IEEE 2800-2022

Standard for Interconnection and Interoperability of IBR Interconnecting with Transmission Systems

ERCOT Inverter-Based Resources Task Force (IBRTF)

Jens Boemer, EPRI
IEEE P2800 Working Group Chair

Remotely from Seattle, WA
March 18, 2022

Classification: Public

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- Part of 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.
- Part of this work is supported by the U.S. Department of Energy, Solar Energy Technologies Office under Award Number DE-EE0009019 Adaptive Protection and Validated MODels to Enable Deployment of High Penetrations of Solar PV (PV-MOD).
- The views expressed in the presentation do not necessarily represent the views of the **DOE or the U.S. Government**.

Reliability Issues with IBR

Several IBR-based system disturbances have and continue to occur:

- August 2016 – Blue Cut Fire Disturbance
- October 2017 – Canyon 2 Fire Disturbance
- April and May 2018 – Angeles Forest & Palmdale Roost Disturbances
- July 2020 – San Fernando Disturbance
- May and June 2021 – Odessa, TX Disturbances

Disturbance Analyses and Guidelines

- ➢ Detailed Analysis of IBR-Based disturbances
- ➢ Two Level 2 NERC Alerts Issued with industry recommendations
- ➢ Reliability Guideline for BPS-connected IBR resources

- ➢ **Odessa Disturbance recommendations call for more than guidelines**

Paradigm shift towards the “Good Citizen”

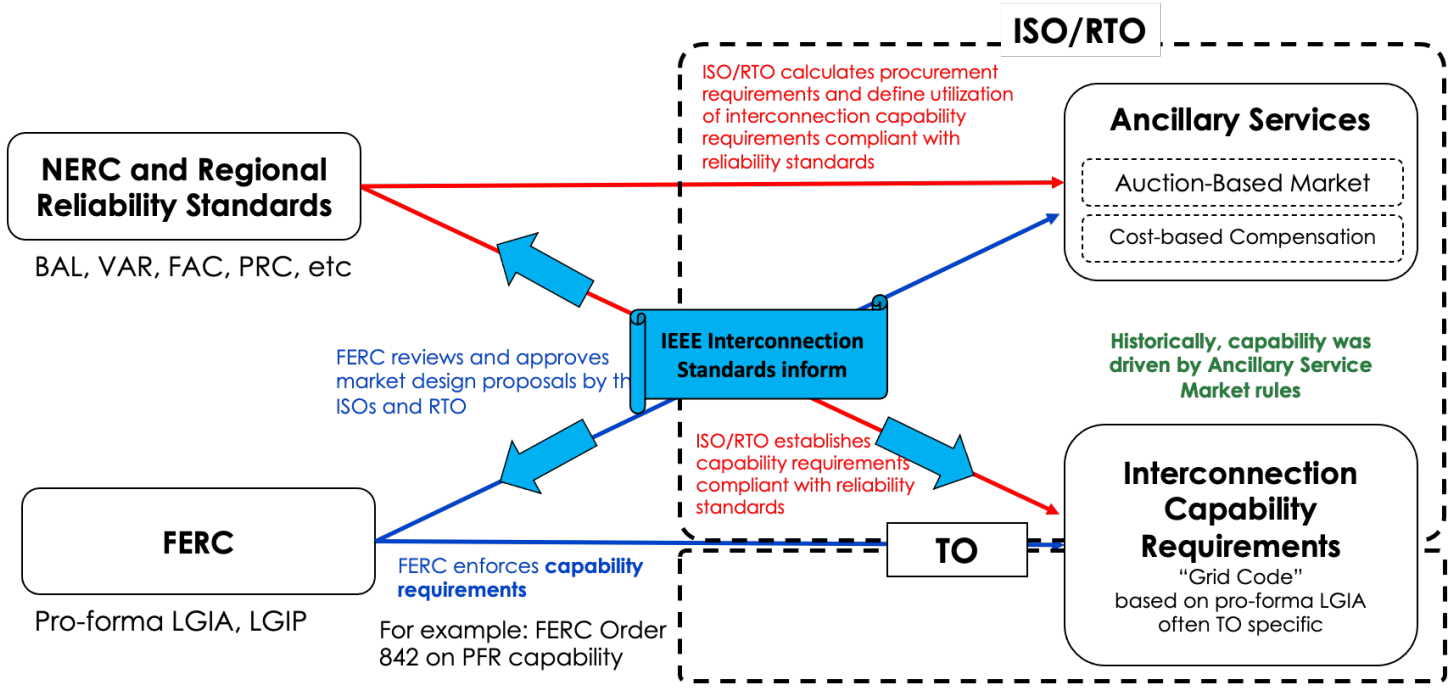
Example Reliability Solutions

- Grid Related Solutions
  - Transmission upgrades
  - Innovative transmission assets
- IBR Related Solutions
  - IBR capability requirements for new plants
  - Curtailment of IBR output
  - Retrofits of existing IBR plants
    - Software patches
    - Hardware retrofits

Cost allocation

- Last resource tends to bear costs

Status Quo: Integration of capability often subject to service agreement



➢ Integrating a **minimum set of IBR capability** from the day of plant commissioning allows for many IBR plants to share the burden and opportunities of a potential **future utilization** of that capability.

Difference between IBR Capability and Utilization

Capability:
"Ability to Perform"

- Functions & controls
- Ranges of available settings
- Minimum performance specifications

Examples

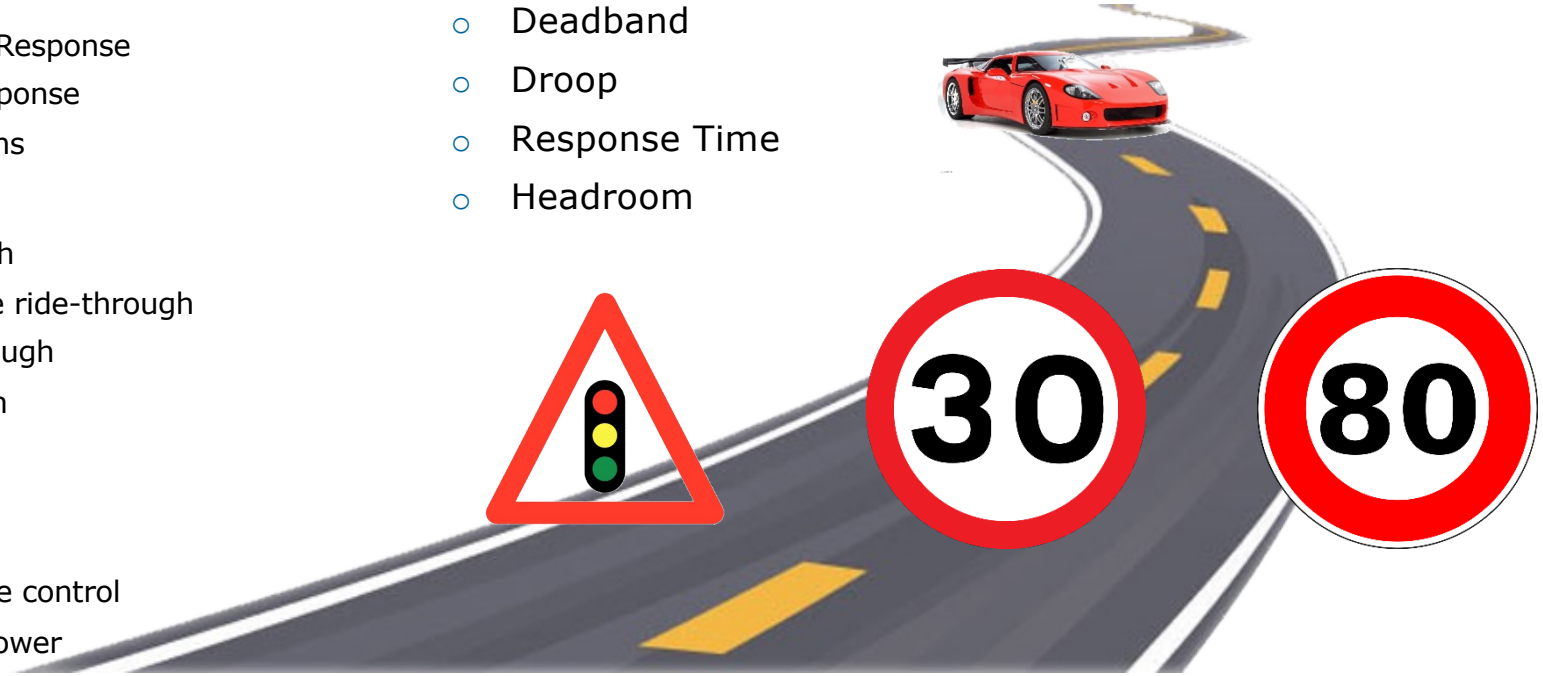
- Frequency Response
  - Primary Frequency Response
  - Fast Frequency Response
  - Ramp rate limitations
- Ride-Through
  - Voltage ride-through
  - Consecutive voltage ride-through
  - Frequency ride-through
  - ROCOF ride-through
  - Phase angle jump ride-through
- Voltage Support
  - Steady state voltage control
  - Dynamic reactive power
  - (Un-)balanced current injection during ride-through

Utilization of Capability:
"Delivery of Performance"

