May 27, 2025 Virtual Meeting

Season 2 Kickoff (~200 attendees)

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

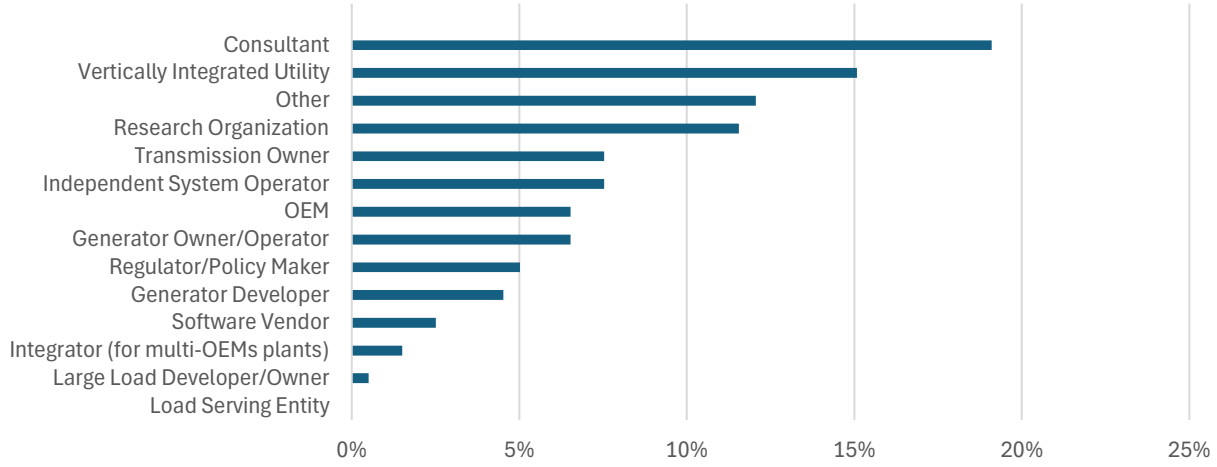

Figure 1: Meeting attendees by industry sector

This first meeting of Season 2 of the DOE i2X FIRST initiative provided a recap of Season 1 highlights and key takeaways, and status updates regarding IEEE 2800-2022 adoption, IEEE P2800.2 progress, and NERC Milestone 2 and 3 standards development efforts. Presentations included the following:

Julia Matevosyan, ESIG

Julia gave an overview of Season 1 topics and shared highlights from the initiate thus far. Season 1 monthly webinars and hybrid workshops were attended by over 1,225 unique participants across a diverse set of stakeholder groups including developers, utilities, system operators, OEMs, and consultants. Consultants comprised the highest percentage of attendees, and this is somewhat to be expected as this group is often supporting generator owner/operators or even independent system operators and utilities through the interconnection process. Season 1 materials can be downloaded on the ESIG i2X FIRST webpage. High-level key takeaways from Season 1 include:

- Harmonizing IBR requirements and enhancing conformity assessments, leveraging IEEE 2800-2022 and IEEE P2800.2, are vital for streamlining the interconnection process while supporting grid reliability.

- NERC or FERC adoption of IEEE 2800-2022 could lead to uniformity and consistency across entities and regions. Coordination with regulatory requirements at the FERC and NERC levels is critical to avoid overlaps, redundancy, and most importantly conflicting requirements. Industry participation in NERC standards development efforts is essential to align with IEEE 2800-2022 and to avoid duplication of effort.
- OEMs are advancing IBR ride-through capabilities and preparing for IEEE 2800-2022 implementation. Guidance is needed from transmission providers on configuration and setting parameters.
- Increased education, engagement, and collaboration is needed between OEMs, transmission providers, IBR plant developers and owners, to enable a streamlined process.
- Accurate IBR unit and IBR plant modeling is a foundational aspect of IEEE 2800-2022 performance conformity assessments. This includes IBR unit model validation based on type testing, IBR plant modeling including in EMT domain, verification of model structures and parameter values, model benchmarking between simulation tools and modeling domains, IBR plant design and as-built/as-left evaluations, commissioning tests, post-commissioning plant-level model validation, and other aspects.
- Retroactively applying advanced requirements to the existing fleet has proven to be difficult, costly, and burdensome on industry overall. Some improvements of IBR plant capability and performance can be achieved with software updates at a minimal cost, these are encouraged.
- Mandatory hardware upgrades have notable risks for existing assets, should be carefully considered.
- Enhancing standards on a regular basis to keep pace with technological advancements, and pro-active requirements for emerging capabilities (prior to their utilization) could minimize the need for retroactivity and ensure continuous improvement of IBR plant performance.

