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

Draft 3 of PRC-029-1 is posted for a formal comment and additional ballot.

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
25-day formal comment period and initial ballot	March 27 – April 22, 2024
15-day formal comment period and additional ballot	June 18 – July 8, 2024

Anticipated Actions	Date
15-day formal comment period and additional ballot	July 22 – August 12, 2024
Final Ballot	August 26 – September 6, 2024
Board adoption	October 8, 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: The entire plant/facility remaining connected to the Bulk Power System and continuing in its entirety to operate through System Disturbances.

The term Inverter-based Resource (IBR) refers to proposed definitions being developed under the Project 2020-06 Verifications of Models and Data for Generators. As of this posting, the proposed definition of an IBR is:

IBR: A plant/facility consisting of individual devices that are capable of exporting Real Power through a power electronic interface(s) such as inverter or converter, and that are operated together as a single resource at a common point of interconnection to the electric system. IBRs include, but are not limited to, plants/facilities with solar photovoltaic (PV), Type 3 and Type 4 wind, battery energy storage system (BESS), and fuel cell devices.

A. Introduction

1. **Title:** **Frequency and Voltage Ride-through Requirements for Inverter-based Resources**

2. **Number:** **PRC-029-1**

3. **Purpose:** To ensure that IBRs Ride-through 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

   4.2 Facilities:

   4.2.1. The Elements associated with (1) Bulk Electric System (BES) IBRs; and (2) Non-BES IBRs that either have or contribute to an aggregate nameplate capacity of greater than or equal to 20 MVA, connected through a system designed primarily for delivering such capacity to a common point of connection at a voltage greater than or equal to 60 kV.

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

Standard-only Definition: None

B. Requirements and Measures

R1. Each Generator Owner shall ensure the design and operation is such that each IBR meet or exceed Ride-through requirements, in accordance with the "must Ride-through[1] zone" as specified in Attachment 1, except for the following: *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*

- The IBR needed to electrically disconnect in order to clear a fault; or
- The voltage at the high-side of the main power transformer[2] went outside an accepted hardware limitation, 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[3]; 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 shall have evidence to demonstrate the design of each IBR will adhere to Ride-through requirements, as specified in Requirement R1. Examples of evidence may include, but are not limited to dynamic simulations, studies, plant protection settings, and control settings design evaluation. Each Generator Owner shall retain evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) to demonstrate that the operation of each IBR did adhere to Ride-through requirements, as specified in Requirement R1. If the Generator 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 shall also retain evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) data to demonstrate that the IBR 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 shall ensure the design and operation is such that the voltage performance for each IBR adheres to the following during a voltage excursion, unless a documented hardware limitation exists in accordance with Requirement R4. *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*

[1] Includes no tripping associated with phase lock loop loss of synchronism

[2] 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 IBRs. In case of IBR connecting via a dedicated Voltage Source Converter High Voltage Direct Current (VSC-HVDC), the main power transformer is the main power transformer on the receiving end.

[3] Current blocking mode may be used for non-fault initiated phase jumps greater than 25 degrees in order to prevent tripping.

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 Real Power or available Real Power[4], whichever is less.[5]

2.1.2 Continue to deliver Reactive Rower up to its Reactive Power limit and according to its controller settings.

2.1.3 Prioritize Real Power or Reactive Power when the voltage is less than 0.95 per unit, the voltage is within the continuous operating region, and the IBR cannot deliver both Real Power and Reactive Power due to a current limit or Reactive Power limit, unless otherwise specified through other mechanisms by an associated 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 under[6]:

- Reactive Power priority by default; or
- Real Power priority if required through other mechanisms by an associated 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 IBR may operate in current blocking mode if necessary to avoid tripping. Otherwise, each IBR shall follow the requirements for the mandatory operation region in Requirement R2.2.

2.3.1 If a IBR enters current blocking 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 IBR shall not itself cause voltage at the high-side of the main power transformer to exceed the applicable high voltage thresholds and time

[4] "Available Real Power" refers to changes of facility Real Power output attributed to factors such as weather patterns, change of wind, and change in irradiance, but not changes of facility Real Power attributed to IBR tripping in whole or part.
[5] Except if this would occur during a frequency excursion. The Real Power response should recover in accordance with the primary frequency controller.
[6] In either case and if required, the magnitude of Real 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 IBR shall restore Real Power output to the pre-disturbance or available level[7] (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 blocking mode) to the continuous operation region, as specified in Attachment 1, unless an associated Transmission Planner, Planning Coordinator, Reliability Coordinator, or Transmission Operator requires a lower post-disturbance Real Power level requirement or requires a different post-disturbance Real Power restoration time through other mechanisms.[8]

M2. Each Generator Owner shall have evidence to demonstrate the design of each IBR will adhere to requirements, as specified in Requirement R2. Examples of evidence may include, but are not limited to dynamic simulations, studies, plant protection settings, and control settings design evaluation. Each Generator Owner shall also retain evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) data to demonstrate that the operation of each IBR did adhere to performance requirements, as specified in Requirement R2, during each voltage excursion measured at the high-side of the main power transformer. In regard to R2.1.3, R2.2, and R2.5, the Generator Owner shall retain 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 through other mechanisms to follow performance requirements other than those in Requirement R2 (e.g. ramp rates, Reactive Power prioritization).

