July 22, 2025 Virtual Meeting

IBR Plant Design Evaluation with Applicable Requirements I (~200 attendees)

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

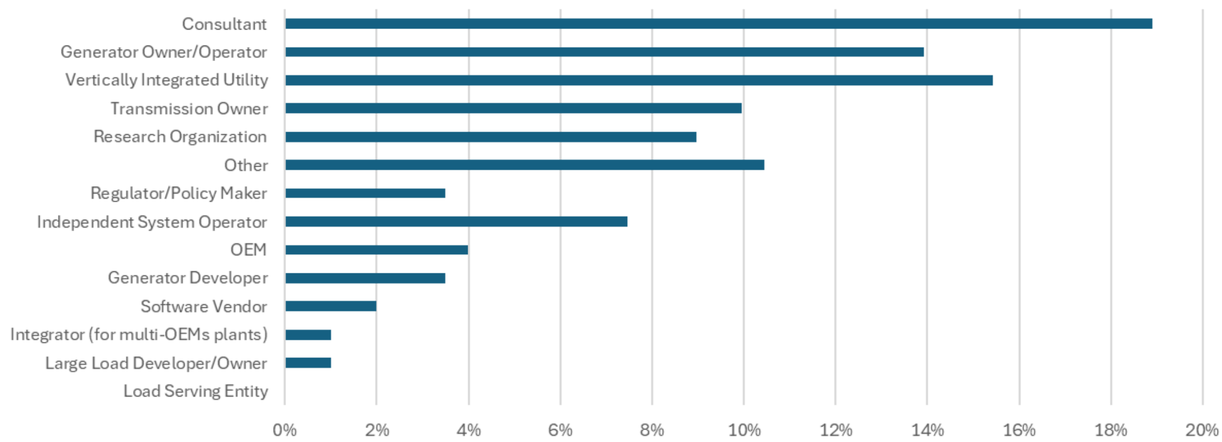

Figure 1: Meeting attendees by industry sector

This third meeting of Season 2 of the DOE i2X FIRST initiative focused on IBR plant design evaluation with applicable IEEE 2800-2022 requirements, providing an overview of IEEE P2800.2 IBR plant design evaluation clauses and sharing perspectives from both an IBR plant developer and owner/operator as well as engineering, procurement, and construction (EPC) provider. Presentations included the following:

Jens Boemer, EPRI

Jens provided an overview of IBR plant design evaluation and related topics. These IBR plant design evaluations are a continuum of IBR scrutiny in terms of conformance against established requirements (see Figure 2). In the past, little to no performance specifications were established and this may have resulted in abnormal performance (e.g., tripping). More recently, transmission providers have established performance specifications (including adoption of IEEE 2800-2022 requirements and other regional requirements). In some instances, such as on the distribution system with IEEE 1547-2018, unit-level certifications are used; however, this approach is not being used by IEEE 2800-2022. Rather, IBR plant-level conformity is assessed using power system models, model quality and verification tests, and performance conformity simulations.

