January 27, 2026 Virtual Meeting

NERC PRC-029 Implementation, Experience, and Recommended Practices (~280 attendees)

Presentation recording and slides are available to download here. Figure 1 shows the makeup of meeting attendees by industry sector:

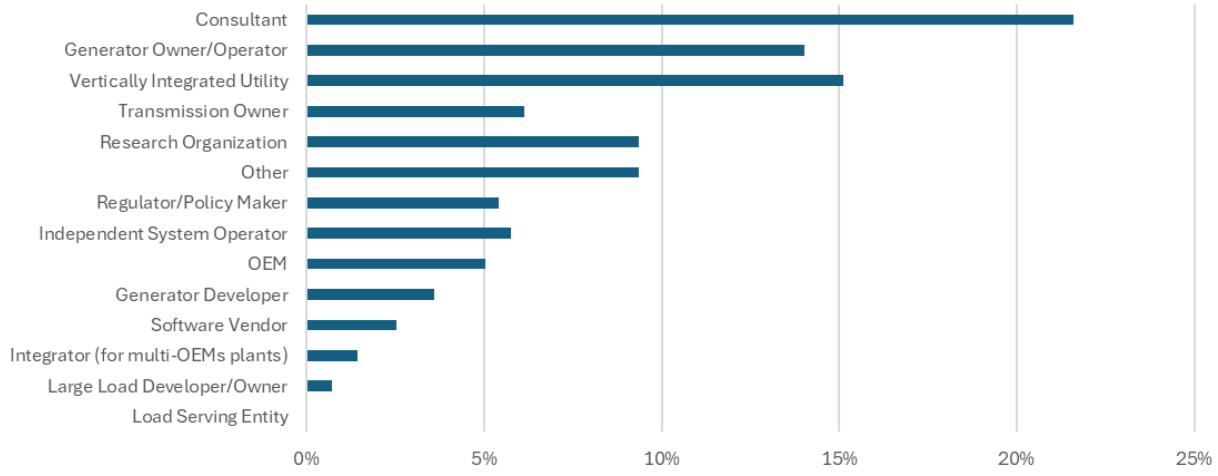

Figure 1: Meeting attendees by industry sector

This ninth meeting of Season 2 of the DOE i2X FIRST initiative focused on NERC PRC-029 implementation, experience, and recommended practices. With initial IBR plant ride-through design evaluations due by October 2026, this session served as an opportunity to hear from NERC and early experience from industry experts supporting these evaluations.

JP Skeath, NERC

JP shared an overview of NERC PRC-029-1 and FERC Order 909. NERC PRC-029-1 was developed as part of NERC implementation plan to meet the directives in FERC Order 901. The NERC Milestone 2 standards include NERC PRC-028-1, PRC-029-1, and PRC-030-1 (see Figure 2); NERC PRC-029-1 establishes performance-based ride-through criteria as well as capability-based ride-through criteria. FERC Order 901 directed 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." IBR plants must "continue to inject current and perform frequency support" within ride-through conditions.

