INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

Forum for the Implementation of Reliability Standards for Transmission (i2X FIRST) | 01/27/26

A DOE initiative supported by the Office of Critical Minerals and Energy Innovation (CMEI)

BERKELEY LAB

EPRI

ESIG

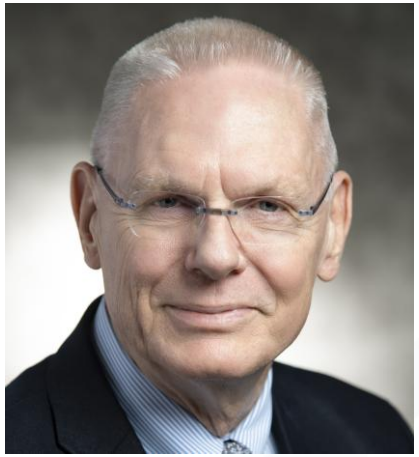
The first half of this meeting call is being recorded and may be posted on ESIG's website. If you do not wish to have your voice recorded, please do not speak during the call. If you do not wish to have your image recorded, please turn off your camera or participate by phone. If you speak during the call or use a video connection, you are presumed consent to recording and use of your voice or image.

Key Goals and Outcomes from i2X FIRST

- To facilitate understanding and adoption of new and recently updated standards relevant for existing and newly interconnecting inverter-based resources.
- The Forum will convene the industry stakeholders to enable practical and more harmonized implementation of these interconnection standards.
- The presentation portion of the meeting will be recorded and posted, and presentation slides will be shared.
- Additionally, the leadership team will produce **a summary of each meeting** capturing:
  - Recommended best practices
  - Challenges
  - Gaps that require future work

Leadership Team

Cynthia Bothwell, Boston Government Services, contractor to DOE



Robert Reedy, Lindahl Reed, contractor to DOE

Will Gorman, Lawrence Berkley National Laboratory

Jens Boemer, Electric Power Research Institute

Julia Matevosyan, Energy Systems Integration Group

Ryan Quint, Elevate Energy Consulting

Summary of the Last Meeting: IBR Plant Commissioning Best Practices

- **Meeting Introduction:** Julia Matevosyan, ESIG
- **IBR Developer Perspective:** Zachary Hammond, Rishi Maharaj, Engie
- **PPC Perspective:** Lars Johnson , Merit Controls
- **ISO Perspective:** Phillip Hiusser, Independent Electricity System Operator (IESO)
- **Q&A and Structured Discussion**, led by Julia Matevosyan, ESIG
  - Commissioning Testing
    - Measurements needed at commissioning
    - What is the best practice process if parameters need to be tuned during commissioning
  - IBR plant model validation based on commissioning testing
    - When should this be done?
    - What happens if the model shows discrepancies?

Meeting summary, recording & presentations are posted here

Key Themes from the Last Meeting

- **Commissioning Is a Critical Reliability Gate:** Last chance to verify reliable operation before COD; post-COD fixes are costly. Treating commissioning as a grid reliability risk checkpoint.
- **Inconsistent Requirements Lead to Uneven Rigor:** Wide regional variations lead to gaps in testing, verification, and performance validation—robust commissioning is still essential even in absence of mandatory NERC requirements.
- **Standard Tests Miss Real-World Conditions:** AVR/PFR/curtailment tests alone are insufficient; failure modes (e.g. communication failures) and edge cases (e.g. zero-power operation) are often untested.
- **Models Must Match As-Built Performance:** Study models often diverge from field implementation; validation at commissioning and lifecycle updates are needed to reflect “as-left” configuration.
- **End-to-End Integration Is Essential:** Reliable operation requires coordinated controls, SCADA, comms, and telemetry—early, disciplined, end-to-end commissioning reduces risk, delays, and rework.

Upcoming i2X FIRST Meetings – Season 2

1. May 27, 2025, 11 a.m. - 1 p.m. ET – **Season 2 Kick-Off**
2. June 24, 2025, 11 a.m.- 1 p.m. ET – **NERC Milestone 3 Standards**
3. July 22, 2025, 11 a.m.- 1 p.m. ET – **IBR Plant Design Evaluation with Applicable Requirements I**
4. August 26, 2025, 11 a.m.- 1 p.m. ET – **IBR Plant Design Evaluation with Applicable Requirements II**
5. September 23, 2025, 11 a.m.- 1 p.m. ET – **IBR Plant Modeling Requirements and Best Practices**
6. October 21, 2025, 11 a.m.- 1 p.m. ET – **Challenges with IEEE2800-2022, Planned Revisions**
7. November 25, 2025, 11 a.m.- 1 p.m. ET – **Change Management during IBR Plant Interconnection Process and Commissioning, How to Maintain Conformity**
8. December 16, 2025, 11 a.m.- 1 p.m. ET **– IBR Plant Commissioning Best Practices**
9. January 27, 2026, 11 a.m.- 1 p.m. ET **– NERC PRC-029 Implementation, Experience, and Recommended Practices**
10. February 24, 2026, 11 a.m. - 1 p.m. ET – TBD (**go to slido.com, FIRST9 and propose a topic**)
11. March 16, 2026, hybrid event during ESIG Spring Workshop: Grid Forming IBR Needs, Specifications, Projects – Lessons Learned

Sign up for all future i2X FIRST Season 2 Meetings here

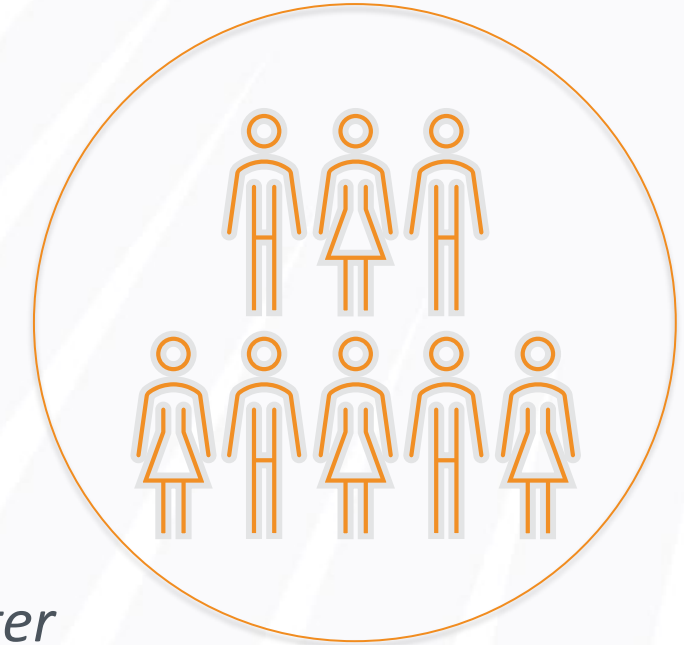
Follow ESIG i2X FIRST website https://www.esig.energy/i2x-first-forum/ for meeting materials & recordings and for future meeting details & agendas

NERC PRC-029 Implementation, Experience, and Recommended Practices – Agenda

- **Meeting Introduction:** Julia Matevosyan, ESIG
- **Recap of NERC PRC-029-1 and FERC Order 909:** JP Skeath, NERC
- **OEM Perspective and Recommended Practices:** Yaw A. Akpaloo, GE Vernova
- **Recommended Practices for IBR Plant Ride-Through Evaluations:** Amin Banaie, Elevate Energy Consulting
- **Q&A and Structured Discussion**, led by Julia Matevosyan, ESIG
  - What is the best practice to identify legacy/inflight IBR plant's limitations to comply with NERC PRC-029?
  - What are the best practices to streamline the assessment of legacy/inflight plants' capability to comply with PRC-029?
  - Based on what method could NERC and RCs assess potential BPS reliability risks to inform decisions about limits to exemptions?

Virtual Meetings Code of Conduct

1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*
6. *Please go to slido to ask questions: **slido.com** and enter event code **FIRST9***



Mutual Respect . Collaboration . Openness

Stakeholder Presentations

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5. *Seek to learn from others*

Mutual Respect . Collaboration . Openness

Q & A Session

Interactive Group Discussion Topics

Topic #1: What is the best practice to identify legacy/inflight IBR plant's limitations to comply with NERC PRC-029

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST9**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - Is equipment documentation alone sufficient evidence, if not, what is sufficient?
  - What to do when equipment hasn't been tested to PRC-029 limits?
  - How to verify limitations of an entire IBR plant, when EMT models are not available/not detailed enough/not accurate enough?
  - Would it be helpful if there was a database listing equipment that is known to be compatible with PRC-029 ride-through requirements?

Topic #2: What are the best practices to streamline the assessment of legacy/inflight plants' capability to comply with PRC-029?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST9**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - Can OEMs streamline the assessment of existing equipment capabilities and provide same information to all equipment users?
  - Can acceptable evidence of limitations be agreed upon and same set produced for all IBR plants or are the plant-by-plant nuances?
  - Are there any lessons learned that should be considered for new IBR plants (e.g. IBR unit type tests, IBR unit compatibility certification, modeling details, documentation, support contracts with OEMs etc.)?