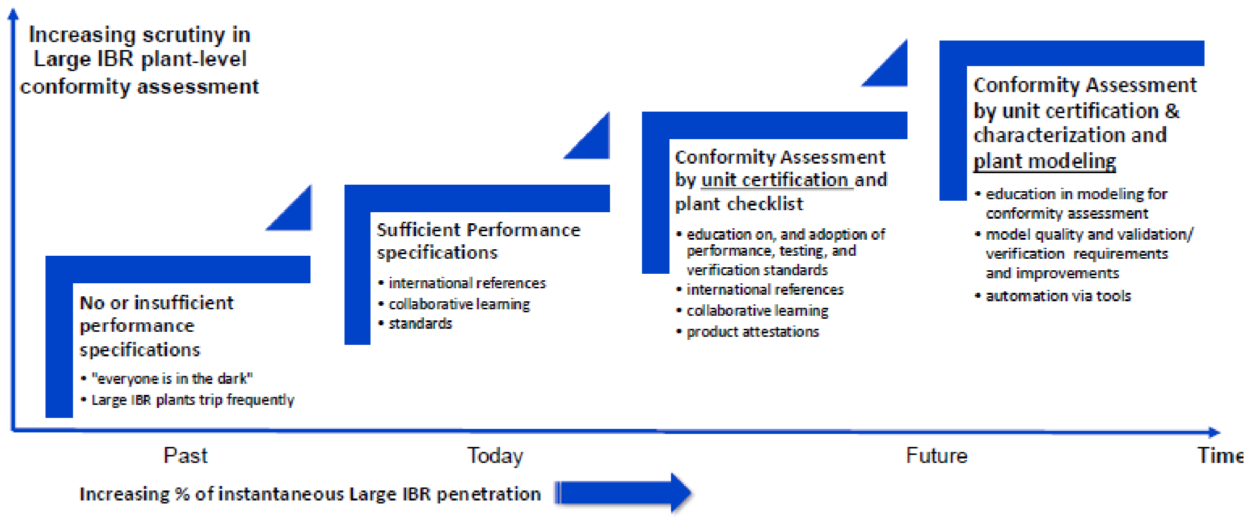

Figure 2: Large IBR Plant Interconnection Reliability Roadmap [Source: EPRI]

It is important to acknowledge and recognize the meaning of different terms used in this space, including:

- **Compatibility:** Design equipment to support conformity or compliance of a complex system (e.g., IBR plant) – equipment level.
- **Conformity:** Adherence to certain voluntary industry standards or procedures (e.g., IEEE P2800.2) – plant level.
- **Compliance:** Meeting mandatory and enforceable legal and regulatory obligations (e.g., NERC standards or interconnection requirements) – plant level.

Nonconformity with IEEE 2800-2022 requirements can be assessed, and there are historical examples such as the large NERC disturbance reports that illustrate failures to meet specific requirements.

Additionally, conformity with requirements can be assessed and tested as part of the interconnection process. For example, MISO is currently proposing to implement IBR modeling requirements that also include performance tests that can be used to test the IBR plant conformity against established requirements, to some extent. While the tests may not mirror IEEE 2800-2022, MISO is starting with a set of test procedures that can be effectively implemented by interconnection customers.

The IBR plant design evaluation uses the complete IBR plant model once it is fully developed. This model includes the validated IBR unit model(s), the verified IBR plant model components, and verified balance of plant protection elements as well. With this model, simulations are conducted to assess plant conformity with IEEE 2800-2022 requirements (see Figure 3). In these tests, it is important to remember that the requirements regarding current injection during abnormal voltage conditions apply at the POC whereas the other requirements apply at the POM.

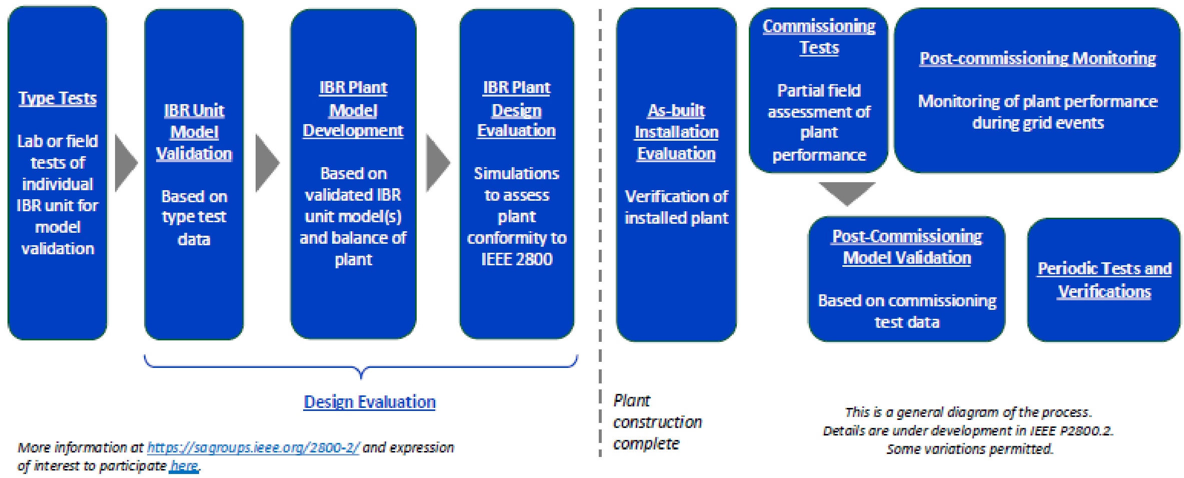

Figure 3: IEEE P2800.2 IBR Plant Conformity Assessment Framework [Source: IEEE]