Julia also introduced the agenda for Season 2 which will focus on IBR plant design evaluations, change management during the interconnection process, IBR plant commissioning best practices, and emerging standards developments and technology adoption. Lastly, a brief industry survey conducted at the end of Season 1 also recommended other topics of interest including real-world examples of challenges in overcoming issues to get the most benefit from resources (i.e., tariffs or market limitations), impacts of large loads on transmission grids, oscillations due to changes in load and IBR interactions, and minimum modeling requirements needed for system studies.

Jens Boemer, EPRI

Jens described industry progress towards adoption of IEEE 2800-2022 and the various adoption methods for the standard. He described four generally recognized methods of adoption:

- General reference
- Detailed reference and customization
- Hybrid reference, customization, and specification
- Full specification and customization.

Each method has benefits and challenges yet the hybrid integration approach and the detailed reference approach appear to be widely adopted by industry stakeholders depending on their unique circumstances. Figure 2 shows a recap of an ongoing assessment that EPRI is conducting that shows how industry is adopting the standard. While Clause 7 (ride-through requirements) are widely adopted by most entities, power quality and protection requirements are much less widely adopted. The front matter clauses of IEEE 2800-2022 (Clauses 1-3) are often not referenced, or generally referenced (without customization).

The following are a few adoption methods and approaches used by entities across the country:

- SPP has used a phased adoption strategy with detailed reference to IEEE 2800-2022, and is applying this to the SPP 2025 DISIS queue and beyond. This approach appears to be following the successful adoption strategy used by MISO, with planned additions for grid forming (GFM) inverters.
- ERCOT has also used a phased adoption strategy with NOGRR 245, NOGRR 255, and NOGRR 272 and PGRR 121 nodal operating guide and planning guide revision requests (with additions for GFM batteries). This effort is using a hybrid reference, customization, and specification approach. Phase 1 efforts with NOGRR 245 were delayed three years, mainly due to the fact that ERCOT applied these rules retroactively to existing resources.
- ISO-NE has also adopted IEEE 2800-2022 via planning procedure changes using a detailed reference approach for Clauses 3 to 7, with only 3 succinct pages of material. This applies to new IBRs on or after February 2, 2024.
- NERC has used a full specification approach and is not adopting IEEE 2800-2022 directly or by reference; rather, requirements are individually being aligned with the standard through stakeholder efforts. IEEE 2800-2022 also conflicts with some aspects of the FERC Generator Interconnection Agreement (GIA) such as reactive power capability requirements.