Topic #3: Based on what method could NERC and RCs assess potential BPS reliability risks to inform decisions about limits to exemptions?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST9**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - How could Reliability Coordinators study the impact of aggregate legacy IBRs with limitations to comply with PRC-029 on their system?
  - What are reasonable thresholds for allowing aggregate legacy IBR generation to be temporarily lost, and what system characteristics may these depend on?
  - What could be economic impacts of maximizing legacy IBRs' capabilities, and how would such aggregate cost compare to mitigations options available to ISOs/RTOs, TPs, and TOs?

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NERC PRC-029

Overview and FERC 909

JP Skeath, Manager, Engineering and Security Integration

DOE i2X FIRST

Jan 27th, 2026

Order 901 Summary

STANDARDS MILESTONES: ORDER 901

1 COMPLETED JANUARY 2024

Order No. 901 Work Plan submission

2 DUE NOVEMBER 4, 2024

Standards development and filing to address performance requirements and post-performance validations for Registered IBRs

3 DUE NOVEMBER 4, 2025

Development and filing of Reliability Standards to address data sharing and model validation for all IBRs

4 DUE NOVEMBER 4, 2026

Development and filing of Reliability Standards to address use of performance data in Operational and Planning studies

Milestone 2 Summary

New PRC-028

- Installation of disturbance monitoring equipment
- Share data on request

New PRC-029

- Performance based ride-through criteria
- Capability based ride-through criteria

New PRC-030

- Analysis of performance during a disturbance
- Triggers what is evaluated for ride-through performance

Milestone 2 Summary

New PRC-028

83.85%

- Installation of disturbance monitoring equipment
- Share data on request

New PRC-029

77.8%

- Performance based ride-through criteria
- Capability based ride-through criteria

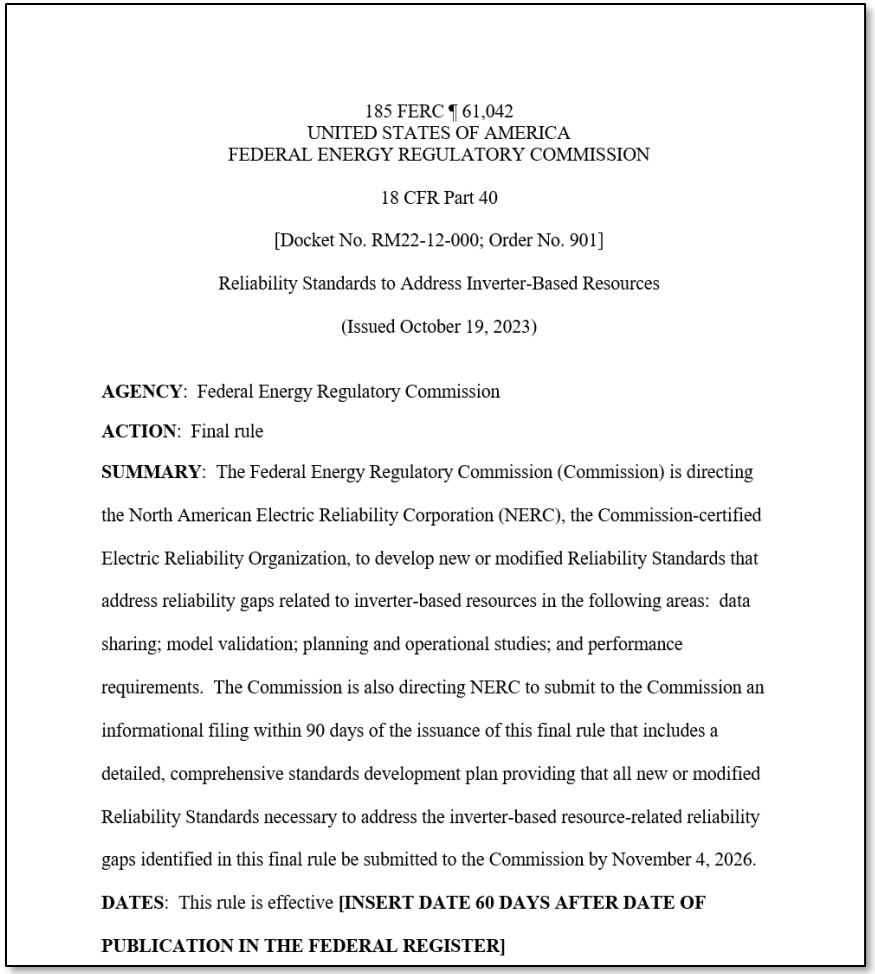
New PRC-030

70.88%

- Analysis of performance during a disturbance
- Triggers what is evaluated for ride-through performance

Order 901

- IBR Ride-through, modeling, and other issues
- Order No. 901 (2023)
  - Directs NERC to develop standards addressing IBR reliability issues at “all states of interconnection, planning, and operations”
  - 4 Milestones
    - Milestone 1: Work Plan
    - Milestones 2-4: The Standards



185 FERC ¶ 61,042
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 40

[Docket No. RM22-12-000; Order No. 901]

Reliability Standards to Address Inverter-Based Resources

(Issued October 19, 2023)

AGENCY: Federal Energy Regulatory Commission

ACTION: Final rule

SUMMARY: The Federal Energy Regulatory Commission (Commission) is directing the North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization, to develop new or modified Reliability Standards that address reliability gaps related to inverter-based resources in the following areas: data sharing; model validation; planning and operational studies; and performance requirements. The Commission is also directing NERC to submit to the Commission an informational filing within 90 days of the issuance of this final rule that includes a detailed, comprehensive standards development plan providing that all new or modified Reliability Standards necessary to address the inverter-based resource-related reliability gaps identified in this final rule be submitted to the Commission by November 4, 2026.

DATES: This rule is effective **[INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER]**

Order 901 Directives for IBR Ride-through

- "Pursuant to section 215(d)(5) of the FPA, we adopt the NOPR proposal and direct NERC to develop new or modified Reliability Standards that require registered IBR generator owners and operators to use appropriate settings (i.e., inverter, plant controller, and protection) to **ride through frequency and voltage system disturbances** and that permit IBR tripping **only to protect the IBR equipment** in scenarios similar to when synchronous generation resources use tripping as protection from internal faults."
- "The new or modified Reliability Standards must require registered IBRs to **continue to inject current** and **perform frequency support** during a Bulk-Power System disturbance."
- "Any new or modified Reliability Standard must also require registered IBR generator owners and operators to **prohibit momentary cessation in the no-trip zone during disturbances**."
- "NERC must submit new or modified Reliability Standards that establish IBR performance requirements, including requirements addressing **frequency and voltage ride through**, post-disturbance ramp rates, **phase lock loop synchronization, and other known causes of IBR tripping or momentary cessation**."

Order No 901 P190

Potential Exemptions

- [W]e direct NERC through its standard development process to determine whether the new or modified Reliability Standards should provide for a **limited and documented exemption for certain registered IBRs** from voltage ride-through performance requirements.
- Any such exemption should be only for voltage ride-through performance for those **existing IBRs that are unable to modify their coordinated protection and control settings** to meet the requirements without physical modification of the IBRs' equipment

Order No. 901 P193

- "To the extent NERC determines that a **limited** and **documented exemption** for those registered IBRs currently in operation and unable to meet voltage Ride-through requirements is appropriate due to their **inability to modify their coordinated protection and control settings**, we direct NERC to develop new or modified Reliability Standards to mitigate the reliability impacts to the Bulk-Power System of such an exemption."

