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

Forum for the Implementation of Reliability Standards for Transmission (i2X FIRST) | 5/28/24

An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office

BERKELEY LAB

EPRI

ESIG

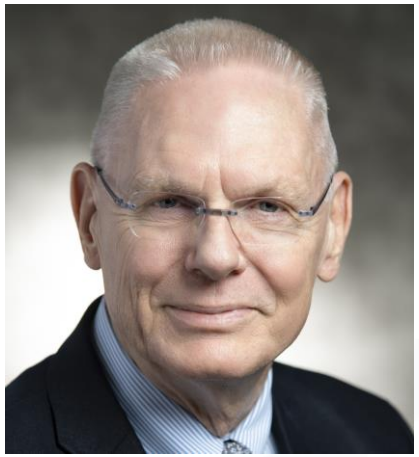
The first half of this meeting call is being recorded and may be posted on DOE's website or used internally. If you do not wish to have your voice recorded, please do not speak during the call. If you do not wish to have your image recorded, please turn off your camera or participate by phone. If you 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 wind, solar and battery storage plants
- 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 and
  - Gaps that require future work.

Leadership Team

Cynthia Bothwell, Boston Government Services, contractor to DOE's Wind Energy Technologies Office



Robert Reedy, Lindahl Reed, contractor to DOE's Solar Energy Technologies Office

Will Gorman, Lawrence Berkley National Laboratory

Jens Boemer, Electric Power Research Institute

Julia Matevosyan, Energy Systems Integration Group

Ryan Quint, Elevate Energy Consulting

Agenda

- Intro to i2X Roadmap (10 min) – Cynthia Bothwell, BGS, contractor to DOE's WETO
- Intro to i2X FIRST (5 min) – Julia Matevosyan, ESIG
- NERC Disturbance Events and Reliability Guidelines (5 min) – Alex Shattuck, NERC
- IEEE 2800-2022 and Ongoing Adoption Efforts (15 min) – Jens Boemer, EPRI
- IEEE P2800.2 Status Update (15 min) – Andy Hoke, NREL
- FERC Order 901 and NERC Workplan (15 min) – Alex Shattuck, NERC
- Q&A (15 min)
- Interactive Group Discussion (40 min)
  - Slow pace of improvement of interconnection requirements
  - Can interconnection requirements for IBRs be harmonized?
  - Role of regional interconnection requirements vs NERC Standards vs FERC Orders
  - Is improving interconnection requirements sufficient for improving IBR performance?

Upcoming i2X FIRST Meetings

1. June 25th, 2024, 11 a.m.- 1 p.m. ET:
2. July 30th, 2024, 11 a.m.- 1 p.m. ET:
3. August 20th, 2024, 11 a.m.- 1 p.m. ET:
4. September 24th, 2024, 11 a.m.- 1 p.m. ET:
5. October 24th, 2024 hybrid full day event during ESIG Fall Workshop, Providence, Rhode Island
6. November 26th, 2024, 11 a.m.- 1 p.m. ET:
7. December 17th, 2024, 11 a.m.- 1 p.m. ET:
8. January 28th 2025, 11 a.m.- 1 p.m. ET:
9. February 25th 2025
10. March 20th, 2025 hybrid full day event during ESIG Spring Workshop, Austin, Texas

Sign up for all future i2X FIRST Meetings here: https://www.zoomgov.com/meeting/register/vJItceuorTsiErIC-HInpPbWuTUtrYQAuoM#/registration

Follow DOE i2X FIRST website: https://www.energy.gov/eere/i2x/i2x-forum-implementation-reliability-standards-transmission-first for meeting materials & recordings and for future meeting details & agendas

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*

Mutual Respect . Collaboration . Openness

Word Cloud Icebreaker:

What are you looking to learn/gain from the i2X FIRST?

[Go to **slido.com** and enter event code **i2xFIRST1**, then go to **Polls** tab]

What are you looking to learn/gain from the i2X FIRST?

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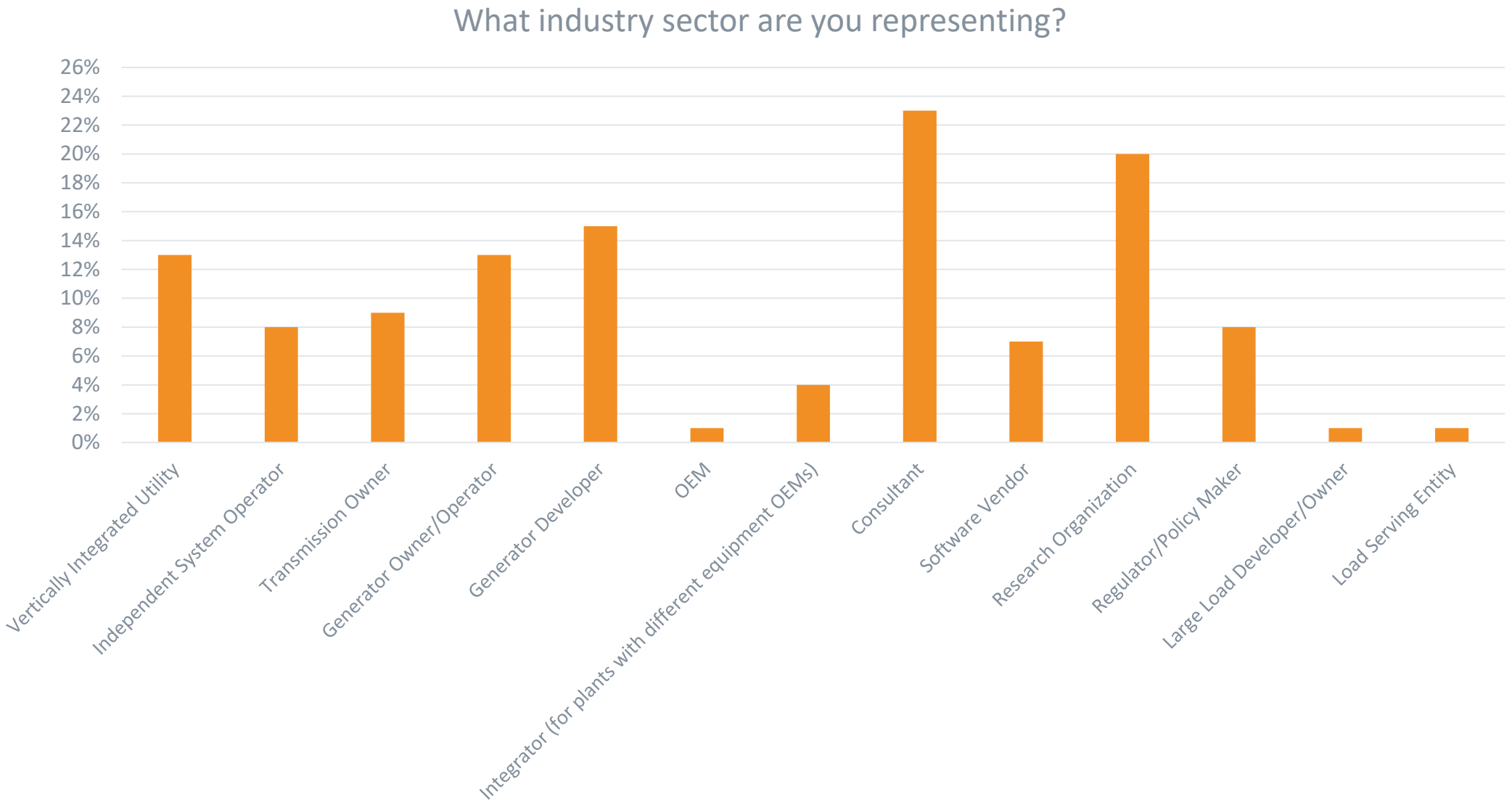
Polling Question 1

What industry sector are you representing?

[Go to **slido.com** and enter event code **i2xFIRST1**, then go to **Polls** tab]

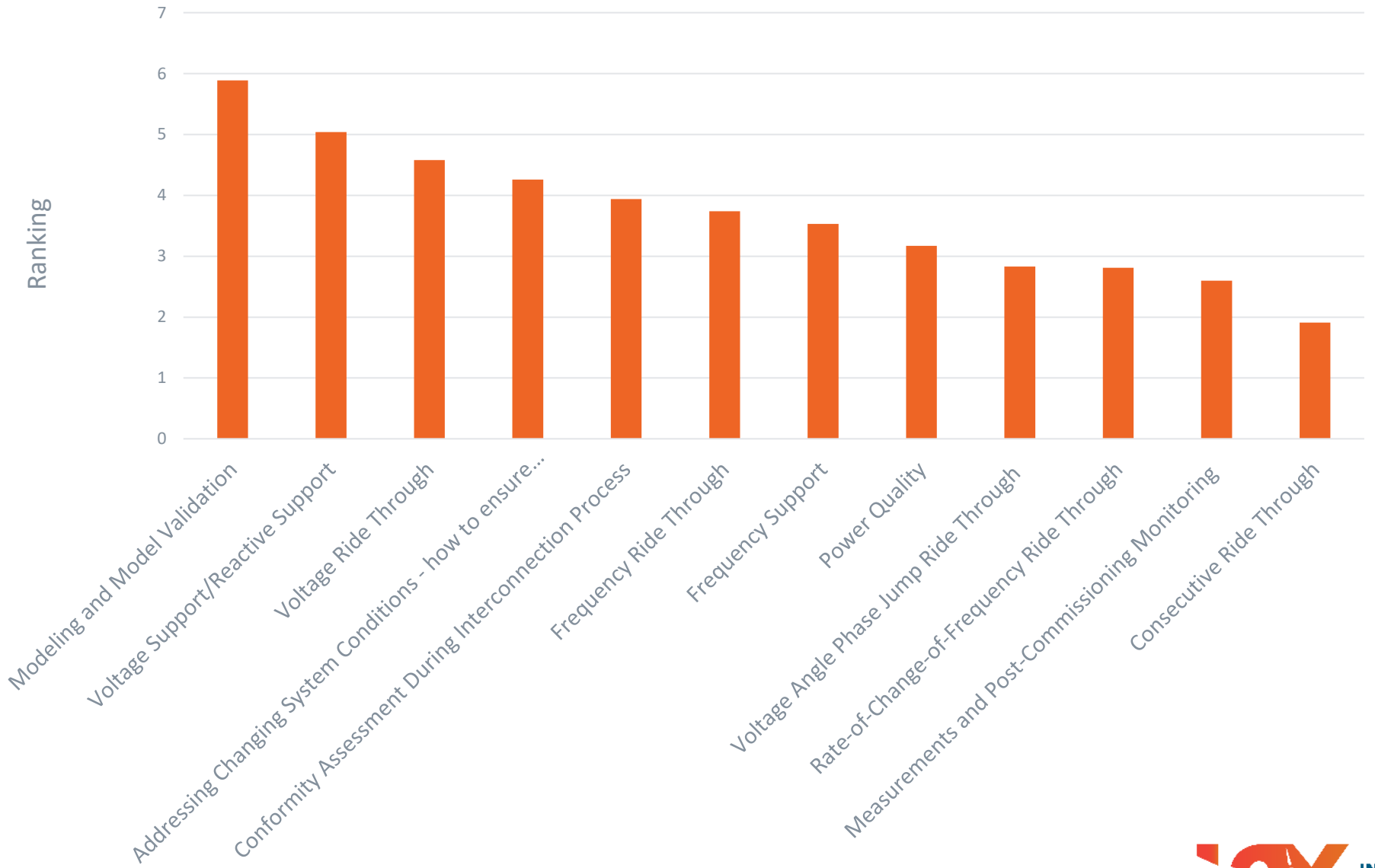

What industry sector are you representing?
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Vertically Integrated Utility
Independent System Operator
Transmission Owner
Generator Owner/Operator
Generator Developer
OEM
Integrator (for plants with different equipment OEMs)
Consultant
Software Vendor
Research Organization
Regulator/Policy Maker
Large Load Developer/Owner
Load Serving Entity

Polling Question 2

Which interconnection requirements/topics are of higher priority/interest for you?

[Go to **slido.com** and enter event code **i2xFIRST1**, then go to **Polls** tab]

Which interconnection requirements/topics are of higher priority/interest for you? – Ranking



Stakeholder Presentations

Q & A Session

Interactive Group Discussion Topics

Topic #1: Why has industry taken such a long time to improve interconnection requirements?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **i2xFIRST1**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - With the first IBR disturbance event reported in 2016 and several NERC Reliability Guidelines published shortly after, only a few entities have undertaken proactive steps to boost requirements to the level they should be at. What's holding industry back?
  - All delays in generation interconnect requirement improvements increase the difficulty of applying retroactive requirements and lowers the overall ability of IBR to provide services that support the reliable operation of the BPS.

Discussion Best-Practices

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*

Topic #2: Can interconnection requirements for transmission/sub-transmission connected IBRs be harmonized across North America?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **i2xFIRST1**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - What are the reasons for differentiating interconnection requirements across North America?
  - Will a harmonized set of requirements for IBRs lead to a more streamlined interconnection process?
  - Will a harmonized set of interconnection requirements for IBRs lead to improved IBR performance?
  - Will a harmonized set of interconnection requirements lead to fully leveraging modern inverter technology?

Discussion Best-Practices

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*

Topic #3: Role of regional interconnection requirements (including regional adoption of IEEE 2800-2022) vs NERC Standards vs FERC Orders

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **i2xFIRST1**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - What are the purposes of each organization in terms of setting / working on standards (e.g. FERC, NERC, IEEE, regional entity)?
  - Is there a clear hierarchy of requirements or it's more of a grey area?
  - What are the benefits and drawbacks of the different approaches?

Discussion Best-Practices

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*

Topic #4: Is improving interconnection requirements sufficient for improving IBR performance in operation?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **i2xFIRST1**

- For verbal commentary, please use the raise hand feature and we will call on you

- Additional related / associated questions:
  - How to ensure that IBRs plants are designed in conformity with applicable interconnection requirements?
  - How to ensure the latest IBR plant models are used for grid impact assessment and conformity assessment?
  - How to ensure that IBRs conform with applicable requirements during project lifetime?

Discussion Best-Practices

1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
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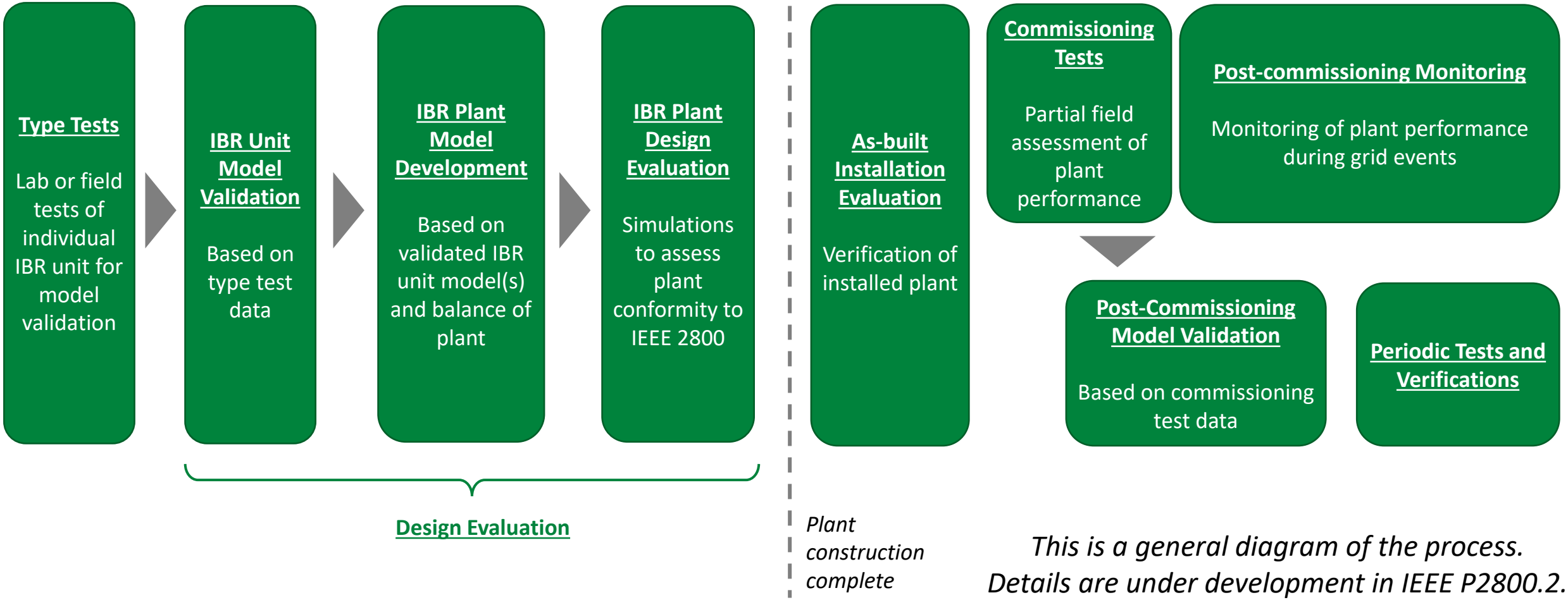
Overview of conformity assessment steps in IEEE P2800.2 Recommended Practice for Test and Verification Procedures for IBRs Interconnecting with Bulk Power Systems



This is a general diagram of the process. Details are under development in IEEE P2800.2. Some variations permitted.

Source: Andy Hoke (NREL), Jens Boemer (EPRI)

i2X Mission: To enable a **simpler**, **faster**, and **fairer** interconnection of clean energy resources all while enhancing the **reliability**, **resiliency**, and **security** of our electric grid.