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

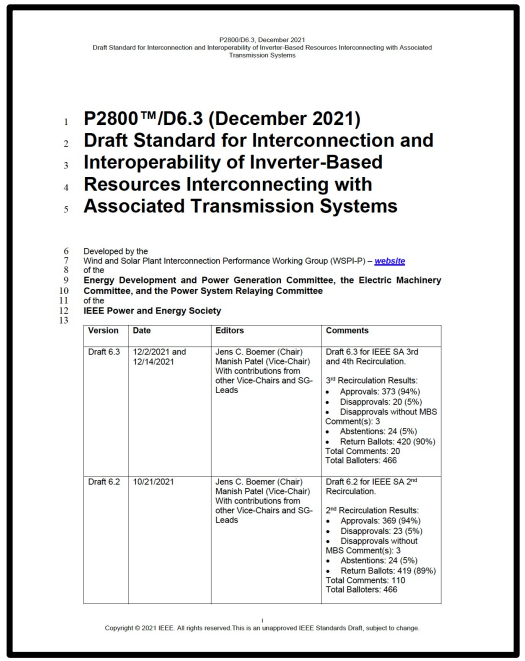
Examples

- Deadband
- Droop
- Response Time
- Headroom



Common Ground: IEEE 2800-2022

- **Harmonizes technical minimum capability** for Large Solar, Wind, and Storage Plants at the time of interconnection, including those connected via VSC-HVDC like offshore wind
  - Could create a “level playing field” for IBR developers, *if adopted*
- A **consensus-based, voluntary IEEE performance standard**
  - Developed by over 175 working group participants from transmission owners, OEMs, developers, and consultants
  - Successfully passed the industry peer review by 466 IEEE SA balloters **(>94% approval**, >90% response rate)
- Approved in January 2022, **publication in April/May 2022**



P2800/D6.3, December 2021
Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Systems

P2800™/D6.3 (December 2021)
Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Systems

Developed by the
Wind and Solar Plant Interconnection Performance Working Group (WSPI-P) – website
of the
Energy Development and Power Generation Committee, the Electric Machinery Committee, and the Power System Relaying Committee
of the
IEEE Power and Energy Society

Version	Date	Editors	Comments
Draft 6.3	12/2/2021 and 12/14/2021	Jens C. Boemer (Chair) Manish Patel (Vice-Chair) With contributions from other Vice-Chairs and SG-Leads	Draft 6.3 for IEEE SA 3rd and 4th Recirculation. 3rd Recirculation Results: • Approvals: 373 (94%) • Disapprovals: 20 (5%) • Disapprovals without MBS Comment(s): 3 • Abstentions: 24 (5%) • Return Ballots: 420 (90%) Total Comments: 20 Total Balloters: 466
Draft 6.2	10/21/2021	Jens C. Boemer (Chair) Manish Patel (Vice-Chair) With contributions from other Vice-Chairs and SG-Leads	Draft 6.2 for IEEE SA 2nd Recirculation. 2nd Recirculation Results: • Approvals: 369 (94%) • Disapprovals: 23 (5%) • Disapprovals without MBS Comment(s): 3 • Abstentions: 24 (5%) • Return Ballots: 419 (89%) Total Comments: 110 Total Balloters: 466

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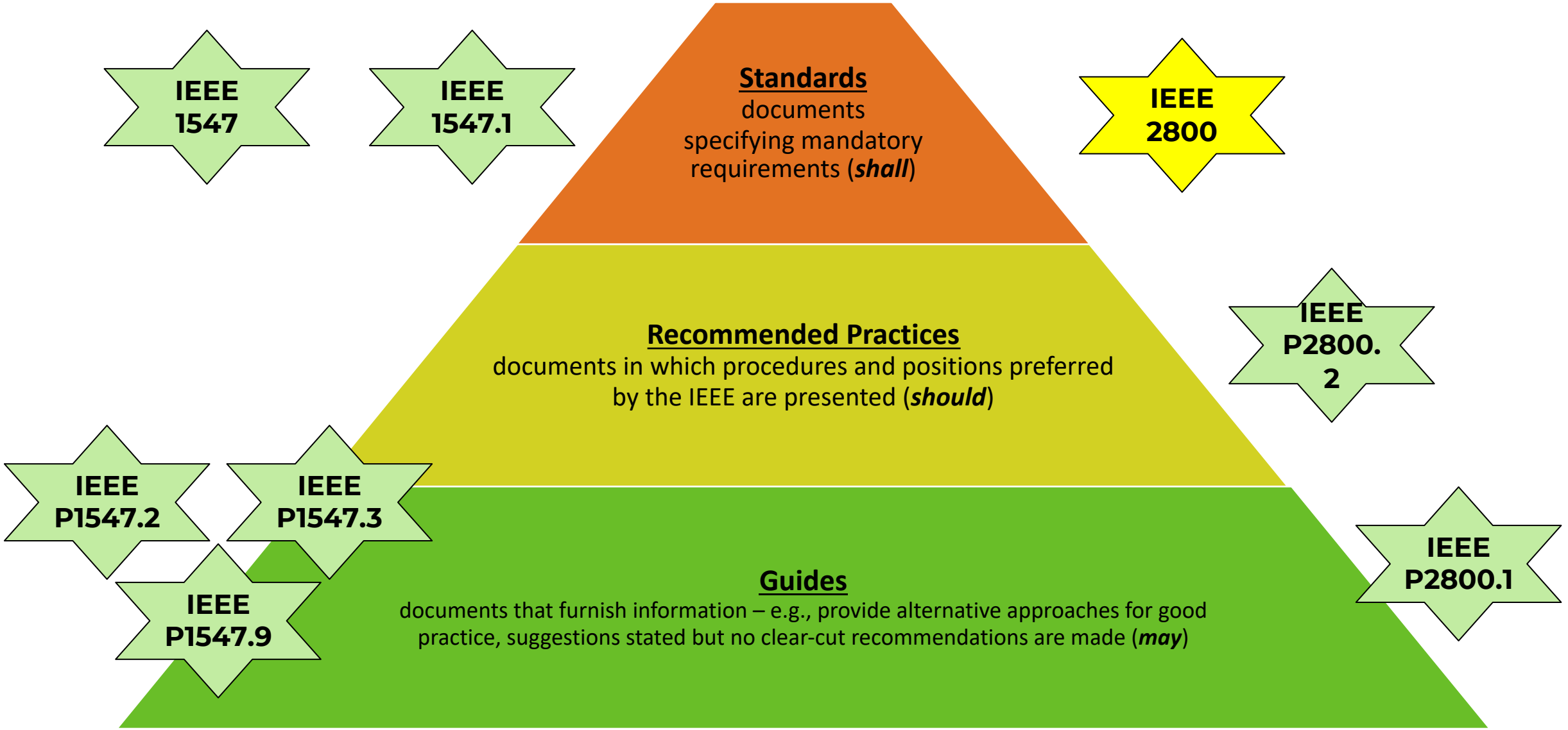
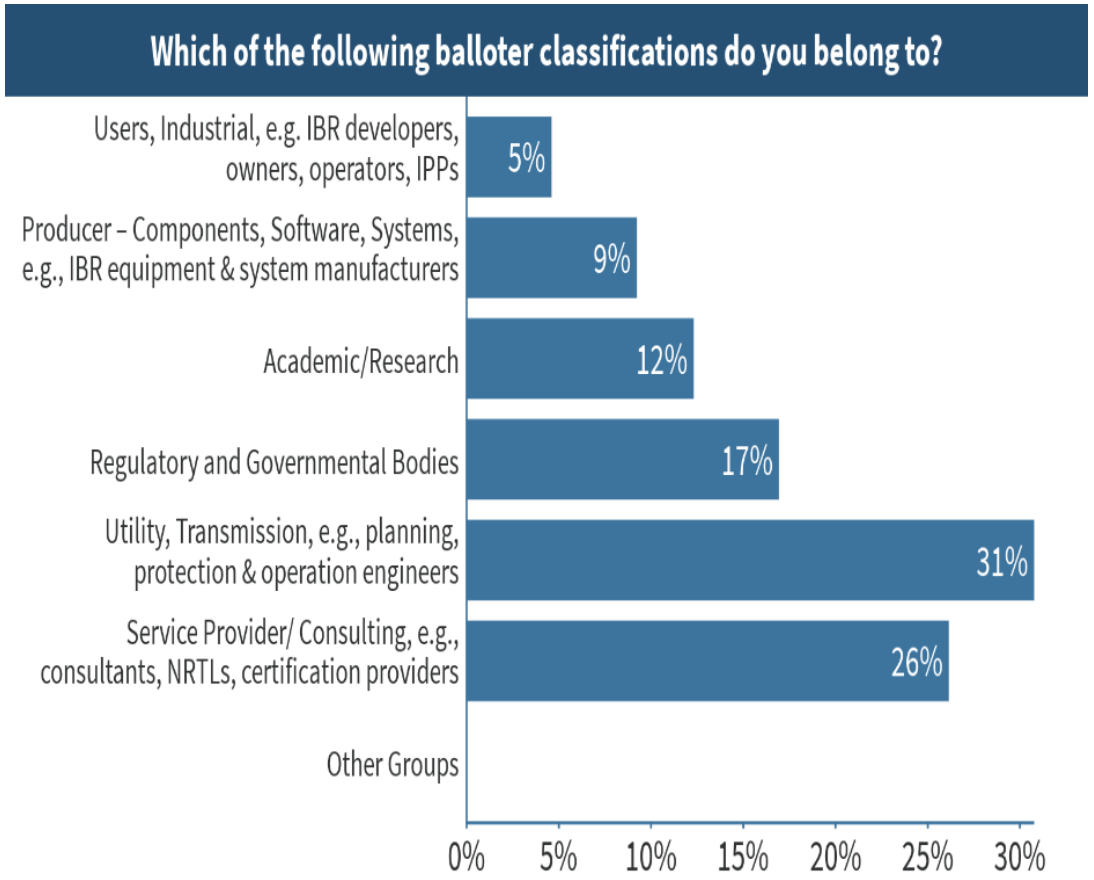
Latest draft is available from IEEE at https://standards.ieee.org/project/2800.html