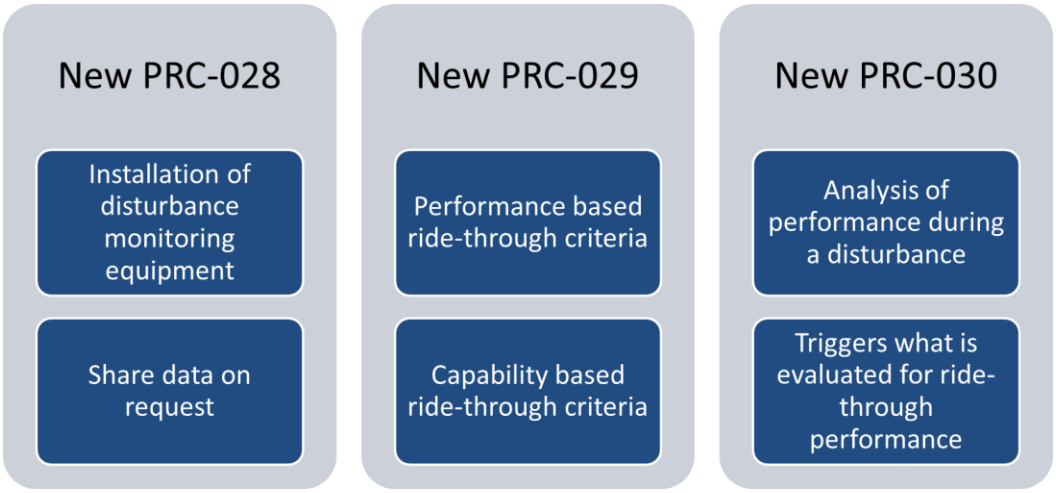

Figure 2: Overview of NERC Milestone 2 Projects [Source: NERC]

NERC was also directed to determine whether PRC-029-1 should allow for limited and documented exemptions for certain registered IBRs for voltage ride-through performance requirements. Subsequent stakeholder workshops and feedback justified that frequency exemptions are also credible and should be considered and were subsequently addressed in the proposed standard.

NERC PRC-029-1 includes four requirements. Requirements R1–R3 establish frequency and voltage ride-through capability and performance requirements for IBRs (see Figure 3) and include performance criteria regarding IBR plant dynamic performance during ride-through conditions. Requirement R4 defines the limited exemptions applicable to IBRs in service by the effective date of NERC PRC-029-1 (October 1, 2026). The exemptions are limited to known hardware limitations that prevent the IBR plant from meeting documented frequency and voltage ride-through criteria. Exemptions are to be submitted to the Compliance Enforcement Authority (CEA), Planning Coordinator, Transmission Planner, Transmission Operator, and Reliability Coordinator. IBR owners are expected to follow-up on requests for additional information, and IBR owners are also expected to notify the applicable entities within 90 days of CEA acceptance of hardware limitation.

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

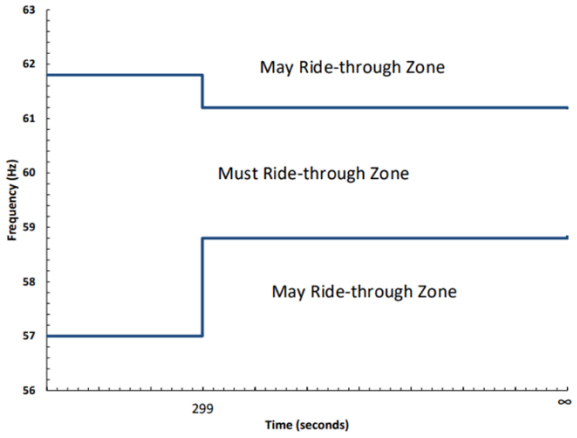

Figure 1: PRC-029 Frequency Ride-through Requirements

Figure 3: NERC PRC-029-1 Voltage and Frequency Ride-Through Criteria [Source: NERC]

FERC subsequently issued Order 909 on July 24, 2025, to approve PRC-029-1 and PRC-024-4,[1] and also issued several directives to NERC including addressing the following topics through its standards development process:

- 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
- Address concerns about absent documentation for legacy IBR units (e.g., modify requirement, expand Measures to include non-exhaustive list of acceptable evidence) within 12 months
- Following full implementation of the standard, submit an informational filing to FERC including certain data and an assessment of the reliability impacts of the exemption process.

FERC subsequently issued Order 909-A on Sept 25, 2025, denying a request for clarification of Order 909. The request raised concerns about potential timing mismatch between NERC's anticipated filing of a modified standard in August 2026 and the standard's effective date of October 1, 2026. Specifically, the concern was that some registered entities could be placed in a noncompliant status on the effective date while simultaneously seeking exemptions related to the issues raised in Order 909. In denying the request, the Commission stated that NERC retains "the flexibility to address the Energy Trades' timing concern whether through the implementation plan for a modified Standard, NERC's enforcement discretion, or some other means."