Company	Phase (if applicable)	Adoption Approach (End)	Retroactive Application on Legacy IBRs	Reference Point of Applicability (RPA)	Performance and Capability?	Clause 1: Overview	Clause 2: Normative references	Clause 3: Definitions, acronyms, abbreviatio	Clause 4: General requirements	Clause 5: Reactive power—voltage contro	Clause 6: Active power—frequency respon	Clause 7: Response to TS abnormal condition	Clause 8: Power quality	Clause 9: Protection	Clause 10: Modeling data	Clause 11: Measurement data	Clause 12: Test and verification	Grid-forming Requirements
Ameren IL		Hybrid Reference Customization &	✗	POI	✓	○	○	○	○	◗	○	○	○	○	○	○	○	○
Ameren Transmission Company of Illinois (ATXI)	Interim Phase 1 (ahead of MISO)	Detailed Reference & Customization	✗	POI	✓	○	○	○	○	○	○	◕	○	○	●	○		
	Phase 1 (aligned with MISO)	Hybrid Reference Customization &	✗	POI	✓	○	○	○	●	○	○	◕	○	○	○	○		
Bonneville Power Administration (BPA)		Detailed Reference & Customization	✗	POI	✓	○	○	◗	●	●	●	●	◗	◗	●	◗		
Duke Energy		Hybrid Reference Customization &	✗	POI	✓	○	○	◗	◕	●	●	●	◕	●	●	●	◗	○
ERCOT	Phase 1	Hybrid Reference Customization &	✓	POI	✓	○	○	○	◔	●	○	●	○	●	◔	◔	◔	
	Phase 2	Hybrid Reference Customization &	✓	POI	✗	○	○	○	○	○	○	○	○	○	○	◗	○	○
HECO	Stage 3 Hawaii RFP	Hybrid Reference Customization &	✗	POI	✓	○	○	○	◔	●	◕	◗	●	●	●	●	○	
ISO-NE		Detailed Reference & Customization	✗	POM	✓	○	○	●	◕	◕	◕	◕	○	○	○	○	○	○
MISO	Phase 1	Detailed Reference & Customization	✗	POM	✓	○	○	○	◗	○	○	◕	○	○	◔	○	○	
	Phase 2	Detailed Reference & Customization	✗	POM	✓	○	○	○	◗	◕	◕	◕	○	○	◔	◕	○	
NYSRC		Detailed Reference & Customization	✗	POI	✓													
North American Electric Reliability Corporation (NERC)	Milestone 2	Full Specification & Customization	✓	POM	✓	○	○	◔	○	○	○	◕ PRC-029	○		○	◕ PRC-028	◔ PRC-030	○
Natural Resources Department of Canada	SREPs Program	General Reference	✗	POI	✓	○	○	○	○	○	◗	○	○	○	○	○	○	○
San Diego Gas & Electric Co.		Hybrid Reference Customization &	✗	POI	✓	○	○	○	○	◗	◗	◗	◔	◗	◗	◕	◔	○
SaskPower		Hybrid Reference Customization &	✗	POI	✓	○	○	○	○	◕	●	◕	○	○	○	○	○	○
Southern California Edison (SCE)	Phase 1	Detailed Reference & Customization	✗	POI	✓	●	●	●	●	◗	◗	●	●	●	○	○		
Southern Company	Phase 1	Detailed Reference & Customization	✗	POI	✓	○	○	○	◗	●	●	●	◗	●		◕		○
	Phase 2	Detailed Reference & Customization	✗	POI	✓	○	○	◕	◗	●	●	●	◗	●	●	◕	◔	○
	Phase 3	Detailed Reference & Customization	✗	POI	✗	○	○	◕	○	○	○	○	○	○	●	○	◕	○
SPP	Phase1	Detailed Reference & Customization	✗	POM	✓	○	○	○	◗	○	○	◕	○	○	○	●	○	
SRP	Phase 1	Hybrid Reference Customization &	✗	POI	✓	○	○	●	●	●	●	◕	◕	●	●	●	●	○
Tennessee Valley Authority (TVA)	Phase 1	Hybrid Reference Customization &	✗	POM	✓	●	○	●	●	●	◕	●	◕	●	●	●	○	○

Legend: ○ – not adopted | ◔ , ◗ , ◕ , ● – various adoption degrees | ◔ , ◗ , ◕ , ● – various degrees of own specs

Figure 2: Recap of Ongoing Assessment of Industry Adoption of IEEE 2800-2022

The following lessons learned were emphasized:

- Adoption of IEEE 2800-2022 for new IBRs with specified transition period is relatively easy; adoption for legacy IBR is challenging.
- Reference to IEEE 2800-2022 or its specific clauses increases harmonization and clarity.
- Include a table listing exceptions for clauses or sub-clauses of IEEE 2800-2022.
- Some sub-clauses of IEEE 2800-2022 require specified decisions by the Transmission System (TS) owner/operator or Authority Governing Interconnection Requirements (AGIR).
- Drafting new language may trigger significant stakeholder discussions and debate, as well as inadvertent loss of specific details of IEEE 2800-2022 language (footnotes in IEEE 2800-2022 contain important clarifying details but are often overlooked while drafting new language).
- Some requirements or language in IEEE 2800-2022 likely needs to be revised such as addressing challenging requirements or removing implied barriers for GFM technology.

Lastly, Jens discussed the future plans for IEEE 2800-2022 and what EPRI considers to be the "preferred" approach (see Figure 3). This includes near-term revisions to the standard and IEEE 2800.1/.3 recommended practices for GFM equipment as well as longer term incremental changes to the standard to keep pace with technology.

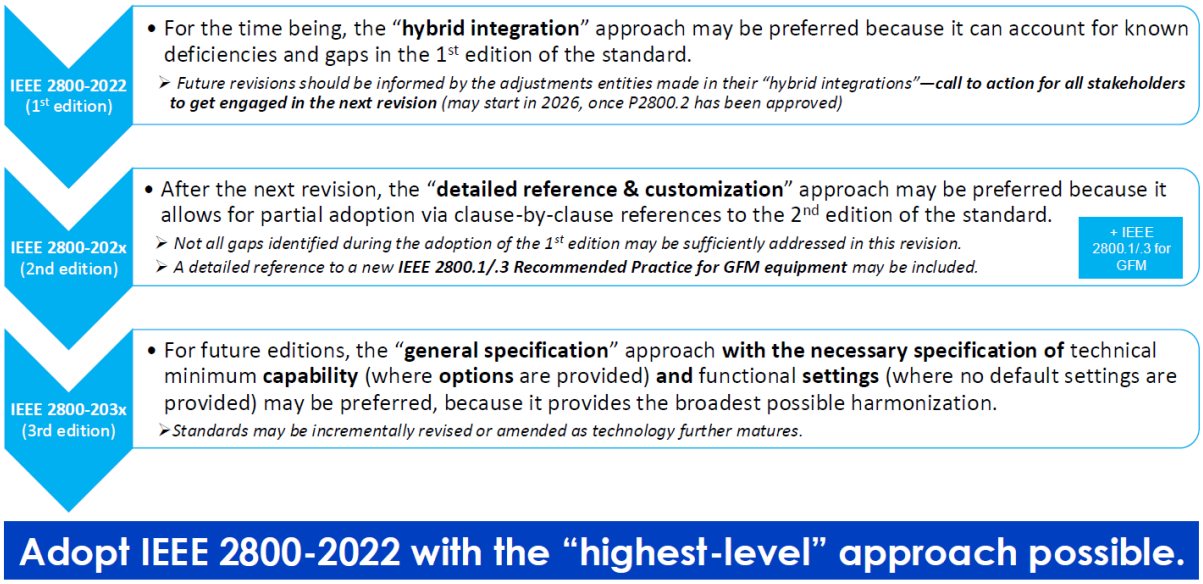

Figure 3: IEEE 2800-2022 Adoption and Revision Roadmap

Andy Hoke, NREL

Andy provided an overview of IEEE P2800.2 content and an update on drafting progress. The requirements of IEEE 2800-2022 each have a Reference Point of Applicability (RPA) – they point where the requirements apply – and almost all requirements have the RPA at the Point of Measurement (POM) of the IBR plant (see Figure 4). Thus, IEEE 2800-2022 requirements are mostly applicable to the entire IBR plant, not to specific devices or components within the plant.