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

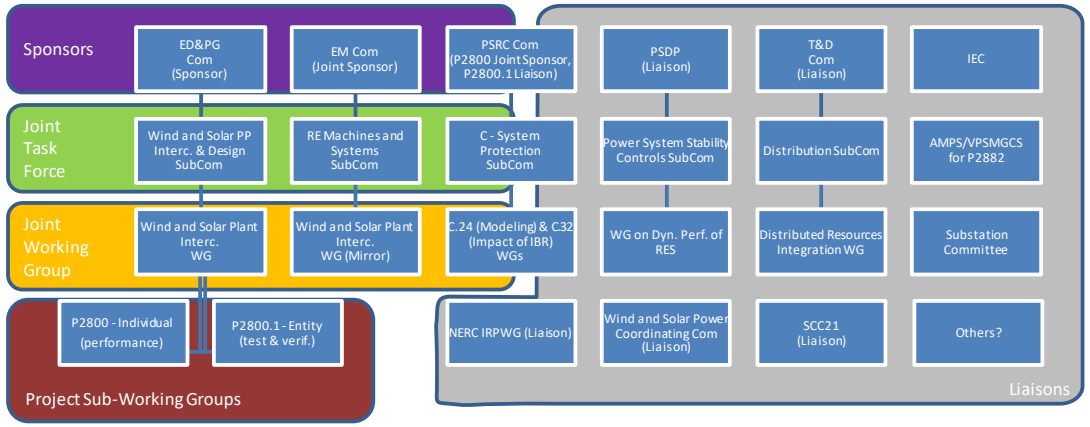
IEEE Standards Classification and Consensus Building



Diversity of Stakeholder Contributions

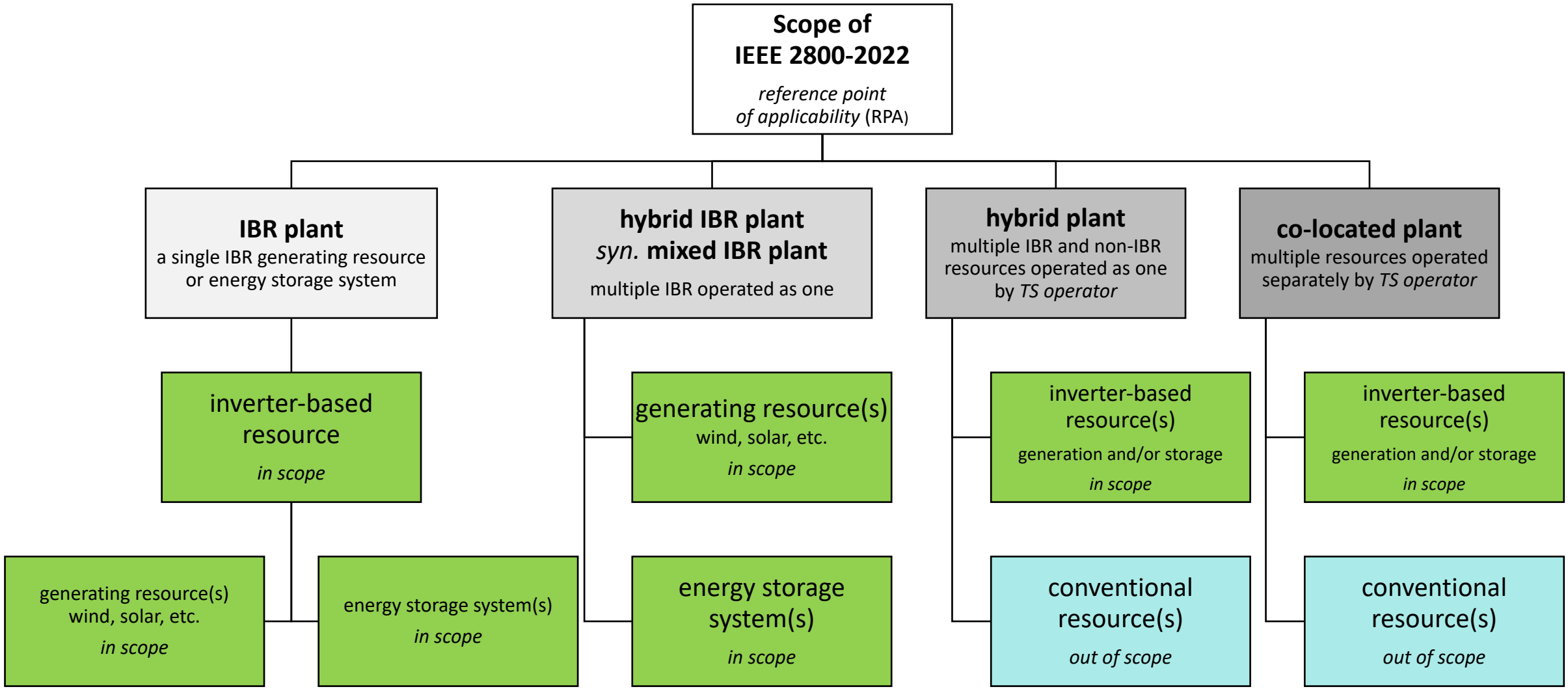


Broad Collaboration & Coordination within IEEE



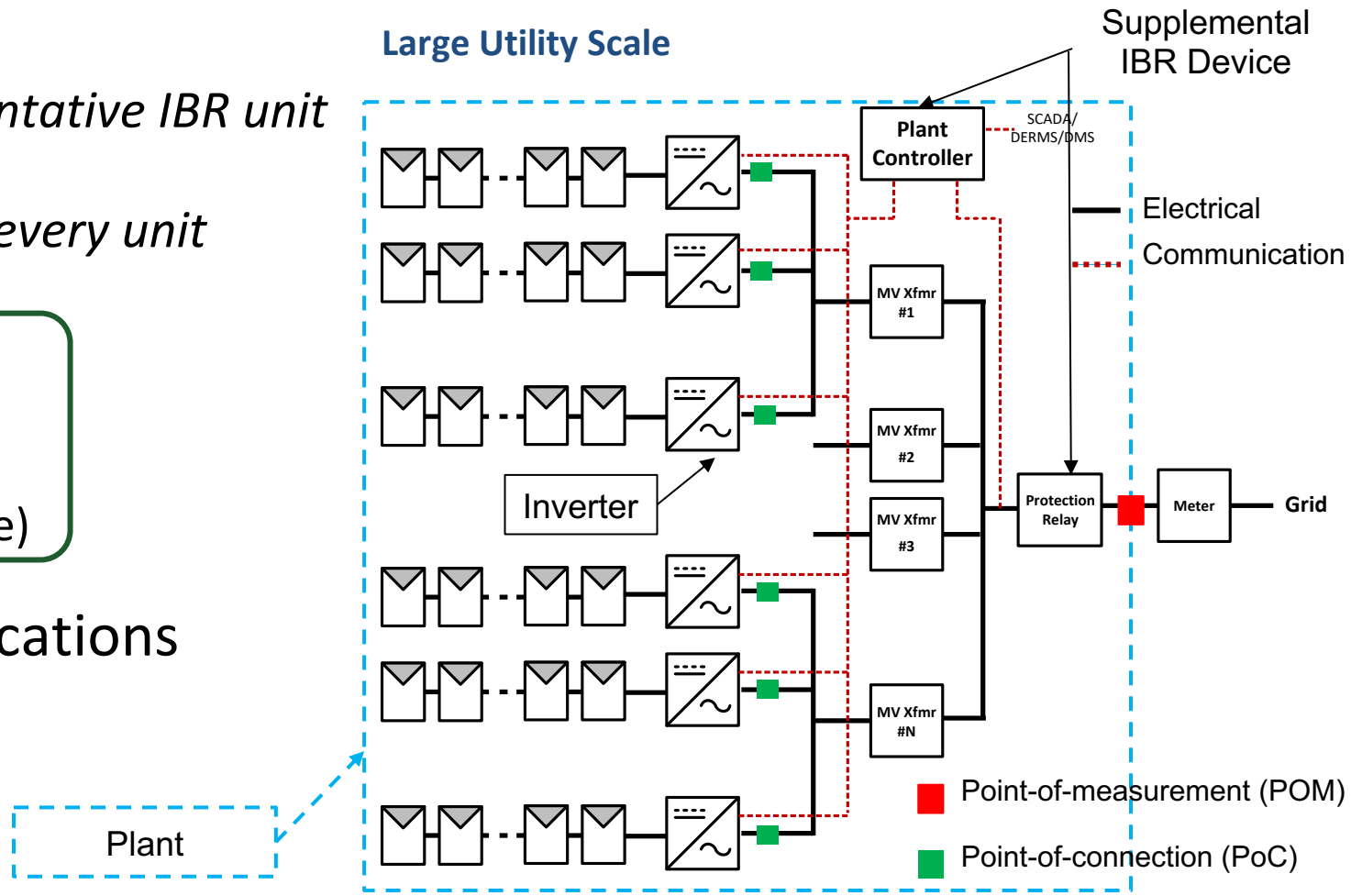
- IEEE/PES/EDPG Main Sponsor
- IEEE/PES/EMC & PSRC Joint Sponsors
- HVDC-VSC Subject Matter Experts
- IEEE/PES/Substations Committee SMEs
- IEEE/PES/Analytic Methods for Power Systems (AMPS) SMEs
- NERC Inverter-Based Resources Performance WG SMEs