An IBR plant design evaluation and performance conformity assessment is notably different from a system impact or reliability study. The IBR plant design evaluation ensures that the IBR plant meets the minimum requirements established whereas the system impact study ensures that the IBR plant reliably operates when connected to the grid. The IBR plant design evaluation includes both documentation checks (verification) and modeling and simulations. The documentation checks focus on reviewing capabilities, settings, and equipment model validation reports; modeling and simulations focus on model quality checks, plant model development and verification, and simulations of capability and performance.

The simulation tests can be set up with a controllable AC source connected to the POM through an impedance (see Figure 4). The controllable source induces POM grid conditions which are used to invoke a response from the IBR plant model, which can be assessed. The adjustable impedance is used to simulate different grid strength conditions.

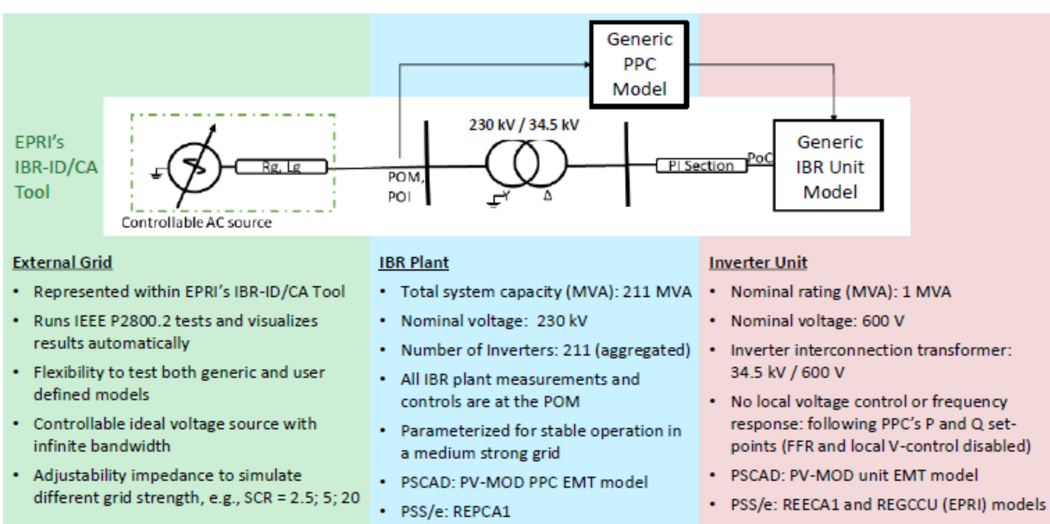

Figure 4: Example of IBR Plant Design Evaluation Simulation Setup [Source: EPRI]

Rishi Maharaj, Engie

Rishi shared practical experience from an IBR plant developer and generator owner/operator pertaining to IBR plant conformity assessment gaps and opportunities. Development and operation of a new IBR plant is often perceived as involving two primary categories of entities: the developer or generator owner/operator (before and after commercial operation date (COD), respectively) and the transmission entities such as Transmission owner/operators, transmission planners, RTO, etc. While the IBR plant developer/owner has obligation to comply with applicable interconnection requirements, in some organizations nearly all work upon which the performance and conformity of the plant depends will be performed by the following third parties (see Figure 5):

- OEMs
- Engineering consultants
- EPC contractors who may subcontract either of the above

Therefore, achieving conformity with technical requirements (NERC, ISO, Transmission Planner, etc.) requires coordination and communication between many parties through the project phases from interconnection application to commercial operation. The primary tool for a developer to obtain any technical deliverable is to write it into the contractual scope of work of a consultant, EPC, or OEM. Gaps in these scopes of work, and limited coordination between parties, are often where problems and eventual non-conformity originate.