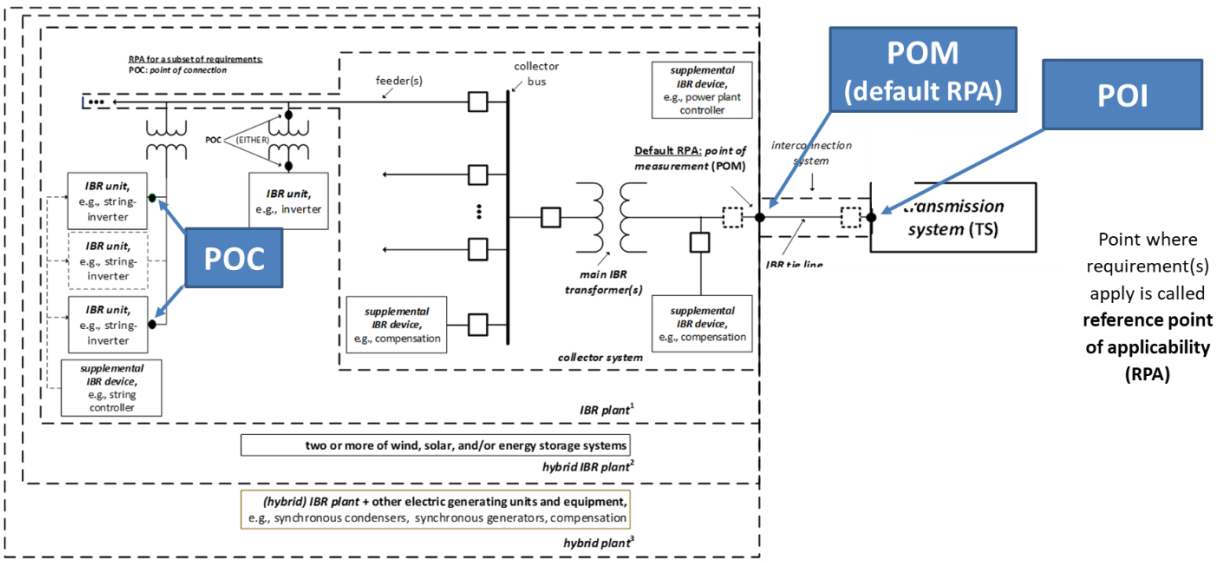

Figure 4: Visualization of IEEE 2800-2022 Reference Points of Applicability

IEEE P2800.2 includes recommended practices regarding the test and verification methods and practices that ensure IBR plant conformity with the standard requirements. The drafting team is compiling and seeking consensus on industry recommended practices and producing them in a consolidated way in IEEE P2800.2. Note that IEEE P2800.2 includes recommended practices; therefore, it primarily uses "should" language rather than "shall" language.

The document will include a framework and procedures for IBR plant standards conformity assessment including the following (see Figure 5) steps that cross multiple stakeholders:

- IBR unit-level type tests (results used for unit-level model validation)
- Design evaluation using verified IBR plant model (including procedures to validate the IBR plant model)
- As-built evaluations
- Commissioning tests
- Post-commissioning model validation, monitoring, periodic tests, and verifications