Stakeholder Engagement

- 800+ people at 530+ organizations partnered with i2X
- 20+ public events and engagements (e.g., RE+ 2022, 2023)
- 22 Solution e-Xchange meetings covering six topics
- EEJ Technical Advisory Committee
- 85+ Office-Hour Calls with stakeholders

Data & Analytics

- BPS interconnection cost reports for MISO, PJM, NYISO, SPP, and ISO-NE, plus a summary published (LBNL)
- Queued Up report on BPS interconnection timelines (LBNL)
  - https://emp.lbl.gov/queues
- EERE letter to EIA on the need to collect interconnection related grid upgrade costs in future EIA-860 survey (>1MW)

Review of data availability for DER IX timelines by state

Technical Assistance

- 12 technical assistance projects covering flexible interconnection, utility data management, streamlining interconnection modeling, and alternatives to costly grid network upgrades
- Workforce upskilling with i2X/NERC bootcamps for BPS grid engineers on using Electromagnetic Transient (EMT) modeling methods and techniques

Strategic Roadmap

- Final Transmission Interconnection Roadmap released on April 17th, 2024.
- Distribution Interconnection Roadmap draft release via a request for information process (RFI) planned for Q3 FY 24.

Transmission Interconnection Measurable Success Targets for 2030

Interconnection processes align well with Federal, state, and customer's decarbonization goals

	Target Value by 2030	Recent Value
 **Reduced interconnection process time** Average time from request to agreement	< 12 months	33 months (2022)
 **Lowered cost uncertainty** Standard deviation of interconnection costs	< $150/kW	$551/kW (2020-2021)
 **Increased Completion rates** Completion rate for projects that entered facility study phase	> 70%	45% (2016)
 **Maintained system reliability** Number of system disturbances due to modeling inaccuracy	Zero	4 (2022)

Transmission Roadmap- 35 solutions organized under four goals

#1: Increase Data Access and Transparency

Queue Data

1.1 Improve the scope, accessibility, quality, and standardization of data on projects already in interconnection queues, including project attributes, cost estimates, and post-interconnection agreement information

Grid Models and Capacity

1.2 Enhance the scope, timeliness, accuracy, and **consistency of interconnection study models and modeling assumptions** that transmission providers make available to interconnection customers

#2: Improve Process and Timing

Queue Management

2.5 Create new and expand **fast-track options** for interconnection (e.g. surplus, generator replacement, energy-only)

2.7 Consider **market-based approaches** to rationing interconnection access

Affected System Studies

2.8 Increase **voluntary collaboration on affected system studies**

Workforce Development

2.11 Assess scale of **interconnection workforce growth requirements**

#3: Promote Economic Efficiency

Cost Allocation

3.2 Ensure that generators have option to connect without paying for congestion-related upgrades (energy-only)

Planning Coordination

3.5 More closely align interconnection and transmission planning processes

Interconnection Studies

3.6 Continue to develop new best practice study methods, and harmonize methods to adapt to a changing generation mix

3.8 Explore options for generator self-funding of their own interconnection studies

#4: Maintain a Reliable Grid

Models and Tools

4.1 Require submission **of verified EMT models** for all IBRs, and develop **screening criteria** to determine when EMT studies are necessary within a region

4.3 Develop **study process flow** that is better aligned with generation project development timelines

Interconnection Standards

4.4 Adopt comprehensive set of generation interconnection requirements consistent with **IEEE Standard 2800-2022**

4.7 Evaluate **cybersecurity concerns** during the interconnection process

FY24 FOA: Solar and Wind Interconnection For Future Transmission (SWIFTR)

$5 million

Topic Area 1: Improved Efficiency of EMT Simulations for Interconnection Studies of IBR

- Solution 4.1 – Require submission of verified EMT models for all IBR during the interconnection process… and **develop screening criteria** to determine **when EMT studies are necessary** in a region.
- Solution 4.2 – Develop rules for **dynamic model quality testing and validation** in both RMS and EMT domains, ensuring that plant performance conforms with applicable interconnection requirements
- Solution 4.3 – Develop **study process flow** that is better aligned with generation project development timelines.

$5 million

Topic Area 2: Dynamic Stability-Enhanced Network Assessment Tools

- Solution 1.1 – Improve the **scope, accessibility, quality, and standardization of data** on projects already in interconnection queues, including project attributes and cost estimates
- Solution 1.3 – **Develop tools** to manage, analyze, and visualize transmission and interconnection data

i2X FIRST: Forum for the Implementation of Reliability Standards for Transmission

Goal: Education and Technical Assistance to facilitate implementation of model and validation requirements as well as standards.

- Led by SETO and WETO i2X Team with support from LBNL and ESIG
- Primary activity – Industry forum to share practical implementation ideas on IEEE 2800 and 2800.2 and NERC implementation of FERC order 901.
- Leverages peer learnings for practical implementation of early adopters.

Transmission Interconnection Roadmap Connections

- Solution 2.13 - **Upskill the existing workforce** through continuing education programs.
- Solution 4.2 – Develop rules for **dynamic model quality testing and validation** in both RMS and EMT domains, ensuring that plant performance conforms with applicable interconnection requirements
- Solution 4.5 – Adopt and implement a harmonized and comprehensive set of **generation interconnection requirements or standards,** consistent with IEEE Standard 2800-2022.
- Solution 4.6 - Adopt and implement harmonized requirements for **plant conformity assessment** as a part of generator interconnection procedures and consistent with IEEE P2800.2.
- Solution 4.7 - Assess need for new interconnection requirements and standards to cover expected performance from **emerging technologies**.

IEEE 2800-2022 and Ongoing Adoption Efforts

DOE i2X FIRST - Forum for the Implementation of Reliability Standards for Transmission

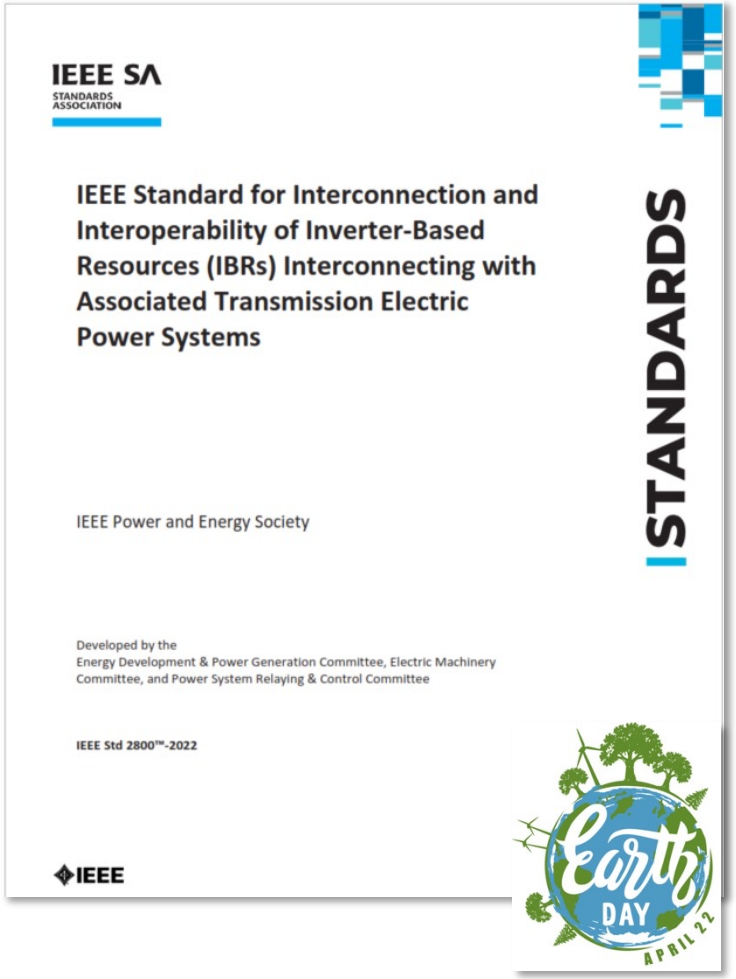
Jens C. Boemer
Technical Executive, jboemer@epri.com

Tuesday, May 28, 2024
Virtual

Classification: Public

IEEE Std 2800™-2022

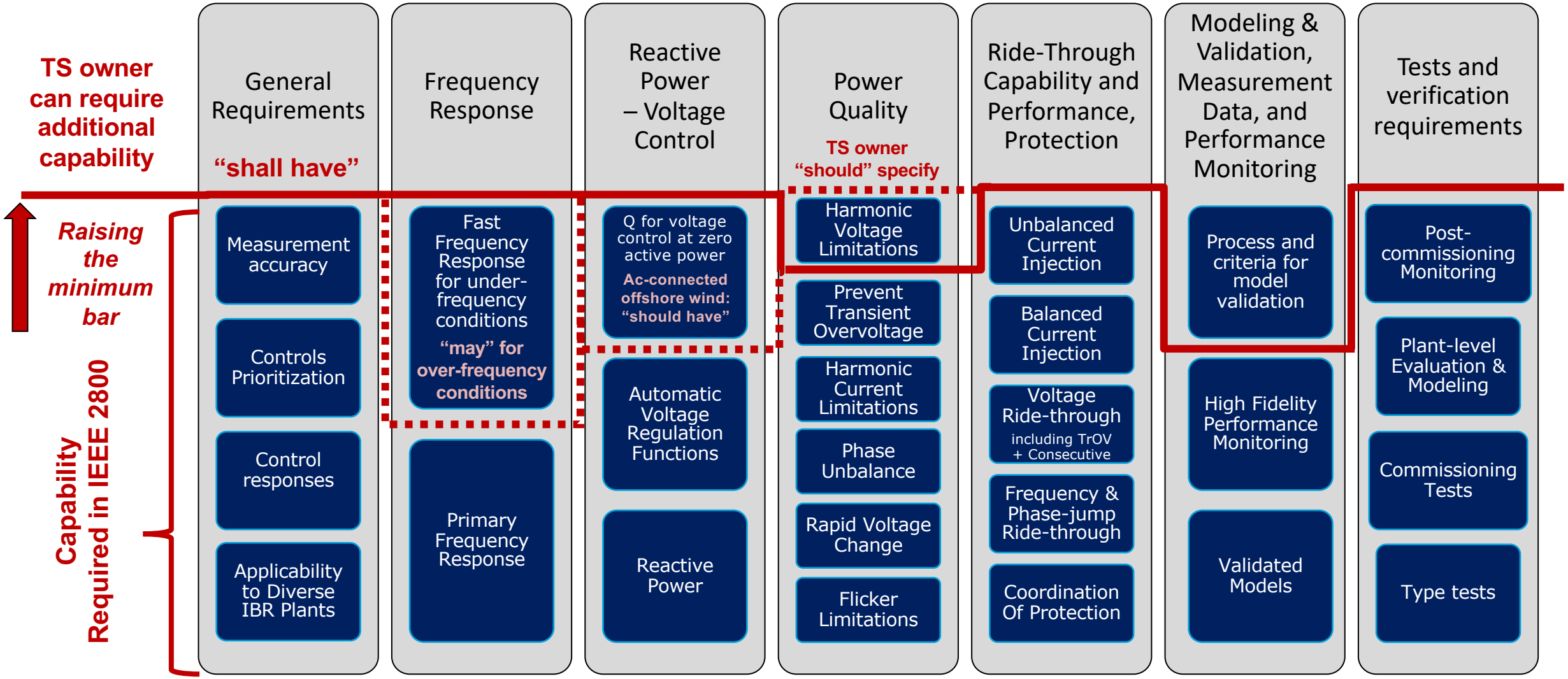
- Harmonizes **technical minimum** interconnection **capability** and performance requirements for **large solar**, **wind** and **storage plants**, and **any IBR connected via VSC-HVDC** like offshore wind
- A **consensus-based** standard developed by over ~175 Working Group participants from utilities, system operators, transmission planners, & OEMs over 2 years
- Passed the IEEE SA ballot among 466 SA balloters with high approvals **(>94% approval**, >90% response rate)
- **Published on April 22, 2022 (Earth Day)**



Available from IEEE at https://standards.ieee.org/project/2800.html and via IEEExplore: https://ieeexplore.ieee.org/document/9762253/

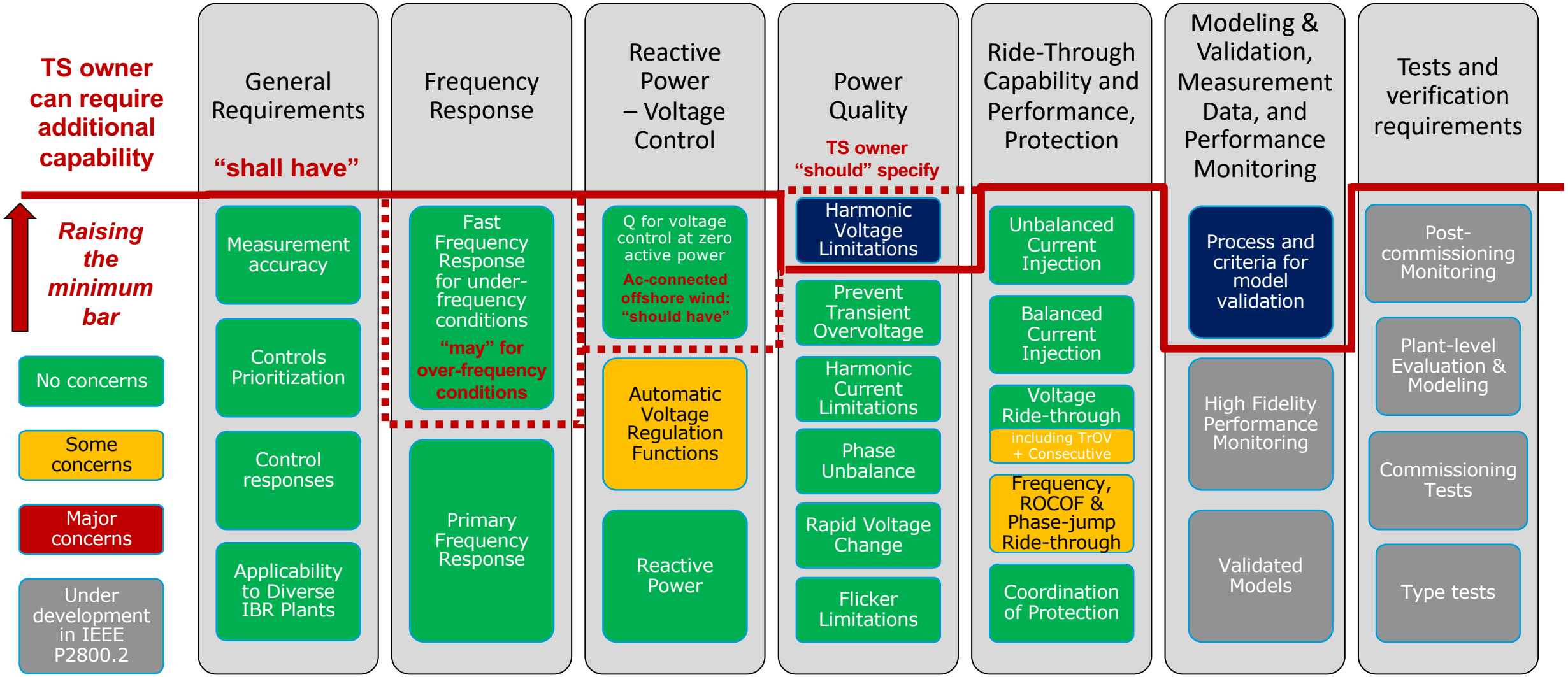
Technical Foundation Enables Paradigm Shift Towards *Minimum Capabilities*

IEEE 2800-2022 Technical Minimum Capability Requirements



Utilization of these capabilities is outside the purview of IEEE 2800

Technology Readiness / Compatibility of New IBR Units with IEEE 2800



Inverter OEMs have flagged concerns about certain requirements.

Examples taken from: ERCOT OEM assessment as presented on the Dec 8, 2023, IBRWG meeting; note that assessment depends on specific requirements language.