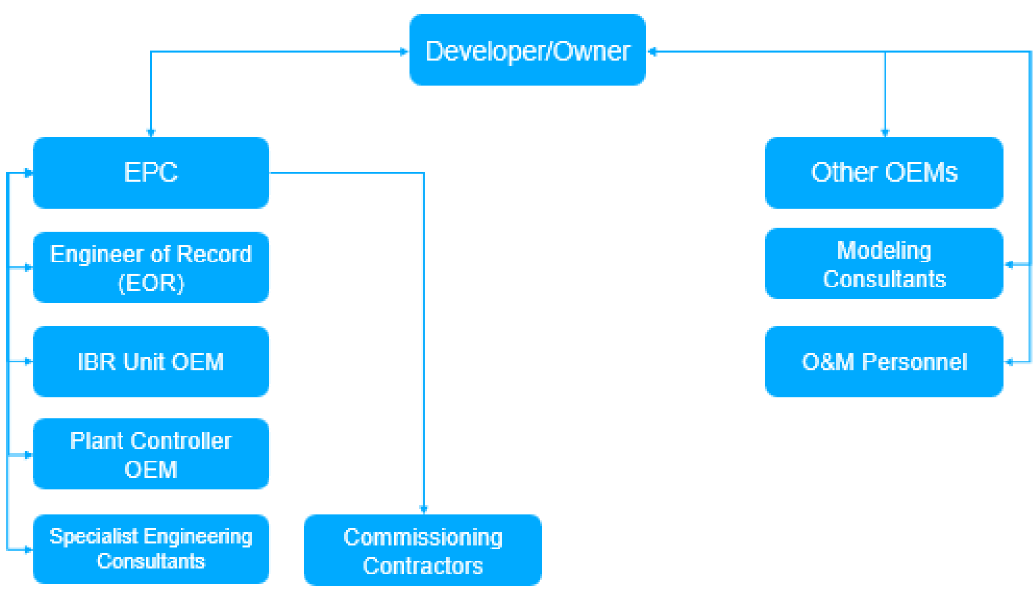

Figure 5: Simplified IBR Plant Project Hierarchy of Organizations [Source: Engie]

With this structure, an IBR plant developer/owner is therefore responsible for a tremendous number of activities that lead to eventual conformity, such as:

- Map out required scopes of work from each project participant to achieve the new requirement; and
- Negotiate with each party to include that scope in their respective contracts; and
- Monitor each party's delivery of their component from their respective subcontractors at the correct time; and
- Perform an overall plant conformity assessment to the new requirement considering the entire project holistically (perhaps by assigning it to yet another consultant); and
- If possible, verify performance with commissioning tests.

This is a lot for a non-expert IBR plant developer who may have very limited or no internal power systems expertise. Achieving and assessing conformity with a requirement that is relatively simple from a technical point of view can still be quite complex from a project execution perspective, requiring a consistent effort from the IBR plant developer/owner to coordinate all parties.

Rishi also explained that there is a basic conflict between the desire of IBR plant developers/owners to contract out technical work and the fact that only the owner has visibility of the entire project and the ability to deliver the required technical coordination.

The definition of conformity assessment is "demonstration that specified requirements are fulfilled."[1] However, to an IBR plant developer, it is unclear which requirements. Interconnection requirements applicable to a particular transmission-connected IBR plant in North America can originate from multiple sources:

- NERC Standards – uniform, but largely do not address IBR performance (especially prior to Order 901 standards)
- ISO Rules that apply uniformly to all facilities meeting certain thresholds (e.g., ERCOT Nodal Protocols and Operating Guides)
- ISO, RTO, or TO requirements that are specific to a particular GIA

A non-trivial amount of work is required simply to identify all applicable requirements. Writing "comply with all interconnection requirements" into a contract is largely useless. Without both parties being aware of the specific requirements in sufficient detail to enumerate them, it is very difficult to deliver and validate conformity. Since most requirements apply at the IBR plant level and require coordination between multiple parties, trying to write IBR plant-level conformity obligations into any one party's contract is not practically workable. Thus, in many projects, a comprehensive understanding of "all applicable interconnection requirements" does not exist.

[1] IEEE P2800.2 referencing ISO/IEC 17000:2020.