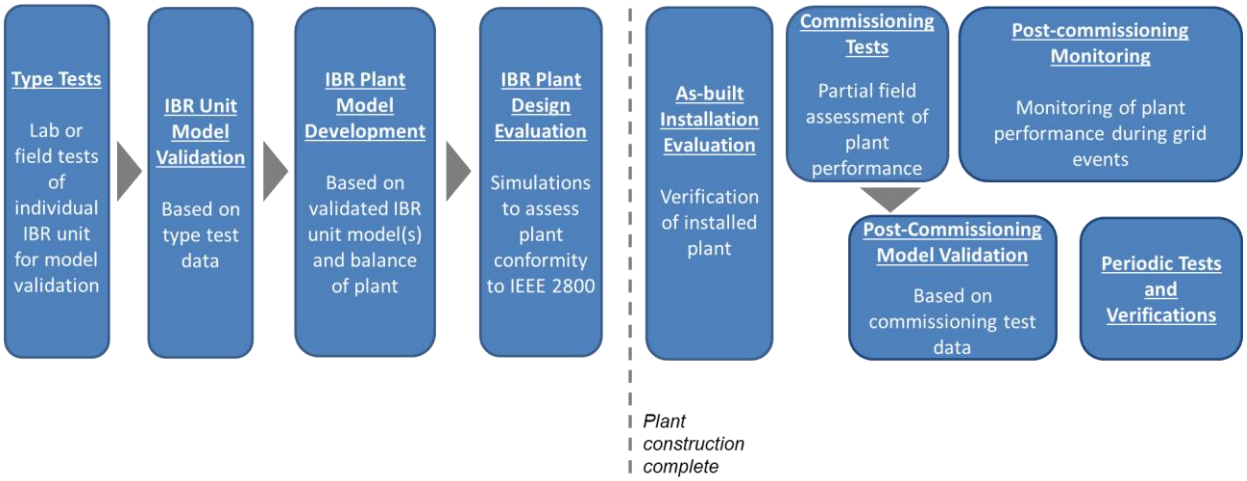

Figure 5: Overview of Conformity Assessment Steps in IEEE P2800.2

The recommended practices are not intended to define (or redefine) the interconnection process for new generators – this is specifically out of the scope of IEEE P2800.2. The procedures are intended to be used as a part of the interconnection process – particularly around designing, evaluating, verifying, and validating the performance of an IBR plant.

As almost all requirements in IEEE 2800-2022 apply to the IBR plant and not individual inverters/turbines, certification of inverters/turbines is not applicable because conformity is assessed at the plant level. Additionally, the type tests in IEEE P2800.2 do not generally include pass/fail criteria and instead provide data to be used in unit-level model validation. This concept differs from the IEEE 1547/1547.1 and UL 1741 paradigm used on the distribution system.

Andy emphasized that adoption of IEEE 2800 is not necessarily contingent upon publication of IEEE P2800.2. In the absence of IEEE P2800.2, IBR owners, TS owners/operators, original equipment manufacturers (OEMs), etc., can develop their own conformity assessment procedures or use existing procedures. For systems experiencing IBR ride-through events/problems, some requirements may be higher priority than others (e.g., ride-through, transient overvoltage (TOV), rate-of-change-of-frequency (ROCOF), and phase jump).

The IEEE P2800.2 working group continues to develop the recommended practices and test procedures following the proposed schedule shown in Figure 6. The group has been working on IEEE P2800.2 for over three years, and 94% of members agreed to send the draft recommended practice to ballot. The ballot pool has been established and SA initial ballot is open presently; public comments can be submitted through July 7, 2025, here. The group expects to gather useful feedback to move the draft towards completion with a tentative publication time of around Q1/Q2 2026 if everything remains on track.

Figure 6: IEEE P2800.2 Working Group Timeline

After IEEE P2800.2 is approved, revisions to IEEE 2800-2022 will likely start in 2026. Various industry efforts are working towards a standard for GFM IBR equipment or plants (with an initial focus on battery energy storage systems (BESS)) connected to the bulk power system (BPS).

Alex Shattuck, ESIG

Alex provided a refresher on FERC Order 901 directives to NERC to enhance or develop new NERC Reliability Standards to address IBR-related reliability risk in data sharing, model validation, planning and operational studies, and performance requirements. Milestone 2, submitted to FERC in Q4 2024, focused on IBR disturbance monitoring (PRC-028-1), ride-through performance (PRC-029-1), and post-event performance validation (PRC-030-1). PRC-028-1 and PRC-030-1 are approved by FERC and industry is awaiting next steps regarding PRC-029-1.