[1] NERC PRC-024-4 is the revised generator voltage and frequency protection settings standard for synchronous generators, Type 1 and Type 2 wind resources, and synchronous condensers.

NERC held a virtual workshop on Order 909 to address the topics describe above. Lastly, also received an industry Standard Authorization Request (SAR) from the American Clean Power Association (ACPA) and initiated Project 2025-05. The SAR was posted for comment, ending December 18, 2025. The scope of the SAR seeks to 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, and to clarify the non-exhaustive acceptable evidence to aid entities. The SAR has not been approved as of this meeting, and the drafting team is responding to solicited comments first.

Yaw Akpaloo and Lukas Sales, GE Vernova

Yaw and Lukas shared GE Vernova's perspectives with onshore wind equipment regarding PRC-029-1 implementation. GE has over 75 GW of double-fed induction generator (DFIG) wind turbine generators (WTGs) installed in the North American market. This includes the new and active 2.X-127, 3.X, and 6.X platforms. All newly delivered and currently active products are designed to meet NERC PRC-029-1 and IEEE 2800-2022 requirements. Software-based upgrades enable full alignment with the applicable requirements for some legacy models. This includes the legacy 1.X-10Y, 2.X, and early 1.X platforms which can meet most of the PRC-029-1 requirements through targeted software upgrades, unlocking enhanced ride-through and recovery capability. Older variants have meaningful capability expansion opportunities, with performance aligned to turbine design and plant configuration. Achievable outcomes are upgrade-enabled and turbine-specific, which allows customers to "pursue practical, value-driven capability pathways" across their fleets.

GE Vernova has supported its customers with the following:

- **Position Papers & Technical Capability Reports:** These papers have been shared with applicable generator owners to explain turbine-level capabilities and upgrade options, support exemption evaluations where applicable, and 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 for customers. These IBR unit models are intended to be incorporated into the full IBR plant models for subsequent compliance evaluation studies.
- **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 validation to ensure performance and deployment is planned with customers to align with site access and outage windows, operational priorities, and regulatory milestones.

GE Vernova elaborated on observations and questions raised by customers, including:

- Some customers have mixed interpretation of whether NERC PRC-029-1 R1–R3 enforcement aligns with PRC-028-1 implementation dates and deadlines.
- Maximization requirements in the NERC requirements are less prescriptive and in some ways unclear.
- Continued alignment discussions around exemptions for in-kind replacements and partial repowering where hardware changes are limited as well as uncertainty on specifics for demonstrating achievable capability including justification where physical constraints exist.
- Process for wind plant upgrade and simulation models updates, particularly with respect to how ISOs and utilities use different processes for plant upgrades, model updates, and validation, which reinforces establishing an upgrade pathway and gathering OEM-supported documentation to streamline multi-region deployment.

GE Vernova stated that they remain committed to engaging with their customers, ISOs, utilities, and other industry stakeholders as implementation efforts continue. Early coordination across GOs, OEMs, consultants, and regulators helps unlock clarity, alignment, and efficient execution at scale.

Amin Banaie, Elevate Energy Consulting

Amin shared recommended practices and experience conducting IBR ride-through evaluations on IBR plants pursuant to NERC PRC-029-1 requirements. Amin shared the compliance deadlines for both Bulk Electric System (BES) IBRs as well as registered Category 2 IBRs (see Figure 4) and described the assessment methodology and lessons learned from conducting evaluations on various IBR plants and technology types.