EPRI Inventory of Utility Approaches for IEEE 2800 Adoption

General Reference

- Florida Power and Light (FPL)
- Salt River Project (SRP)[2]
- Southwest Power Pool (SPP)[7]

Detailed Reference

- Duke Energy[4]
- ISO New England[1,8]
- MISO[5]
- New York ISO[3] / NYSRC
- Southern Company[1]

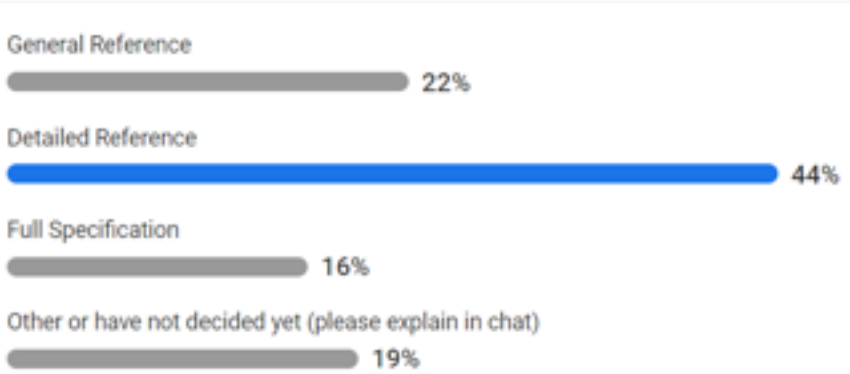
Full Specification

- ERCOT[2,9]
- Ameren IL[6]

- Other utilities/ISOs considering IEEE 2800-2022 adoption: AESO, BPA, Great River Energy, Long Island Power Authority, Manitoba Hydro, TVA

Live Poll: Which adoption approach are you considering? 32

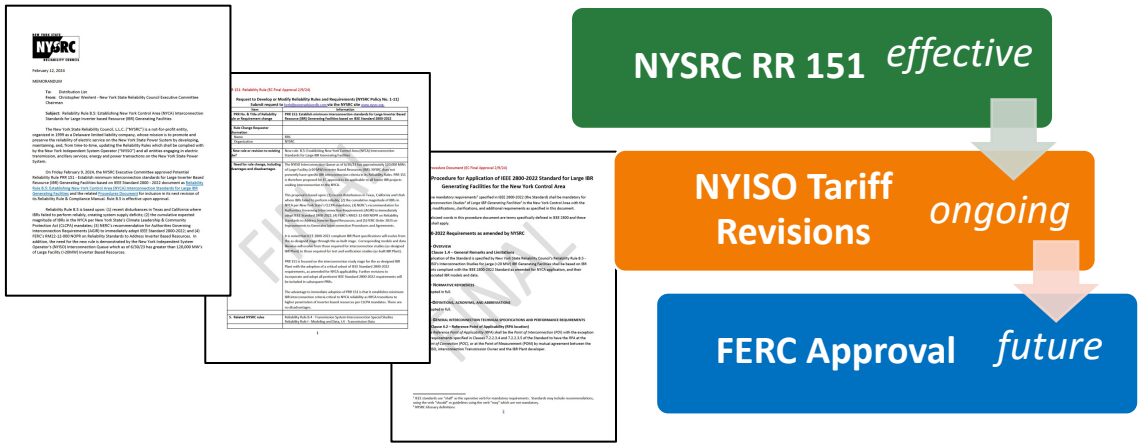
(based on February 15, 2023 webcast: link)



[1]: Presented on November 15, 2022 webcast: link
[2]: Presented on February 15, 2023 webcast: link
[3]: Presented on March 15, 2023 webcast: link
[4]: Presented on April 12, 2023 webcast: link
[5]: Presented on May 17, 2023 webcast: link
[6]: Presented on June 14, 2023 webcast: link
[7]: Presented on September 20, 2023 webcast: link
[8]: Presented on November 15, 2023 webcast: link
[9]: Verbal update on Jan 17, 2024 webcast: link

Example 1: NYSRC Adoption via Reliability Rule RR151

Strategy: Full Adoption of IEEE 2800-2022



Source:
NYSRC Reliability Rule Revisions (2024)

- **Drivers:** NERC disturbance reports, FERC Orders 901 & 2023
- **Approach:** Detailed Reference, cites specific clauses, adopts almost all “shall” requirements with some exceptions and modifications
- **Scope:** new IBRs only; targeted requirements with greatest potential reliability impact in Phase 1; Phase 2 started in Jan. ‘24
- **Timing:** effective immediately

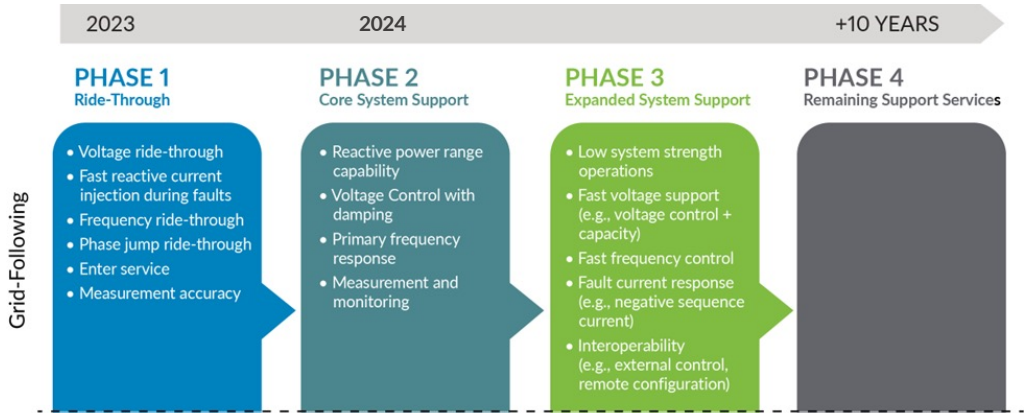
Detailed Reference: IEEE 2800 Clause Numbers and Additional Specifications in Procedure Document

Clauses 1 Overview, 2 Normative References, 3 Definitions, 4 General	•Adopted in full •Reference Point of Applicability is Point of Interconnection instead of Point of Measurement (default)
Clause 5 Reactive Power-Voltage Control	•Adopted in full, with clarifications •Adequate consideration of losses between POI and POM. •Utilization per NYISO specification
Clause 6 Active Power-Frequency Response	•Adopted in full, with clarifications
Clause 7 Response to TS Abnormal Conditions, 9 Protection	•Clause 7 adopted in full, major clarifications •Clause 9 adopted in full without clarifications •Utilization per NYISO specification
Clause 8 Power Quality, 10 Modeling Data, 11 Measurement data, 12 Test & Verification	•Excluded •Reference to forthcoming P2800.2 for T&V •Self-certification of compliance

First and (Almost) Full Regional Adoption of IEEE 2800-2022

Example 2: MISO Adoption via Tariff Changes

Strategy: Phased Adoption of IEEE 2800-2022



Source: MISO Attributes Roadmap (2023)

- **Drivers:** NERC disturbance reports, FERC Orders 901 & 2023
- **Approach:** Detailed Reference, cites specific clauses
- **Scope:** new IBRs only; targeted requirements with greatest potential reliability impact in Phase 1; Phase 2 started in Jan. '24
- **Timing:** MISO's 2022 interconnection queue* and beyond, first IBR plants expected to be in operation by end of 2026

*with GIA's signed after Jan 1, 2025

IEEE 2800-2022 References Incorporated into Generator Interconnection Agreement (GIA)

Clause 4 General
- Reference Point of Applicability
- Applicable Voltages and Frequency
- Measurement Accuracy
- Return-to-Service (Enter Service)

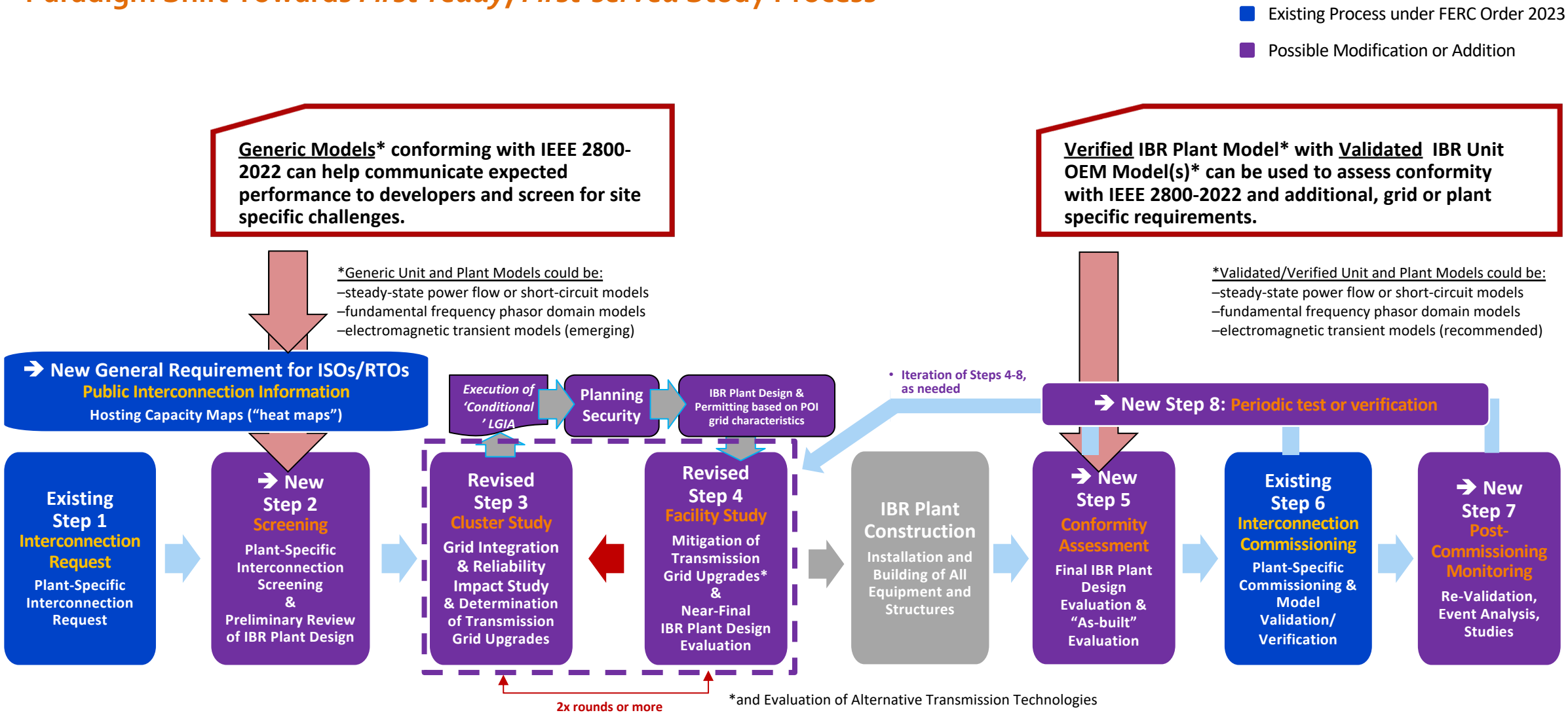
Clause 7.2.2 Voltage Ride-Through
- Voltage Ride-Through (VRT)
- Current Injection During VRT
- Transient Overvoltage Ride-Through
- Restore Output after VRT

Clause 7.3.2 Frequency Ride-Through
- Frequency Ride-Through
- Rate-of-Change-of-Frequency (ROCOF) Ride-Through
- Voltage Phase Angle Jump Ride-Through

Successful Stakeholder Process with Clear Expectations and Transitioning Timelines

FERC LGIP Interconnection Procedure per FERC Order 2023

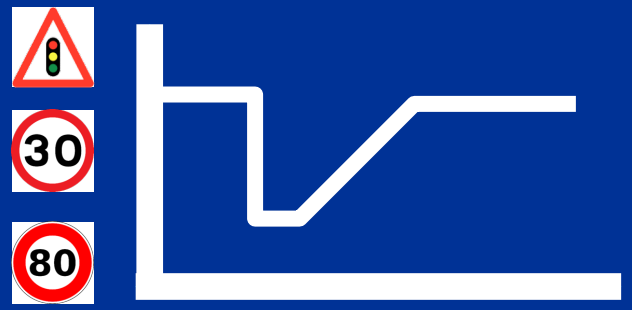
Paradigm Shift Towards *First-ready*, *First-served* Study Process



Preliminary IBR Plant **Conformity Assessment** Prior to IBR Interconnection?

Potential NERC Reliability Requirements In Response to FERC Order 901

Performance-based Requirements



- define a specific **reliability objective** or outcome
- achieved by one or more **entities**
- can be measured using **power system data or trends**
- has four components: ***who***, under what conditions, shall perform ***what action***, to achieve what particular result or outcome.

Risk-based Requirements

- define **actions**
- by one or more **entities**
- can be measured by **evaluating a particular product** or outcome
- framed as: ***who***, under what conditions, shall perform ***what action***, to achieve what particular result or outcome

Capability-based Requirements

- define **capabilities**
- needed by one or more **entities to perform** reliability functions
- **can be measured** by demonstrating that the capability exists
- framed as: ***who***, under what conditions, shall have ***what capability***, to achieve what particular result or outcome to perform

Source: NERC Rules of Procedure. Effective November 28, 2023. Section 2.4.

IEEE 2800-2022 Could Address NERC Odessa 2 Issues*

NERC Odessa 2 Report Table 1.1: Causes of Solar PV Active Power Reductions	*FERC Orders*	*UNIFI Performance Need*	*IEEE 2800-2022*	
			Requirements	*Clause*
Inverter Instantaneous AC Overcurrent	2023	Y	R	4.3, 4.4, 7.2.2.1, 9.4
Passive Anti-Islanding (Phase Jump)	2023	Y	R	7.3.2.4, 9.5
Inverter Instantaneous AC Overvoltage	2023	Y	R	7.2.3, 9.3
Inverter DC Bus Voltage Unbalance	N	Y	R	(7.2.2)
Feeder Underfrequency	661a, 2023	Y	R	4.3, 4.4, 7.3.2.1, 9.1
Unknown/Misc.	N/A	N/A	N/A	N/A
Incorrect Ride-Through Configuration	N	N	R + P2800.2 design eval.	7.2, 7.3, 12.2.3, 12.2.4, 12.2.5
Plant Controller Interactions	N	TBD	R + P2800.2 design eval.	7.2, 7.3, 12.2.3, 12.2.4, 12.2.5
Momentary Cessation	2023	Y	R	7.2.2, 7.2.2.3.4
Inverter Overfrequency	661a, 2023	Y	R	4.3, 4.4., 7.3.2.1, 9.1
PLL Loss of Synchronism	2023	Y	R	4.3, 7.2, Footnote 91, 7.2.2.3.4, 7.3, 7.3.2.3.5, 11
Feeder AC Overvoltage	661a, 2023	Y	R	4.3, 4.4, 9.3
Inverter Underfrequency	661a, 2023	Y	R	4.3, 4.4, 7.3.2.1, 9.1
Not Analyzed	N/A	N/A	N/A	N/A

Mapping to Causes listed in NERC Odessa 2 Report

Additional IEEE 2800-2022 Requirements

Category	Performance Capability	*IEEE 2800-2022*	
		Requirements	*Clause*
General	Range of Available Settings	R	4.10.2, 4.10.3, 5.1, 5.2, 6.2.2, 6.2.3
	Prioritization of Functions	R	4.7
	Ramping for control parameter change	R	4.6.2
Monitoring, Control, and Scheduling	Responding to external control inputs	R	4.6
	Remote Configurability	R	5.2.2, 5.2.3, 5.2.4
Voltage Support	Capability at Zero Active Power	R	5.1
	Constant Reactive Power	R	5.2.4
Dynamic Responses and Reliability Services	Consecutive Voltage Deviation Ride-Through	R	7.2.2.4
	Underfrequency Fast Frequency Response	R	6.2.1
	Overfrequency Fast Frequency Response	R	6.2.1
	Primary Frequency Response	R	

Acknowledgements: Strawman provided by courtesy of MISO (see monthly call on May 17, 2023 at this link); reviewed by EPRI staff A. Haddadi, D. Ramasubramanian and J. Boemer.

More Quantitative Analysis Needed to Fully Understand IEEE 2800 Reliability Impacts

*Disclaimer: This statement does not infer that adoption of IEEE Std 2800-2022 for new installed IBRs will address the potential reliability issues of existing IBRs that may not comply with IEEE Std 2800-2022.

EPRI Perspective on Draft NERC PRC-029 (IBR Ride-through) Reliability Standard

- 7-pages of technical EPRI comments indicate a **need for diligent revisions of the proposed draft** PRC-029
  - For **harmonization** and **compliance** of IBR across North America, proposed requirements could be further aligned with requirements that are **testable** and **verifiable** as specified in **industry standards** developed through an open process such as ANSI, CIGRE, IEC, or IEEE.
- **IEEE Std 2800™-2022 is one example** applicable industry standard—other standards like IEC may apply.
  - R1 and R2 relate to Clause 7.2.2 (Voltage disturbance ride-through requirements).
  - R3 relates to Clause 7.2.3 (Transient overvoltage ride-through requirements), R4 relates to Clause 7.3.2 (Frequency disturbance ride-through requirements), and R5 relates to Clause 7.3.2.4 (Voltage phase angle changes ride-through).
- Due to the general objective of "Completeness" for NERC Reliability Standards per Paragraph 302.6 of NERC's Rules of Procedure, neither FERC nor NERC currently see room for **"incorporation by reference"** of voluntary industry standards.
  - If that position changed, **EPRI recommends incorporating references to IEEE 2800 at relevant sections**, such as in R1, as illustrated in the comments:
  - **Precedence exists** in FAC-008-56, PRC-002-27, PRC-019-28, PRC-023-49, PRC-025-210.
  - ➢ Incorporation by reference could **potentially expedite the successful balloting and support the delivery of PRC-029 to FERC** by November 2024.

R1. Each Generator Owner or Transmission Owner of an applicable IBR shall ensure that each IBR remains electrically connected and continues to exchange current in accordance with at least one of the following:

* the no-trip zones and operation regions as specified in Attachment 1, or
* requirements specified in industry standards developed through an open process such as ANSI, CIGRE, IEC, or IEEE)[Footnote 1],

unless needed to clear a fault or a documented equipment limitation exists in accordance with Requirement R6. [Violation Risk Factor: High] [Time Horizon: Operations Assessment]

[Footnote 1] For example, technical minimum requirements as they are specified in IEEE Std 2800™.

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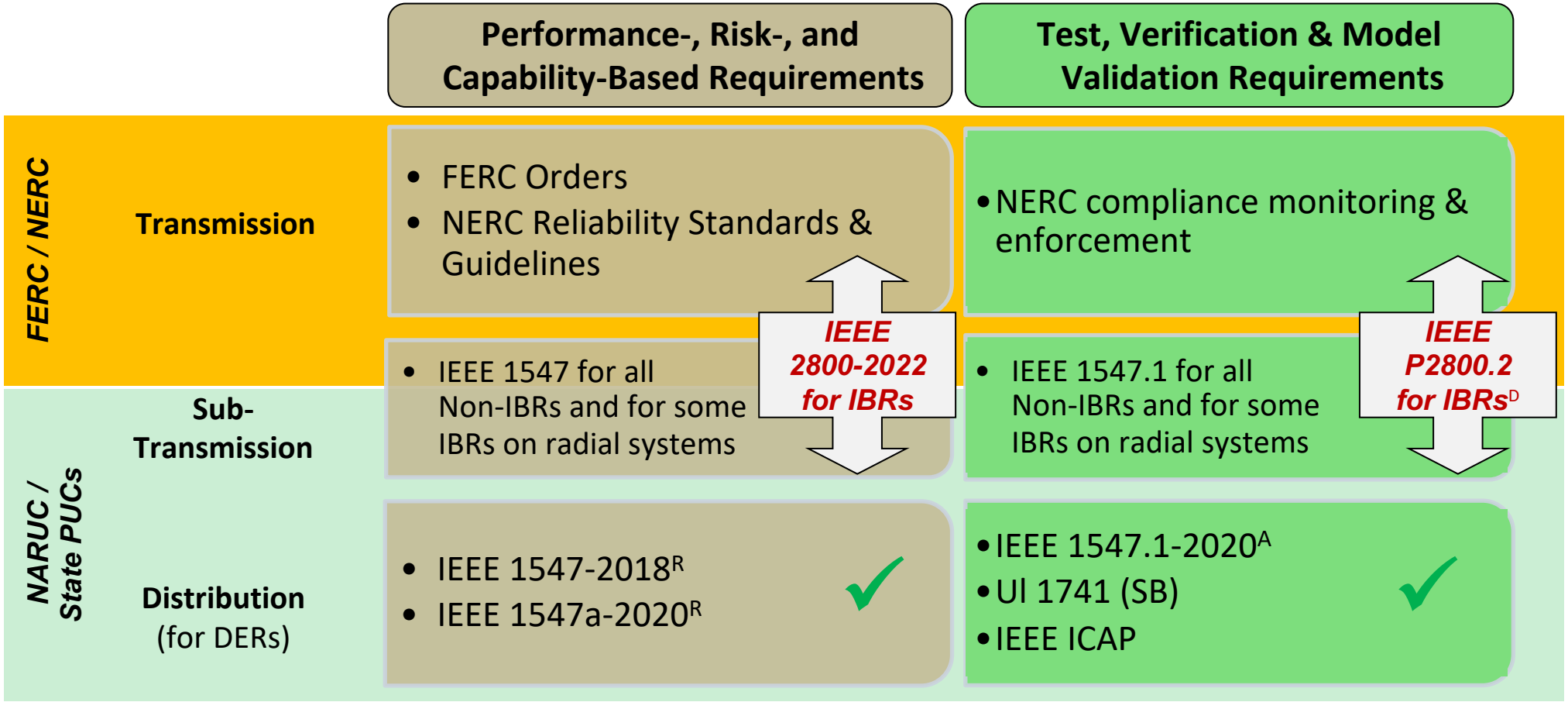
Scope of IEEE Std 2800

This standard establishes the required interconnection capability and performance criteria for inverter-based resources interconnected with transmission and sub-transmission systems. Included in this standard are performance requirements for reliable integration of inverter-based resources into the bulk power system, including, but not limited to: **voltage and frequency ride-through, active power control, reactive power control, dynamic active power support under abnormal frequency conditions, dynamic voltage support under abnormal voltage conditions, power quality, negative sequence current injection, and system protection.**

Applicable to IBRs like wind, solar & energy storage, and any IBR connected via VSC-HVDC.

