

## Standard PRC-024-1 — Generator Performance During Frequency and Voltage Excursions

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### Standard Development Roadmap

*This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.*

#### Development Steps Completed:

1. SAR posted for comment (April 20–May 21, 2007).
2. Revised SAR and response to comments posted.
3. Revised SAR and response to comments approved by SC (June 14, 2007).
4. SDT appointed on (August 18, 2007).
5. Initial draft of PRC-024-1 was posted for a 45 day formal comment period (February 17 – April 2, 2009).
6. Draft 2 of PRC-024-1 was posted for a 45 day concurrent comment and ballot period from June 15 – August 1, 2011.
7. Draft 3 of PRC-024-1 was posted for a 30 day concurrent comment and successive ballot period from February 29 – March 29, 2012.

#### Proposed Action Plan and Description of Current Draft:

This is the fourth draft of the standard and includes Time Horizons, Data Retention, Violation Risk Factors, and Violation Severity Levels. This fourth posting is for a 30-day comment and successive ballot period.

#### Future Development Plan:

Anticipated Actions	Anticipated Date
1. Develop responses to comments and develop third version draft standard.	April - July 2012
2. Post response to comments and conduct successive ballot.	October-November 2012
3. Develop responses to ballot comments.	December 2012 – January 2013
4. Post responses to comments and conduct recirculation ballot.	February 2013

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5. BOT adoption.	March 2013
6. File with regulatory authorities.	April 2013

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### Definitions of Terms Used in Standard

*This section includes all newly defined or revised terms used in the proposed standard. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed standard is approved. When the standard becomes effective, these defined terms will be removed from the individual standard and added to the Glossary.*

**None**

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### A. Introduction

1. **Title:** Generator Performance During Frequency and Voltage Excursions
2. **Number:** PRC-024-1
3. **Purpose:** Ensure generating units remain connected during frequency and voltage excursions and ensure expected generating unit performance during frequency and voltage excursions is communicated to Reliability Coordinators, Planning Coordinators, Transmission Operators and Transmission Planners for accurate system modeling.
4. **Applicability:**
  - 4.1. Generator Owner
5. **Effective Date:**
  - 5.1. In those jurisdictions where regulatory approval is required:
    - 5.1.1 By the first day of the first calendar quarter, two calendar years following applicable regulatory approval, each Generator Owner shall have verified at least 40 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
    - 5.1.2 By the first day of the first calendar quarter, three calendar years following applicable regulatory approval, each Generator Owner shall have verified at least 60 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
    - 5.1.3 By the first day of the first calendar quarter, four calendar years following applicable regulatory approval, each Generator Owner shall have verified at least 80 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
    - 5.1.4 By the first day of the first calendar quarter, five calendar years following applicable regulatory approval, each Generator Owner shall have verified 100 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
    - 5.1.5 By the first day of the first calendar quarter, six calendar years following applicable regulatory approval, each Generator Owner shall have verified 100 percent of its Facilities are fully compliant with Requirement R5.
  - 5.2. In those jurisdictions where regulatory approval is not required:
    - 5.2.1 By the first day of the first calendar quarter, two calendar years following Board of Trustees approval, each Generator Owner shall have verified at

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least 40 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.

- 5.2.2 By the first day of the first calendar quarter, three calendar years following Board of Trustees approval, each Generator Owner shall have verified at least 60 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
- 5.2.3 By the first day of the first calendar quarter, four calendar years following Board of Trustees approval, each Generator Owner shall have verified at least 80 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
- 5.2.4 By the first day of the first calendar quarter, five calendar years following Board of Trustees approval, each Generator Owner shall have verified 100 percent of its Facilities are fully compliant with Requirements R1, R2, R3, R4, and R6.
- 5.2.5 By the first day of the first quarter, six calendar years following Board of Trustees approval, each Generator Owner shall have verified 100 percent of its Facilities are fully compliant with Requirement R5.