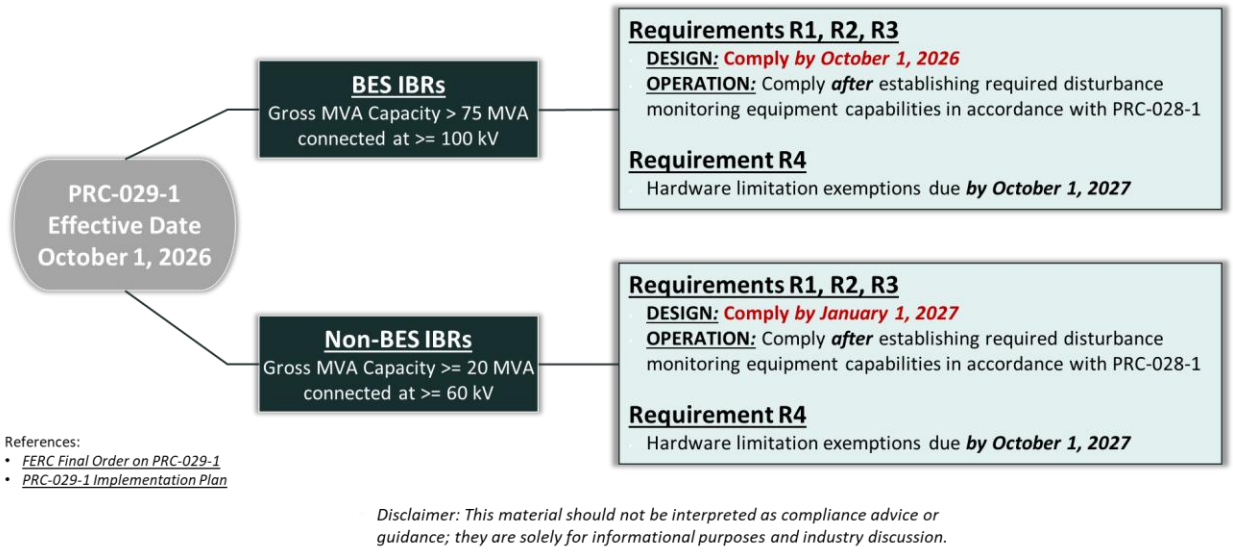

Figure 4: NERC PRC-029-1 Compliance Deadlines [Source: Elevate Energy Consulting]

The IBR plant ride-through design evaluation methodology involves a multi-step process to assess IBR plant protection, controls, and settings to ensure the overall IBR plant meets the requirements set forth in NERC PRC-029-1. This includes the following steps (see Figure 5):

- **As-Left Site Data Collection:** The IBR plant as-left settings and data are collected and verified to ensure that the latest on-site configuration is represented and documented. This is often an overlooked step that can result in errors that progress through the entire process if not carefully reviewed.
- **Verification with OEMs (as needed):** In many cases, gathering the necessary protection and control information, particularly for the IBR units, requires requesting access to data and information from the OEMs. This information is not always (or even often) readily available to the end-user/owner and must be requested. Additionally, there are protection and control settings that may not be visible to the owner that are hard-coded by the OEM and warrant careful attention. In many cases, multiple iterations with the OEM are required to gather the necessary information to verify site details.
- **Protection and Control Verification:** Once all data has been collected, a desktop evaluation of protection and control settings occurs. This includes the frequency and voltage ride-through settings of the IBR units, the PPC (if applicable), and the balance of plant relays. Additionally, protections such as phase jump, ROCOF, anti-islanding, DC-side protections, and other protections are also evaluated, particularly since they are often not represented in the dynamic models.
- **Site Configuration, Model Verification, and Simulation Ride-Through Testing:** Once the site as-left settings, protections, and controls are verified, then the IBR plant dynamic model(s) can be verified. This step involves ensuring that the dynamic models do not have any errors or omissions. Again, not all protections are reflected in the dynamic models, and older sites may not have access to EMT models. Thus, careful evaluation of protection and control settings may be more accurate and sufficient than simulation tests. Regardless, these tests provide additional assurance that the IBR plant is able to ride through specific events and provide the appropriate dynamic response (active and reactive current/power) as specified in the sub-requirements.
- **IBR Plant Updates, Corrective Actions:** Once the evaluation is complete, any corrective actions to get the plant into compliance with the requirements are identified, where applicable. This may involve additional coordination with the OEM(s).
- **Exemption Request Documentation Preparation:** In some cases, all applicable software-based updates may not be sufficient for legacy assets to meet the established requirements. In these cases, careful collection of exemption documentation and additional coordination with the OEM is needed. These materials are to be shared with the CEA and applicable entities for evaluation.