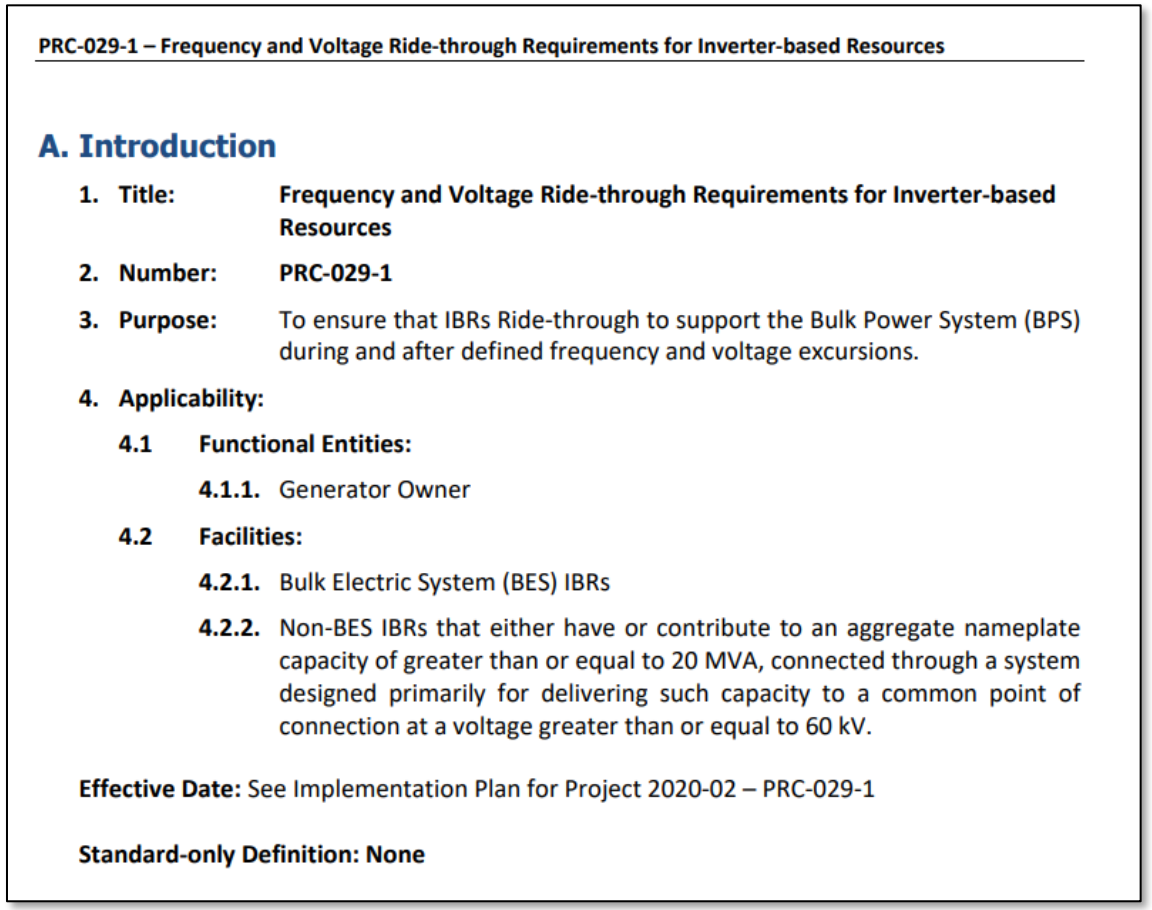
Order No. 901 P199

PRC-029-1

- Developed as a reflection from synchronous generator performance seen in PRC-024
- 4 Requirements
  - Establishes frequency and voltage Ride-through requirements for IBRs (R1 – R3)
  - R4, exemptions from IBR Ride-through criteria available for:
    - IBRs **in service** by PRC-029-1 effective date (10/1/2026)
    - For known **hardware** limitations that **prevent the IBR** from meeting documented frequency or voltage Ride-through criteria.
- Exception Processes submitted to CEA, PC, TP, TOP, and RC.
  - IBR owner to follow-up on requests for additional information
  - IBR owner to notify PC, TP, TOP, RC within 90 days of CEA acceptance of hardware limitation

PRC-029-1

- R1 – Shall design to meet or exceed Ride-through, except:
  - To clear fault
  - Voltage outside of hardware limit (R4)
  - Instantaneous +seq phase angle shift of 25 degrees (at high side of MPT)
  - V/Hz exceed 1.1 p.u. for 45 seconds or 1.18 p.u. for 2 seconds
- R2 – Shall design to meet or exceed specified voltage performance
- R3 – Shall design to meet or exceed specified frequency performance
- R4 – Exemption process for in-service IBR with hardware limits.



PRC-029-1 – Frequency and Voltage Ride-through Requirements for Inverter-based Resources

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.** Bulk Electric System (BES) IBRs
     - **4.2.2.** 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

https://www.nerc.com/globalassets/standards/approved-standards/prc/prc-029-1.pdf

Voltage and Frequency Performance Expectations

Attachment 1: Voltage Ride-Through Criteria

Table 1: Voltage Ride-through Requirements for AC-Connected Wind IBR [13]

Voltage (per unit)[14]	Operation Region	Minimum Ride-Through Time (sec)
> 1.20	N/A[15]	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)[16]	Operation Region	Minimum Ride-Through Time (sec)
> 1.20	N/A[17]	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

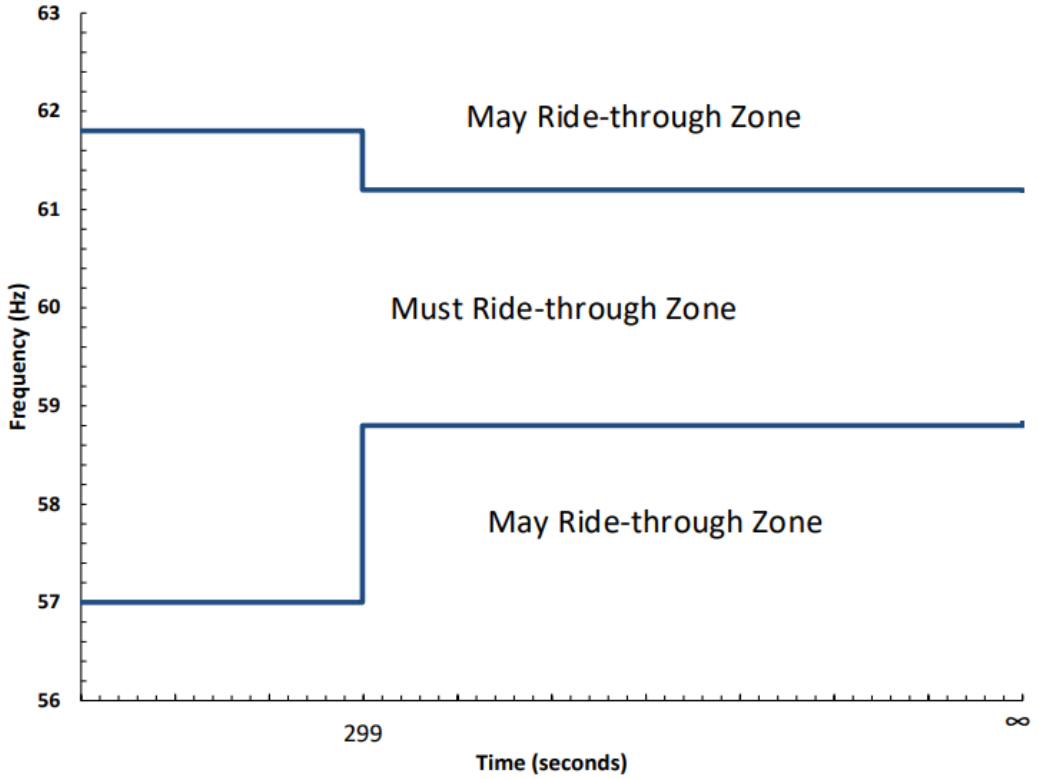


Figure 1: PRC-029 Frequency Ride-through Requirements

R4 Exemptions in PRC-029-1

- Data
  - Identify the information from the IBR (name and facility number)
  - The specific aspects of Ride-through requirements that the IBR would be unable to meet due to the hardware limitation
  - Identification of the specific piece(s) of hardware causing the limitation
  - Technical documentation verifying the limit is due to hardware that would need to be physically replaced to meet all Ride-through criteria, and that the limitation cannot be remedied by software updates or setting changes
  - Information for any plans to remedy the hardware limitation (e.g., estimated date)
- Duration
  - Submit within 12 months of PRC-029-1 effective date
  - If hardware replaced, exemption ends and need to notify entities within 90 days.