### B. Requirements

- R1. Each Generator Owner that has generator frequency protective relaying<sup>1</sup> activated to trip its generating unit shall set such protective relaying so that the frequency protective relaying does not operate to trip the unit within the “no trip zone” of PRC-024 Attachment 1, subject to the following exceptions: *[Violation Risk Factor: Medium]*  
*[Time Horizon: Long-term Planning]*

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<sup>1</sup> Each Generator Owner is not required to have frequency or voltage protective relaying (including but not limited to frequency and voltage protective functions for discrete relays, volts per hertz relays evaluated at nominal frequency, impedance relays, voltage controlled overcurrent relays, multi-function protective devices or protective functions within control systems that directly trip or provide tripping signals to the generator based on frequency or voltage inputs) installed or activated on its unit.

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- Generation may trip if the protective functions (such as out-of-step functions or loss-of-field functions) operate due to an impending or actual loss of synchronism or due to instability in power conversion control equipment.
  - Generation may trip if clearing a system fault necessitates disconnecting the generation.
  - Generation may trip within a portion of the “no trip zone” of PRC-024 Attachment 1 for documented and communicated equipment limitations in accordance with Requirement R3 for an existing generating unit<sup>2</sup>.
- R2.** Each Generator Owner that has generator voltage protective relaying<sup>1</sup> activated to trip its generating unit shall set its protective relaying such that the voltage protective relaying does not trip as a result of a voltage excursion (at the point of interconnection<sup>3</sup>) caused by an event on the transmission system external to the generating plant that remains within the “no trip zone” of PRC-024 Attachment 2 or within the voltage recovery characteristics of a location-specific Transmission Planner’s study if the Transmission Planner allows less stringent voltage relay settings than those required to meet PRC-024 Attachment 2 subject to the following exceptions : *[Violation Risk Factor: Medium]*  
*[Time Horizon: Long-term Planning]*
- Generation may trip in accordance with a Special Protection System (SPS) or Remedial Action Scheme (RAS).
  - Generation may trip if clearing a system fault necessitates disconnecting a generating unit.
  - Generation may trip by action of protective functions (such as out-of-step functions or loss-of-field functions) that operate due to an impending or actual loss of synchronism or, for asynchronous generating units, due to instability in power conversion control equipment.
  - Generation may trip within a portion of the “no trip zone” of PRC-024 Attachment 2 for documented and communicated equipment limitations in accordance with Requirement R3 for an existing generating unit
- R3.** Each Generator Owner of an existing generating unit shall document each known equipment limitation (excluding limitations that are caused by generator frequency and voltage protective relays) that prevents a generating unit, from meeting the criteria in Requirements R1 or R2 including (but not limited to) study results, experience from an

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<sup>2</sup> To include generating units previously commissioned, or generating units under construction, or generating units with an executed interconnection agreement or power purchase agreement by the effective date of PRC-024-1 Requirement R5,

<sup>3</sup> For the purposes of this standard, point of interconnection means the transmission (high voltage) side of the generator step-up or collector transformer.

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actual event, or manufacturer's advisory [*Violation Risk Factor: Lower*] [*Time Horizon: Long-term Planning*].

**3.1.** The Generator Owner shall communicate the documented equipment limitation, or the removal of a previously documented equipment limitation, to its Reliability Coordinator, Planning Coordinator, Transmission Operator and Transmission Planner within 30 calendar days of identifying the equipment limitation or when either of the following occurs:

- The equipment causing the limitation is repaired or replaced with equipment that removes the limitation.
- The equipment causing the limitation is modified or upgraded resulting in an increase of generator nameplate capacity rating greater than 10 percent (cumulative from the first effective date of this Standard).

**R4.** Each Generator Owner of an existing generating unit shall provide an estimate of the time duration the existing generating unit will remain connected (considering performance of the auxiliary systems as well as the generator) if the unit were to experience a frequency or voltage excursion. The voltage or frequency profile at the point of interconnection is determined by dynamic simulation provided by a Reliability Coordinator, Planning Coordinator, Transmission Operator or Transmission Planner that monitors or models the associated generating unit and has requested the time duration estimate. The estimate is to be provided to the requesting Reliability Coordinator, Planning Coordinator, Transmission Owner, or Transmission Planner within 60 calendar days of receipt of a written request.