- "Type 3" wind turbines (doubly-fed induction generators) are in scope
- HVDC-VSC connected resources, e.g., onshore connection point of a VSC-HVDC tie-line interconnecting an offshore resource is also in scope.

IEEE Standards Could Complement North American Reliability Standards



[A] in amendment; [D] in development; [R] in revision

ICAP: IEEE Conformity Assessment Program

IEEE Standards become mandatory only when adopted by the appropriate authorities.

Industry Terms for Safety, Quality, and Efficiency

Compatibility

- Design equipment to support conformity or compliance of a complex system (e.g., IBR plant)

Conformity[1]

- Adherence to certain voluntary industry standards or procedures (e.g., IEEE 2800.2)

Compliance

- Meeting mandatory legal and regulatory obligations (e.g., NERC Reliability Standards)

[1] The term “conformance” is depreciated and should not be used any longer.

References:

- https://www.inboundlogistics.com/articles/conformance-vs-compliance
- https://www.linkedin.com/pulse/conformity-vs-conformance-compliance-carlos-cisneros-cqa/
- https://www.standardsuniversity.org/e-magazine/september-2017/introduction-conformity-assessment-compliance/
- https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8082574

Capability versus Utilization

Capability:

Scope of IEEE 2800

"Ability to Perform"

- Functions
- Ranges of available settings
- Minimum performance specifications

Examples

- Frequency Response
  - Primary frequency response
  - Fast frequency response

- Ride-Through
  - Voltage ride-through
  - Current injection during ride-through
  - Consecutive voltage ride-through
  - Frequency ride-through
  - ROCOF ride-through
  - Phase angle jump ride-through

Utilization of Capability:

Scope of Interconnection or Ancillary Services Agreement

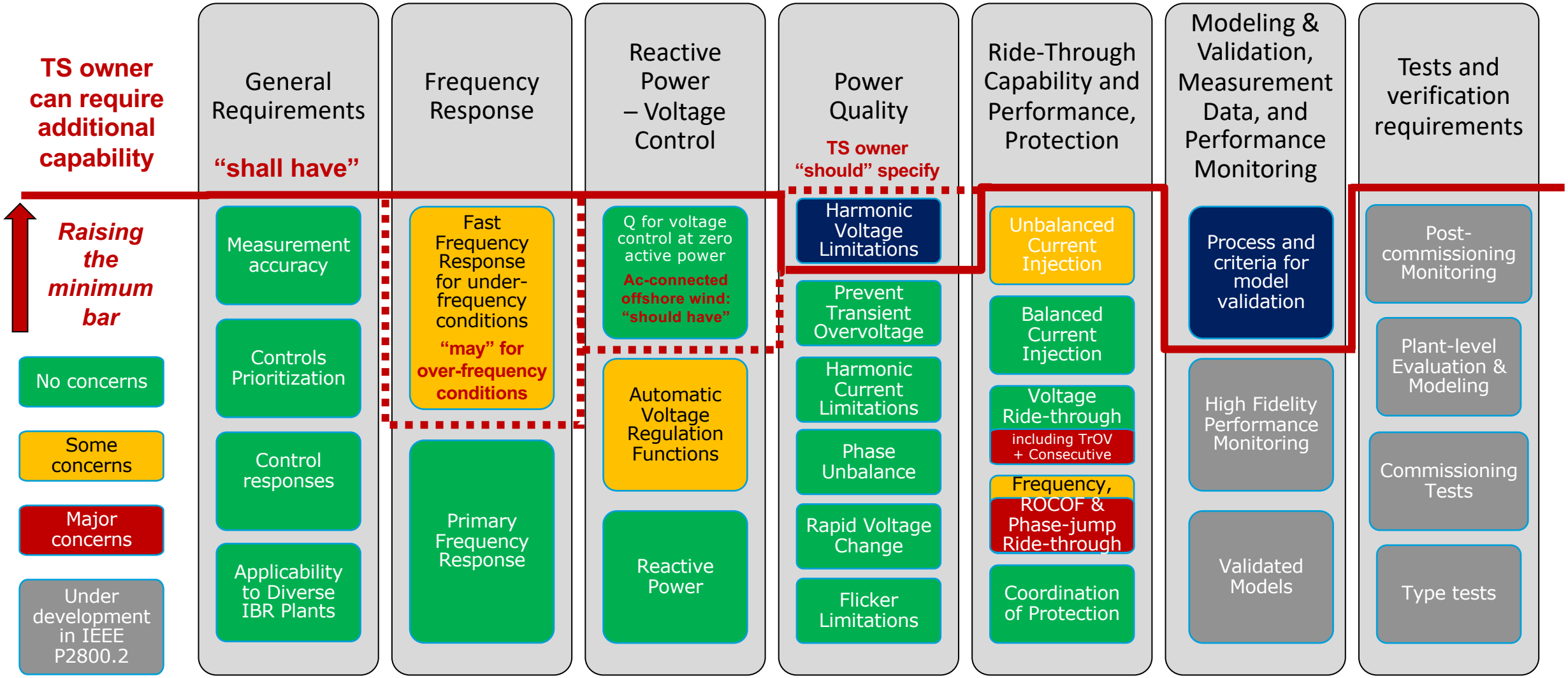
"Delivery of Performance"

- Enable/disable functions
- Functional settings / configured parameters
- Operate accordingly (e.g., maintain headroom, if applicable)

Examples

- Deadband
- Droop
- Response Time
- Headroom

Technology Readiness / Compatibility of Some Legacy IBR Units with IEEE 2800



Inverter OEMs have flagged concerns about certain requirements.

Examples taken from: ERCOT OEM assessment as presented on the Dec 8, 2023, IBRWG meeting; note that assessment depends on specific requirements language.

Example Challenges

Solar PV

- OEM deals with unit-level design; IEEE 2800 is mostly a plant-level requirement.
- Vagueness of certain clauses of 2800
  - e.g. Clause 7.2.2.3.4 regarding criteria for LV condition.
- IBR unit design by OEM may not consider the system-specific needs of TSO.
  - e.g., k-factor selection.

Wind Power

- Consecutive voltage ride-through

Main WTG Type (ref.: Vestas)	Thermal Limitation	Mechanical Limitation
Type I, II	Yes	Yes
Type III	Yes	Yes
Type IV A—with DC chopper	Yes	No
Type IV B—without DC chopper	Yes	Yes

- Not straightforward to translate requirements from PoI to WTG unit.
- Not defined by 2800:
  - Evaluation criteria
  - Project specific conditions that will affect the compliance outcome.
- Validation of 3rd party plant controllers & models requires coordination between parties during IC process.

Energy Storage

- Unit-level vs plant-level testing, responsibility of OEM or developer?
- Need for clarification of certain clauses.
  - TrOV - what kind of waveshape is to be used for testing.

I. Introduction

1. The Electric Power Research Institute (EPRI)[1] respectfully submits these comments (This Response) in response to North American Electric Reliability Corporation (NERC)'s request for formal comment on Project 2020-02 Modifications to PRC-024 (Generator Ride-through), issued on March 27, 2024. EPRI closely collaborates with its members inclusive of electric power utilities, Independent System Operators (ISOs), and Regio stakeholders, domestically an development relating to the ger make electricity more reliable technical in nature based upon 50 years in planning, analyzing

2. EPRI research and tec public, either for free or for requirements.[2] The publicly a Energy (DOE)- and EPRI men Enable Deployment of High P made in This Response.[3]

3. While not a standard demonstration projects in rele

[1] EPRI is a nonprofit corporation orga as a tax-exempt organization under furtherance of its public benefit missi Alto, Calif.; Charlotte, N.C.; Knoxv generation, delivery, and use of elec together its scientists and engineers as reliability, efficiency, health, safety, a long-range research and development
[2] https://www.epri.com (last accessed
[3] PV-MOD Project Website. EPRI. P

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Unofficial Comment Form
Project 2020-02 Modifications to PRC-024 (Generator Ride-through)

Do not use this form for submitting comments. Use the Standards Balloting and Commenting System (SBS) to submit comments on **Project 2020-02 Modifications to PRC-024 (Generator Ride-through)** by **8 p.m. Eastern, Monday, April 22, 2024.**

Additional information is available on the project page. If you have questions, contact Manager of Standards Development, Jamie Calderon (via email), or at 404-960-0568.

Background Information
The goal of Project 2020-02 is to mi issues identified across multiple Int Regions. These issues have been as tripping or cessation unrelated to v effective version of PRC-024, PRC-0 limit its applicability to synchronou protection-based standard. A new s Reliability Standard with applicabili

In October 2023, FERC issued Orde Reliability Standards that include n performance validation, and correc identified by NERC that must be co No. 901 directives. At their Decemb Project 2020-02, allowing formal cc pools reduced from 30 days to as fe few as 5 calendar days.

Questions

1. Do you agree with the need for Based Resource Performance S SAR and to address the expecta

X Yes
☐ No

EPRI COMMENTS:

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2. Do you agree that the language within PRC-029-1 requirements R1, R2, and R6 regarding IBR plant-level performance during grid voltage disturbances is clear?

☐ Yes
X No

EPRI COMMENTS

1. The standard requires IBR to ri IBR is typically designed to r Considering 24 hour/365day planning events. During such a disturbances as specified. The transmission lines are added tc the transmission system. The operating conditions at the tin network and operating conditi recognizes such issues, for e Reliability Coordinator, or Trar expected (similar to IEEE 280 outside of conditions identical
2. The SDT proposes to add conti region terms to the Glossary o through requirements. There capability only. The definitions also apply to frequency ride-t 2022 where Clauses 3.1, 7.2.2 ride-through capabilities.
3. Continuous/mandatory/permi
   a. The SDT uses continuous/mandator "operation" throughou
   b. Following comments t
      i. Continuous Op at a high side
      ii. Mandatory Op at the high-sid 1.1 per unit ar
      iii. Permissive Op at the high-sid
   c. These terms specify vc 1. Per attachment 1, to-ground or phase-to IBR is allowed to oper

Project 2020-02 Modifications to PRC-024 (Ge
Unofficial Comment Form | March 2024

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9. Limitations to the Applicability of R1 and R2 to (Legacy) IBRs with Documentation of Equipment Limitation per R6
   a. The exemptions based on documented equipment limitations per requirement R6 are only given for R1 and R2 and not for R3–R5. While the approach aims at consistency with FERC Order 901, it remains unclear why R3 (transient overvoltage ride-through) is not also included in the proposed exemptions subject to R6.
10. For the purpose of harmonization and compliance of IBR across North America, proposed requirements could be aligned with requirements that are testable and verifiable as specified in industry standards developed through an open process such as ANSI, CIGRE, IEC, or IEEE. For example, requirement R1 and R2 relate to IEEE Std 2800™-2022, Clause 7.2.2 (Voltage disturbance ride-through requirements). Refer to our additional comments in response to question 3) below for further suggestions.

3. Do you agree with the drafting team's proposals for including IBR transient overvoltage, frequency, ROCOF, and instantaneous voltage phase-angle jump ride-through performance criteria in PRC-029-1 Requirements R3, R4, and R5?

☐ Yes
X No

EPRI COMMENTS

1. We agree with the intent of the proposed requirements R3 (TrOV ride-through), R4 (frequency and ROCOF ride-through), and R5 (phase-angle jump ride-through). However, we have notable concerns related to R3 (TrOV) and offer additional observations related to R4 and R5.
2. Requirement R3:
   a. We caution the Transient Overvoltage Ride-Through (TrOV) requirement R3 may not be mature enough for inclusion in this first version of NERC PRC-029, primarily because currently no commonly accepted test and verification procedures for IBR plants exists, see items 2.c–e below.
   b. Another observation is that the draft standard specifies "nominal instantaneous phase-to-ground or phase-to-phase voltage" as the voltage base for per unit calculation in the proposed Table 3. It is not clear what voltage this refers to. IEEE 2800-2022 specifies in detail the *applicable voltages* in its Clause 4.3, and further clarifies in its Clause 7.2.3 for TrOV ride-through requirements that the voltages in its Table 14 are per unit values of the "nominal instantaneous peak voltage" at the *reference point of applicability*. We suggest clarifying this specification.
   c. While some testing laboratories are reportedly testing inverter units for overvoltage condition of up to "1.5 pu", these testing capabilities are currently limited in North America and cannot be used at an IBR plant for which R3 applies. In order to test inverters for the specified voltage range between 1.5 – 1.80 pu, alternate methods such as harmonic voltage injection would have to be explored (e.g., injection of 3rd harmonic voltage).

[3] For example, see the test plan and inverter test results from DOE-funded EPRI research under the PV-MOD project at https://www.epri.com/pvmod that is using NREL's Controllable Grid Interface (CGI) testing at their Flatirons Campus.

Project 2020-02 Modifications to PRC-024 (Generator Ride-through)
Unofficial Comment Form | March 2024 7

EPRI Comments on Draft PRC-029 (IBR Ride-through) Reliability Standard

- Submitted via NERC's Commenting Tool on April 22, 2024
- EPRI research **supports the need for creating reliability standards for bulk power system connected inverter-based resources** ride-through capability and performance requirements:
  - *A Fundamental Evaluation of the Interactions Between Different Loads and Different Inverter Based Resources Control/Technology Types. Stability and Voltage Support Issues Driven by Current Limits of IBRs.* EPRI. Palo Alto, CA: 2022. 3002024270.
  - *Impact of Inverter-Based Resources on Protection Schemes Based on Negative Sequence Components.* EPRI. Palo Alto, CA: 2019. 3002016197.
  - *Impact of Variable Generation on Voltage and Frequency Performance of the Bulk System. Case Studies and Lessons Learned.* Technical Update. EPRI. Palo Alto, CA: 2014. 3002003685.

➢ **7-pages of detailed technical comments**

(Un-)Related News!