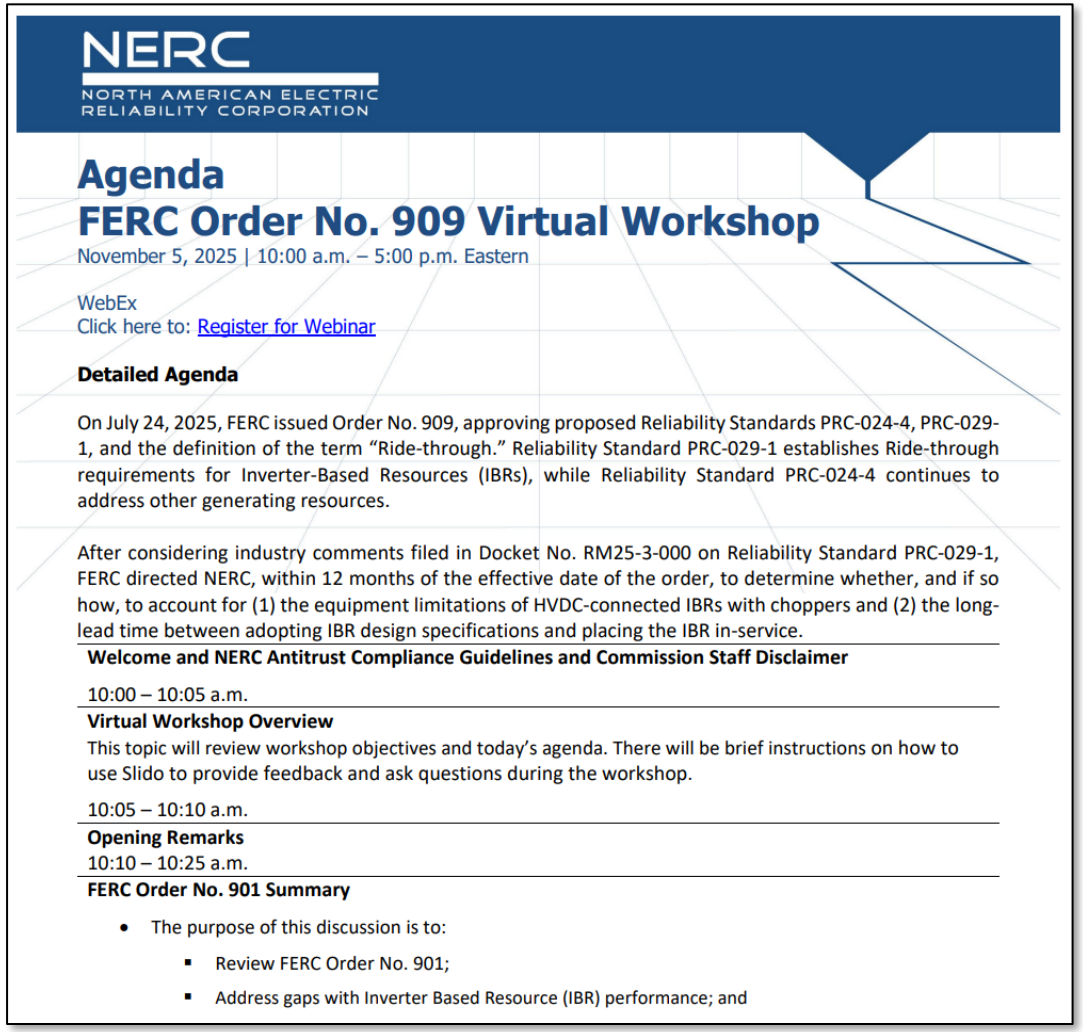
FERC Order 909

- Issued July 24, 2025 to approve PRC-029-1 and PRC-024-4
- Several directives to NERC
  - Due August 28, 202
    - P 87: Address the issues, raised in the rulemaking proceeding, regarding HVDC-connected IBRs with choppers and long-lead time equipment, and submit its determination within 12 months
    - PP: 107-108: Address concern about absent documentation for legacy IBR units (examples: modify requirement, expand Measure to include non-exhaustive list of acceptable evidence), within 12 months
  - Following full implementation
    - PP 120-122: Submit an informational filing including certain data and an assessment of the reliability impacts of the exemption process.
- FERC 909-A issued Sept 25, 2025
  - Suggests enforcement discretion of a “timing mismatch” for implementation of PRC-029-1 and a revised standard (P8)

Order 909 Virtual Workshop

- Clarification on Documentation Obligations Relative to Legacy IBRs
- Equipment Limitations of HVDC-Connected IBRs with Choppers
- Equipment Limitations of Long Lead Time Projects

Recording: link



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Agenda
FERC Order No. 909 Virtual Workshop

November 5, 2025 | 10:00 a.m. – 5:00 p.m. Eastern

WebEx
Click here to: Register for Webinar

Detailed Agenda

On July 24, 2025, FERC issued Order No. 909, approving proposed Reliability Standards PRC-024-4, PRC-029-1, and the definition of the term "Ride-through." Reliability Standard PRC-029-1 establishes Ride-through requirements for Inverter-Based Resources (IBRs), while Reliability Standard PRC-024-4 continues to address other generating resources.

After considering industry comments filed in Docket No. RM25-3-000 on Reliability Standard PRC-029-1, FERC directed NERC, within 12 months of the effective date of the order, to determine whether, and if so how, to account for (1) the equipment limitations of HVDC-connected IBRs with choppers and (2) the long-lead time between adopting IBR design specifications and placing the IBR in-service.

Welcome and NERC Antitrust Compliance Guidelines and Commission Staff Disclaimer

10:00 – 10:05 a.m.

Virtual Workshop Overview

This topic will review workshop objectives and today's agenda. There will be brief instructions on how to use Slido to provide feedback and ask questions during the workshop.

10:05 – 10:10 a.m.

Opening Remarks

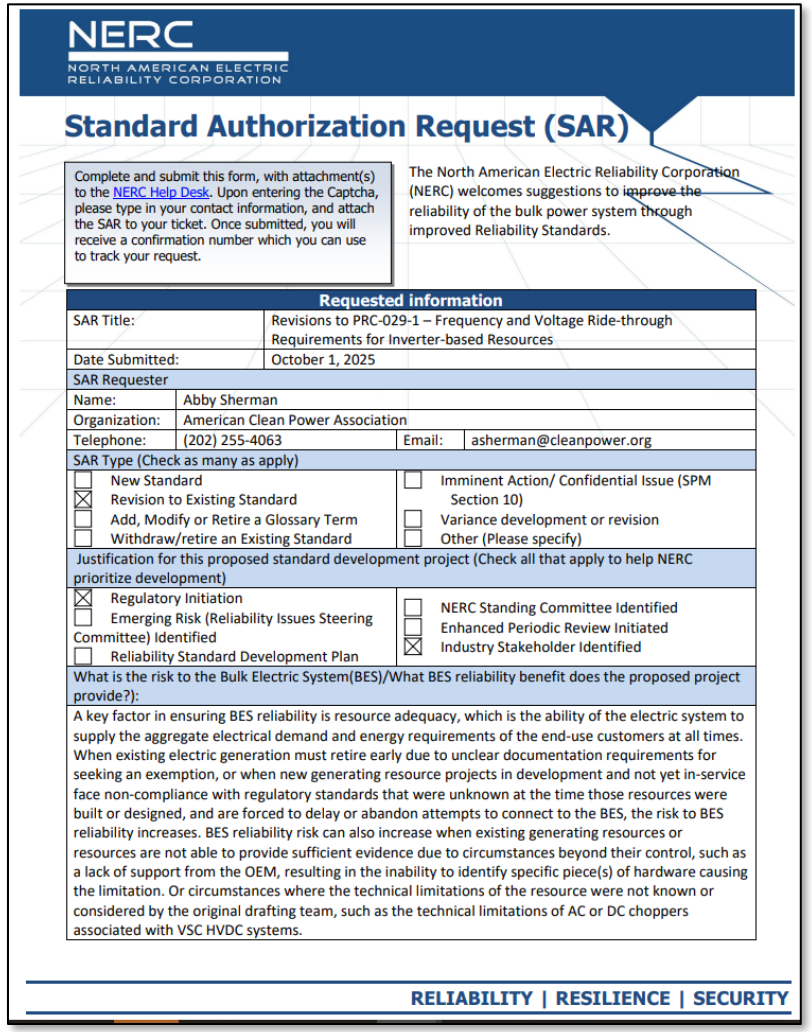
10:10 – 10:25 a.m.

FERC Order No. 901 Summary

- The purpose of this discussion is to:
  - Review FERC Order No. 901;
  - Address gaps with Inverter Based Resource (IBR) performance; and

NERC Received Industry SAR

- Received Oct. 2025
- Initiated Project 2025-05
  - Posted for Comment ending 12/18/2025
  - Nominations for SDT closed 12/12/2025
- Scope:
  - Extend PRC-029-1 Requirement R4 exemption eligibility to include long-lead time IBR projects in active development.
  - Extend exemption eligibility to include chopper limitations
  - Clarify the non-exhaustive acceptable evidence to aide entities
- Not yet approved (SDT to respond to solicited comments first)



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Standard Authorization Request (SAR)

Complete and submit this form, with attachment(s) to the NERC Help Desk. Upon entering the Captcha, please type in your contact information, and attach the SAR to your ticket. Once submitted, you will receive a confirmation number which you can use to track your request.