If the Generator Owner expects the existing generating unit will remain connected for longer than 10 minutes, the estimate should indicate the existing unit is not expected to trip. The Generator Owner may develop the estimates based on experience, actual event histories, or sound engineering judgment. Detailed unit performance studies are not required to develop the estimate. [*Violation Risk Factor: Lower*] [*Time Horizon: Long-term Planning*]

**R5.** Each Generator Owner shall design, build, and maintain new <sup>4</sup> generating units and plants (including auxiliary systems) consistent with the parameters set forth in PRC-024 Attachments 1 and 2, such that the generation, when operating at or above the minimum sustainable generation threshold (and for a generating plant consisting of multiple units with total generation greater than 75 MVA gross aggregate nameplate rating, when the generating plant is producing at least 20 percent of the plant's aggregate nameplate capacity) will not trip due to a frequency excursion or voltage excursion at the point of interconnection, caused by an event on the transmission system external to the generating

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<sup>4</sup> Excluding generators referenced in PRC-024-1 Footnote 2.

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plant, subject to the following exceptions: *[Violation Risk Factor: Medium] [Time Horizon: Real-time Operations]*

- For a new generating plant consisting of multiple units less than 20 MVA each with total plant generation greater than 75 MVA (gross aggregate nameplate rating), up to 10 percent of the individual generating units may disconnect as a result of the frequency or voltage excursion.
- If the Transmission Planner has provided the Generator Owner with location-specific voltage recovery characteristics as described in Requirement R2, Part 2.2, then the generation may operate to a less stringent voltage ride-through performance criterion than the duration curve identified in PRC-024 Attachment 2 consistent with those provided characteristics.
- Generation may trip if this action is designed as part of a Special Protection System (SPS) or Remedial Action Scheme (RAS).
- Generation may trip if clearing a system fault necessitates disconnecting the generation.
- Generation may trip if the Generator Owner has a temporary exemption granted by its Reliability Coordinator based on a documented equipment limitation. If an equipment limitation is identified following a plant trip caused by a frequency or voltage excursion, the Reliability Coordinator may grant a retroactive temporary exemption for that limitation if the Generator Owner develops and implements an acceptable plan to address the limitation.
- Generation may trip if the protective functions (such as out-of-step functions, or loss-of-field functions) operate due to an impending or actual loss of synchronism or, for asynchronous generating units, due to instability in power conversion control equipment.

**R6.** Each Generator Owner shall provide its generator protection trip settings to the Reliability Coordinator, Planning Coordinator, Transmission Operator and Transmission Planner (that monitors or models the associated unit), within 60 calendar days of receipt of a written request for the data, and within 60 calendar days of any change to those previously requested trip settings unless otherwise directed by the requesting Reliability Coordinator, Planning Coordinator, Transmission Operator, or Transmission Planner.  
*[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

### C. Measures

**M1.** Each Generator Owner shall have evidence such as dated setting sheets, calibration sheets, or other documentation, that generator frequency protective relays have been set in accordance with Requirement R1.

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- M2. Each Generator Owner shall have evidence such as dated setting sheets, voltage-time curves, calibration sheets, coordination plots or dynamic simulation studies, that generator voltage protective relays have been set in accordance with Requirement R2.
- M3. Each Generator Owner shall have evidence that it has documented and communicated any equipment limitations (excluding limitations that are caused by generator frequency and voltage protective relays) that resulted in an exception to Requirements R1 or R2 in accordance with Requirement R3 such as a dated email or letter that contains such documentation as study results, experience from an actual event, or manufacturer's advisory.
- M4. Each Generator Owner shall have evidence such as a copy of the estimate of time duration report and correspondence, such as dated e-mails, or other documentation that an estimate of the time duration of its existing generating unit(s) as a result of a frequency excursion or voltage excursion has been communicated in accordance with Requirement R4, and copies of any requests it has received for that information.
- M5. Each Generator Owner shall have evidence, such as dated unit output records, trip investigation reports or disturbance monitoring records, showing that each unit trip did not result from a frequency excursion or voltage excursion as specified in Requirement R5, or evidence that a listed exception applied.
- M6. Each Generator Owner shall have evidence such as dated e-mails, correspondence or other evidence that it communicated generator protective relay settings to a requesting entity within 60 calendar days of a request or change in setting(s) in accordance with Requirement R6 and copies of any requests it has received for that information..