Comprehensive, proactive "grid code compliance" studies addressing all applicable requirements are not typically done by IBR plant developers. The extent to which engineering studies (i.e., IBR plant design evaluations) are done to assess conformity with applicable interconnection requirements is almost entirely driven by processes formally mandated by the transmission provider or other authority governing interconnection requirements (AGIR). Reactive power studies, stability studies, subsynchronous oscillation (SSO), etc., are all examples of IBR plant studies that are on a mandatory path to COD. However, mandatory studies only address a relatively small subset of interconnection requirements.

Further, various mandatory studies may be done by different project participants without coordination with each other, resulting in conflicting, inaccurate, or wrong models being used by different entities to study the same plant. The items specifically verified or checked by the AGIR to grant commercial operation are the core focuses of the IBR developer; everything else is, for practical purposes, optional. The net result is passive or inadvertent non-conformity with a significant fraction of the presently enforceable requirements.

Power plant controllers (PPCs) are also an under-appreciated risk in IBR plant design evaluations. The current trend of procuring PPCs from EPCs, which cannot be accurately simulated until very late in the project (if at all), limits the ability to perform IBR plant design evaluations for certain requirements earlier in the interconnection process. Design evaluation is only one aspect of conformity assessment. Even when design evaluation is done, gaps exist in feeding required changes back into the IBR plant design and implementing them in the field. Most AGIRs in North America have no enforced requirement for verification of IBR plant parameters and settings. Consultants may tune model parameters without OEM involvement, resulting in a plant model that "passes" assessments but cannot be implemented in the field. OEMs may be willing to update EMT models to provide favorable results in ways that do not accurately reflect their actual product as deployed in the field. The lack of a standardized format for exchanging IBR unit and plant controller parameters causes inadvertent errors. Again, Rishi emphasized that what is mandatory is what gets done.

Fortunately, many of the pain points and pitfalls mentioned above are directly addressed in IEEE P2800.2, which comprehensively maps how conformity assessments should take place. It does not (and cannot) define exactly how IBR plant owners/developers, TS owners, operators and planners execute that process in actual projects. The 2024 NERC Alert on IBR Model Quality Deficiencies results show that many IBR plant owners do not have basic facility information available to them. Layering new, more comprehensive and more complex requirements with current and future adoption of IEEE 2800-2022 by AGIRs requires process improvement to successfully attain conformity. IBR plant developers/owners will need to devote significant resources to building internal expertise to successfully build plants that conform with IEEE 2800-2022.

Patrick Hart, Mortenson

Patric shared EPC perspectives on IBR plant design and commissioning. EPCs may span different portions of the IBR plant design and commissioning processes (see Figure 6).