- **Compliance Documentation and Evidence Tracking:** Upon completing the evaluation, all documentation, models, and evidence are tracked and retained for ongoing compliance purposes.

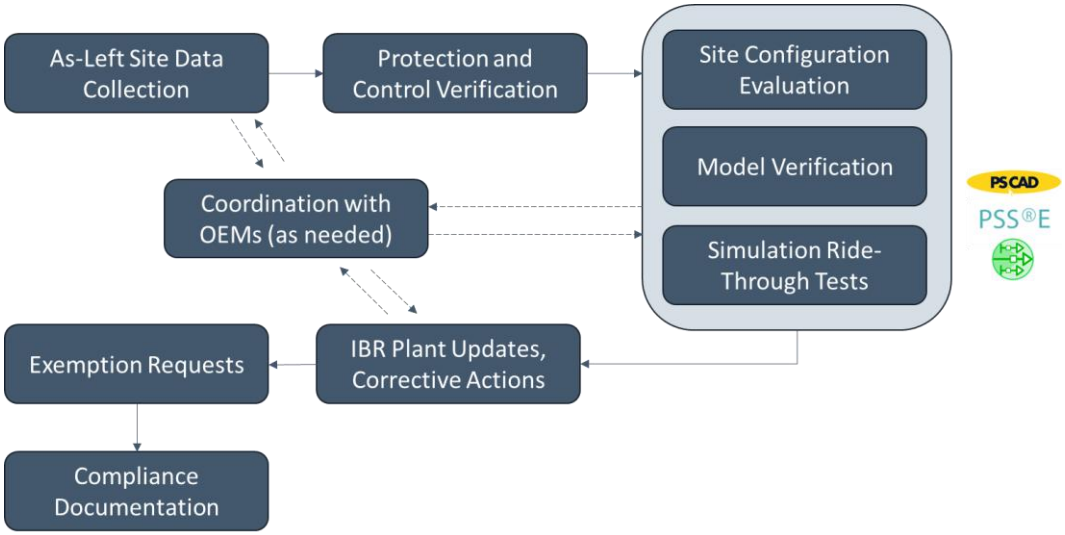

Figure 5: Elevate IBR Plant Ride-Through Design Evaluation Methodology [Source: Elevate Energy Consulting]

As mentioned, careful consideration of all the sub-requirements in Requirements R1–R3 is needed during the evaluations. Some of these require careful analysis of simulation results under defined operating conditions, such as speed of active power recovery, active versus reactive current priority during ride-through modes of operation, maintaining active power during continuous operation, etc. Figure 6shows an example of a simulation result evaluating the post-fault recovery of active power per the sub-requirement.

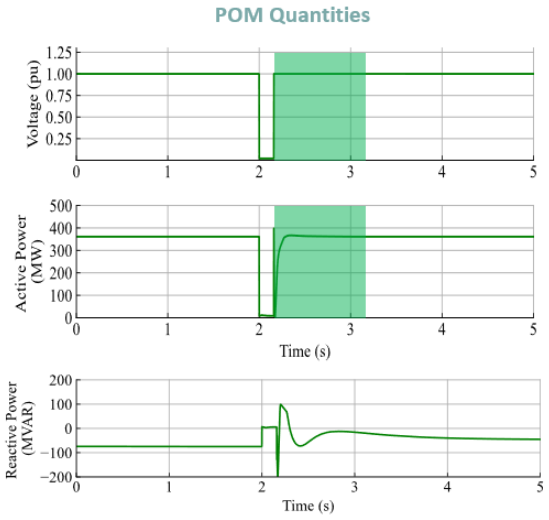

Figure 6: Illustration of Evaluating Simulation Results Against Sub-Requirements of PRC-029-1 [Source: Elevate Energy Consulting]

Some requirements cannot be adequately assessed using simulation results. For example, it is very rare for simulation models to represent consecutive voltage ride-through thresholds as they may often involve mechanical impacts that are not included in the electrical models. Thus, desktop evaluations are key to ensuring an adequate and comprehensive evaluation is conducted. Simulation results should not be overly relied upon to justify ride-through, as this could result in a false sense of acceptable performance. Further, both EMT and phasor domain positive sequence models can be effective for conducting IBR plant ride-through design evaluations; it is first and foremost important that accurate models reflective of the actual as-left settings are used for the studies and careful use of the models and understanding their limitations is key.