### D. Compliance

#### 1. Compliance Monitoring Process

##### 1.1. Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance enforcement authority unless the applicable entity is owned, operated, or controlled by the Regional Entity. In such cases, the ERO or a Regional entity approved by FERC or other applicable governmental authority shall serve as the CEA.

##### 1.2. Data Retention

The following evidence retention periods 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.

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The Generator Owner shall retain evidence of compliance with Requirement R1 through R6, Measures M1 through M6; for 3 years or until the next audit, whichever is longer.

If a Generator Owner is found non-compliant, the Generator Owner shall keep information related to the non-compliance until mitigation is complete and approved for the time period specified above, whichever is longer.

The Compliance Enforcement Authority shall keep the last audit records and all requested and submitted subsequent audit records.

### **1.3. Compliance Monitoring and Assessment Processes**

Compliance Audit

Self-Certification

Spot Checking

Compliance Investigation

Self-Reporting

Complaint

### **1.4. Additional Compliance Information**

None

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**2. Violation Severity Levels**

R #	Lower VSL	Moderate VSL	High VSL	Severe VSL
<b>R1</b>	N/A	N/A	N/A	The Generator Owner that has frequency protection activated to trip a generating unit has no documented and communicated equipment limitation per Requirement R3 and failed to set its generator frequency protective relaying so that it does not trip within the criteria listed in Requirement R1
<b>R2</b>	N/A	N/A	N/A	The Generator Owner with voltage protective relaying activated to trip a generating unit has no documented and communicated equipment limitation per Requirement R3 and failed to set its voltage protective relaying so that it does not trip as a result of a voltage excursion at the point of interconnection, caused by an event external to the plant per the criteria specified in Requirement R2
<b>R3</b>	The Generator Owner documented the known non-protection system equipment limitation that prevented it from meeting the criteria in Requirement R1 or R2 and	The Generator Owner documented the known non-protection system equipment limitation that prevented it from meeting the criteria in Requirement R1 or R2 and	The Generator Owner documented the known non-protection system equipment limitation that prevented it from meeting the criteria in Requirement R1 or R2 and	The Generator Owner failed to document any known non-protection system equipment limitation that prevented it from meeting the criteria in Requirement R1 or R2.

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R #	Lower VSL	Moderate VSL	High VSL	Severe VSL
	communicated the documented limitation to its Reliability Coordinator, Planning Coordinator, Transmission Operator and Transmission Planner more than 30 calendar days but less than or equal to 40 calendar days of identifying the limitation.	communicated the documented limitation to its Reliability Coordinator, Planning Coordinator, Transmission Operator and Transmission Planner more than 40 calendar days but less than or equal to 50 calendar days of identifying the limitation.	communicated the documented limitation to its Reliability Coordinator, Planning Coordinator, Transmission Operator and Transmission Planner more than 50 calendar days but less than or equal to 60 calendar days of identifying the limitation.	OR The Generator Owner failed to communicate the documented limitation to its Reliability Coordinator, Planning Coordinator, Transmission Operator and Transmission Planner within 60 calendar days of identifying the limitation.
<b>R4</b>	The Generator Owner provided an estimate of a unit's performance more than 60 calendar days but less than or equal to 70 calendar days of a written request.	The Generator Owner provided an estimate of a unit's performance more than 70 calendar days but less than or equal to 80 calendar days of a written request.	The Generator Owner provided an estimate of a unit's performance more than 80 calendar days but less than or equal to 90 calendar days of a written request.	The Generator Owner failed to provide an estimate of a unit's performance within 90 calendar days of a written request.
<b>R5</b>	N/A	N/A	N/A	The Generator Owner's generator tripped due to a frequency excursion within the no-trip parameters set forth in Attachment 1 and did not meet any of the exceptions specified in the bulleted list within Requirement R5.  OR