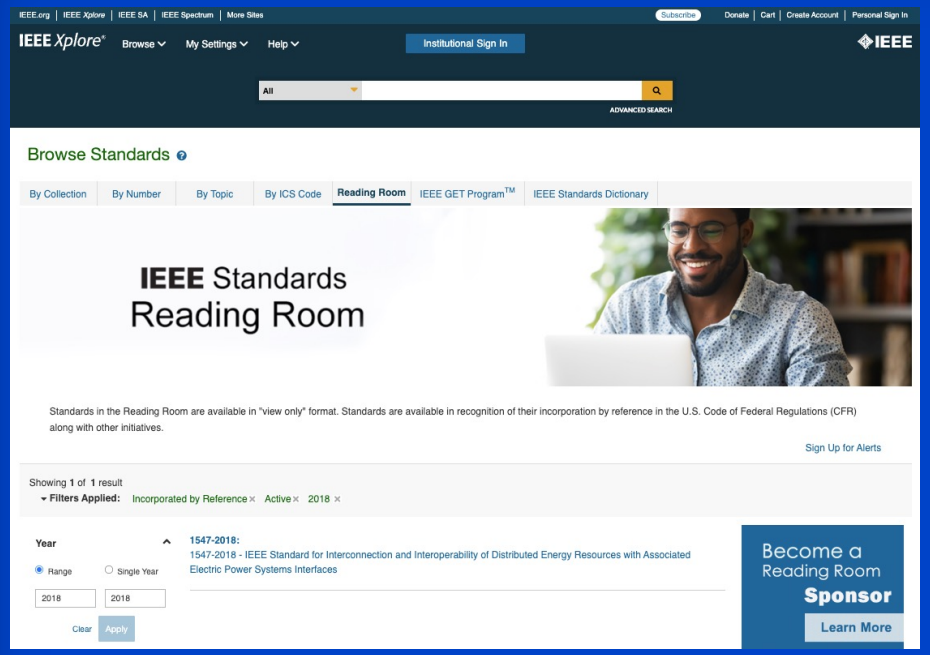
IEEE 1547 available in IEEE Standards Reading Room

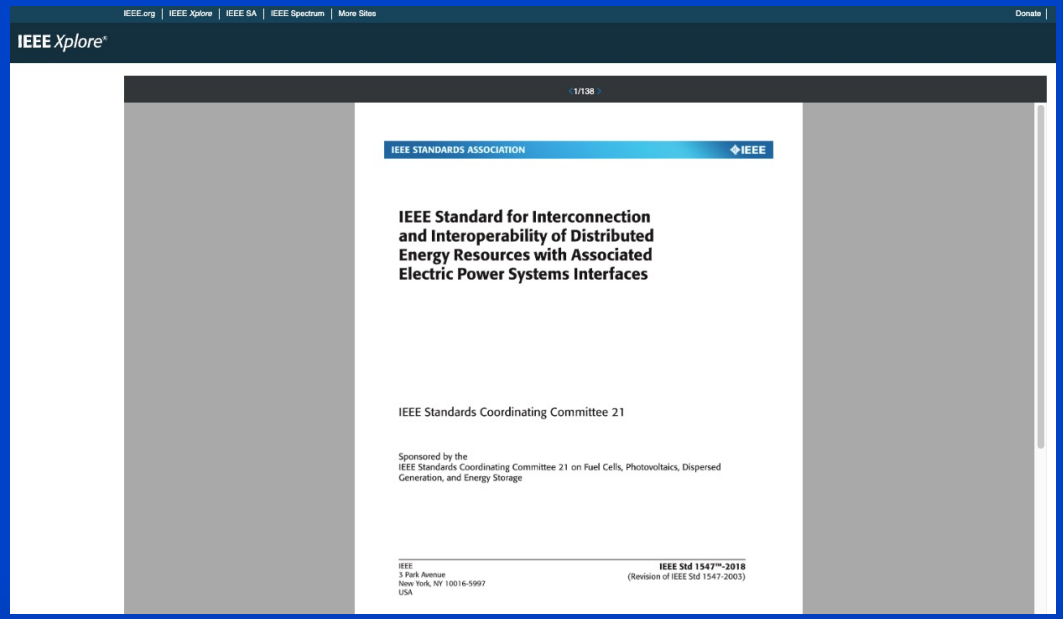
The U.S. Federal Register **incorporates IEEE 1547 by reference** in Public Law:

- **Energy Policy Act** issued August 8, 2005 (link)
- **FERC Order No. 2006** issued May 12, 2005 (link)

In accordance with IEEE protocol and in compliance with the law, ***IEEE made IEEE 1547 base standard and amendments available*** *in the* ***IEEE Standards Reading Room*****.**

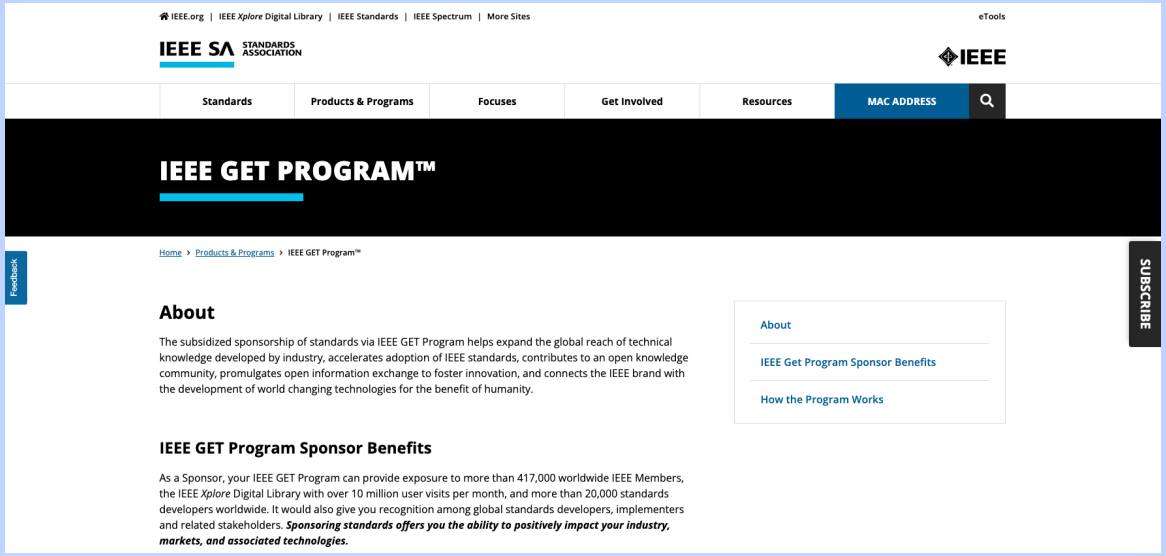
- Anyone can read the standard in their web browser
- Search, navigation pane, and other features are not available

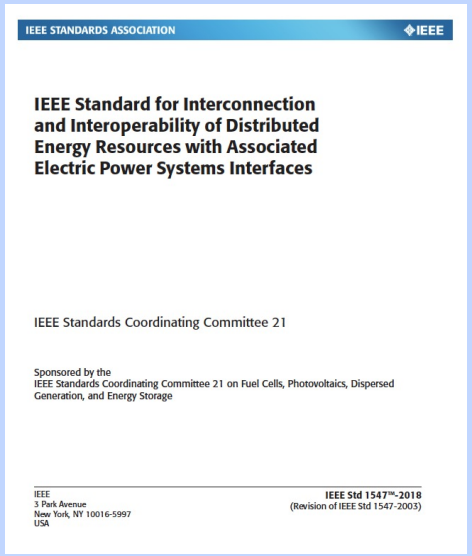


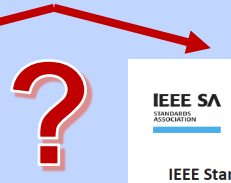


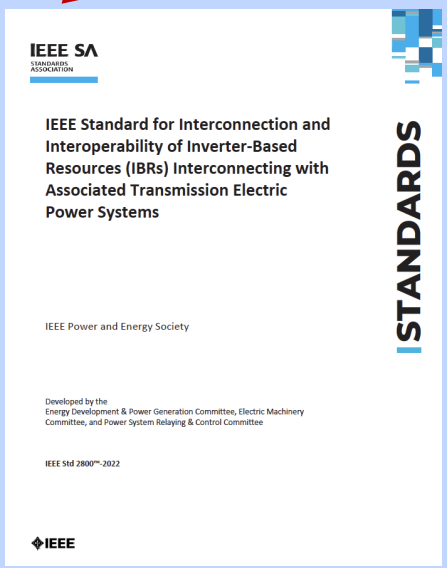
IEEE GET Program™

An Opportunity to Make IEEE 2800-2022 Publicly Available?









Q: Would your company be interested in sponsoring inclusion of IEEE 2800-2022 into the IEEE GET Program™ ?

How the Program Works

- Requires one or more entities to sponsor selected standard(s)
- Standard(s) will be made available for download at no cost
- Cost of being an IEEE GET Program Sponsor varies
- IEEE remains the sole copyright holder of the document(s)
- Require users to accept of these *Terms and Conditions of Use*
- IEEE distributes monthly users statistics

Example Standards

- GET 802(R) Standards
- GET Design Automation Standards
- GET Program for AI Ethics and Governance Standards
- GET 1680 Environmental Assessment
- GET IEEE/ANSI N42 Standards: Radiation Detection Standards
- GET C95 Standards: Safety Levels with Respect To Human Exposure To Radio Frequency Electromagnetic Fields

DOE i2X FIRST - Forum for the Implementation of Reliability Standards for Transmission

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Julia Matevosyan
Chief Engineer
ESIG

05/28/2024

IEEE 2800-2022 Standard

- The standard **harmonizes** Interconnection Requirements for Large Solar, Wind and Storage Plants
- It is a **consensus-based** standard developed by over ~175 Working Group participants from utilities, system operators, transmission planners, & OEMs over 2 years
- It has successfully passed the IEEE SA ballot among 466 SA balloters **(>94% approval**, >90% response rate)
- **Published on April 22, 2022 (Earth Day)**
- **Only when adopted by the appropriate authorities, IEEE standards become mandatory**

More Info at https://sagroups.ieee.org/2800/

Available from IEEE at https://standards.ieee.org/project/2800.html and via IEEExplore: https://ieeexplore.ieee.org/document/9762253/

Source: IEEE 2800,SEIA-ACP Joint Webinar, May 2022

IEEE 2800-2022 Adoption Efforts

Source: Adapted from Jens Boemer, EPRI

'wholesale adoption'

General Reference

- Florida Power and Light
- Salt River Project (reference to IEEE2800 in the PPA)
- Southwest Power Pool

Detailed Reference

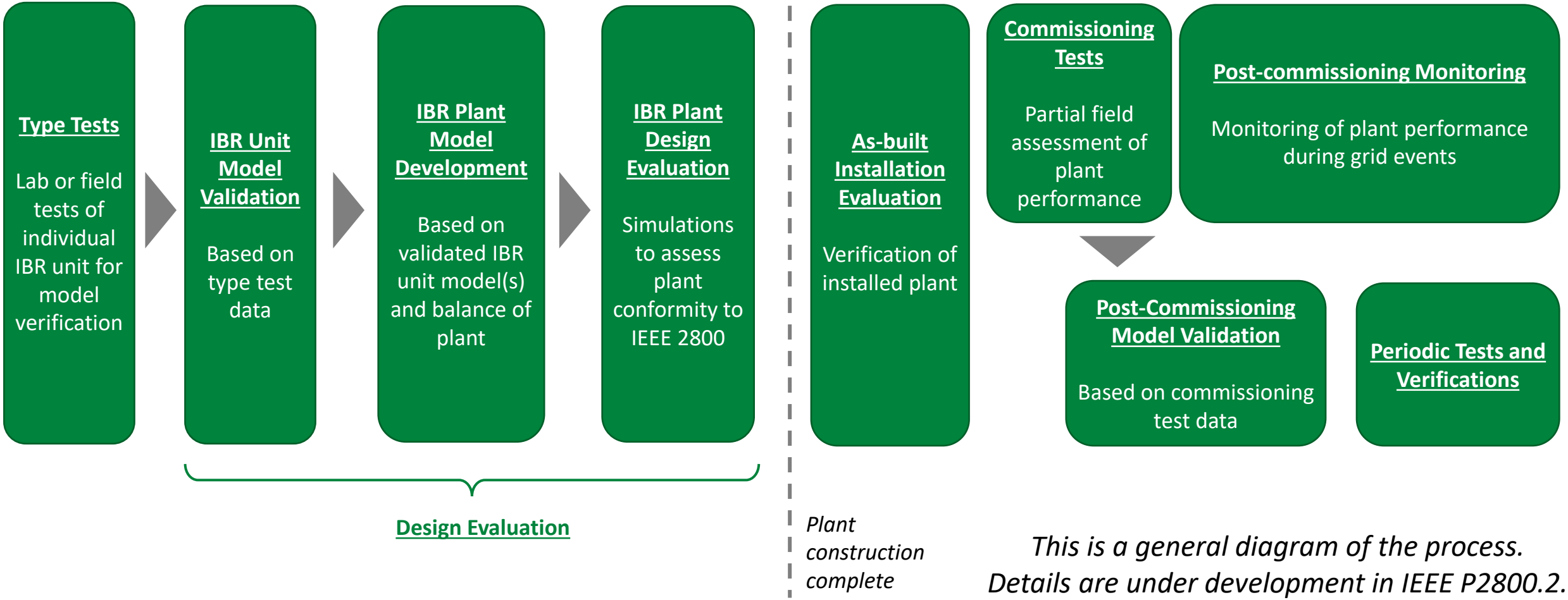
- Duke Energy
- ISO-NE
- MISO
- New York ISO
- Ameren ATXI (reference to adopted clauses in the GIA)
- Southern Company

Full Specification

- ERCOT
- Ameren IL

Other Utilities and ISOs Considering IEEE2800-2022 adoption: AESO, BPA, Long Island Power Authority, Great River Energy, Manitoba Hydro, TVA

IEEE P2800.2 Recommended Practice for Test and Verification Procedures for IBRs Interconnecting with Bulk Power Systems

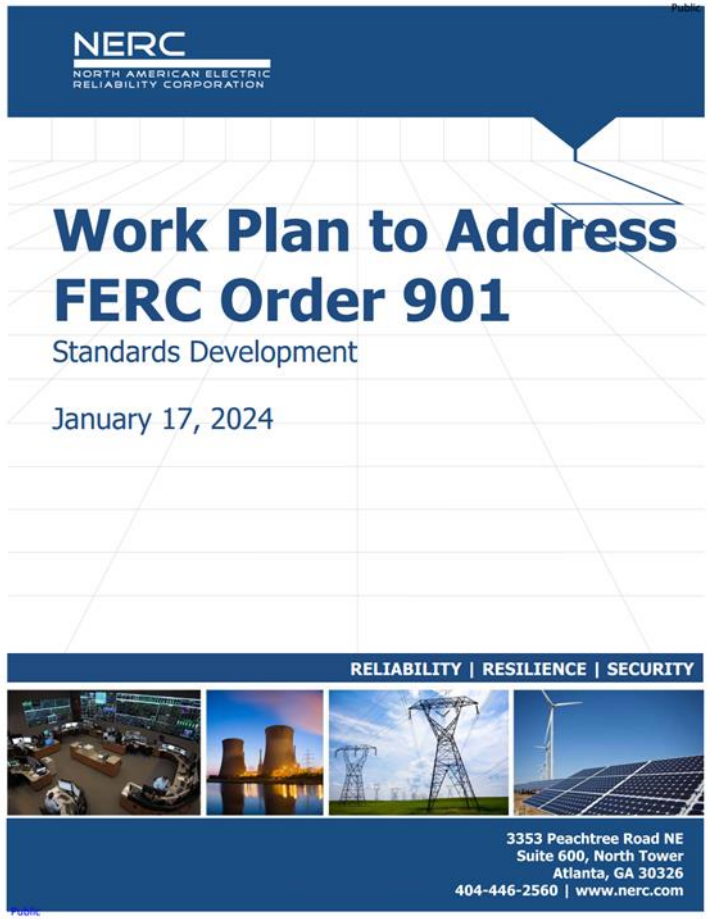


This is a general diagram of the process. Details are under development in IEEE P2800.2. Some variations permitted.

Source: Andy Hoke (NREL), Jens Boemer (EPRI)

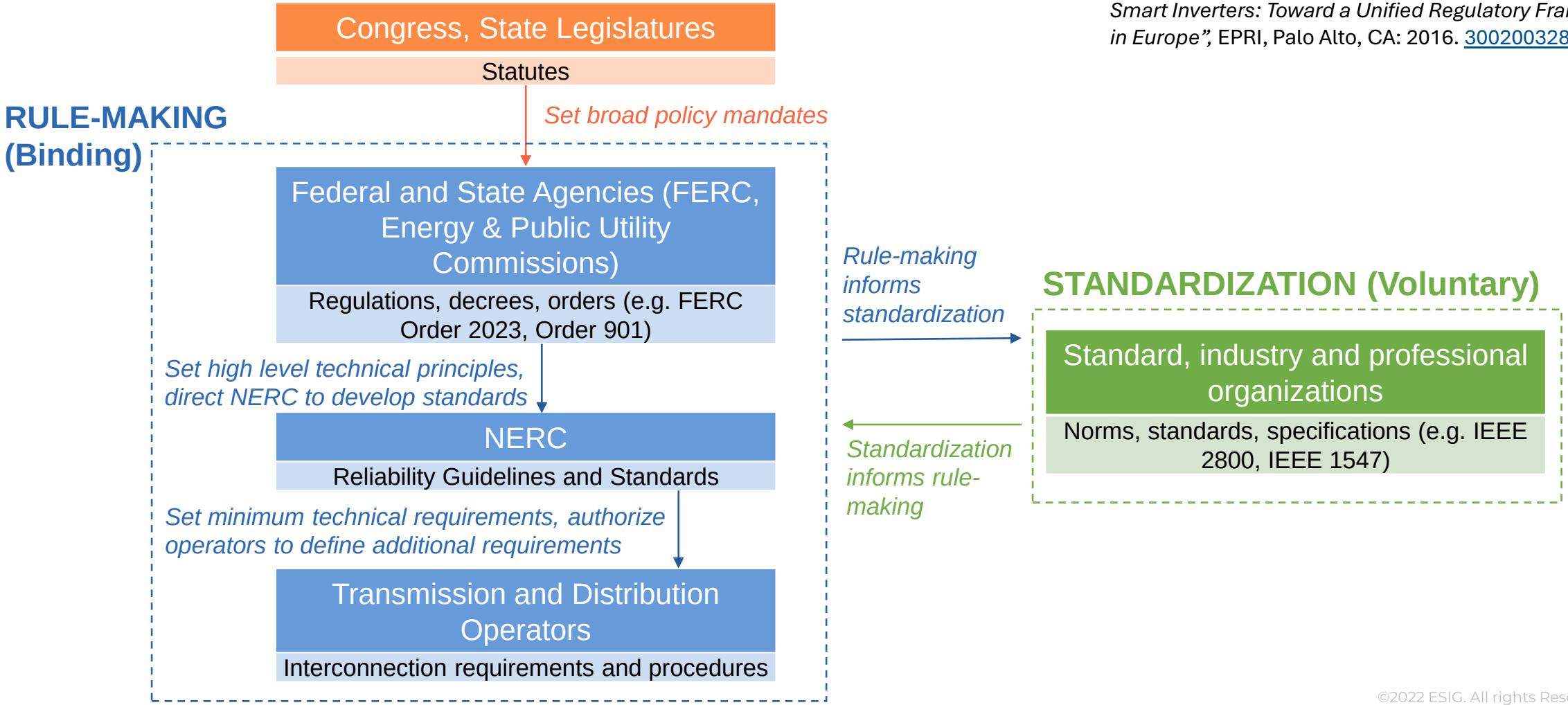
FERC Order 901 and NERC Work Plan

- FERC Order 901 issued on October 19, 2023
- Directs NERC to submit a detailed standards development plan to address IBR reliability gaps in four areas:
  - Data sharing
  - Model validation
  - Performance requirements
  - Planning and operational studies
- Informational filing by NERC to FERC on January 17, 2024
- New or modified standards to be submitted by November 2024, 2025 and 2026 (based on priorities set by NERC)



How does it all fit together? – Relationship of Policy, Regulations and Standards

Adapted from "Advanced Grid Support Functions for Smart Inverters: Toward a Unified Regulatory Framework in Europe", EPRI, Palo Alto, CA: 2016. 3002003288.