Q&A and Interactive Group Discussion

Where do the requirements of NERC PRC-029-1 apply?

The requirements apply at the point of measurement (POM) of the IBR plant, which is the high side of the main power transformer(s).

How can the IBR plant ride-through design evaluation be completed to meet compliance by 10/1/2026 yet the exemptions are due by 10/1/2027? It seems that the exemptions would be due by 10/1/2026. Please clarify.

Prior to the October 1, 2026, cut-off date, resources are considered legacy and follow the legacy rules. If exemption documents are available, the 12-month window is used to bridge between the effective date of PRC-029-1 and the last date to seek exemption being on October 1, 2027.

PRC-029-1 Requirement R4 lists "known hardware" but what about older inverters that do not have documentation of sufficient detail and could have "unknown" limitations?

JP stated that if the IBR unit preventing the IBR plant from meeting Requirement R4 is getting replaced, then there are no issues. For older inverters with unknown limitations, JP noted that the NERC team is still identifying the specific requirements, so the formal process is in development. If equipment data is not available to necessary parties, OEMs are encouraged to participate, which was mentioned in the FERC Order 909 virtual conference.

Regarding exemptions for Requirement R4, there is no template. The standard is also under revision with Project 2025-05. Entities are encouraged to reach out to their applicable CEA. There are no published recommendation documents at this time. NERC does not write compliance guidance materials for industry. Since PRC-029-1 has no guidance, it is up to entities to find the evidence to present against the standard. Comments and feedback can be brought to Project 2025-05 and entities are encouraged to reach out with concerns.

Is there any mandate that PRC-029-1 should only be performed using EMT models? Are RMS models acceptable? Some jurisdictions do not have EMT modeling requirements during generator interconnection and thus those models are not available. Are standard library PSSE/PSLF models effective to perform evaluations? What will NERC accept / expect in the evaluation? Is a standard library model sufficient or is a UDM required?

Amin highlighted that both EMT and phasor domain models should be considered acceptable by the regulatory bodies, and the best available model and information should be used for all evaluations. Many existing IBR plants do not have an EMT model available or constructed, and it is extremely time-intensive and costly to build these models from scratch in coordination with the OEMs. Thus, for these types of sites, a phasor domain model should be deemed adequate and additional desktop evaluation efforts can be performed to ensure a thorough evaluation of ride-through is conducted. Symmetrical faults do not strictly require EMT for PRC-029-1 IBR ride-through evaluations, although phasor software may be an inferior representation than EMT in many ways. Generally, if a high quality EMT model is available, it should be used for the PRC-029-1 evaluation.

NERC recommended to use the currently available information about the site. There is no defined requirement regarding which models to use, but NERC does recommend that the most accurate model available be used, which is generally a UDM rather than generic and an EMT model over a phasor domain model.

GE Vernova highlighted that momentary cessation is not captured in the phasor domain models that they release for their wind fleet. Thus, EMT models are encouraged; however, not all sites have an EMT model.

It was mentioned that voltages within the IBR plant are important to consider when setting up a power flow case. How is this done with an aggregated model? Do you suggest detailed IBR plant models for PRC-029-1 evaluations?

Amin explained that an aggregate model is sufficient and generally the only model of the IBR plant available; it is relatively uncommon for a detailed, disaggregated dynamic model of the IBR plant to be readily available and verified. Regardless, aggregate representation is adequate to capture worst-case assumptions of voltage drop across the collector system and PRC-029-1 is at an IBR plant-level rather than an inverter-level so aggregate models are again useful here.