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

Requested information			
SAR Title:	Revisions to PRC-029-1 – Frequency and Voltage Ride-through Requirements for Inverter-based Resources		
Date Submitted:	October 1, 2025		
SAR Requester			
Name:	Abby Sherman		
Organization:	American Clean Power Association		
Telephone:	(202) 255-4063	Email:	asherman@cleanpower.org

SAR Type (Check as many as apply)

- ☐ New Standard
- ☒ Revision to Existing Standard
- ☐ Add, Modify or Retire a Glossary Term
- ☐ Withdraw/retire an Existing Standard
- ☐ Imminent Action/ Confidential Issue (SPM Section 10)
- ☐ Variance development or revision
- ☐ Other (Please specify)

Justification for this proposed standard development project (Check all that apply to help NERC prioritize development)

- ☒ Regulatory Initiation
- ☐ Emerging Risk (Reliability Issues Steering Committee) Identified
- ☐ Reliability Standard Development Plan
- ☐ NERC Standing Committee Identified
- ☐ Enhanced Periodic Review Initiated
- ☒ Industry Stakeholder Identified

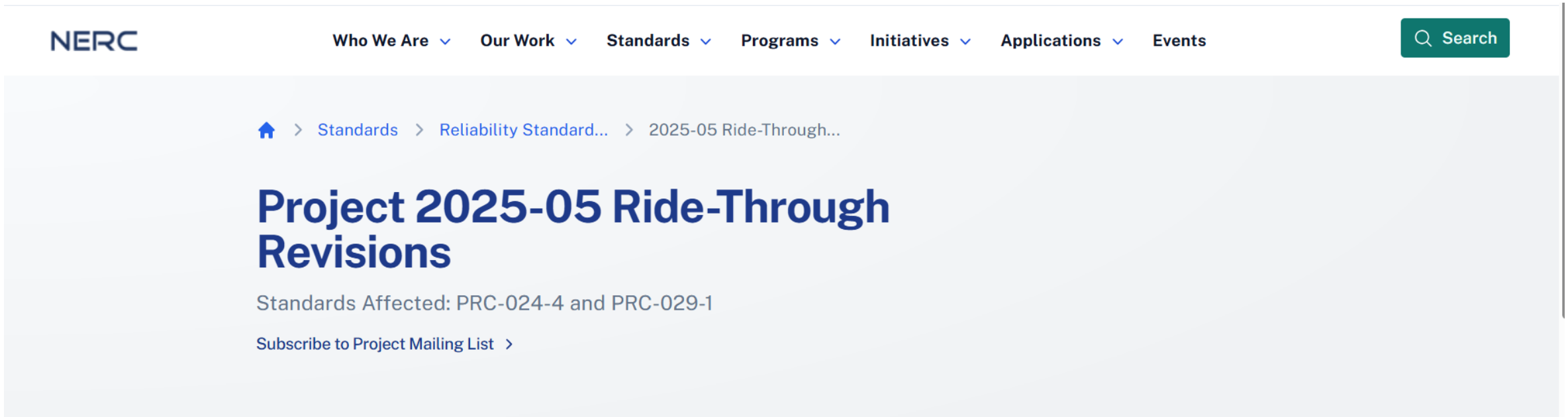
What is the risk to the Bulk Electric System(BES)/What BES reliability benefit does the proposed project provide?):

A key factor in ensuring BES reliability is resource adequacy, which is the ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times. When existing electric generation must retire early due to unclear documentation requirements for seeking an exemption, or when new generating resource projects in development and not yet in-service face non-compliance with regulatory standards that were unknown at the time those resources were built or designed, and are forced to delay or abandon attempts to connect to the BES, the risk to BES reliability increases. BES reliability risk can also increase when existing generating resources or resources are not able to provide sufficient evidence due to circumstances beyond their control, such as a lack of support from the OEM, resulting in the inability to identify specific piece(s) of hardware causing the limitation. Or circumstances where the technical limitations of the resource were not known or considered by the original drafting team, such as the technical limitations of AC or DC choppers associated with VSC HVDC systems.

RELIABILITY | RESILIENCE | SECURITY

Standard Revisions Responsive to FERC 909

- How to Monitor
  - Distribution List
  - Project Page/Postings



https://www.nerc.com/standards/reliability-standards-under-development/2025-05-ride-through-revisions

Questions and Answers

John Paul "JP" Skeath
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North American Electric Reliability Corporation
3353 Peachtree Road NE, Suite 600 – North Tower
Atlanta, GA 30326
404-446-9630 office | 404-823-1365 cell
Email: John.Skeath@nerc.net

GE VERNOVA
Our portfolio of energy businesses

GE Vernova Onshore Wind Perspectives on PRC-029-1 Implementation

i2X FIRST | 27-Jan-2026
Yaw A. Akpaloo, GE Vernova Wind, Grid Integration & WindCONTROL Product Manager
Lucas Amaral Sales, GE Vernova Wind, Systems Engineer

i2X First – 01/27/2026

PRC-029-1 | GE Vernova Onshore Wind Products: Current Status

Over 75GW / 36k of DFIG Technology WTGs Installed in NAM… Readiness Across the Fleet

- **New & active platforms**
  - 2.X-127, 3.X and 6.X platforms
  - All newly delivered and currently active products are designed to meet PRC-029-1 & IEEE 2800-2022 requirements
  - Software-based upgrades enable full alignment with the applicable requirements

- **Legacy platforms**
  - 1.X-10Y, 2.X and Early 1.X platforms
  - Legacy platforms can meet most PRC-029-1 requirements through targeted software upgrades, unlocking enhanced ride-through and recovery capability.
  - Older variants offer meaningful opportunities for capability expansion, with performance aligned to turbine design and plant configuration.
  - Achievable outcomes are upgrade-enabled and turbine-specific, allowing customers to pursue practical, value-driven capability pathways across their fleets.

Newer WTGs deliver full capability, while legacy platforms unlock expanded capability through upgrades.

PRC-029-1 | How Do We Support Customers

Structured Technical & Compliance Support

- **Position Papers & Technical Capability Reports**
  - Developed and shared with Generator Owners (GOs) to:
    - Articulate turbine-level capabilities and upgrade options
    - Support exemption evaluations where applicable
    - Enable informed compliance strategies
- **Validated WTG simulation models**
  - Turbine models (e.g. PSS/E, PSCAD) with current capability and upgraded controls are created on a case-by-case basis.
  - Intended for incorporation by GOs into:
    - Plant-level models
    - Interconnection and compliance studies
  - Modeling approaches remain ISO/Utility and project-specific
- **Software-based upgrade development & deployment**
  - Software upgrades are delivered through a structured, platform-based roadmap, aligned with fleet needs and regulatory priorities.
  - Each upgrade undergoes robust validation to ensure dependable performance.
  - Deployment is planned collaboratively with customers to align with:
    - Site access and outage windows
    - Operational priorities
    - Regulatory milestones

A proven, end-to-end capability pathway built on expertise, validated models, and scalable upgrades.

PRC-029-1 | Observed Industry Challenges & Open Questions

What We're Hearing Across Customers & Stakeholders

- **Compliance dates interpretation for IBRs in operation before effective date**
  - Mixed interpretation on whether PRC-029-1 R1–R3 enforcement aligns with PRC-028-1 implementation dates / deadlines.
- **Maximization requirements**
  - ERCOT provides more explicit and well-defined maximization criteria.
  - NERC-wide guidance on maximization remains less prescriptive
- **Exemptions**
  - Continued alignment discussions around exemptions for In-kind replacements and partial repowering where hardware changes are limited.
  - Uncertainty on specifics for demonstrating achievable capability including justification where physical constraints exist remains.
- **Process for wind plant upgrade and simulation models updates**
  - ISOs and utilities apply different processes for plant upgrades, model updates, and validation, reinforcing the value of proven upgrade pathways and OEM-supported documentation to streamline multi-region deployment.

Continued clarification supports aligned planning and prioritization.

PRC-029-1 | Path Forward & Ongoing Engagement

Working Together Towards Practical PRC-029-1 Outcomes

- **We remain committed to transparent engagement with customers, ISOs, utilities and industry stakeholders as PRC-029-1 implementation continues to evolve.**
- **Our focus is on:**
  - Clearly communicating turbine-level capabilities and limitations
  - Supporting risk-informed compatibility strategies, including exemption evaluations where appropriate
  - Developing unique software-based upgrades to expand grid integration capabilities
  - Providing validated models, documentation, and technical insights to enable informed decision-making
- **Early coordination across GOs, OEMs, consultants, and regulators helps unlock clarity, alignment, and efficient execution at scale.**
- **As additional guidance, testing expectations, and interpretations mature, we will continue to:**
  - Refine technical assessments, align on implementation pathways and support customers in navigating PRC-029-1 with clarity and confidence.