Applicable Resources in Scope of IEEE 2800-2022



IEEE 2800-2022 Test and Verification Methods

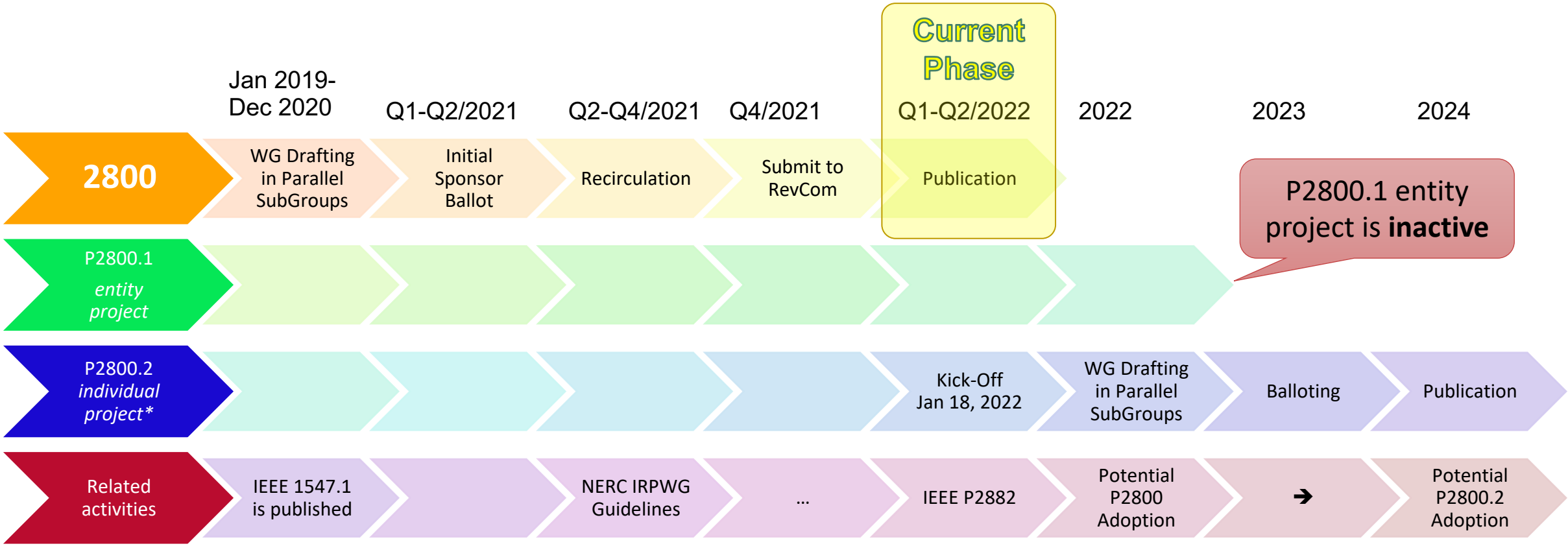
1. Type Tests – *performed on representative IBR unit*
2. Production Tests – *performed on every unit*
3. IBR Evaluations
   a. Design Evaluation (desk study)
   b. As-built Installation Evaluation (on-site)
4. Commissioning Tests and Verifications
5. Periodic Interconnection Tests



IEEE 2800-2022 requires IBR plant-level conformity → more than just IBR unit conformity

Modified based on *DER Plant-Level Performance Verification and Commissioning Guideline: First Edition.* Technical Update. EPRI. Palo Alto, CA: December 2020. 3002019420

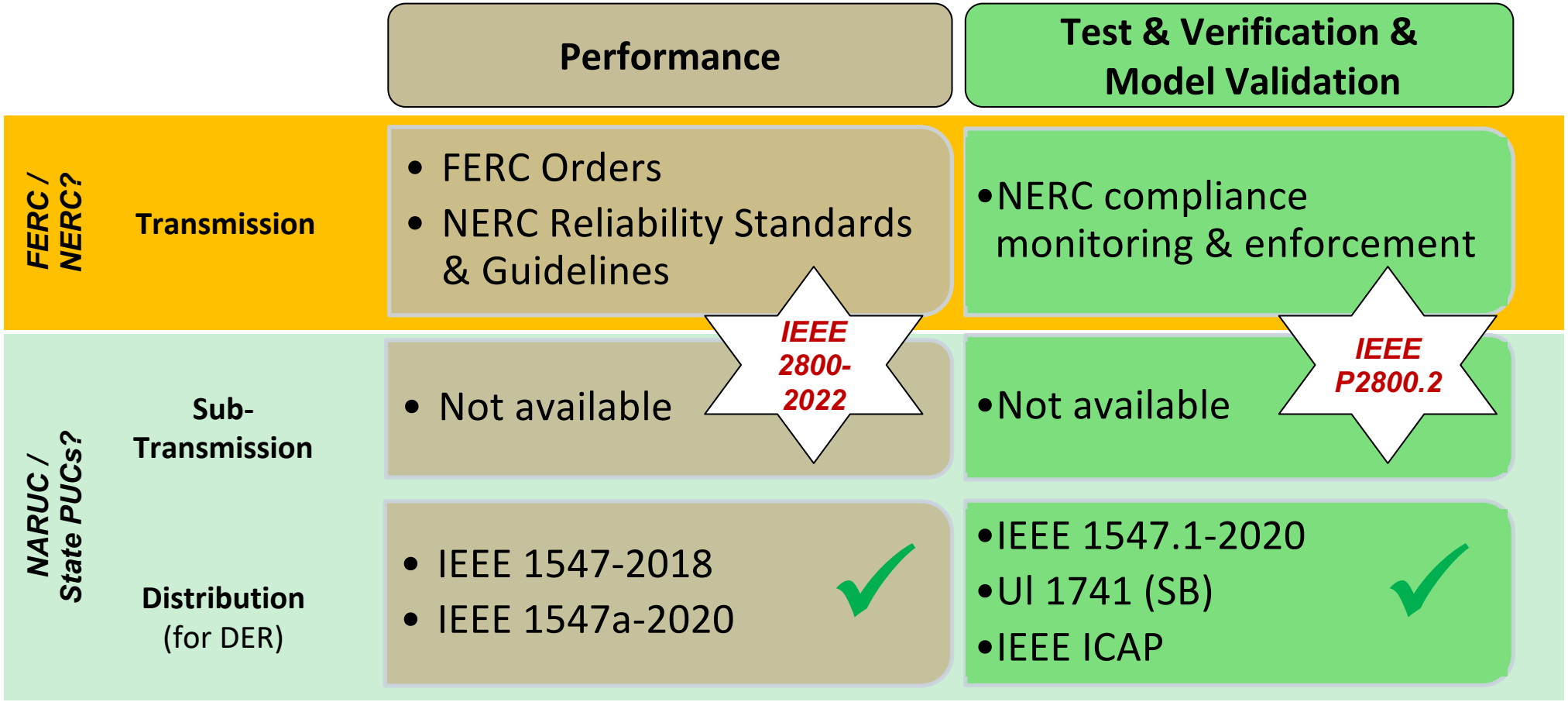
Anticipated Timeline, and What Comes Next?



*Project authorization request (PAR) approved by NesCom on May 21, 2021 (https://development.standards.ieee.org/myproject-web/app#viewpar/12623/9133); contact andy.hoke@nrel.gov and sign up for P2800.2 Working Group and Task/Project on IEEE SA myProject at https://development.standards.ieee.org/myproject-web/app#interests

Now that IEEE 2800-2022 has been successfully approved, entities can start adopting the standard and the drafting of conformance procedures commences in projects like IEEE P2800.2 and P2882.