Voltage ride-through is specified at the high side of the main power transformer(s). Is there recommended guidance for translating the high side values to the inverter settings at the inverter terminal voltage base? Transformer taps and power flow conditions have a large impact on the voltage difference.

Amin recommended that simulations be performed to verify the settings and establish stressed operating conditions to verify ride-through performance. Using playback-based approaches, the

POM voltages can be controlled and the IBR plant components, protections, and controls can be evaluated via simulation.

Who will evaluate the IBR plant model compliance?

JP stressed that the IBR plant ride-through design evaluation is the responsibility of the generator owner, including modeling performance tests. The IBR plant owner will report any exemptions to the CEA and other entities; otherwise, they must have evidence of the evaluation to meet compliance and then the IBR plant must also perform to these capabilities operationally. The Reliability Coordinator or Transmission Operator may identify ride-through failures and the IBR owner may also detect failures, both of which may require performance evaluation per NERC PRC-030.

Is there a need for disaggregated models of the IBR plant to assess PRC-029-1 compliance or are aggregate models sufficient?

Aggregate models should be considered sufficient for conducting these ride-through design evaluations.

How should PRC-029 findings be addressed if the OEM is no longer in business to support remediation?

This is still a relatively rare occurrence where the OEM is no longer in business, but it does exist for some facilities. In these cases, careful evaluation of the site should be addressed on a case-by-case basis based on the data, information, and models available. If a relatively accurate model is available, and can be used for the evaluation, then there are likely no additional software updates to make. However, some OEMs have transferred support services to a third party and thus software-based updates may still be viable. Acquiring accurate EMT models and phasor domain UDMs will be very challenging in these cases, so standard library models may be required for the simulation portion of the evaluation.

The grid is evolving rapidly, and current stability margins are being reduced by the current IBR interconnection and planning processes. What are the main updates in WTG Type 3 and 4 in this area?

All GE Vernova platforms are grid following inverter technology. Although new controls enable meeting new requirements, low voltage leads to torque loss and later recovery, causing electrical power fluctuation. Mechanical implications may damage equipment, so these must be addressed to mitigate mechanical load. With other stringent power recovery rates, they are evaluating more than just the electrical aspect.

With much more stringent requirements in PRC-029-1 as compared with NERC PRC-024-3, as OEM are you pushing limits or identifying limits?

GE Vernova stated that for turbine models being produced, EMT simulations and sub-component tests are conducted in the lab. For simultaneous events, they are doing lab tests for the next level requirements, specifically turbine-level validation. They are executing voltage ride-through testing on the 3.8 type turbine right now. However, the level of validation for lab tests on legacy turbines is limited, so they rely a lot on simulations.

Can GE Vernova share their PRC-029 evaluation documents with the whole industry so other OEMs can see and consider applying the same approach?

GE Vernova stated that they must respect customer confidentiality. Limitations on GE Vernova's equipment do not apply to other OEMs and they may have their own limitations. GE Vernova plans to publish a report for a group of turbines for their ride-through capabilities. Most of the requirements are at the POM but the ride-through capabilities are defined at the WTG terminals.

Is it required to simulate the 1800sec period for the 1.05-1.1 voltage range?

EMT models take a relatively long time to run an 1800-second simulation; phasor domain software is designed to run 60-100s. Thus, these dynamic models are not intended to run simulations for this long and are not accurate at this time scale. IBR plant settings can be reviewed to verify the performance with this sub-requirement beyond 60-100 second simulation timeframe.

How can phasor domain simulation programs be used to prove functions such as DC bus tripping or PLL trips are not occurring? Are EMT models therefore required?

Amin stated that this is a concept that requires careful consideration by the subject matter expert conducting the evaluation. Not all inverters have DC-side protection; however, some may have instantaneous protections that require careful consideration against the requirements. If they do have these protections, they are not generally represented in the phasor domain models and are often not even modeled in the EMT models adequately. Desktop evaluations may prove just as effective in assuring ride-through performance in these cases.

How are transformer on load tap changer settings evaluated for PRC-029-1?