NERC is presently working on its Milestone 3 efforts with four standards projects underway:

- Project 2020-06 – Verifications of Models and Data for Generators (MOD-026, MOD-027, FAC-002)
- Project 2021-01 – System Model Validation with IBRs (MOD-033)
- Project 2022-02 – Uniform Model Framework for IBR (MOD-032, TOP-003, IRO-010)
- Project 2022-04 - Electromagnetic Transient Modeling (MOD-032, FAC-001, FAC-002)[1]

[1] Related but not technically a Milestone 3 project.

Alex shared some keys for success for these projects such as learning from Milestone 2 experience; leveraging industry consensus through efforts like IEEE P2800-2022 and P2800.2; using existing best practices such as the NERC dynamic modeling recommendations, NERC alerts, and disturbance reports; gathering input from OEMs; carefully handling retroactivity; and recognizing that FERC directive can have flexibility in interpretation with sufficient technical justification.

Interactive Group Discussion

The MOD-033 drafting team is making minimal revisions to the standard and stating this will meet the FERC Order 901 directives. Any thoughts on how FERC will respond or what actions FERC or NERC may take?

When a drafting team comes to this conclusion, the team needs to have technical justification and rationale for why they believe that this decision meets the FERC directive. The more technical basis possible, the more likely that FERC will accept their perspective. Part of the last drafting team ballot asked these questions to the industry. If NERC or FERC has issues with these perspectives, then FERC will likely respond to NERC's submittal of the standard revisions accordingly later in 2025.

What is the most efficient way to adopt IEEE 2800 as part of enforceable standards?

There are varying ways to adopt IEEE 2800-2022 ranging from general reference to full customization. Most entities are using a detailed reference or hybrid integration approach where the standard (or specific clauses) are adopted, and specific details are provided to help aid in effective implementation. This minimizes rework, enables adoption with minimal additional language in requirements documents while also providing the technical details that interconnection customers need throughout the process. Pros and cons of various adoption methods are covered in ESIG's Brief for Decision-makers: IBR Interconnection Requirements, Status and Needs posted here.

Are there any pertinent updates on IEEE P2800.2 drafting efforts?

The type testing section is nearly complete and in "good shape" according to the team. The plant-level design evaluation materials are likely where most the technical work is still needed. This is one of the last steps in the design process. The team has lots of content and work, but the content needs further refining. Portions of the commissioning and post-commissioning steps are relatively mature. Refer to above link to submit public comments by early July 2025.

Will it be possible for OEMs to state that they tested according to IEEE P2800.2 recommended practices and can prove it has capabilities?

OEMs will be expected to provide type test results and data for IBR unit model validation efforts to demonstrate the model matches reality. IBR developers should be requesting from OEMs documentation and information regarding these reports. This will also tie in with the revisions to NERC MOD-026-2 underway. OEMs may be able to provide information about the "compatibility" of their equipment with IEEE 2800-2022, including a list of equipment capabilities that can support IBR plant conformity with the standard—the draft P2800.2 currently does not include procedures to verify such OEM self-declarations.

Were there any situations where test and verification methods could not be created to demonstrate conformity with IEEE 2800-2022 requirements?

Some requirements have proven challenging to develop test and verification procedures such as transient overvoltage. These can be tested but they are probabilistic in nature and thus make testing very difficult and burdensome. Some of these findings may help inform future revisions to standard but could also—for the time being—be a requirement that is not assessed pre-commissioning yet could be monitored during operations if sufficiently accurate measurement devices were used.

Does it make sense to have hardware-in-the-loop (HIL) testing and certification to a certain "typical" plant setup?

IEEE P2800.2 does not provide options for using a typical or generic plant setup. This concept may be used for some of the inverter-level requirements, but the IBR plant-level requirements should be tested on a site-specific basis.[2]

What are lessons learned from ERCOT NOGRR 245 and IBR ride-through maximization?