R3. Each Generator Owner shall ensure the design and operation is such that each IBR meets or exceeds 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)[9] magnitude is less than or equal to 5 Hz/second. *[Violation Risk Factor: High] [Time Horizon: Operations Assessment]*

M3. Each Generator Owner shall have evidence to demonstrate the design of each IBR will adhere to Ride-through requirements, as specified in Requirement R3. Examples of evidence may include, but are not limited to dynamic simulations, studies, plant protection settings, and control settings design evaluation. Each Generator Owner shall also retain evidence of actual disturbance monitoring (i.e. Sequence of Event Recorder, Dynamic Disturbance Recorder, and Fault Recorder) data to demonstrate the operation of each IBR did adhere to Ride-through requirements, as specified in

[7] "Available Real Power" refers to changes of facility Real Power output attributed to factors such as weather patterns, change of wind, and change in irradiance, but not changes of facility Real Power attributed to IBR tripping in whole or part.
[8] Except if this would occur during a frequency excursion. The Real Power response should recover in accordance with the primary frequency controller.
[9] 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.

Requirement R3, during each frequency excursion event measured at the high-side of the main power transformer.

R4. Each Generator Owner identifying an IBR that is in-service by the effective date of PRC-029-1, has known hardware limitations that prevent the IBR from meeting voltage Ride-through criteria as detailed in Requirements R1 and R2, and requires an exemption from specific voltage Ride-through criteria shall*:[10] 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 and facility #);

4.1.2 Which aspects of voltage Ride-through requirements that the IBR would be unable to meet and the capability of the hardware due to the limitation;

4.1.3 Identify the specific piece(s) of hardware 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 hardware limitation (such as an estimated date).

4.2. Provide a copy of the information detailed in Requirement R4.1 to the associated Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and the CEA no later than 12 months following the effective date of PRC-029-1.

4.2.1 Any response to additional information requested by the associated Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and the CEA shall be provided back to the requestor within 90 days of the request.

4.2.2 Provide a copy of the acceptance of an hardware limitation by the CEA to the associated Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), and Reliability Coordinator(s).[11]

4.3. Each Generator Owner with a previously accepted limitation that replace the hardware causing the limitation shall document and communicate such a hardware change to the associated Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), and Reliability Coordinator(s) within 90 days of the hardware change.

[10] 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.

[11] Acceptance by the CEA is verification that the information provided includes all information listed in Requirement R4.1.

4.3.1 When existing hardware causing the limitation is replaced, the exemption for that Ride-through criteria no longer applies.

M4. Each Generator Owner submitting for an exemption for an IBR that is in-service by the effective date of PRC-029-1, shall have evidence of submission to the CEA consistent with the information listed in Requirement R4.1. Each Generator Owner shall have evidence of communicated copies of each submission in accordance with Requirement R4.2 and to the associated entities described in Requirement R4.2. Acceptable types of evidence for submittals include but are not limited to, meeting minutes, agreements, copies of procedures or protocols in effect, or email correspondence. Acceptable types of evidence for a hardware 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 that receives a request for additional information under Requirement R4.2.1 shall have evidence of providing that information within 90 calendar days. Each Generator Owner that replaces hardware at an IBR that is directly associated with an accepted exemption and that hardware is the cause for the limitation, shall have evidence of communicating the hardware change to the associated entities described in Requirement R4.3 within 90 calendar days of the hardware 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 shall retain evidence with Requirements R1, R2, and R3 in this standard for 36 calendar months or the date of the last audit, whichever is greater.
- Each Generator Owner shall retain evidence with Requirement R4 in this standard for five calendar years or the date of the last audit, whichever is greater.