DOE I2x FIRST - Forum for the Implementation of Reliability Standards for Transmission

- **Led** by the SETO and WETO at the DOE in partnership with LBNL, ESIG and EPRI
- **Goal**: To drive the implementation of i2X Roadmap Solutions related to standards cohesively, leveraging insights from early adopters.
- **Participants:** Key stakeholders and industry participants interested in challenges around new standard implementation (OEMs, plant developers/owners, utilities, ISOs, consultants)
- **Format:** Monthly virtual meetings (4th Tue of the month). In-person (hybrid) meetings during ESIG workshops. Meetings will be jointly organized by DOE's i2X Team, incorporating facilitated discussion of key issues.
- **Focus**:
  - Transcend mere dissemination of standard language,
  - Delve into specific requirements and collaborate with the stakeholders to facilitate practical implementation
  - Integrate practices outlined in the draft of IEEE P2800.2 and best practices from early adopters
  - Discuss ongoing NERC standard revision efforts related to FERC Order 901 to ensure alignment with completed and ongoing IEEE2800 adoption endeavors.

Members will stay informed, engage in standard development, and ensure coherence with variety of industry initiatives already underway.

Meeting schedule/scope

- **Intro:** motivation for changing standards, IEEE2800 and ongoing/complete adoption efforts and process, IEEE2800.2 status, FERC Order 901 and NERC Work Plan/Ongoing standard development efforts and status.
- **Delve into specific IEEE2800 requirements**: purpose & meaning, conformity assessment during interconnection, commissioning, post commissioning (elements of IEEE P2800.2), challenges & lessons learned from early adopters, OEM readiness, alignment with ongoing NERC Standard development efforts.
  - **Ride Through** (i.e. voltage, frequency, phase jump, consecutive ride through)
  - **Measurement and Monitoring**
  - **Modeling**
  - **Frequency support**
  - **Voltage support/Reactive support**
  - **Power Quality**
- Addressing changing system conditions – how to ensure IEEE2800 conformity of IBRs as system conditions are changing over time?

Summarize discussion and main conclusions, agreement / disagreement points from each meeting, identify solutions and remaining gaps. This may also inform future meetings.

Wrap-Up and Kick-off

1. Transitioning the power system to integrate inverter-based resources is an exciting engineering challenge.
2. Besides some technical challenges, there are significant knowledge transfer, people, and institutional challenges.
3. We are all human!—and therefore we need to manage issues along the road by anticipating them, encouraging honesty about them, and learning collaboratively how to overcome them.
4. Technical standards play a major role in this process as they can help inform and support the implementation of policy mandates, regulatory rule-making, and stakeholder education. For that to be successful, alignment between all these levels of decision-making is essential.
5. If developed, referenced, and adopted appropriately and timely, technical standards can streamline and expedite the interconnection of IBRs to the grid and reduce interconnection queue backlogs.

Mindset shift related to the interconnection process that may require overhaul of process and thinking form all involved parties!

THANK YOU

Julia Matevosyan

julia@esig.energy

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NERC Work Plan Regarding FERC Order No. 901

Forum for the Implementation of Reliability Standards for Transmission

Alex Shattuck, Senior Engineer
May 28, 2024

Order 901 Summary

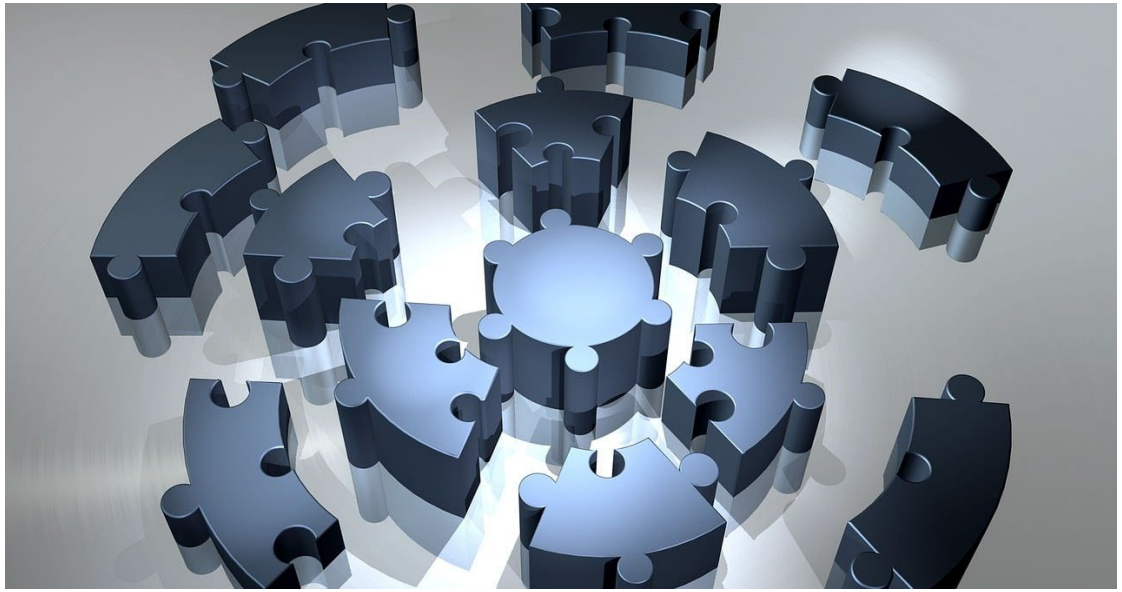
- FERC Order 901
  - Issued October 2023
  - Includes 4 Milestones dates through November 2026
  - Addresses a wide spectrum of IBR related performance issues and Reliability Standards
  - Brings forward RSTC guidance and expertise into standards projects

Overall Approach

- Key Factors Included in Strategy
  - Ongoing prioritization of NERC Standards Projects
  - Continual coordination between NERC Engineering, Legal, and Standards
  - Frequent communication to industry
  - Balancing other Projects, FERC directives, and risks to the BPS

Continual Coordination

- Continual coordination between NERC Engineering, Legal, and Standards
  - Assure new SARs meet all FERC directives and NERC expectations
  - Assure upstream/downstream projects coordinate between developers and the drafting team leadership
- Assure that approach to new SARs account for existing projects.
- Assure performance-based modeling can be built throughout and is effective.



Frequent Communication

- Frequent communication to industry
  - Maintain single source location for information updates on 901 development
  - Coordinate updates with other IBR related efforts (new registrations)
  - Updates to FERC
  - Updates to MRC and NERC Board of Trustees (including new BOT Regulatory Oversight Committee)
  - Updates to Standards Committee and subcommittees
  - Individual Project pages
  - Information included with Formal/Informal Comment Period Announcements
  - Individual/joint Standard Project webinars
  - Updates to RSTC/IRPTF/SPIDERWG

Frequent Communication

Quick Reference Guide: IBR Registration Initiative

February 2024

As part of its *Inverter-Based Resource Strategy*, NERC is dedicated to identifying and addressing challenges associated with inverter-based resources (IBR) as the penetration of these resources continues to increase. ERO Enterprise assessments identified a reliability gap associated with the increasing integration of IBRs as part of the grid in which a significant level of bulk power system-connected IBR owners and operators are not yet required to register with NERC or adhere to its Reliability Standards.

In response, FERC issued an order in 2022 directing NERC to identify and register owners and operators of currently unregistered bulk power system-connected IBRs. Working closely with industry and stakeholders, NERC is executing a FERC-approved work plan to achieve the identification and registration directive by 2026. Resources are also posted on the Registration page of the NERC website.

Key Activity

- NERC submitted its quarterly work plan update to FERC on February 12.
- NERC's Board of Trustees approved proposed Rules of Procedure revisions on February 22.
- NERC plans to submit these proposed revisions to FERC in early March.

IBR Registration Milestones

Phase 1: May 2023–May 2024

- Complete Rules of Procedure revisions and approvals
- Commence Category 2 GO and GOP candidate outreach and education (e.g., through trade organizations)

Phase 2: May 2024–May 2025

- Complete identification of Category 2 GO and GOP candidates
- Continue Category 2 GO and GOP candidate outreach and education (e.g., quarterly updates, webinars, workshops, etc.)

Phase 3: May 2025–May 2026

- Complete registration of Category 2 GO and GOP candidates thereafter subject to applicable NERC Reliability Standards
- Conduct specific Category 2 GO and GOP outreach and education (e.g., quarterly updates, webinars, workshops, etc.)

LEARN MORE ABOUT NERC AND THE E-ISAC

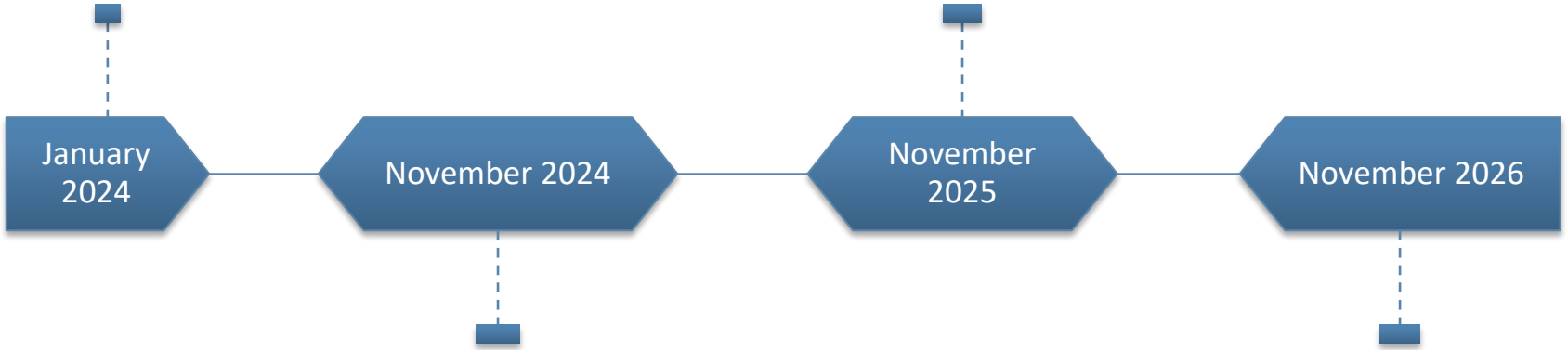
Available Resources

- Frequently Asked Questions – Rules of Procedure Approach to Registration of Unregistered IBRs
- IBR Webinar Series and FAQs
- Quick Reference Guide: Candidate for Registration
- Quick Reference Guide: Inverter-Based Resource Activities
- NERC Registration Page
- Join the E-ISAC

General Milestone Summary

Milestone 1: Submit Information Work Plan

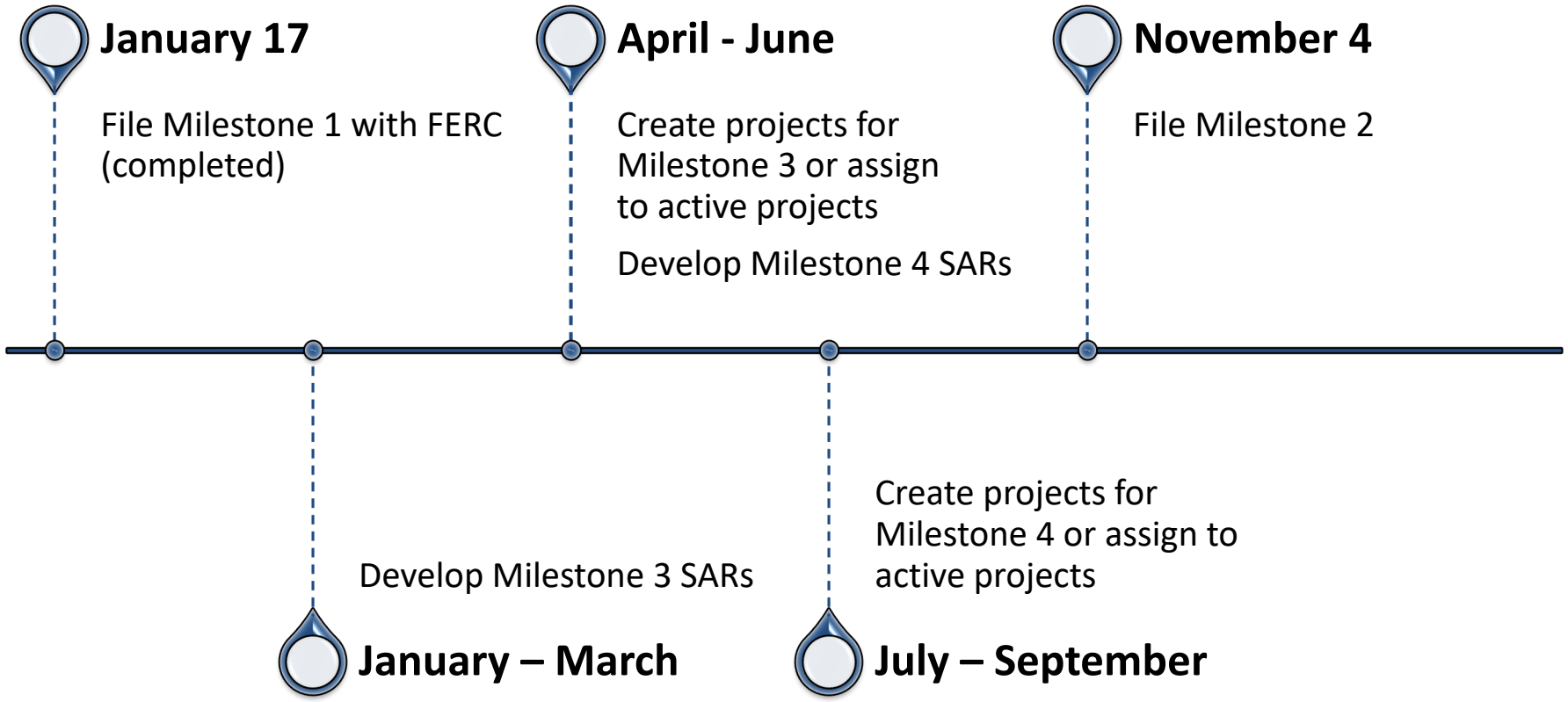
Milestone 3: Modeling Data Sharing and Validation based on Performance



Milestone 2: IBR Performance based on disturbance monitoring data requirements and post-event analytics

Milestone 4: New Requirements for Operational and Planning Studies to Leverage Performance Data

Next Steps – 2024 Timeline



Milestone 3: Data Sharing and Model Validation

File November 2025

- **Complete Active Projects:**
  - Project 2022-02 Modifications to TPL-001-5.1 and MOD-032-1
  - Project 2023-05 FAC-001, FAC-002
  - Project 2023-08 MOD-031 Demand and Energy
  - Project 2020-06 Verifications of Models and Data for Generators
  - Project 2021-01 Modifications to MOD-025 and PRC-019
- **Complete New Projects to address**:
  - Data Sharing for Registered IBRs, Unregistered IBRs, and DERs

2025 Stretch Targets

- **Create SARs (as needed) and begin new Projects to address Planning and Operational Studies for**:
  - Unregistered IBRs, DER, and use of performance data
- **Perform Gap Analysis on downstream data impacts**

Milestone 4: Planning and Operational Studies

File November 2026

- **Complete Active Projects:**
  - Project 2022-02 (Modifications to TPL-001-5.1 and MOD-032-1)
  - Project 2022-03 (Energy Assurance with Energy-Constrained Resources),
  - Project 2023-07 (Transmission System Planning Performance Requirements for Extreme Weather
- **Complete New Projects to address Planning and Operational Studies for**:
  - Registered IBRs, Unregistered IBRs, and DERs

2026 Stretch Targets

- Complete Project 2022-04 (EMT Modeling)
- Integrate EMT Modeling into:
  - Model validation processes
  - Operational and Planning assessments

Questions and Answers

Feel free to reach out to us if interested in participating in the NERC IRPS or EMTTF!