How IEEE P2800 May Complement North American Electric Reliability Standards & Guidelines

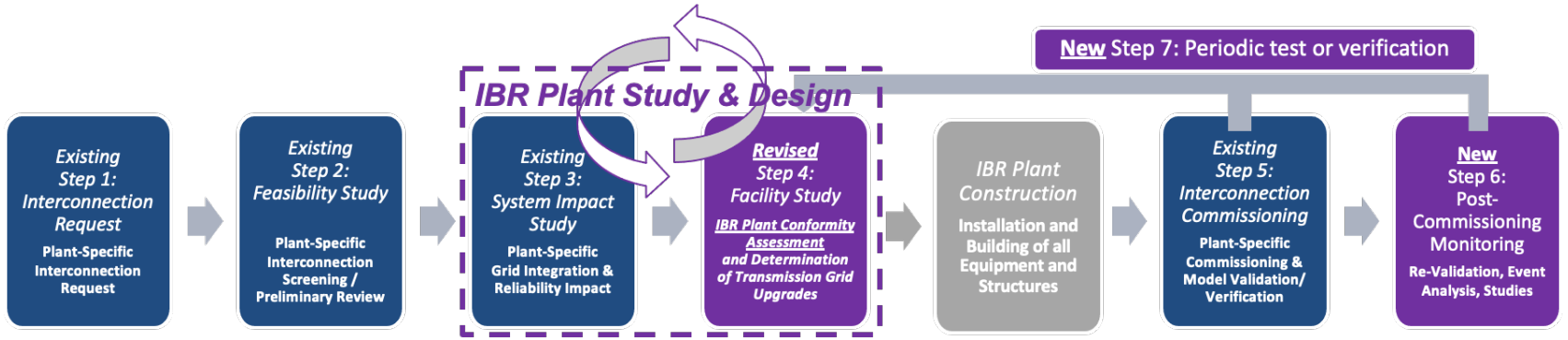


DER: Distributed Energy Resources

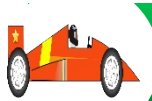
When adopted by the appropriate authority (e.g., Transmission Owners, NERC, FERC), IEEE standards become mandatory

Some Thoughts on IEEE 2800-2022 Adoption

- Transmission Owners / Planners may play a key role
  - Gap assessment, improvement of existing requirements, preferably “full adoption” of IEEE 2800
- Adoption may not be contingent on publication of IEEE P2800.2 *Draft Recommended Practice for Test and Verification Procedures*
  - Determine reasonable interconnection application enforcement date, grandfathering
- Opportunities for further improvements of interconnection process
  - Potential implications for FERC Large-Scale Generators Interconnection Process (LGIP) and *pro-forma* Agreement (LGIA), e.g., reference for “good utility practice”

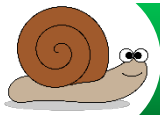


Possible IEEE 2800-2022 Adoption Methods



General Reference

- Full adoption of standard by general reference
- Specification of
  - technical minimum capability per IEEE 2800-2022
  - functional settings/ performance (in ranges of available settings)
- Decision whether to specify additional requirements or not
  - e.g., for non-exhaustive reqs.



Detailed Reference

- Full or partial adoption of std
- Clause-by-clause references
- Any additional requirements

Benefit: *Consistency to standard*

Risk: *Fragmentation of requirements, certification challenges, additional costs*

Full Specification

- All on the left
- Clause-by-clause own language
- Any additional requirements

Benefit: *No need to buy standard*

Risk: *Inconsistencies to standard and fragmentation of requirements, certification challenges, additional costs*

Preliminary High-Level Gap Assessment of ERCOT Nodal Protocols

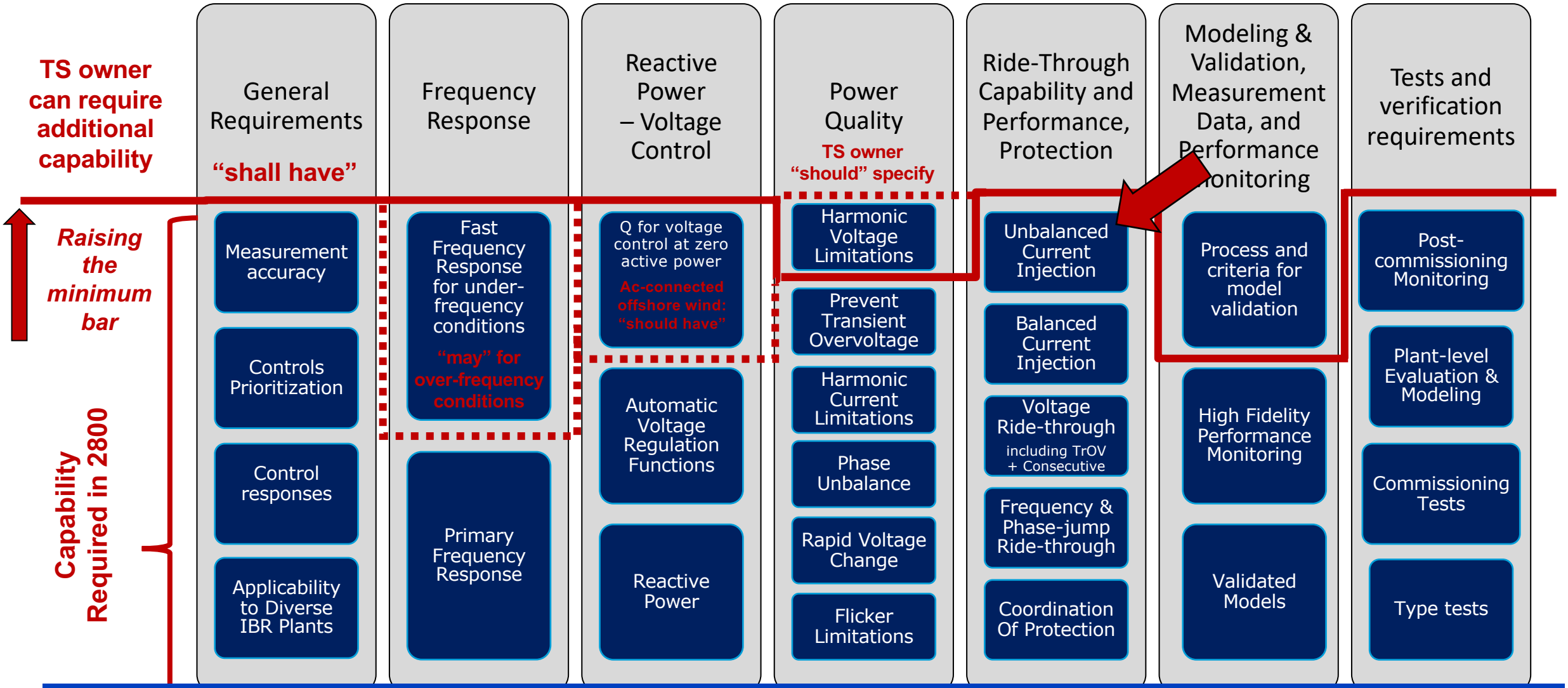
Legend: X Prohibited, √ Allowed by Mutual Agreement, ‡ Capability Required,
(‡) Procedural Step Required as specified, Δ Test and Verification Defined

Function Set	Advanced Functions Capability	ERCOT Nodal Protocols	IEEE 2800-2022
General	Adjustability in Ranges of Available Settings		‡
	Prioritization of Functions	‡	‡
Monitoring, Control, and Scheduling	Ramp Rate Control		
	Communication Interface	‡	‡
	Disable Permit Service (Remote Shut-Off, Remote Disconnect/Reconnect)	‡	‡
	Limit Active Power	‡	‡
	Monitor Key Data	‡	‡
	Remote Configurability		√
	Set Active Power	‡	√
	Scheduling Power Values	‡	√
Reactive Power & (Dynamic) Voltage Support	Constant Power Factor	‡	‡
	Voltage-Reactive Power (Volt-Var)	‡	‡
	Autonomously Adjustable Voltage Reference	?	
	Capability at zero active power ("VArs at night")	NR	‡
	Active Power-Reactive Power (Watt-Var)		
	Constant Reactive Power	NR	‡
	Voltage-Active Power (Volt-Watt)	NR	
	Dynamic Voltage Support / Current Injection during VRT — Balanced	‡	‡
	Dynamic Voltage Support / Current Injection during VRT — Unbalanced	NR	‡

Function Set	Advanced Functions Capability	ERCOT Nodal Protocols	IEEE 2800-2022
Bulk System Reliability & Frequency Support	Frequency Ride-Through (FRT)	‡	‡
	Rate-of-Change-of-Frequency (ROCOF) Ride-Through	NR	‡
	Voltage Ride-Through (VRT)	‡	‡
	Transient Overvoltage Ride-Through	√	‡
	Consecutive Voltage Dip Ride-Through	NR	‡
	Voltage Phase Angle Jump Ride-Through	NR	‡
	Frequency Droop / Frequency-Watt	‡	‡
	Fast Frequency Response / Inertial Response — Underfrequency FFR	√	‡
	Fast Frequency Response / Inertial Response — Overfrequency FFR	NR	√
	Return to Service (Enter Service)	?	‡
	Black Start	NR	√
Protection Functions and Coordination	Abnormal Frequency Trip		√
	Rate of Change of Frequency (ROCOF) Protection		√
	Abnormal Voltage Trip		√
	AC Overcurrent Protection		√
	Unintentional Islanding Detection and Trip		√
	Interconnection System Protection		√
Power Quality	Limitation of DC Current Injection		
	imitation of Voltage Fluctuations		‡
	Limitation of Current Distortion		‡
	Limitation of Voltage Distortion		√
	Limitation of (Transient) Overvoltage		‡

Acknowledgements for contributions and peer-review: Julia Matevosyan (ESIG)

IEEE 2800-2022 Technical Minimum Capability Requirements



Example: Voltage Ride-Through Performance Requirements for Current Injection during VRT

No specification of current magnitude

The 1-cycle time required for DFT (to derive phasor quantities) is included in specified response/settling time.