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 failed to demonstrate the design capability of each applicable IBR to Ride-through in accordance with Attachment 1, except for those conditions identified in Requirement R1.	N/A	N/A	The Generator Owner failed to demonstrate each applicable IBR adhered to Ride-through requirements in accordance with Attachment 1, except for those conditions identified in Requirement R1.
R2.	The Generator Owner failed to demonstrate the design capability of each applicable IBR to adhere to performance requirements during voltage excursions, as specified in Requirement R2.	N/A	N/A	The Generator Owner failed to demonstrate each applicable IBR adhered to performance requirements during voltage excursions, as specified in Requirement R2.
R3.	The Generator Owner failed to demonstrate the design capability of each applicable IBR to Ride-through in accordance with Attachment 2.	N/A	N/A	The Generator Owner failed to demonstrate each applicable IBR adhered to Ride-through requirements in accordance with Attachment 2.
R4.	The Generator Owner with a previously communicated hardware limitation that replace the documented limiting hardware but failed to document and communicate	The Generator Owner with a previously communicated hardware limitation that replace the documented limiting hardware but failed to document and communicate	The Generator Owner with a previously communicated hardware limitation that replace the documented limiting hardware but failed to document and communicate	The Generator Owner failed to document complete information for IBR identified with known hardware limitations that prevent the IBR from meeting voltage

R #	Violation Severity Levels			
	Lower VSL	Moderate VSL	High VSL	Severe VSL
	the change to its Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s), Reliability Coordinator(s), and CEA more than 90 calendar days but less than or equal to 120 calendar days after the change to the hardware. OR The Generator Owner provided a copy to the applicable entities as detailed in Requirement R4.2 more than 12 months but less than or equal to 15 months after the effective date of Requirement R4. OR The Generator Owner failed to respond to the applicable entities as detailed in Requirement R4.2.1 more than 90 days but less than or equal to 120 days after receiving a request for additional information by an entity listed in Requirement R4.2.1.	the change to its Planning Coordinator(s), Transmission Planner(s), Reliability Coordinator(s), Transmission Operator(s), and CEA more than 120 calendar days but less than or equal to 150 calendar days after the change to the hardware. OR The Generator Owner failed to respond to the applicable entities as detailed in Requirement R4.2.1 more than 120 days but less than or equal to 150 days after receiving a request for additional information by an entity listed in Requirement R4.2.1.	the change to its Planning Coordinator(s), Transmission Planner(s), Reliability Coordinator(s), Transmission Operator(s), and CEA more than 150 calendar days but less than or equal to 180 calendar days after the change to the hardware. OR The Generator Owner failed to respond to the applicable entities as detailed in Requirement R4.2.1 more than 150 days but less than or equal to 180 days after receiving a request for additional information by an entity listed in Requirement R4.2.1.	Ride-through criteria as detailed in Requirements R1 or R2. OR The Generator Owner with a previously communicated hardware limitation that replace the documented limiting hardware but failed to document and communicate the change to its Planning Coordinator(s), Transmission Planner(s), Transmission Operator(s),Reliability Coordinator(s), and CEA more than 180 calendar days after the change to the hardware. OR The Generator Owner failed to provide a copy to the applicable entities as detailed in Requirement R4.2 within 24 months after the effective date of Requirement R4. OR

R #	Violation Severity Levels			
	Lower VSL	Moderate VSL	High VSL	Severe VSL
				The Generator Owner failed to respond to the applicable entities as detailed in Requirement R4.2.1 more than 180 days after receiving a request for additional information by an entity listed in Requirement R4.2.1.

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 following initial comment review	
Draft 3	7/22/24	Revised following additional comment review	

Attachment 1: Voltage Ride-Through Criteria

Table 1: Voltage Ride-through Requirements for AC-Connected Wind IBR [12]

Voltage (per unit)[13]	Operation Region	Minimum Ride-Through Time (sec)
> 1.20	N/A[14]	N/A
≥ 1.10	Mandatory Operation Region	1.0
> 1.05	Continuous Operation Region	1800
≤ 1.05 and ≥ 0.90	Continuous Operation Region	Continuous
< 0.90	Mandatory Operation Region	3.00
< 0.70	Mandatory Operation Region	2.50
< 0.50	Mandatory Operation Region	1.20
< 0.25	Mandatory Operation Region	0.16
< 0.10	Permissive Operation Region	0.16

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

Voltage (per unit)[15]	Operation Region	Minimum Ride-Through Time (sec)
> 1.20	N/A[16]	N/A
> 1.10	Mandatory Operation Region	1.0
> 1.05	Continuous Operation Region	1800
≤ 1.05 and ≥ 0.90	Continuous Operation Region	Continuous
< 0.90	Mandatory Operation Region	6.00
< 0.70	Mandatory Operation Region	3.00
< 0.50	Mandatory Operation Region	1.20
< 0.25	Mandatory Operation Region	0.32
< 0.10	Permissive Operation Region	0.32

[12] Type 3 and type 4 wind resources directly connected to the AC Transmission System.
[13] Refer to bullet #4 below.
[14] These conditions are referred to as the “may Ride-through zone”.
[15] Refer to bullet #4 below.
[16] These conditions are referred to as the “may Ride-through zone”.