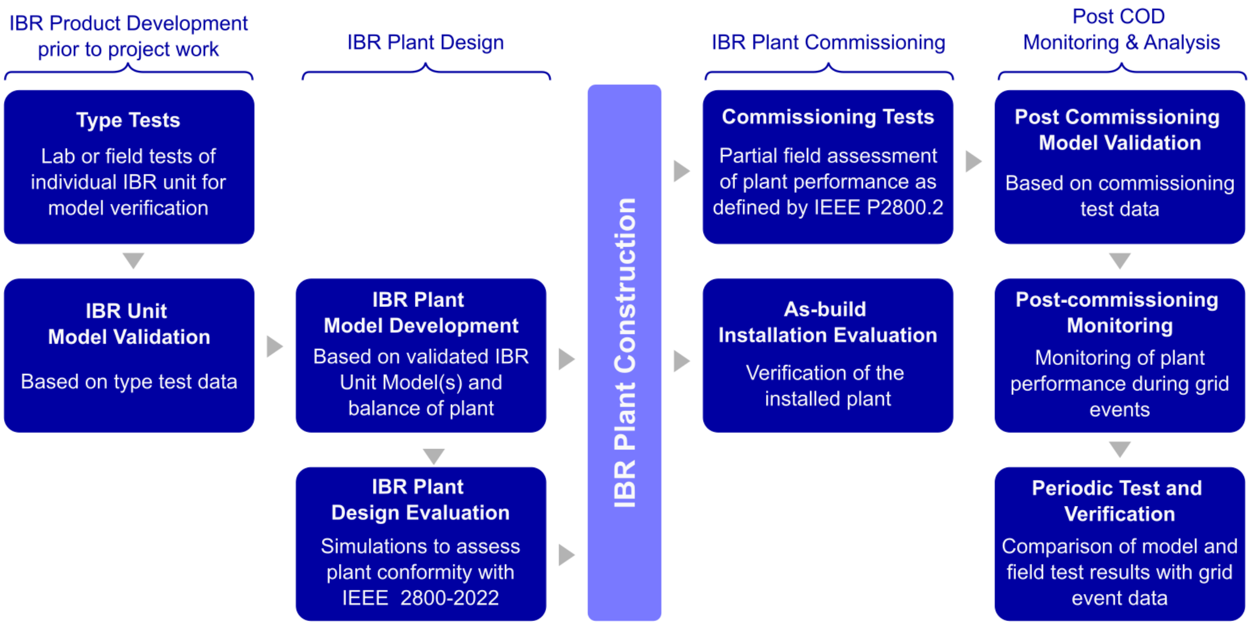

Figure 6: EPC Scope Focused Around Construction [Source: Mortenson]

Standard work is critical for effective deployment of IBR projects. Missing the COD can lead to significant losses for IBR developers, owners, and operators. Product design is centered around test requirements; project design and commissioning are also centered around test requirements. In both cases, if the product or plant are not tested, they likely will not operate as expected. OEM equipment may be capable but must be configured correctly. OEMs serve many markets, and IBR equipment must be inherently designed for that variability. More market variability means more configuration settings, which means more opportunity for errors and failures.

Some of the pain points faced today with IEEE 2800-2022 requirements P2800.2 conformity assessments include:

- IBR plant reaction time less than 200 ms – more difficult to meet with multiple vendors (power conversion system OEM plus PPC OEM(s) plus inverter OEM(s) and challenging for hybrid power plants; leveraging Modbus protocol is a challenge in meeting this requirement, which is common industry practice.
- Data recording requirements – OEMs yet to implement functionality required to log data (e.g., IBR fault codes and oscillography); perceived as "not my problem" by the OEMs.

- Time synchronization – very difficult and expensive to meet at the IBR unit level; IRIG-B, PTP, and NTP protocols[2] all have challenges and costs; can equate to added cost of $200k+ per project just to meet stringent time synchronization costs.
- As-left control settings – control settings often controlled by the OEM engineers; limited visibility into these parameters and settings; hundreds or thousands of parameters, most associated with enabling/disabling features to shape response.

IBR plant developers and owner/operators are including compliance with IEEE 2800-2022 as a contractual requirement. OEMs are working towards compatibility at the unit level; however, plant-wide coordination is still a major hurdle. Industry players continue to get more knowledgeable about specific requirements and how to verify, test, or assess conformity.

Q&A and Interactive Group Discussion

Is IEEE P2800.2 proposing too many tests and is that level of testing necessary?
Some stakeholders believe the volume of proposed tests—spanning various operating conditions, SCR levels, and modeling tools—is impractical for implementation. However, rigorous testing is critical for ensuring grid reliability. Reliability is a shared responsibility among IBR developers, OEMs, and transmission entities to ensure models are accurate and reliable, even if that means conducting a significant number of tests. The key challenge is finding a feasible, coordinated, and efficient approach—some suggest that frameworks like MISO's may offer a manageable path forward. The true challenge lies in coordinating across multiple stakeholders—developers, OEMs, EPCs—to produce a unified and verified model.

Can we automate these tests to reduce the burden?

Standardized test procedures enable automation and incentivize OEMs to build testing features into their equipment. Without standardization, fragmentation reduces the return on investment (ROI) on automation investments. Many of the plant-level tests can be automated (with a human engineer in the loop), especially during IBR plant design evaluation and commissioning. Automation helps reduce effort and improves consistency, particularly with the level of tests required.

What is the distinction between commissioning tests and simulation tests?

Commissioning tests verify performance post-installation, while simulation tests earlier in the project are used to ensure expected behavior. Both are critical but serve different purposes.

[2] These are various protocols used to synchronize time across different systems and devices.

How do we make testing more efficient to avoid project delays?

The goal is not to overload projects with tests but to focus on tests that evaluate the behavior ahead of time—through type testing, design evaluation, and smart scheduling—to avoid surprises later in the process.