alex.shattuck@nerc.net

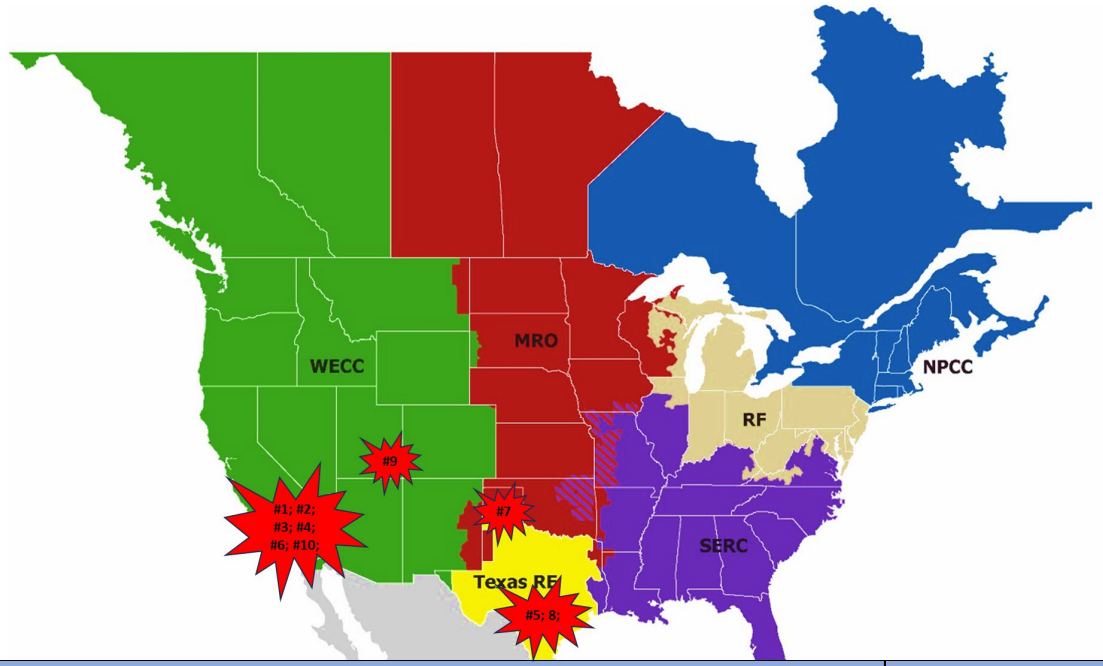
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC Disturbance Reports and Reliability Guidance

i2X Forum for the Implementation of Reliability Standards for Transmission

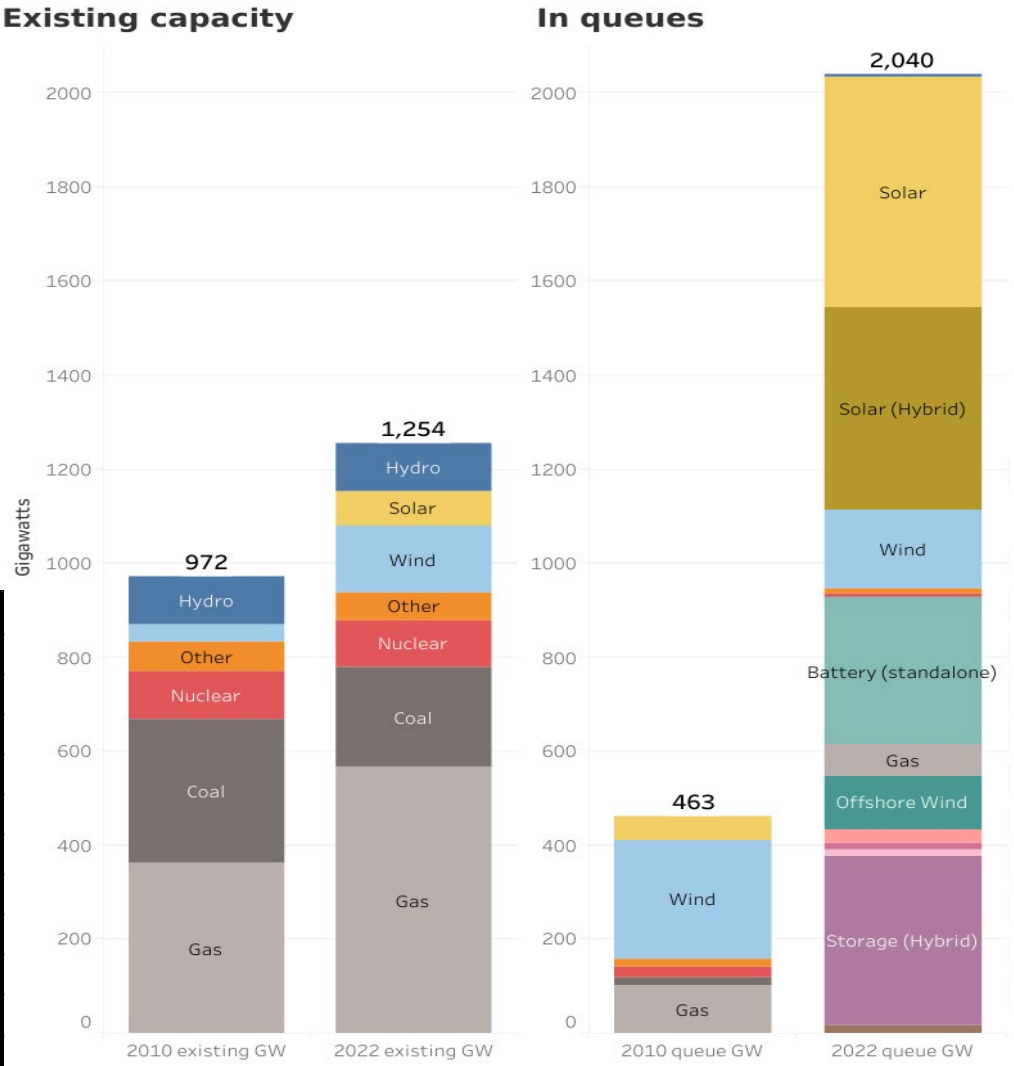
Alex Shattuck, Senior Engineer
May 28, 2024

NERC Disturbances and Motivation



Disturbance		IBR Reduced (MW)	Year
#1	Blue Cut Fire	1,753	2016
#2	Canyon 2 Fire	1,619	2017
#3	Angeles Forest & Palmdale Roost	1,588	2018
#4	San Fernando	1,205	2020
#5	Odessa, 2021	1,112	2021
#6	Victorville; Tumbleweed; Windhub; Lytle Creek Fire	2,464	2021
#7	Panhandle Wind	1,222	2022
#8	Odessa, 2022	1,711	2022
#9	Southwest Utah	921	2022
#10	California Battery Energo Storage	906	2023
Total Reduced Output (MW)		14,501	

Source: LBL.GOV
Generation, Storage, and Hybrid Capacity in Interconnection Queues



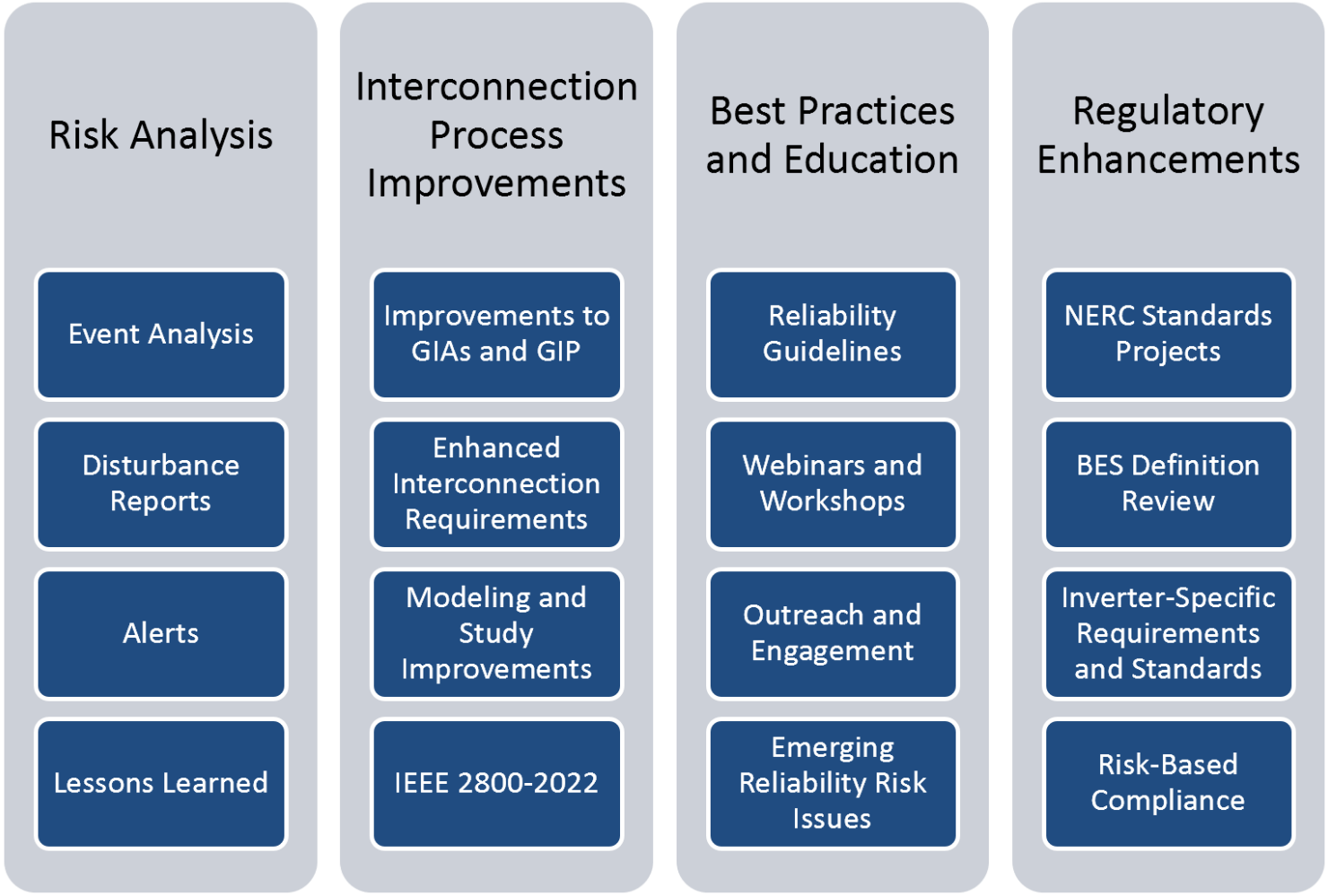
490GW

430GW

312GW

357GW

NERC IBR Strategy



NERC IBR Strategy

NERC Alert on IBR Performance

- Alert findings showed that **the voluntary recommendations set forth in NERC guidelines and other publications are not being implemented.**
- Many Generator Owners indicated that they did not have requested data readily available
- ~5,200 MW of bulk electric system IBR have voltage and frequency settings within NERC PRC-024 “no trip zone”
- ~25% of the reported facilities use ride through modes that do not support BPS reliability
- ~33% of the reported facilities use a “triangle-shaped” reactive power capability curve, leaving significant reactive resources underutilized

Questions and Answers

Feel free to reach out to us if interested in participating in the NERC IRPS or EMTTF!

alex.shattuck@nerc.net

IEEE P2800.2 Overview for i2X FIRST

ANDY HOKE, P2800.2 WG CHAIR
MANISH PATEL, SECRETARY
JENS BOEMER, BOB CUMMINGS, DIVYA CHANDRASHEKHARA,
JULIA MATEVOSYAN, MAHESH MORJARIA, STEVE WURMLINGER, VICE CHAIRS

May 28, 2024

Some content derived from IEEE 2800 WG and Jens Boemer, 2800 WG Chair

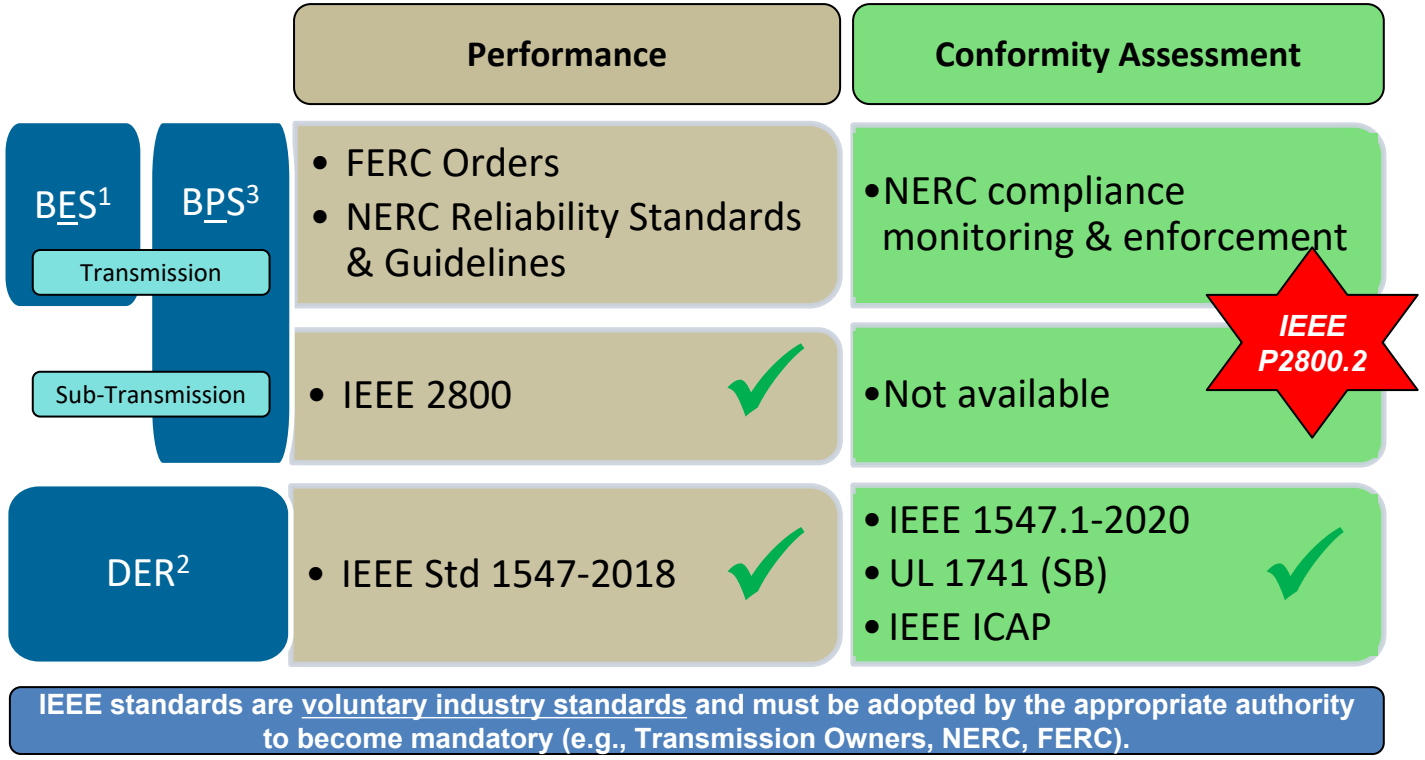
Acknowledgements and disclaimers

- General disclaimer:
  - The views presented in this presentation are the personal views of the individuals presenting it and shall not be considered the official position of the IEEE Standards Association or any of its committees and shall not be considered to be, nor be relied upon as, a formal position of IEEE, in accordance with IEEE Standards Association Standards Board Bylaws 5.2.1.6.

- Draft standard disclaimer:
  - P2800.2 is an unapproved draft of a proposed IEEE Standard. As such, the document is subject to change, any draft requirements and figures shown in this presentation may change.

- For those working group members whose effort on the standard was partially or fully supported by the U.S. DOE's National Renewable Energy Laboratory, the following statement applies:
  - This work was supported in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office and Wind Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

IEEE P2800.2 Objective: Filling Gaps in North American Interconnection Standards for Inverter-Based Resources



[1] NERC definition of Bulk Electric System: ≥100 kV with gross individual / aggregate nameplate rating greater than 20 MVA / 75 MVA

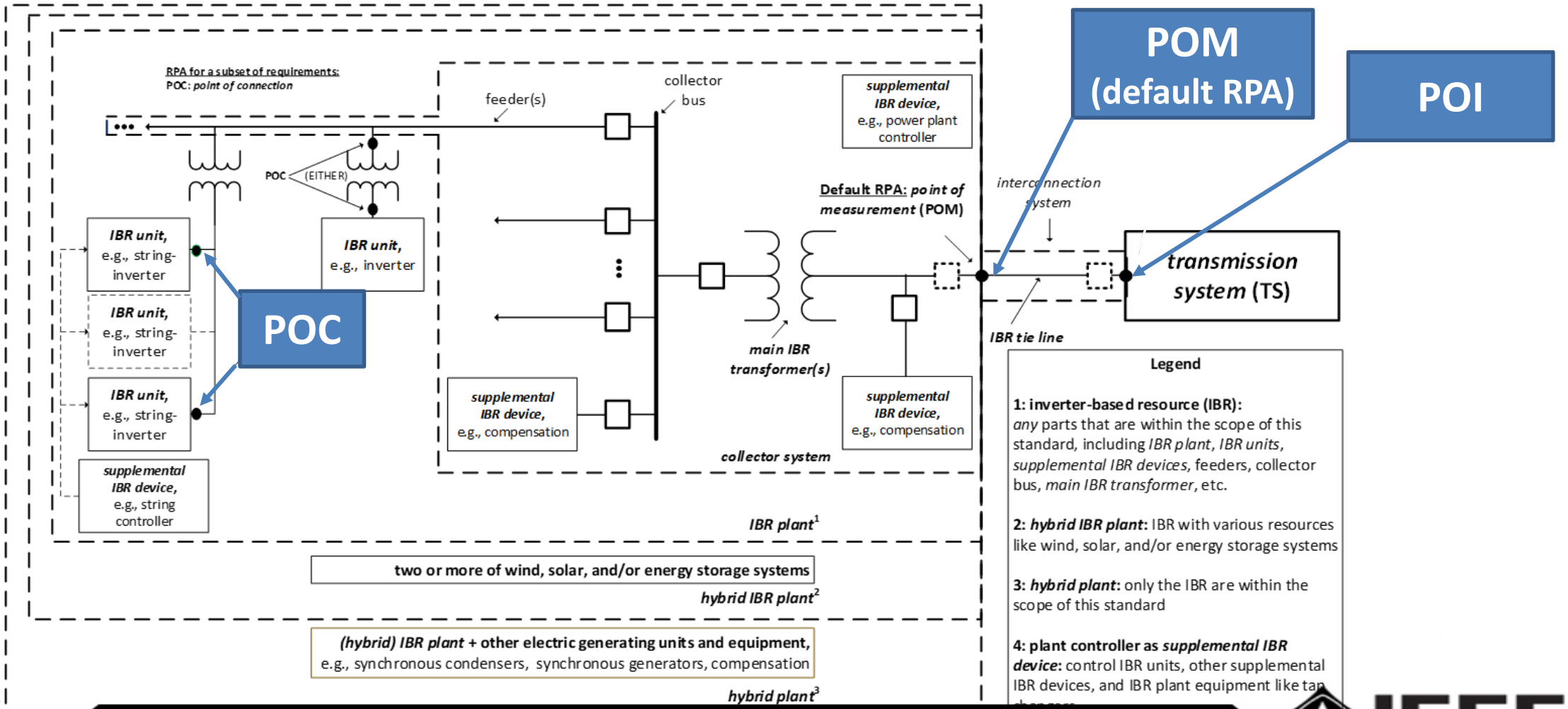
[2] DER connected at typical (radial) primary and secondary voltage levels

[3] transmission and meshed sub-transmission

Slide modified from Jens Boemer, EPRI

Role of P2800.2 in IEEE 2800 Adoption

Almost all **requirements of IEEE 2800 apply at Point of Measurement (POM)** by default



Overview of conformity assessment steps in IEEE P2800.2

Type Tests

Lab or field tests of individual IBR unit for model validation

IBR Unit Model Validation

Based on type test data

IBR Plant Model Development

Based on validated IBR unit model(s) and balance of plant

IBR Plant Design Evaluation

Simulations to assess plant conformity to IEEE 2800

Design Evaluation

Plant construction complete

As-built Installation Evaluation

Verification of installed plant

Commissioning Tests

Partial field assessment of plant performance

Post-commissioning Monitoring

Monitoring of plant performance during grid events

Post-Commissioning Model Validation

Based on commissioning test data

Periodic Tests and Verifications

This is a general diagram of the process. Details are under development in IEEE P2800.2. Some variations permitted.