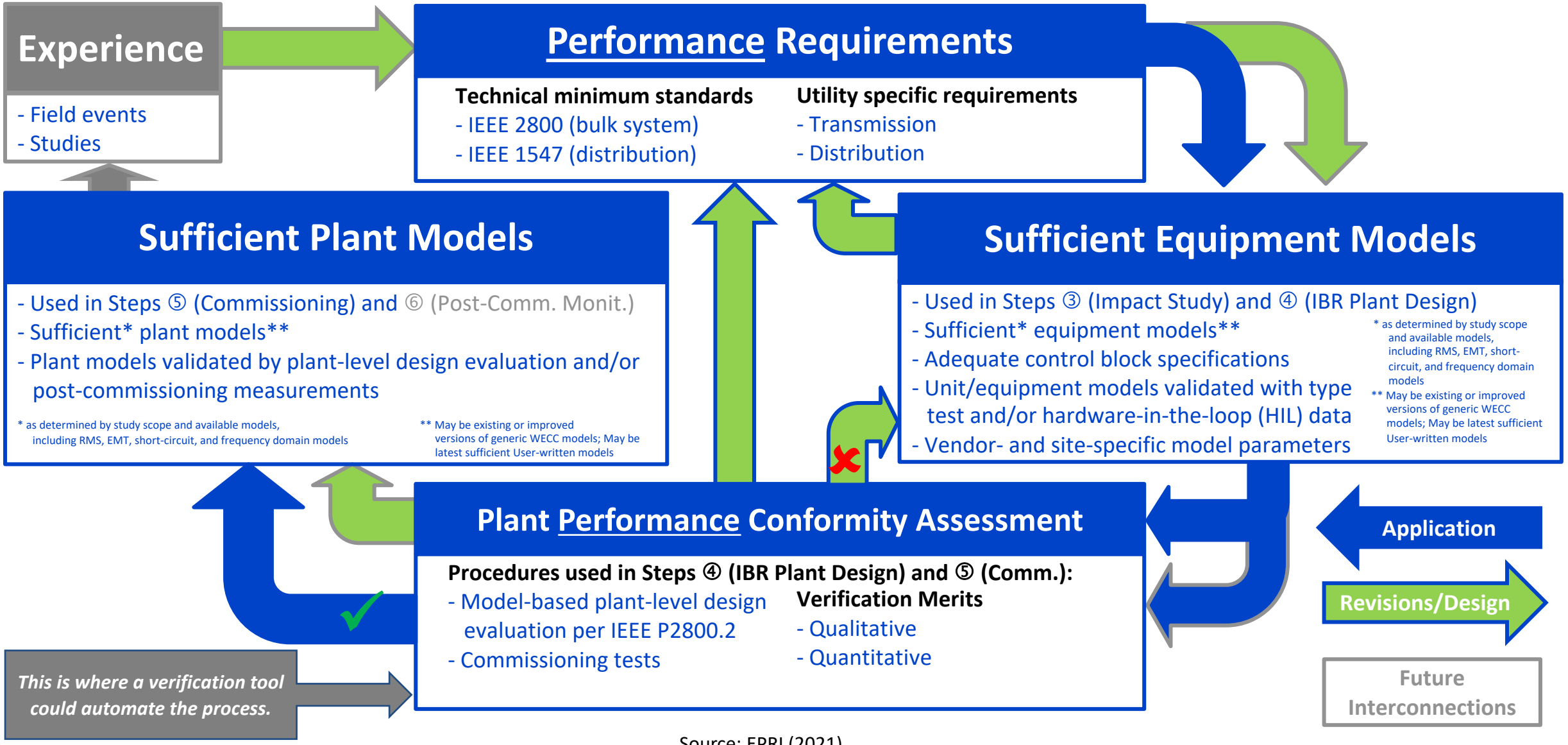
	Type III WTGs	All other IBR Units
Step Response Time	NA[1]	≤ 2.5 cycles
Settling Time	≤ 6 cycles	≤ 4 cycles
Settling Band	−2.5%/+10% of IBR unit maximum current	−2.5%/+10% of IBR unit maximum current

Note 1: Initial response is driven by machine characteristics, & not the control system.

Slower response/settling time is permitted with mutual agreement between TS owner and IBR owner.

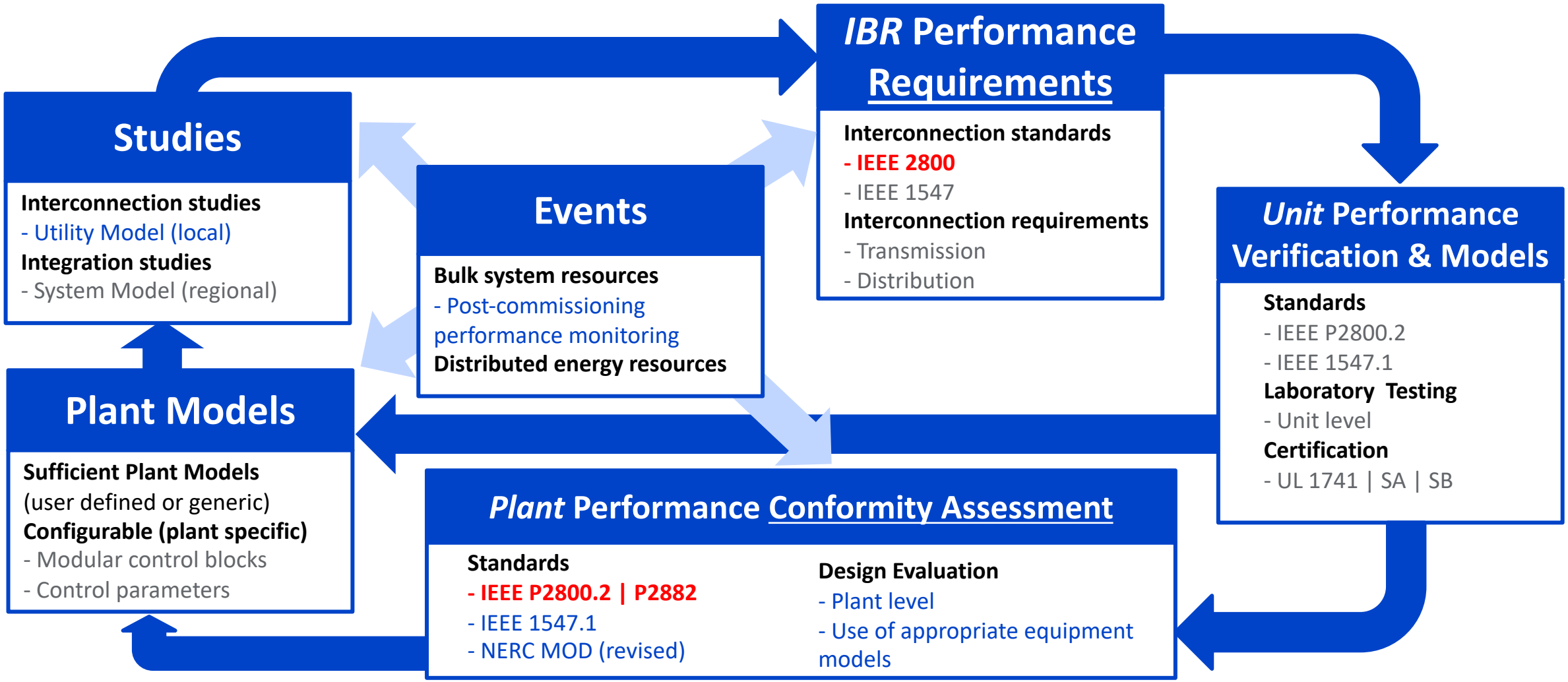
IEEE P2800 Draft 6.3

Continuous and Iterative Improvement of IBR Performance Requirements, Plant-Level Modeling, and Model Validation



Source: EPRI (2021)

Continuation Plant-Level Model Development, Improvement, and Validation of Inverter-Based Resources



SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

This work is, in part, supported by the U.S. Department of Energy, Solar Energy Technologies Office under Award Number DE-EE0009019 *Adaptive Protection and Validated MODels to Enable Deployment of High Penetrations of Solar PV (PV-MOD)*.

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

This work is, in part, supported by the North American Electric Reliability Corporation (NERC) under EPRI contract 20011165 *Inverter-Based Resources Dynamic Response Characterization for Bulk Power System Protection, Planning, and Power Quality*.

