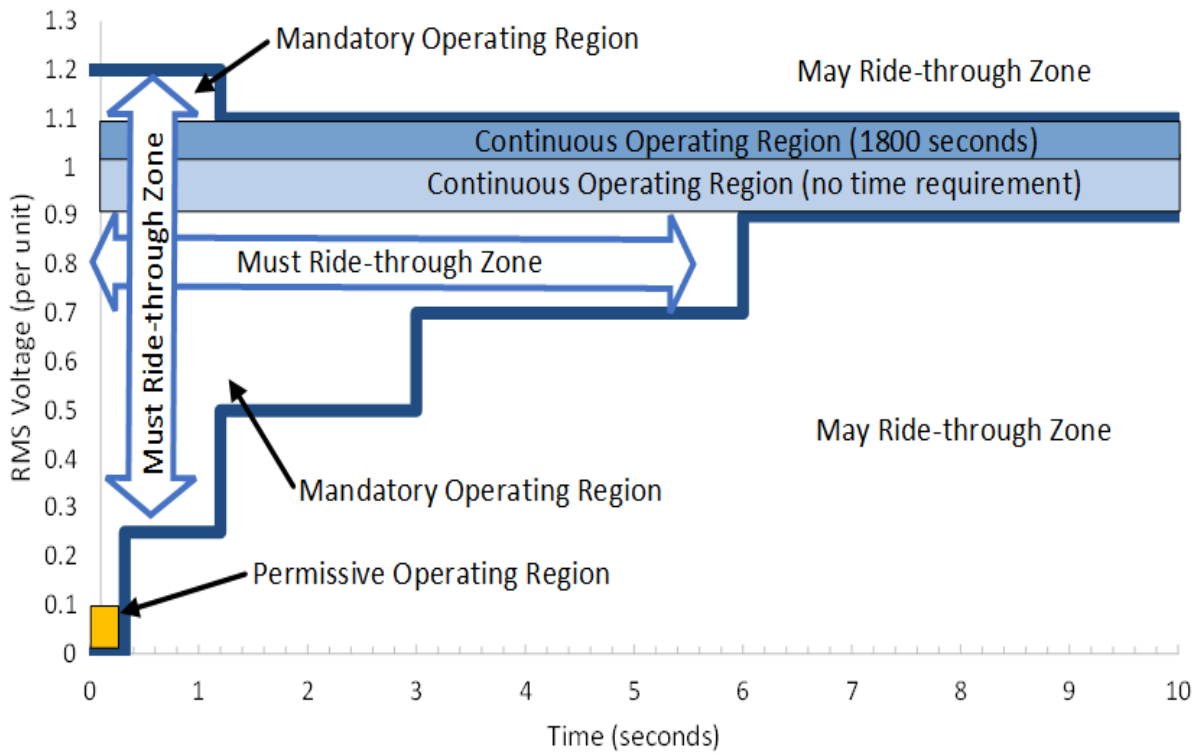


Figure 2: Voltage Ride-Through Requirements for All Other IBR

Attachment 2: Frequency Ride-Through Criteria

Table 3: Frequency Ride-Through Capability Requirements

System Frequency (Hz)	Minimum Ride-Through Time (sec)
≥64	May trip
< 64 and ≥61.8	6
< 61.8 and ≥ 61.5	299
< 61.5 and > 61.2	660
≤ 61.2 and < 58.8	Continuous
≤ 58.8 and < 58.8	660
< 58.5 and ≥ 57	299
< 57.0 and ≥ 56	6
< 56	May trip

1. Frequency measurements are taken at the high-side of the main power transformer.
2. Frequency is measured over a period of time (typically 3-6 cycles) to calculate 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 value, each facility shall Ride-through unless the time duration at that frequency has exceeded the specified minimum ride-through time duration.
5. The specified durations of Table 3 are cumulative over one or more disturbances within a 15-minute time period.

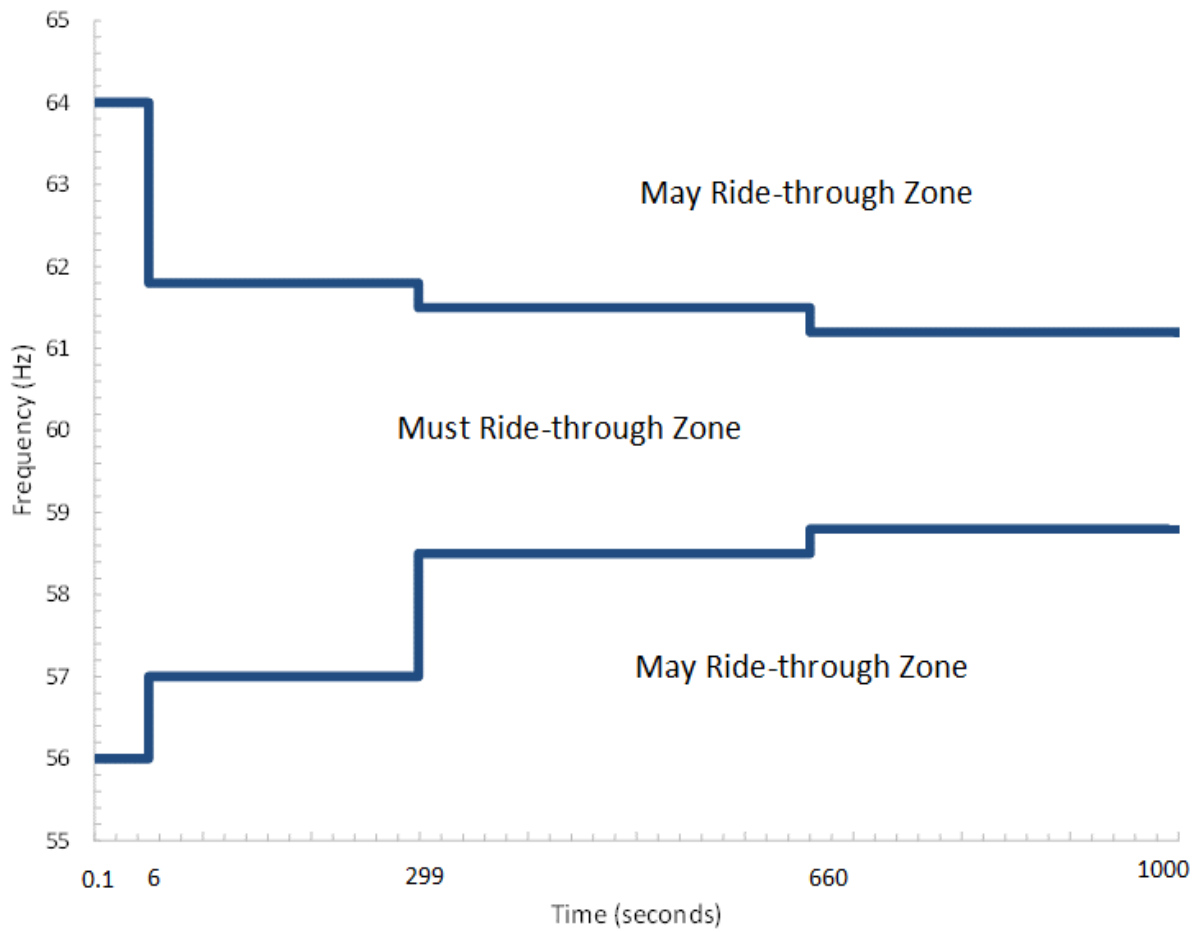


Figure 3: PRC-029 Frequency Ride-Through Requirements