ERCOT embarked on NOGRR 245, which adopted portions of IEEE 2800-2022 requirements. Resource Entities are required to "maximize" IBR ride-through capability within equipment limitations (up to hardware-based limits). IBR ride-through maximization has proven an effective way to improve IBR performance and grid reliability; however, the process and methods for doing so should be carefully implemented. Various ride-through issues have been uncovered through this process; however, working with the OEMs to make changes to equipment and to update the models is a long and arduous (and costly) process. See recent presentation on this topic here.

[2] IEEE 2004-2025 provides a Recommended Practice for Hardware-in-the-Loop (HIL) Simulation Based Testing of Electric Power Apparatus and Controls.

Key Themes

- **Season 1 Recap:** Over 1,225 unique stakeholders participated in Season 1, with consultants making up the largest group. Key takeaways emphasized harmonizing IBR requirements, improving model quality, and the importance of coordination across NERC, FERC, and IEEE efforts.
- **Modeling and Conformity Linkage:** Accurate IBR plant-level modeling and validation—including type testing, commissioning, and post-commissioning verification—are essential for assessing IEEE 2800-2022 conformity.
- **Industry Collaboration and Transparency Needs:** Stronger collaboration between OEMs, developers, and transmission providers is needed to improve modeling quality, clarify expectations, and support streamlined interconnection processes.
- **IEEE 2800-2022 Adoption Methods and Lessons Learned:** Four adoption methods (general reference to full specification) are used across ISOs/RTOs; hybrid and detailed reference approaches are most common. Adoption is easier for new IBRs, but legacy retrofits are more complex and costly.
- **Transmission Provider Implementation Examples:** SPP, ERCOT, and ISO-NE are applying IEEE 2800-2022 using phased and customized strategies. ERCOT's experience with NOGRR 245 highlights the benefits of IBR plant ride-through maximization up to hardware limits but also the challenges of retroactive application.
- **Need for Clarification and Flexibility in Standards:** Some IEEE 2800-2022 requirements may need revision or clarification—particularly those that create challenges for grid-forming inverters or that imply barriers to implementation. Flexibility and coordination are key for practical adoption.
- **IEEE P2800.2 Drafting and Scope:** IEEE P2800.2 provides recommended practices for conformity assessment of IBR plants, including type testing, model validation, commissioning, and post-commissioning steps. It uses "should" language and is not intended to redefine interconnection processes.
- **Plant-Level Conformity Emphasis:** IEEE 2800-2022 applies to the full IBR plant, not individual devices, meaning that model validation and testing must occur at the plant level. Inverter-level certification is not sufficient.
- **NERC Standards and FERC Order 901 Response:** PRC-028, -029, and -030 standards address IBR monitoring, ride-through, and post-event validation. NERC Milestone 3 includes ongoing standards updates that build on IEEE 2800-2022 and require industry consensus, best practice integration, and careful retroactivity planning.
- **Future of IEEE 2800 and GFM Capabilities:** Revisions to IEEE 2800 are expected post-2026, along with additional IEEE recommended practices focused on GFM IBRs,

with the first edition focused on battery energy storage systems (BESS) connected to the bulk power system.

Disclaimers

This is a work in progress and is not yet finalized and published. The content is provided as a summary for the convenience of the public participating in the Interconnection Innovation e-Xchange (i2X) Forum for the Implementation of Reliability Standards for Transmission webinar series. The U.S. Department of Energy (DOE) makes no representations or warranties as to the accuracy, completeness, or timeliness of the information contained in this document. DOE shall not be liable for any loss or damage arising from any use of or reliance on the information contained in this document.

This work was prepared as an account of work sponsored by the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, its contractors or subcontractors. Additionally, the views and opinions of stakeholders expressed in these summary notes do not necessarily state or reflect those of the hosting entities, their contractors or subcontractors.