Next Steps

1. Conduct detailed gap assessment of ERCOT Nodal Protocols

2. Discussions in stakeholder process

3. Adoption of IEEE 2800-2022?

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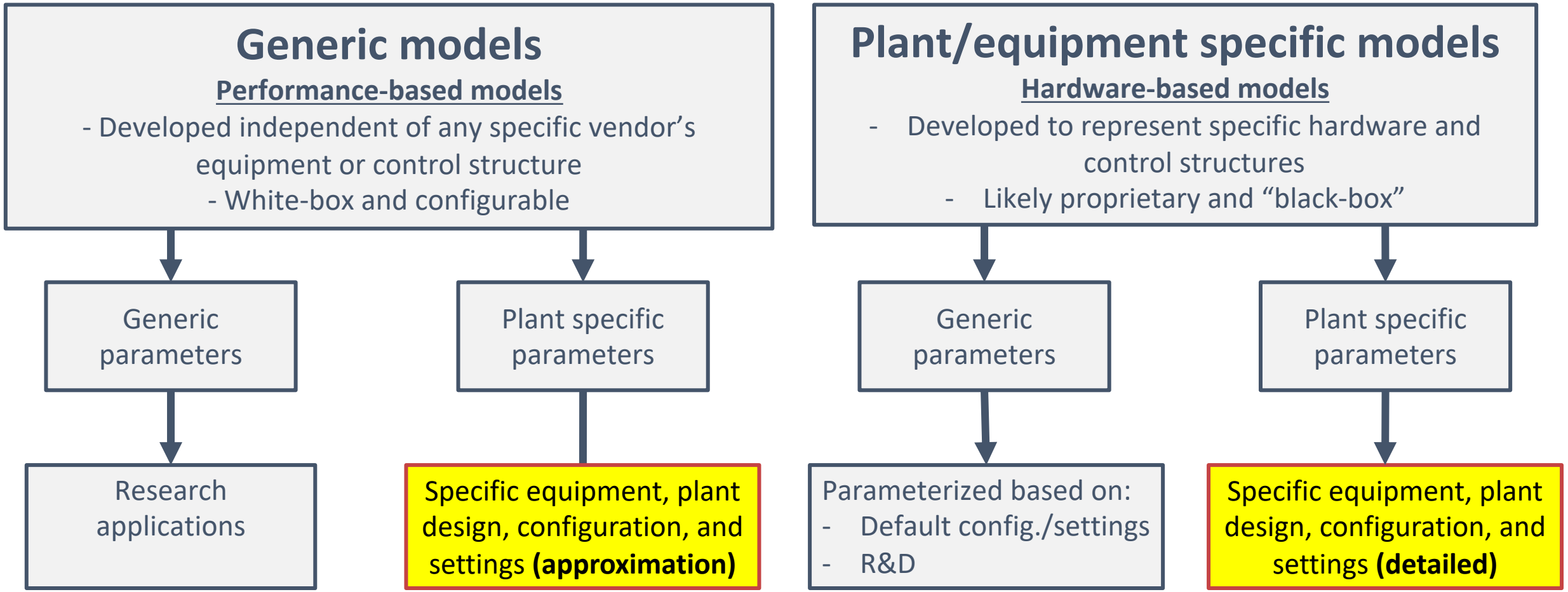
  jboemer@epri.com | 206.471.1180

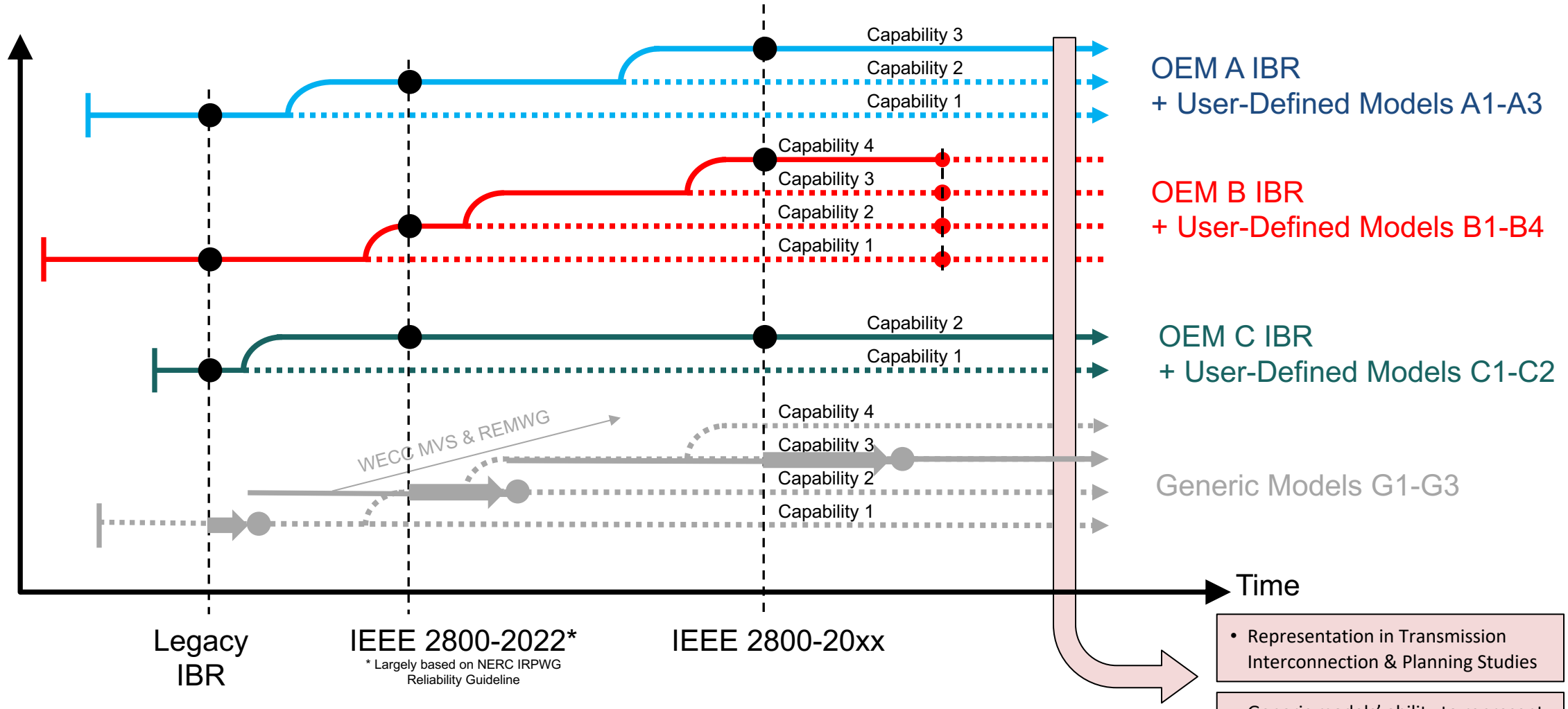
More Information:

- https://sagroups.ieee.org/2800/
- https://sagroups.ieee.org/2800-2/
- https://standards.ieee.org/ieee/2882/10401/
- https://www.epri.com/pvmod

IBR Models: Independent of simulation domain



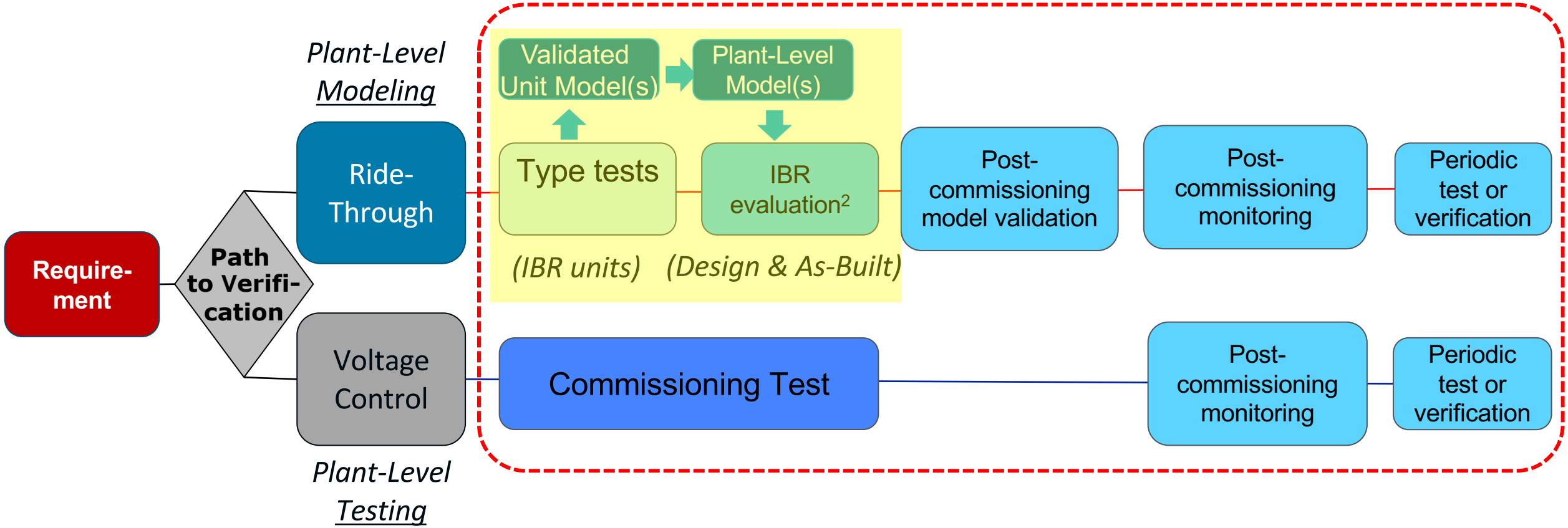
Grid Codes and Generic Models May Always Lag Behind OEMs' Continuous Product Improvements



➢ ***Identification of critical generic model <u>improvements</u> per study type and objective.***

IEEE P2800 Clause 12 (Test and Verification) Framework

What's the requirement? → Where's the reference point of applicability (RPA)? → Required path to verification → Category of test and verification needed



IEEE P2800.2 Motivation

- P2800 contains performance requirements for IBRs, and a table of methods to verify each requirement
  - Details of verification methods not included
- P2800.1 may contain those details, but P2800.1 is developed under the "Entity Method" where participation (voting) requires IEEE-SA Basic (Advanced) Corporate Membership
- **P2800.2** will develop details through "individual standard" process (like P2800, 1547, 1547.1, etc)