P2800.2 – Paradigm shift?

- Note that:
  - Key interconnection requirement conformity assessment steps occur *before* commissioning
  - Models that accurately represent plant performance are needed *before* plant comes online

- Why?
  - IBR performance and model validation are essential to reliability of evolving power system
  - Once an IBR is commissioned, it can be costly to fix any issues. Power system is changing fast.
- Is this going to be easy?
  - Probably not
- But if we do a good job, P2800.2 (along with other ongoing industry efforts) can:
  - Offer a standardized industry-wide practice for IBR conformity assessment
  - Reduce risk of major IBR-related grid events
  - Minimize future need for costly retrofits
  - Help ensure the near-future, highly renewable grid is at least as reliable as today's

P2800.2 – Relationship to the IBR interconnection process

- Defining (or re-defining) an interconnection process is not in the scope of IEEE P2800.2
- Procedures recommended by P2800.2 are intended to be used *as part of* an interconnection process:
  - P2800.2 type tests can inform interconnection process
  - P2800.2 design evaluation, commissioning tests, and post-commissioning model validation can occur during interconnection process (along with other steps not in scope of P2800.2)

Equipment certification?

- Almost all requirements in IEEE 2800 apply to the IBR plant (not the inverter/WTG)
- The type tests in IEEE P2800.2 do not generally have pass/fail criteria.
  - Instead, they generate data (e.g. test waveforms) to validate the unit-level model.
- Certification of inverters/WTGs to 2800 is not applicable because compliance is at the plant level
  - Required unit-level capabilities depend strongly on balance of plant
- Therefore **an "IEEE 2800 *certified* inverter/WTG" probably will not exist**
  - Instead, inverters/WTGs could perhaps be considered "2800 compatible" if 2800 requirements have been taken into consideration so that they can be used to build a 2800-compliant plant.
- This is different from the IEEE 1547/1547.1/UL 1741 paradigm on the distribution system, where pass/fail type tests and NRTL certification play a large role in conformity assessment

IEEE P2800.2 Subgroup Scopes

SG 1

Overall document and general requirements

Excerpt of 2800 Table 20: Verification Methods Matrix

Requirement	RPA at which requirement applies	SG 2 Type tests: *IBR unit*-level tests (at the POC)	SG 3 Design Evals.	SG 4 Commissioning and As-built: *IBR plant*-level verifications (at the RPA)		SG 5 Post-commissioning model validation, monitoring, etc.: *IBR plant*-level verifications (at the RPA)			
		Type tests[152]	Design evaluation (including modeling for most require-ments)	As-built installation evaluation	Commissioning tests	Post-commissioning model validation	Post-commission-ing monitoring	Periodic tests	Periodic verification
		Responsible Entity							
		IBR unit or *supplemental IBR device* manufacturer	*IBR developer / TS owner / TS operator*	*IBR developer / TS owner / TS operator*	*IBR developer / TS owner / TS operator*	*IBR developer / IBR operator / TS owner / TS operator*	*IBR operator / TS owner / TS operator*	*IBR operator / TS owner / TS operator*	*IBR operator / TS owner / TS operator*
4.12 Integration with TS grounding	POM	NR	R	R	NR	NR	NR	D	NR
Clause 5 Reactive Power—Voltage Control Requirements within the Continuous Operation Region									
5.1 Reactive power capability	POM	R	R	R	R	R	D	D	D
5.2 Voltage and reactive power control modes	POM	D	R	R	R	R	D	D	D
Clause 6 Active-Power – Frequency Response Requirements									
6.1 Primary Frequency Response (PFR)	POC & POM	NR[153]	R	R	R	R	D	D	D
6.2 Fast Frequency Response (FFR)	POC & POM	R[154]	R	R	R	R	D	D	D
Clause 7 Response to TS abnormal conditions									
7.2.2 Voltage disturbance ride-through requirements	POC[155] & POM[156]	R	R	R	NR	R	R	D	D
Clause 8 Power quality									
8.2.2 Rapid voltage changes (RVC)	POM	NR	R	R	R	D	R	D	D
8.2.3 Flicker	POM	NR	NR	NR	R	D	R	N/A	D
8.3.1 Harmonic current distortion	POM	R[157]	R	R	R	D	R	N/A	D
~~8.3.2 Harmonic voltage distortion~~	POM	D	D	D	D	D	D	D	D
8.4.1 Limitation of cumulative instantaneous over-voltage	POM	R	R	R	NR	NR	R	NR	NR
8.4.2 Limitation of over-voltage over one fundamental frequency period	POM	D	R	R	NR	NR	R	NR	NR

Power Quality Task Force

IEEE PES Power & Energy Society®

IEEE P2800.2 Structure and Leaders

Subgroup	Vice Chair	Subgroup Chair(s)
2: Type tests	Steve Wurmlinger Stephen.Wurmlinger@sma-america.com	Pramod Ghimire, Michael Ropp
3: Design evaluations	Jens Boemer j.c.boemer@ieee.org	Andrew Isaacs, Alex Shattuck
4: Commissioning and as-built evaluation	Divya Chandrashekhara DKUCH@orsted.com	Chris Milan, Dave Narang
5: Post-commissioning model validation and monitoring, and periodic tests and verifications	Julia Matevosyan julia@esig.energy	Jason MacDowell, Brad Marszalkowski

Lead subgroup and coordinate with other subgroups

Facilitate subgroup calls

Draft specific verification procedures with subgroup input

Most of the detailed work occurs in the subgroups and task force via periodic calls

Chair	Andy Hoke Andy.Hoke@nrel.gov
Secretary	Manish Patel Manish.P@ieee.org
Vice Chair	Bob Cummings
Vice Chair	Mahesh Morjaria

Compile drafts; Lead Subgroup 1 (overall document and general requirements)

Lead overall WG

Power Quality Task Force	
Co-Lead	Eugen Starschich
Co-Lead	David Mueller

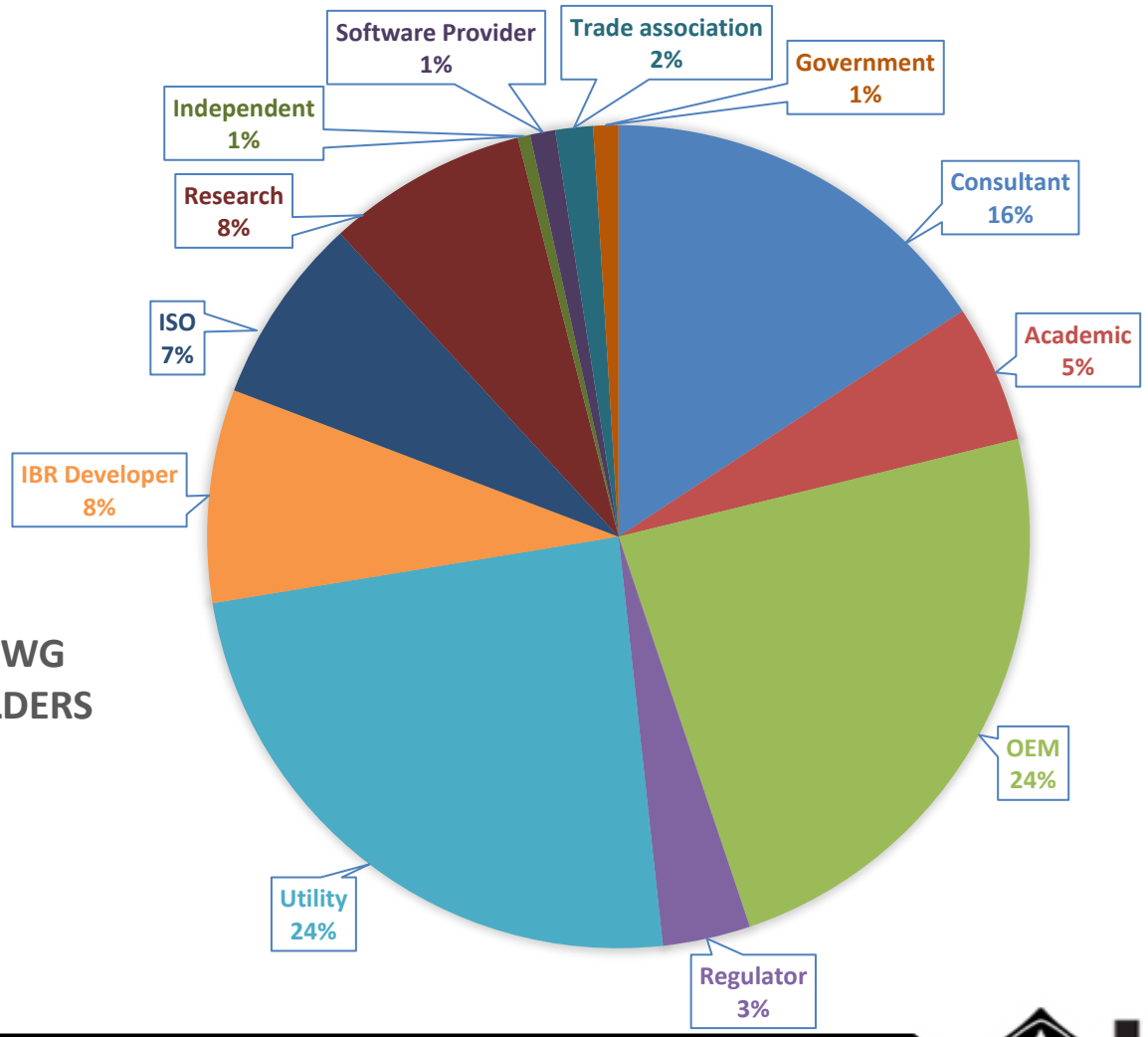
Provide input to subgroups on PQ requirements verification

IEEE PES Power & Energy Society®

IEEE

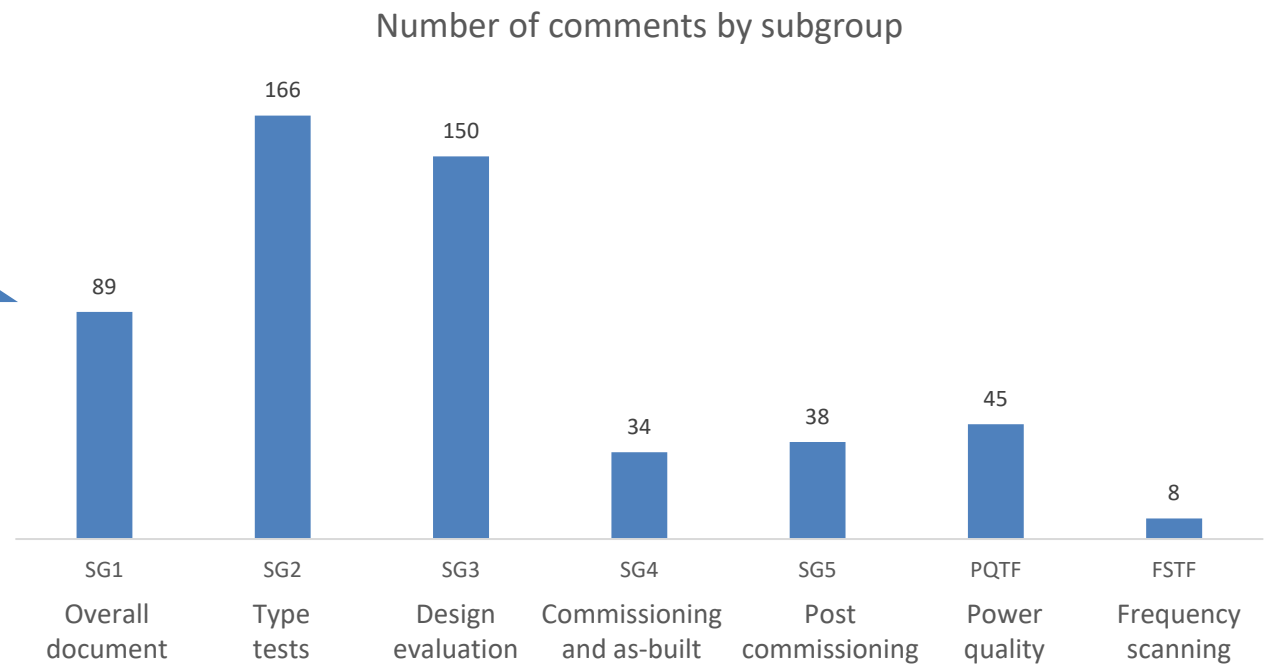
P2800.2 Working Group Membership

- 160 Voting members
- 45 Non-voting members
- All major stakeholder groups represented



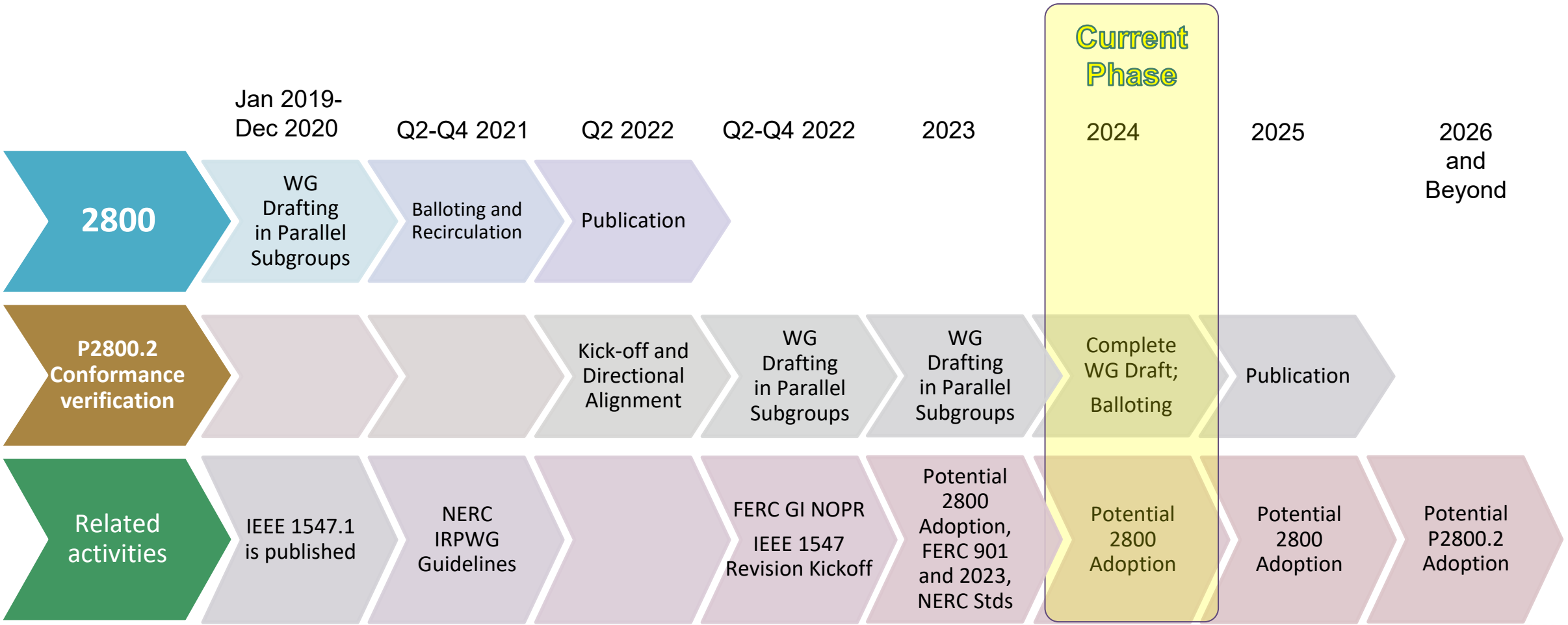
P2800.2 status

- >90% of content is complete
- 7th Working Group meeting held April 30-May 2, 2024
- 530 formal comments received on May 22
  - First round of comments on nearly complete draft
- Over next 3-4 months, subgroups and task force will:
  - Address comments
  - Fill in remaining content
- Near-final draft expected in early fall



P2800.2 WG Timeline

Potential Adoption Timeline



To get involved in IEEE P2800.2:

- To join Working Group:
  - If you have attended two WG meetings and want to be a WG voting member, email Manish Patel: Manish.P@ieee.org; CC Andy.Hoke@nrel.gov
  - If not, attend two meetings and request membership
- Join listserv for any subgroup or task force of interest
- WG member iMeet site: https://ieee-sa.imeetcentral.com/p2800-2/home
  - Contains draft documents, subgroup documents, references, etc.
- Public website: https://sagroups.ieee.org/2800-2/

IEEE P2800.2 Email Listservs

- Overall listserv "P2800-2" will be used to communicate meeting dates, agendas, etc.
- Each subgroup and PQ task force each have listserv – sign up to get involved in that group:
  - Overall Working Group: P2800-2
  - Subgroup 1 (overall document): STDS-P2800-2-SG1
  - Subgroup 2 (type tests): STDS-P2800-2-SG2
  - Subgroup 3 (design evaluation): STDS-P2800-2-SG3
  - Subgroup 4 (commissioning and as-built): STDS-P2800-2-SG4
  - Subgroup 5 (post-commissioning): STDS-P2800-2-SG5
  - Power quality task force: STDS-P2800-2-PQTF
- To join a listserv, send an email message to listserv@listserv.ieee.org
  - In first line of email body, write: ***SUBSCRIBE <list name> <Your Name>***
  - For example, "SUBSCRIBE STDS-P2800-2-SG1 Andy Hoke"