Amin articulated that tap changer settings impacts the power flow base case setup and the voltage on the feeders when setting up the 0.95 lagging and leading power factor cases. If the taps are not reset before solving each power flow case, one might see unreal over- or under-voltage on the feeders. Thus, careful attention to the tap changer settings and treatment in the simulations is key.

In the PRC-029 assessment, is an infinite short-circuit level at the POI assumed or do you consider the prevailing short-circuit levels at the POI (max, min, and eventually absolute min)?

Generally, a single machine infinite bus (SMIB) system is used to control the POM voltage conditions and test ride-through performance under defined voltage profiles.

How is automation of dynamic simulations handled, particularly for large quantities of simulation tests? Are multiple Python scripts used? How is this broken up?

This can depend on how long and how many simulations are performed. If the run time is long, the "Parallel Dynamic Module" of PSS®E could be used which allows running multiple simulations at the same time on different CPU cores. This can significantly improve the overall evaluation simulation speed.

Are asymmetrical voltage disturbances required for simulation in Requirement R2.2? What methods need to be used?

It is generally not necessary to conduct an asymmetrical fault because the symmetrical fault captures the worst-case scenario and pushes the IBR to its limits. Phasor domain tools cannot adequately test asymmetrical faults. However, if an EMT model is available, then additional simulations could be conducted to test asymmetrical faults, but again this may not be necessary.

Key Themes

- **Transition to Performance-Based Ride-Through Requirements:** The implementation of PRC-029-1 represents a shift from a settings-based relay standard to a comprehensive performance-based standard for applicable IBRs. The standard focuses on ride-through capability and performance, as well as the dynamic performance of the IBR plant during ride-through events. Initial compliance deadlines are approaching in October 2026, and all applicable IBR owners are strongly encouraged to start compliance assessment efforts and IBR plant ride-through design evaluations as soon as possible to meet regulatory deadlines.
- **Regulatory Evolution, Exemptions, and Unresolved Gaps:** Directives stemming from FERC Orders 901 and 909 highlight that PRC-029-1 continues to evolve and additional topics are being addressed by a current drafting team. This is particularly with respect to exemptions for legacy equipment, long lead-time projects, and HVDC-connected IBRs with choppers. The exemption process is also still somewhat unclear and entities should ensure they conduct ample due diligence to prepare for these exemption requests fleet-wide. Significant uncertainty remains around documentation sufficiency and timing alignment.
- **OEM Capability Pathways and Fleet-Specific Solutions:** OEM perspectives highlighted that compliance is technology- and platform-specific, particularly for legacy assets. Software-based upgrades can improve ride-through capability and performance for older sites, however, must be acquired by the OEM and implemented. Ride-through evaluations will need to be re-conducted for post-implementation outcomes. Physical

hardware-based design limits exist and should be considered carefully in coordination with the OEM.

- **Importance of Accurate As-Left Data and Desktop Verification:** A recurring theme was that ride-through evaluations are only as credible as the underlying site data and settings used in the assessment. Verifying as-left configurations, hidden protections, and hard-coded OEM logic is often more critical than running extensive simulations. Desktop reviews of protection and control behavior are essential, particularly where dynamic models could fail to represent key trip functions or mechanical constraints.
- **Model Fidelity Over Model Type:** The discussions reinforced that PRC-029-1 does not mandate a specific modeling approach; rather, it expects use of the most accurate model reasonably available. EMT models provide greater visibility into phenomena such as momentary cessation and DC-side protection yet phasor domain models, when paired with careful engineering judgment, are generally sufficient for many evaluations. Over-reliance on simulations without understanding model limitations can lead to false confidence in ride-through capability.
- **Need for Early Coordination and Scalable Processes:** Effective PRC-029-1 implementation depends on early and sustained coordination across generator owners, OEMs, consultants, and compliance authorities. Differences in regional processes for upgrades, model validation, and evidence review can create friction that must be managed proactively. Establishing repeatable methodologies, documentation procedures, and shared expectations is critical to effectively achieving compliance at-scale.