Doesn't the cost of testing pale in comparison to the total project cost?

Yes, testing costs are relatively minor in the context of a $100M+ project. The bigger issue is doing it efficiently to avoid delays and errors, which can be far more costly.

When in the project lifecycle should these studies and tests occur?

They should happen "all along the way"—design, iteration, and adjustment should be embedded throughout the project lifecycle to avoid late-stage surprises.

How should contract language address changing regional requirements and evolving standards?

Don't just meet the minimum. Adopt a forward-looking, high-bar standard that integrates upcoming or likely requirements into the EPC contract. This avoids costly retrofits later.

How can developers handle evolving technical deliverables in long project timelines?

Since standards may change mid-development (e.g., NERC PRC-024 to PRC-029), contracts should include flexible language that anticipates new requirements and ensures compliance by COD.

How are HIL/CHIL simulations being used in IBR projects, and what is their value—particularly for PPCs?

While HIL use on the EPC side is limited due to equipment variation and complexity, it's increasingly recognized as essential for large or hybrid plants. CHIL is especially valuable for PPC validation, allowing testing with actual hardware and firmware to reduce reliance on potentially inaccurate models. This is critical, as PPCs are often under-validated and pose significant modeling risks.

How can industry improve PPC validation and reduce project-by-project inefficiencies?

One solution is to shift PPC procurement outside of EPC scope and rely on high-quality OEMs that offer pre-validated, certified products. Certification is most effective at the product level, with version-controlled, configurable designs. However, integration risks remain, especially between PPCs and inverters, highlighting the importance of system-level testing such as HIL to catch issues like firmware mismatches and configuration errors.

What are key focus areas for improving IBR design evaluation over the next six months to a year?

- **Jens:** Finalize and resolve comments on P2800.2, engage industry to promote adoption.
- **Rishi:** Standardize information exchange formats (e.g., IBR Plant Information Database (IPID) or .IBR file).
- **Patrick:** Focus on areas not covered in typical studies, especially documentation quality and completeness.

What are best practices for contractual language with OEMs and EPCs, particularly when the inverter or turbine OEM is different from the PPC OEM and not all equipment is procured under the EPC contract?

- It is important to ensure that contractual language addresses configuring the equipment in alignment with the model accepted by the transmission provider, at least as reasonably close as possible, and providing proof upon commissioning or upon request that the as-left settings accurately reflect the model that has been provided by the OEM. This is particularly important for IBR unit and PPC models in EMT and positive sequence UDMs. The contractual language should also address troubleshooting of modeling issues by the OEM to support IBR plant-level modeling and studies by the IBR developer or third-party consultant. OEMs should also be obligated to provide field parameter mapping/parameter verification reports of as-left settings any time a change is made to the facility to ensure the model remains accurate.

<u>Key Themes</u>

- Achieving conformity with IEEE 2800-2022 requires coordination across IBR plant developers, OEMs, EPCs, and consultants. Misaligned scopes of work and fragmented responsibilities often lead to non-conformity, even when the technical requirements are achievable.
- Relying solely on the minimum path to commercial operation often results in missed or misunderstood requirements. A proactive, high-bar approach—baked into contracts and internal processes—is needed to future-proof projects and avoid compliance failures down the line.
- Without consistent data formats, simulation procedures, or model verification practices, IBR projects face recurring issues like poor model fidelity, redundant work, and errors in implementation. Standardization is essential to enable automation and reduce risk.
- PPCs are often delivered late, poorly modeled, and disconnected from overall plant validation efforts. They pose high modeling risk and are rarely validated early, making them a weak link unless product-level certification and integration practices improve.

- Design evaluations and testing should occur continuously—from early design through commissioning. Simulation-based assessments and field commissioning tests serve different purposes but are both essential to verifying plant behavior and performance.
- Conformity assessments will not be widely adopted unless AGIRs enforce them—requiring IBR plant design evaluations prior to energization and as-built verification before final commissioning is essential for meaningful implementation.

IBR developers and owner/operators need to build internal capabilities to execute on IBR plant design evaluations effectively. As interconnection standards become more performance-driven, in-house expertise will be critical and can still be supplemented by external support.

Disclaimers