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R #	Lower VSL	Moderate VSL	High VSL	Severe VSL
				The Generator Owner’s generator tripped due to a voltage excursion within the no-trip parameters set forth in Attachment 2 and did not meet any of the exceptions specified in the bulleted list within Requirement R5.
<b>R6</b>	<p>The Generator Owner provided its generator protection trip settings as specified by Requirement R6 more than 60 calendar days but less than or equal to 70 calendar days of any change to those trip settings.</p> <p>OR</p> <p>The Generator Owner provided trip settings more than 60 calendar days but less than or equal to 70 calendar days of a written request.</p>	<p>The Generator Owner provided its generator protection trip settings as specified by Requirement R6 more than 70 calendar days but less than or equal to 80 calendar days of any change to those trip settings.</p> <p>OR</p> <p>The Generator Owner provided trip settings more than 70 calendar days but less than or equal to 80 calendar days of a written request.</p>	<p>The Generator Owner provided its generator protection trip settings as specified by Requirement R6 more than 80 calendar days but less than or equal to 90 calendar days of any change to those trip settings.</p> <p>OR</p> <p>The Generator Owner provided trip settings more than 80 calendar days but less than or equal to 90 calendar days of a written request.</p>	<p>The Generator Owner failed to provide its generator protection trip settings as specified by Requirement R6 within 90 calendar days of any change to those trip settings.</p> <p>OR</p> <p>The Generator Owner failed to provide trip settings within 90 calendar days of a written request for the data.</p>

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### E. Regional Variances

None

### F. Associated Documents

None

### Version History

Version	Date	Action	Change Tracking

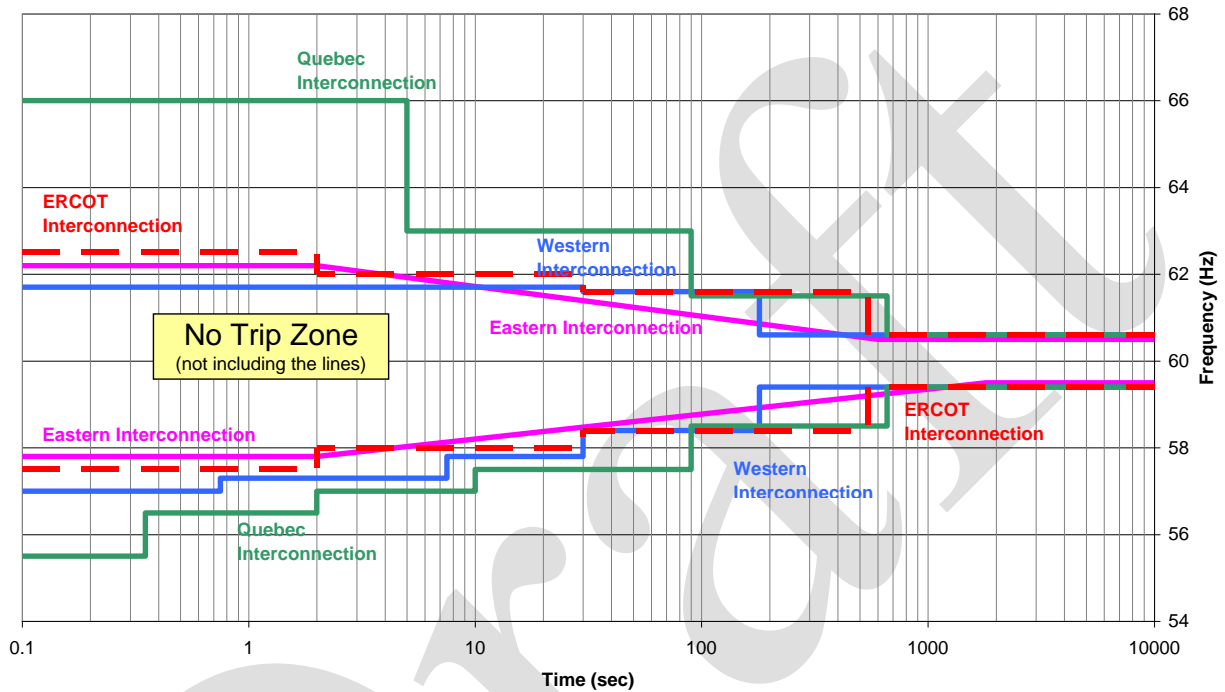
### G. References

1. “The Technical Justification for the New WECC Voltage Ride-Through (VRT) Standard, A White Paper Developed by the Wind Generation Task Force (WGTF),” dated June 13, 2007, a guideline approved by WECC Technical Studies Subcommittee.