GE Vernova's Wind Business committed to supporting grid integration of IBRs

GE VERNOVA

Our portfolio of energy businesses

Thank You

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Recommended Practices for IBR Plant Ride-Through Evaluations

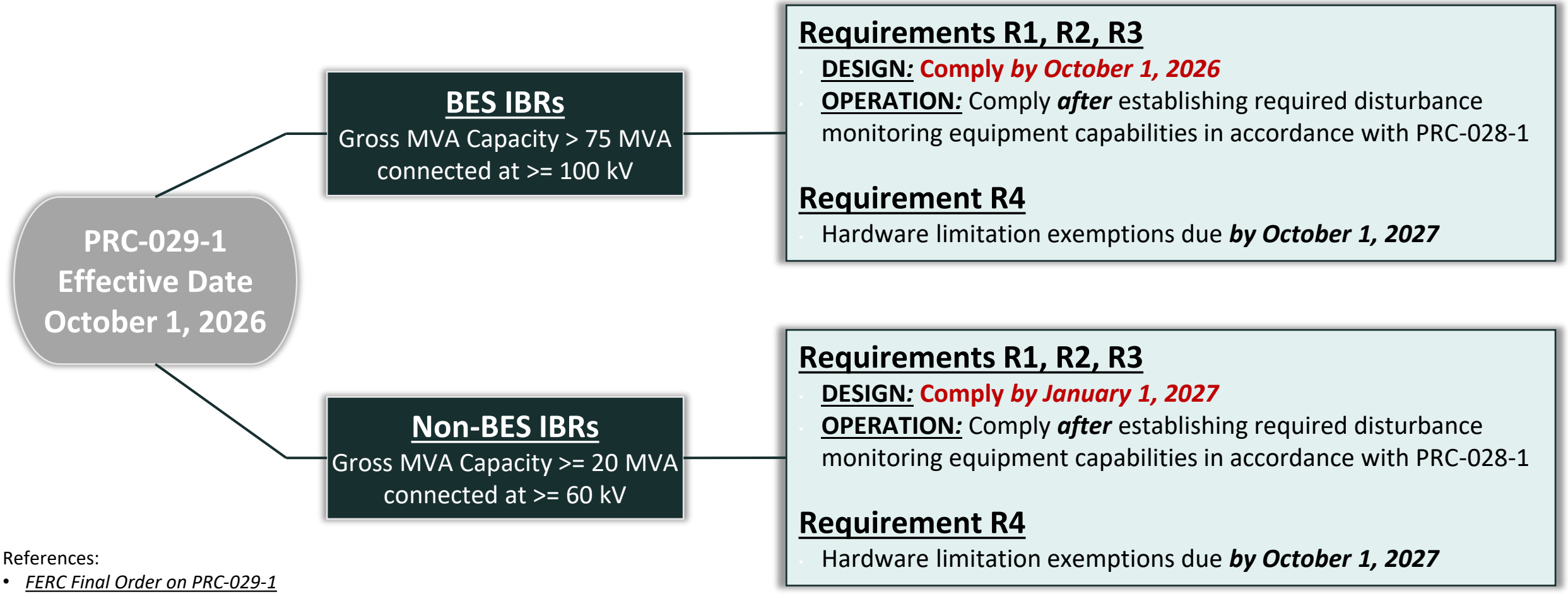
Experience Supporting Generator Owners with NERC PRC-029-1

Amin Banaie, PhD, *Senior Power Systems Engineer*
Ryan Quint, PhD, PE, *President and CEO*

January 2026

COMPLIANCE DEADLINES: NERC PRC-029-1

Frequency and Voltage Ride Through Requirements for Inverter-Based Generating Resources



References:

- *FERC Final Order on PRC-029-1*
- *PRC-029-1 Implementation Plan*

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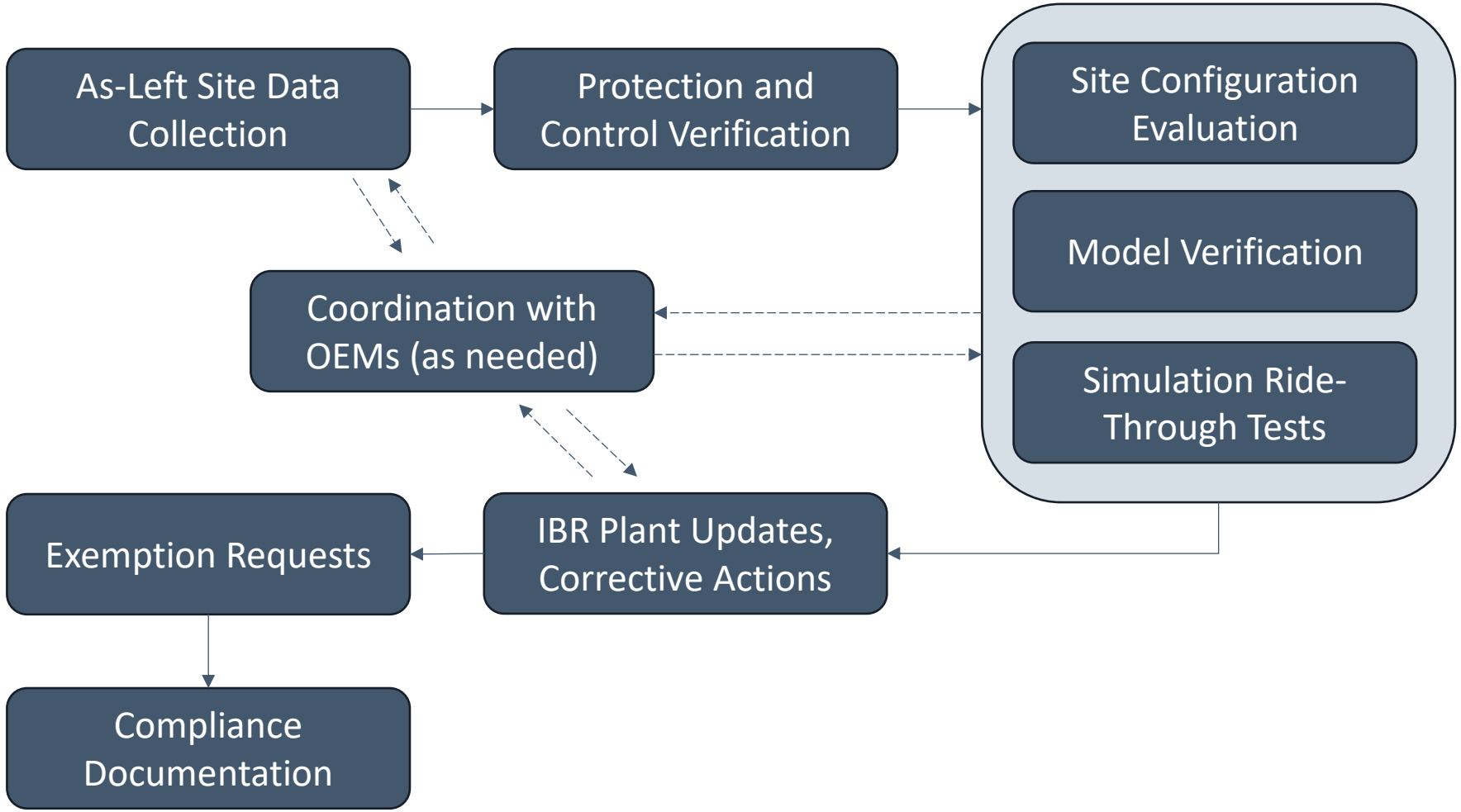
Disclaimer: This material should not be interpreted as compliance advice or guidance; they are solely for informational purposes and industry discussion.

Assessment Methodology and Lessons Learned

PRC-029-1 Design Evaluation Flowchart



Design Evaluation Process

Data Preparation

- As-left inverter/WTG protection and ride-through settings
- As-left relay settings
- Single-line diagram
- Model quality test report
- Model user guide
- PRC-019 report
- PRC-024 report
- Protection philosophy
- Control narrative

Model Check and Configuration

- Document any discrepancy between the model and the actual plant
- Aggregated inverter/WTG model
- Aggregated inverter/turbine level transformer
- Equivalent collector system
- Shunt compensation
- Main power transformer(s) (MPT) with tap changer
- Voltage-based protection settings of inverter/WTG and plant relays

Running Simulations

- Set up the load flow cases
- Run the designed simulation tests for each requirement in PSSE/PSLF/PSCAD

Results Analysis and Compilation

- Analyze simulation results based on the specific details in each requirement
- Evaluate pass or fail for each requirement
- Provide recommendations to address possible compliance failures
- Compile a report and provide necessary documents/settings that can support the compliance procedure