1. Table 1 applies to type 3 and type 4 wind IBR or hybrid IBR that include wind, 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 facilities:
    a. IBR, regardless of their energy resource, interconnecting via a dedicated VSC-HVDC transmission facility.
    b. Other IBR or hybrid IBR consisting of photovoltaic (PV) and BESS.
3. The applicable voltage for VSC-HVDC system with a dedicated connection to an IBR 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. 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, Transmission Planner, or Transmission Owner.
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 main power transformer.
6. Tables 1 and 2 are only applicable when the frequency is within the “must Ride-through zone” as specified in Figure 1 of Attachment 2.
7. At any given voltage value, each IBR 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.
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 any 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. Instantaneous trip settings based on instantaneously calculated voltage measurements with less than filtering lengths of one cycle (16.6 millisecond) are not permissible.
11. 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”.

Attachment 2: Frequency Ride-Through Criteria

Table 3: Frequency Ride-through Capability Requirements

System Frequency (Hz)	Minimum Ride-Through Time (sec)
> 64.0	May trip
≥ 61.8	6
≥ 61.5	299
> 61.2	660
≤ 61.2 and > 58.8	Continuous
≤ 58.8	660
≤ 58.5	299
≤ 57.0	6
< 56.0	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 IBR 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.

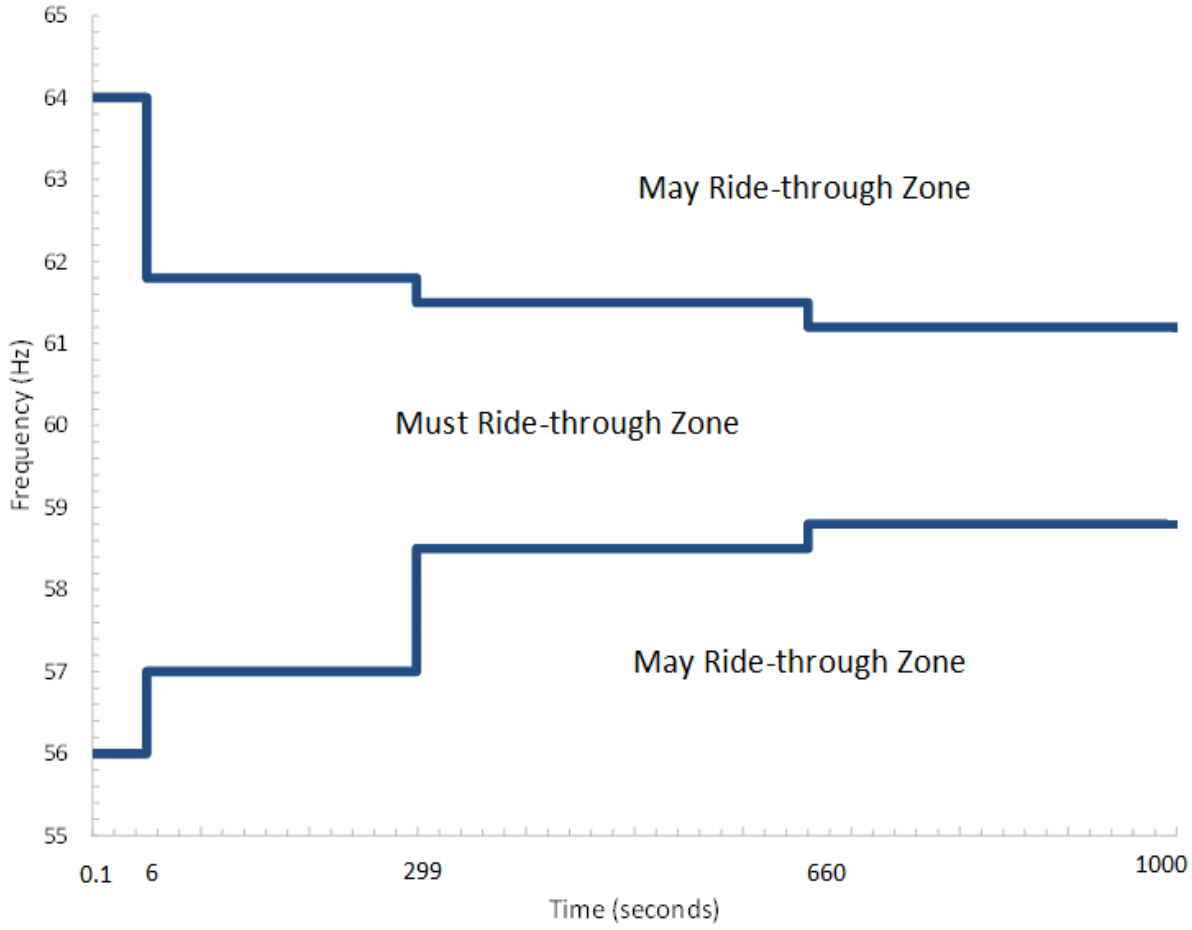

Figure 1: PRC-029 Frequency Ride-through Requirements