# Standard PRC-024-1 — Generator Performance During Frequency and Voltage Excursions

## PRC-024 — Attachment 1

### OFF NOMINAL FREQUENCY CAPABILITY CURVE



#### Curve Data Points:

#### Eastern Interconnection

High Frequency Duration		Low Frequency Duration	
Frequency (Hz)	Time (Sec)	Frequency (Hz)	Time (sec)
≥62.2	Instantaneous trip	≤57.8	Instantaneous trip
≥60.5	$10^{(91.1132-1.46*f)}$	≤59.5	$10^{(1.7373*f-100.116)}$
<60.5	Continuous operation	> 59.5	Continuous operation

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### Western Interconnection

High Frequency Duration		Low Frequency Duration	
Frequency (Hz)	Time (Sec)	Frequency (Hz)	Time (sec)
≥61.7	Instantaneous trip	≤57.0	Instantaneous trip
≥61.6	30	≤57.3	0.75
≥60.6	180	≤57.8	7.5
<60.6	Continuous operation	≤58.4	30
		≤59.4	180
		>59.4	Continuous operation

### Quebec Interconnection

High Frequency Duration		Low Frequency Duration	
Frequency (Hz)	Time (Sec)	Frequency (Hz)	Time (Sec)
>66.0	Instantaneous trip	<55.5	Instantaneous trip
≥63.0	5	≤56.5	0.35
≥61.5	90	≤57.0	2
≥60.6	660	≤57.5	10
<60.6	Continuous operation	≤58.5	90
		≤59.4	660
		>59.4	Continuous operation

### ERCOT Interconnection

High Frequency Duration		Low Frequency Duration	
Frequency (Hz)	Time (Sec)	Frequency (Hz)	Time (sec)
≥62.5	Instantaneous trip	≤57.5	Instantaneous trip
≥62.0	2	≤58.0	2
≥61.6	30	≤58.4	30
≥60.6	540	≤59.4	540
<60.6	Continuous operation	>59.4	Continuous operation

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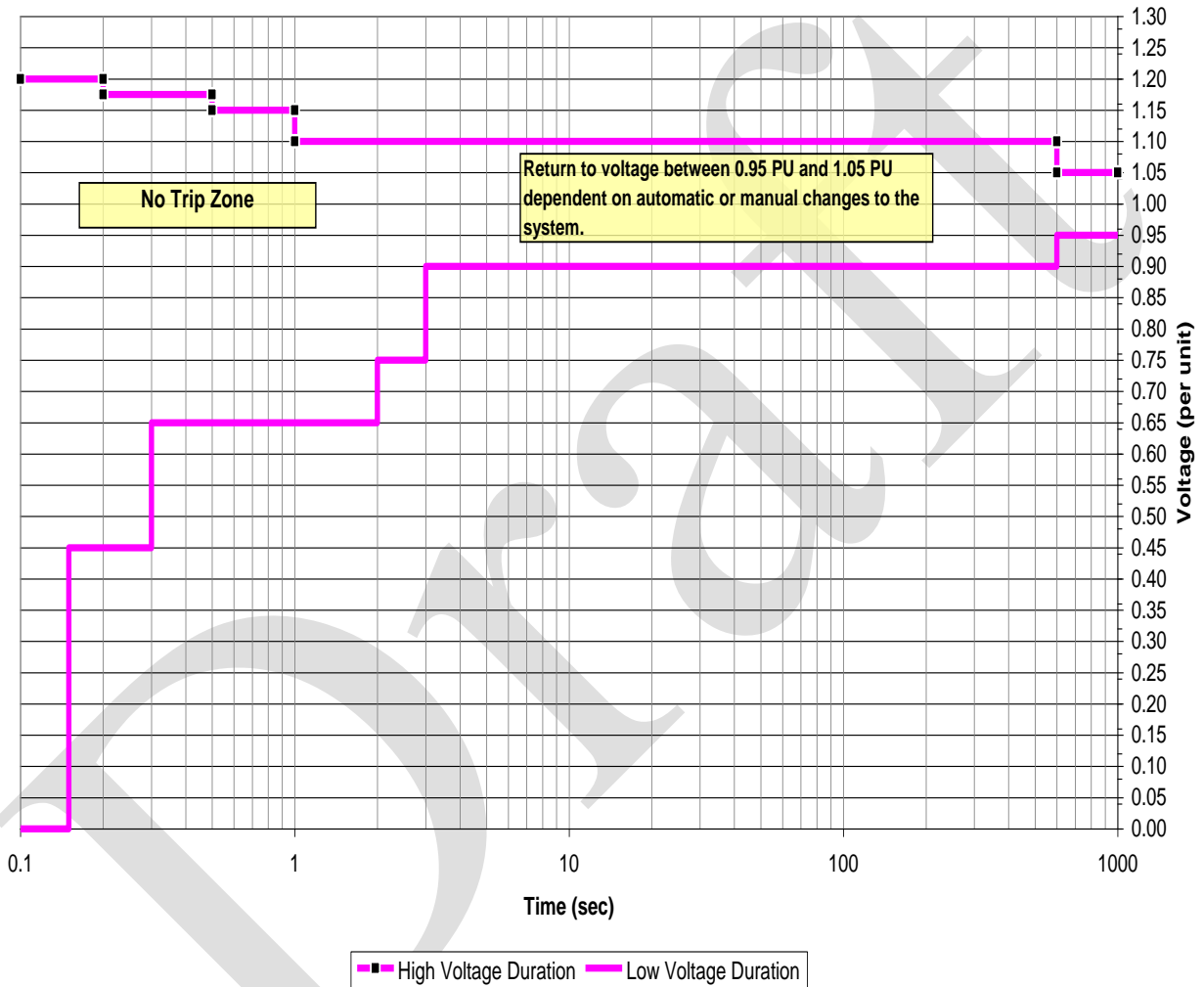