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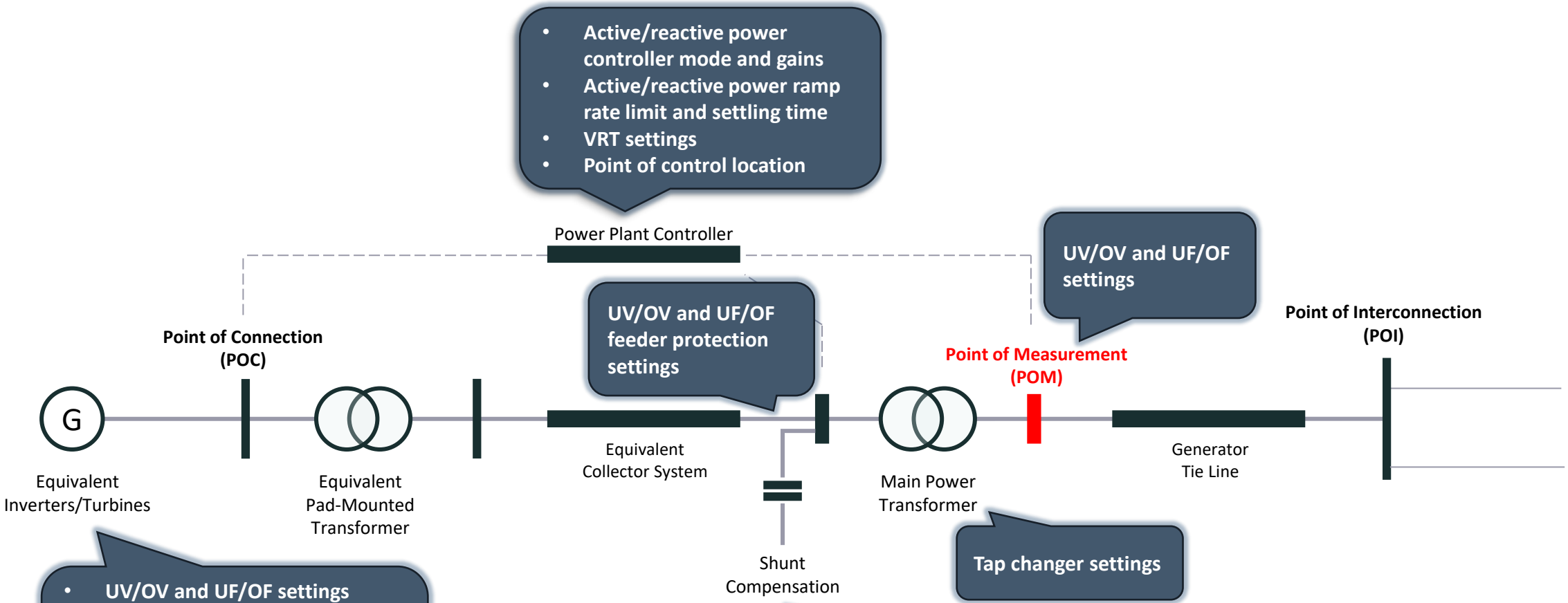
Important Model Checks vs. As-Left Settings



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Steady-State (Power Flow) Setup Considerations

- Consider **worst case scenario** to push the IBR plant as close as possible to its current limit, i.e., rated P and maximum Q.
- **0.95 lagging and leading power factors (PFs) at POI** are applicable operational worst-case scenarios for most plants across North America.
- Keep the **capacitor banks in service** and put the **shunt reactors out of service** for the lagging PF case and do the opposite for the leading PF case.
- Make sure **voltages across the IBR plant** remain within the **[0.95 pu, 1.05 pu]** range in both cases.
- When adding the **playback** function to **POM**, maintain the **power flow results** obtained from 0.95 lagging and leading PFs at **POI**.
- Reset the **tap** value every time that the power flow case is solved.

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R1: Voltage Ride-Through
R2.1: Continuous Active/Reactive Power Delivery

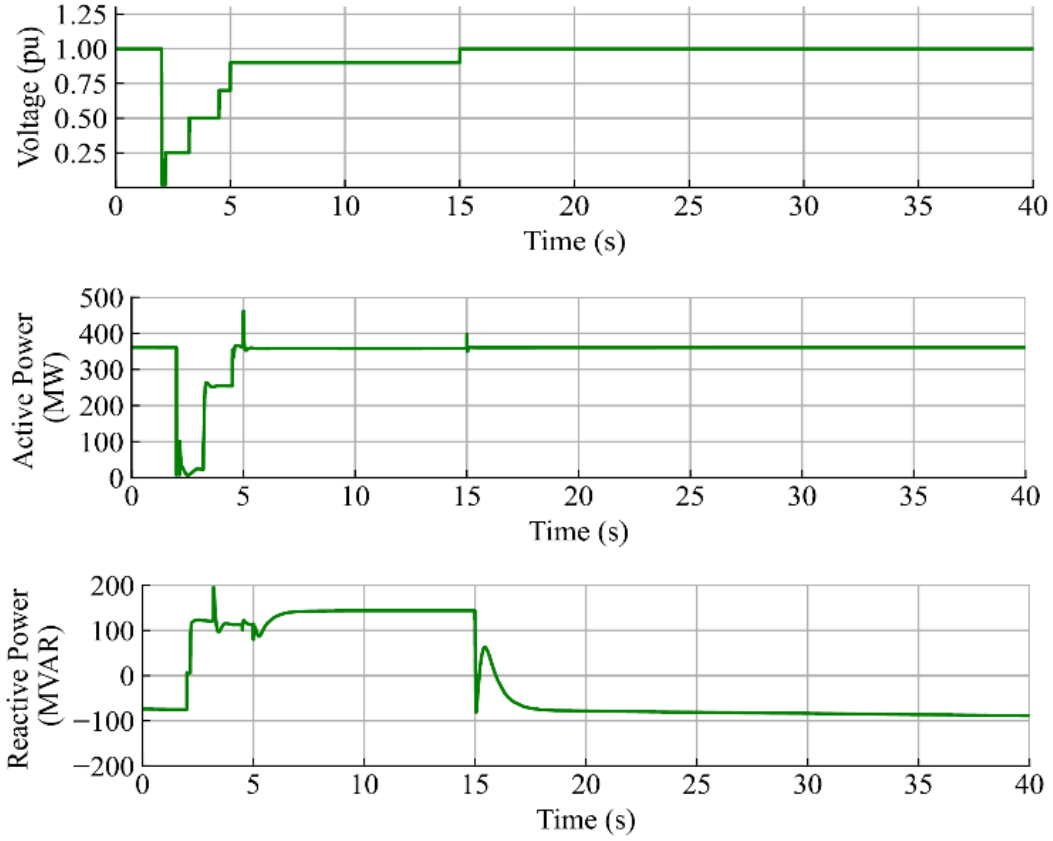
R1 criteria

- IBR plant successfully rides through all voltage levels (stably and with expected dynamic response)

R2.1 criteria

- IBR plant delivers pre-disturbance/available active power in continuous operation region.
- IBR plant delivers reactive power within the hardware limits in continuous operation region.
- IBR plant prioritizes active/reactive power when voltage is in [0.9, 0.95] pu range and a limit is reached.

POM Quantities



Lessons Learned

- **DO NOT DO A CURVE COMPARISON!!!**
- Make sure to set up the case such that the **exceptions** do not apply.
- Disable **UF/OF** protection during this test.
- In case of a **trip**, find the relevant protection element, disable it, and run the simulation again.
- If active or reactive power do not recover to the pre-disturbance value, a **partial trip** may have occurred.
- In case of a **partial trip**, both **R1** and **R2.1** are **not met**.

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R2.2 & R2.3: Active/Reactive Power Priority

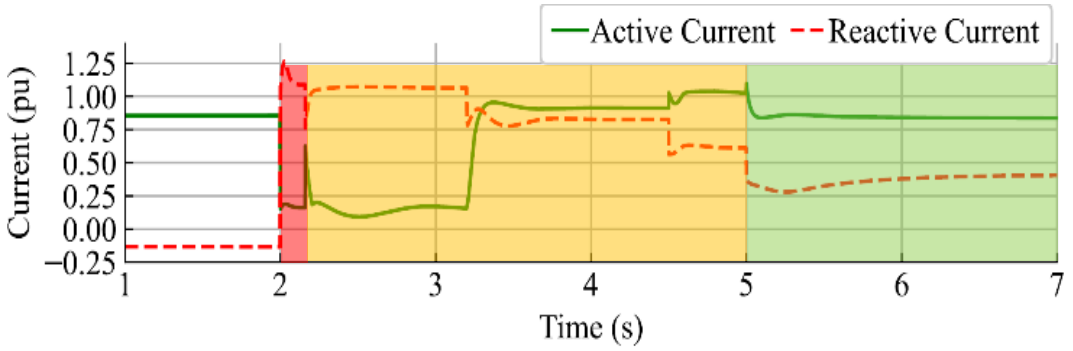
R2.2 criteria

- Reactive (by default)/active current is prioritized in mandatory operation region.

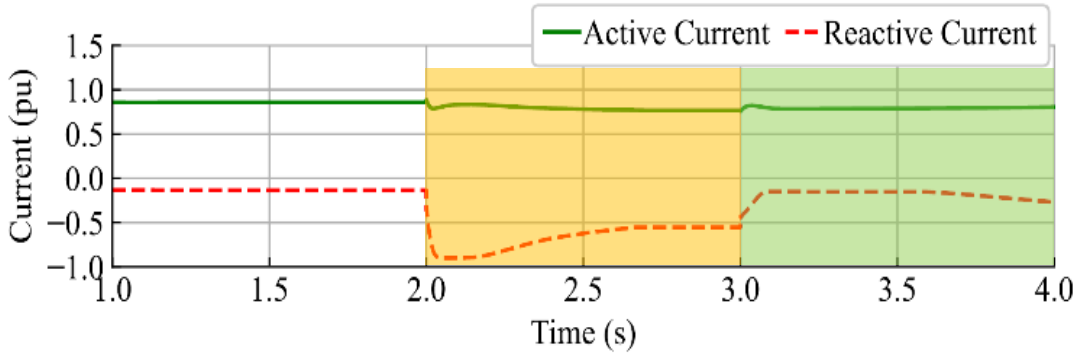
R2.3 criteria

- Reactive (by default)/active current is prioritized in permissive operation region.
- Current exchange is restarted in less than 5 cycles if current blocking mode activated.