Requirement	RPA at which requirement applies	*IBR unit*-level tests (at the POC)	*IBR plant*-level verifications (at the RPA)						
		Type tests[157]	Design evaluation (including modeling)	As-built installation evaluation	Commissioning tests	Post-commissioning model validation	Post-commissioning monitoring	Periodic tests	Periodic Verification
		Responsible Entity							
		IBR Manufacturer	Developer /TS owner/TS operator	Developer /TS owner/TS operator	Developer /TS owner/TS operator	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
6.1 Primary Frequency Response (PFR)	POC & POM	NR[158]	R	R	R	R	D	D	D
6.2 Fast Frequency Response (FFR)	POC & POM	R[159]	R	R	R	R	D	D	D
Clause 7 Response to TS abnormal conditions									
7.2.2 Voltage disturbance ride-through requirements	POC[160] & POM[161]	R	R	R	NR	R	R	D	D
7.2.3 Transient overvoltage ride-through requirements	POM	R	R	R	NR	R	R	D	D
7.3.2 Frequency disturbance ride-through requirements	POM	R	R	R	NR	R	R	D	D
7.4 Return to service after IBR plant trip	POM	refer to line entries for 4.10 (Enter service)							

IEEE P2800.2 Introduction

- New IEEE PAR for P2800.2 approved by IEEE SASB on May 22, 2021
- Title: Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems
- WG not formed yet
- Recruiting participation from P2800 WG, IRPWG, and industry in general
  - Especially need those with knowledge of best practices in designing, studying, interconnecting, commissioning, and operating large IBRs
  - Utilities, project developers, consultants, manufacturers, labs, etc
- P2800.2 WG will start as P2800 finishes (around Q4 2021)
- Express interest through IEEE MyProject, or contact andy.hoke@nrel.gov

IEEE SA STANDARDS ASSOCIATION

IEEE

P2800.2

Submitter Email: andy.hoke@nrel.gov
Type of Project: New IEEE Standard
Project Request Type: Initiation / New
PAR Request Date: 18 Mar 2021
PAR Approval Date: 21 May 2021
PAR Expiration Date: 31 Dec 2025
PAR Status: Active

1.1 Project Number: P2800.2
1.2 Type of Document: Recommended Practice
1.3 Life Cycle: Full Use

2.1 Project Title: Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems

3.1 Working Group: P2800.2 - Test and Verification of BPS-connected Inverter-Based Resources(PE/EDPG/P2800.2 - T&V of BPS-connected IBRs)
3.1.1 Contact Information for Working Group Chair:
Name: Anderson Hoke
Email Address: andy.hoke@nrel.gov
3.1.2 Contact Information for Working Group Vice Chair:
None
3.2 Society and Committee: IEEE Power and Energy Society/Energy Development & Power Generation(PE/EDPG)
3.2.1 Contact Information for Standards Committee Chair:
Name: Robert Thornton-Jones
Email Address: rob.tj@brush.eu
3.2.2 Contact Information for Standards Committee Vice Chair:
None
3.2.3 Contact Information for Standards Representative:
Name: Zhenyu Fan
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3.3 Co-Stds Committee(s):
3.3.1 IEEE Power and Energy Society/Transmission and Distribution (PE/T&D)
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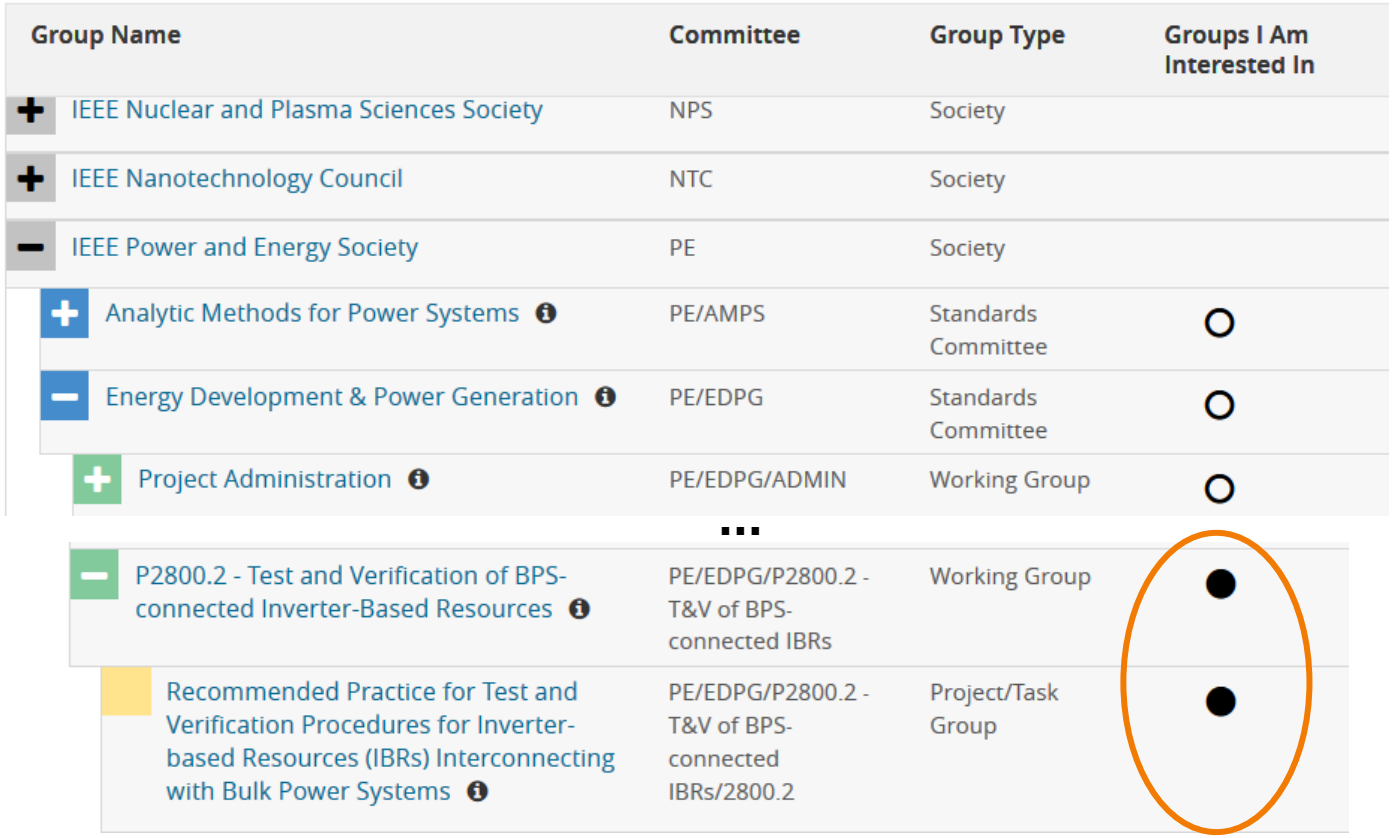
Email Address: innocent.kamwa.1@ulaval.ca
3.3.3 IEEE Power and Energy Society/Analytic Methods for Power Systems (PE/AMPS)
Contact Information for Standards Representative:
Name: Chris Dent
Email Address: chris.dent@ed.ac.uk
3.3.4 IEEE Power and Energy Society/Power System Relaying and Control (PE/PSRCC)
Contact Information for Standards Representative:
Name: Don Lukach
Email Address: dandmlukach92@gmail.com

4.1 Type of Ballot: Individual
4.2 Expected Date of submission of draft to the IEEE SA for Initial Standards Committee Ballot: Jun 2023
4.3 Projected Completion Date for Submittal to RevCom: Jan 2024

5.1 Approximate number of people expected to be actively involved in the development of this project: 150
5.2 Scope of proposed standard: This document defines recommended practices for test and verification procedures that should be used to confirm plant-level conformance of inverter-based resources (IBRs)

How To Express interest in IEEE myProject?

1. On the myProject™ Home Screen, click on Menu and then on “Manage Profile and Interests”
2. Click on the Interests tab, then on “Add Groups”
3. Find P2800.2 under PES/EDPG per screenshot excerpts below
4. Click bullets under “Groups I Am Interested In” and follow instructions on screen



Group Name	Committee	Group Type	Groups I Am Interested In
+ IEEE Nuclear and Plasma Sciences Society	NPS	Society	
+ IEEE Nanotechnology Council	NTC	Society	
− IEEE Power and Energy Society	PE	Society	
+ Analytic Methods for Power Systems	PE/AMPS	Standards Committee	○
− Energy Development & Power Generation	PE/EDPG	Standards Committee	○
+ Project Administration	PE/EDPG/ADMIN	Working Group	○
...			
− P2800.2 - Test and Verification of BPS-connected Inverter-Based Resources	PE/EDPG/P2800.2 - T&V of BPS-connected IBRs	Working Group	●
Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems	PE/EDPG/P2800.2 - T&V of BPS-connected IBRs/2800.2	Project/Task Group	●

To get involved in IEEE P2800.2:

- Sign up for listserv to receive future meeting notices by sending an email to listserv@listserv.ieee.org
  - In first line of email body, write: ***SUBSCRIBE p28002 Your Name***
  - For example, "SUBSCRIBE P2800-2 Andy Hoke"
- In addition, each subgroup will have a Listserv to announce its meetings
  - Details to be announced
- To join Working Group:
  - If you attended 1/18/2022 kickoff meeting, email Manish Patel: Mpatel@southernco.com; CC Andy.Hoke@nrel.gov
  - If not, attend two future meetings and request membership
- Public website (to be populated with more information soon)
  - https://sagroups.ieee.org/2800-2/