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## PRC-024— Attachment 2

### Voltage Ride-Through Time Duration Curve



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### Curve Data Points:

High Voltage Ride Through Duration		Low Voltage Ride Through Duration	
Voltage (pu)	Time (sec)	Voltage (pu)	Time (sec)
≥1.200	Instantaneous trip	0.00	0.15
≥1.175	0.20	<0.45	0.30
≥1.15	0.50	<0.65	2.00
≥1.10	1.00	<0.75	3.00
>1.05	600	<0.90	600
≤1.05	Continuous operation	≥0.95	Continuous operation

### Voltage Ride-Through Curve Clarifications

#### Curve Details:

1. 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).
2. The curves depicted were derived based on three-phase transmission system zone 1 faults with Normal Clearing not exceeding 9 cycles. The curves apply to voltage excursions regardless of the type of initiating event.
3. The envelope within the curves represents the cumulative voltage duration at the point of interconnection with the BES. For example, if the voltage exceeds 1.15 pu at 0.3 seconds after a fault, does not exceed 1.2 pu voltage, and returns below 1.15 pu at 0.4 seconds, then the cumulative time the voltage is above 1.15 pu voltage is 0.1 seconds and is within the no trip zone of the curve.
4. The curves depicted assume system frequency is 60 Hertz. Adjust the magnitude of the high voltage curve in proportion to deviations of frequency below normal.
5. Voltages in the curve assume minimum fundamental frequency phase-to-ground or phase-to-phase voltage for the low voltage duration curve and the greater of maximum RMS or crest phase-to-phase voltage for the high voltage duration curve.

#### Evaluating Protective Relay Settings:

6. Use the following assumptions to evaluate voltage protection relay setting calculations on the static case for steady state initial conditions:
  - a. All of the units connected to the same transformer are online and operating,
  - b. All of the units are at full nameplate real-power output.
  - c. Power factor is 0.95 lagging (i.e. supplying reactive power to the system) as measured at the generator terminals).
7. Evaluate voltage protection relay settings assuming that additional installed generating plant reactive support equipment (such as static VAr compensators, synchronous condensers, or capacitors) is available and operating normally.
8. Evaluate voltage protection relay settings accounting for the actual tap settings of transformers between the generator terminals and the point of interconnection.