POC Quantities (LVRT)



POC Quantities (HVRT)



Lessons Learned

- Check the model for **PQ priority flag** settings.
- Calculate **the expected value** of reactive/active current (based on K factor and voltage drop).
- If **UDM**, rely on the **general pattern** of active/reactive current variations.
- Check the inverter **current limiter** settings.
- If the inverter manual mentions existence of the **current blocking mode**, check for its correct implementation in the model.

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R2.4 & R2.5: Active/Reactive Power Recovery

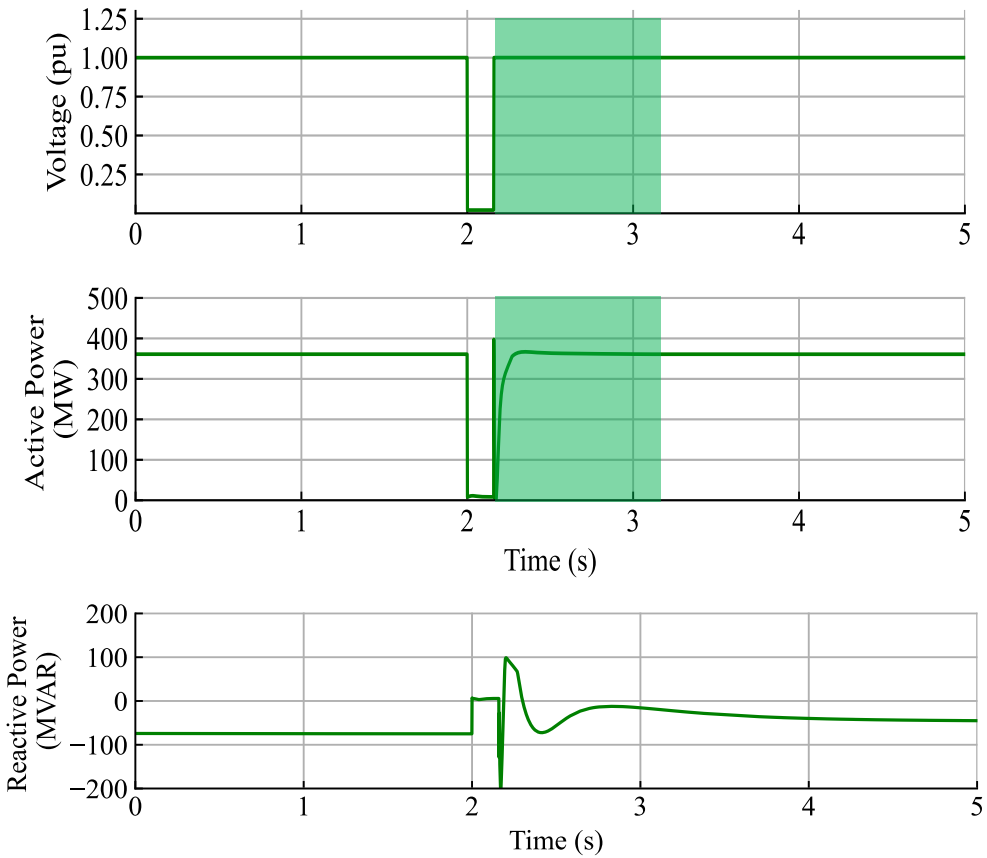
R2.4 criteria

- Reactive power smoothly recovers close to pre-disturbance level.

R2.5 criteria

- Active power restores to pre-disturbance/available level in less than 1 second.

POM Quantities



Lessons Learned

- Active power does not need to **settle** within 1 second. It just needs to **restore!** (Our understanding)
- **1 second** time window starts after the return of the **voltage** to the **continuous operation region**.
- Certain **spikes** in active or reactive power are caused by numerical instability of the model and can be **neglected**.
- If active/reactive power does not recover properly, double check the **PPC settings** before drawing a conclusion.

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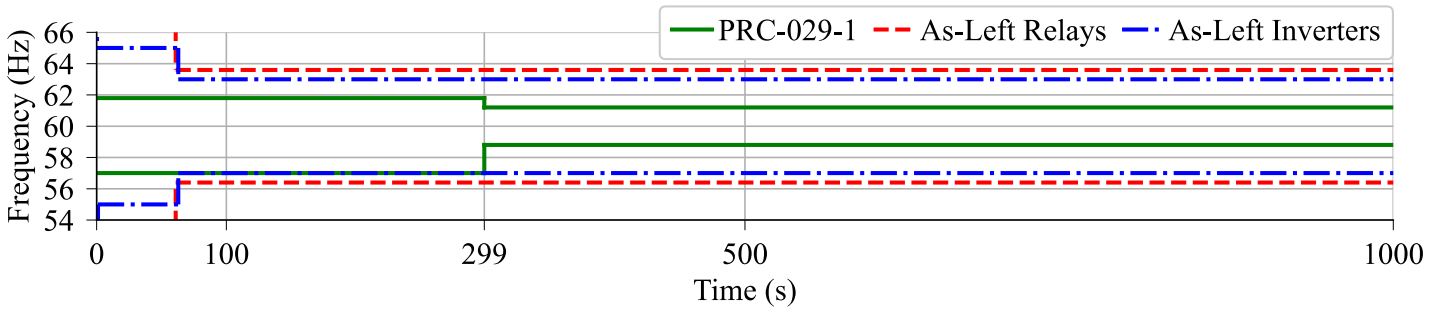
R3: Frequency Ride-Through

Considerations:

- For frequency ride-through assessment, one may use **curve comparison;** simulations are not necessarily needed.
- For ROCOF assessment, refer to **documentations from OEMs and verify as-left settings.**
- R3 is generally **met** if as-left relays and inverters FRT curves are outside the PRC-029-1 FRT curve **AND** the plant can ride through ROCOF of less than or equal to 5 Hz/s.



Lessons Learned

- If the curves **overlap**, flag that protection element to ensure changing its settings.
- Check the **relay settings files** (.rdb, .urs files) and investigate if **UF** and **OF** elements are included in the **trip equation**. This applies to **UV** and **OV** elements too.
- Do not rely on the **as-left settings** reported in the previous studies/reports. Ask the GO to extract an **up-to-date version** of the as-left settings from the field.

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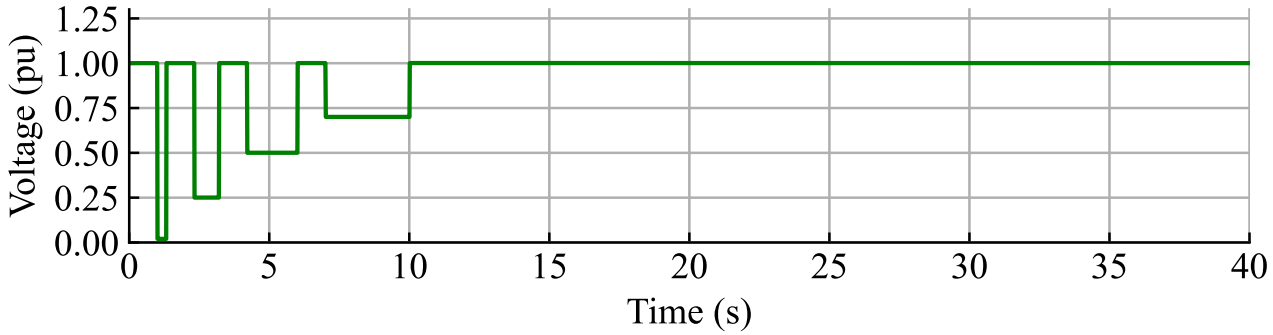
Consecutive Voltage Disturbance Ride-Through

Considerations:

- Consecutive voltage disturbance ride-through requirement is generally **met** if the inverters are capable of riding through at least four consecutive voltage disturbance within a 10-s time window.



Lessons Learned

- Although PSS®E and PSLF **simulations** can be run to test, generally **not recommended** for this assessment since **such protections are typically not modeled**.
- If running a simulation, make sure that the **cumulative time** of the four disturbances does not exceed **10 s**.
- If running a simulation, our recommendation is to consider **sufficient time gap** between the disturbances (a 20-cycle gap is recommended in IEEE P2800.2).
- Refer to **documentation from OEMs and engagement with the OEM** to support compliance with this specific requirement.

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Summary and Conclusions

Comprehensive verification of IBR plant **as-left documentation** and **IBR models** is a necessary first step in starting a PRC-029-1 design evaluation.

Both **EMT** and **RMS** tools can be **effective** for conducting design evaluations for NERC PRC-029-1.

Comprehensive compliance requires **not only simulation but also documentation** from equipment manufacturers, especially for protections not typically modeled.

Ongoing collaboration with OEMs and adherence to evolving standards (e.g., IEEE 2800-2022) are essential for meeting technical and regulatory requirements.

Capability to store, retrieve, and analyze IBR plant documentation effectively can **save significant time**.

Automation can significantly streamline and simplify analysis – focus on engineering work!

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