

IEEE 2800-2022 Overview and Roadmap to Adoption

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Many slides courtesy of IEEE 2800 Officers:

- Jens C. Boemer, WG Chair
- Bob Cummings, Babak Enayati, Ross Guttromson, Mahesh Morjaria, Manish Patel, Chenhui Niu, Vice-chairs
- Diwakar Tewari, Secretary & Treasurer

General information for the interested public - <https://sagroups.ieee.org/2800/> and <https://sagroups.ieee.org/2800-2/>

Full IEEE 2800 standard: <https://standards.ieee.org/ieee/2800/10453/> or <https://ieeexplore.ieee.org/document/9762253>

Acknowledgements and disclaimers

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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:

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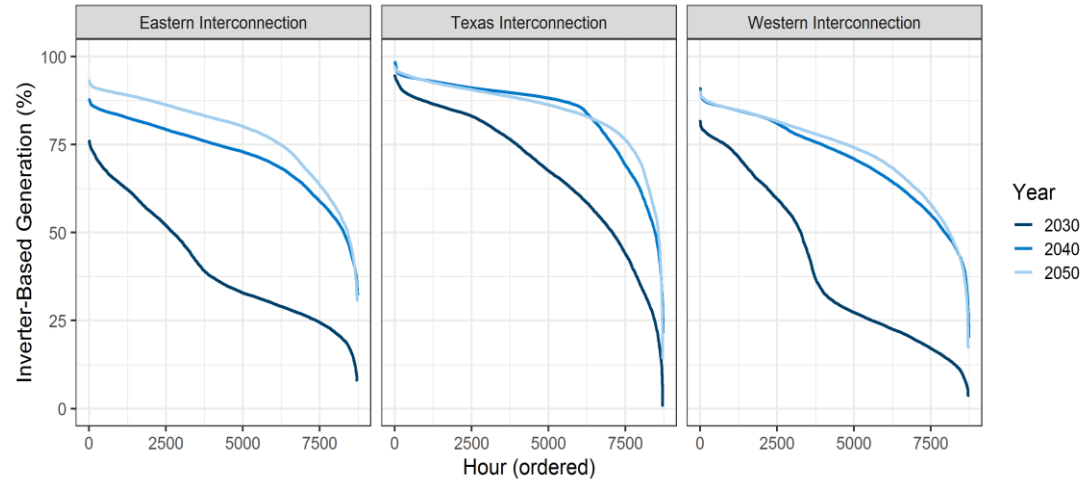
Use of an IEEE standard is wholly voluntary

- IEEE SA can provide information and education if an agency or body (i.e., FERC or DOE) requests information on a standard and can also provide a mechanism by which they can obtain copies of standards for review
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- Agencies/bodies can have independent discussions outside of IEEE SA
- If a body wants to pursue “requiring” IEEE 2800 via rulings or placing the standard on their respective approved lists for use, that is up to them
- If the individual WG Chair or WG members wish to have discussions with FERC, DOE, etc. about such a required use of the standard, they can have that conversation, but they must be clear they are having that conversation as independent individuals and/or on behalf of their respective organizations, and not IEEE/SA

Pace of IBR Interconnections

All major U.S. interconnections are expected to reach peak **instantaneous IBR levels of 75-98%** *within the lifetime of IBRs being connected today.*

- These plants will need to not just remain online, but contribute to system recovery and reliability.
- IEEE 2800 addresses minimum technical requirements deemed needed from IBRs.

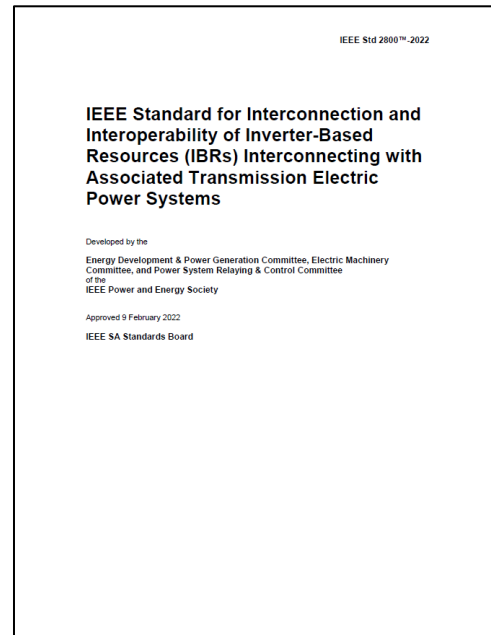


Data from 2021 DOE/NREL Solar Futures Study: <https://www.nrel.gov/analysis/solar-futures.html>

IBRs: inverter-based resources like wind, solar, storage

Summary of IEEE 2800 Standard

- ❑ Harmonizes interconnection requirements for solar, wind, and storage plants connected to transmission and subtransmission
- ❑ A consensus-based draft 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 (>94% approval, >90% response rate)
- ❑ **Published April 22, 2022**



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

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

Status Quo - Solar, Wind & Storage Interconnection Requirements

- Diverse & different requirements across various jurisdictions

...requires more effort and time to address

- Inverter-based resources (IBRs) are different from synchronous generators

...higher (and sometimes lower) capability

- Requirements may not be balanced

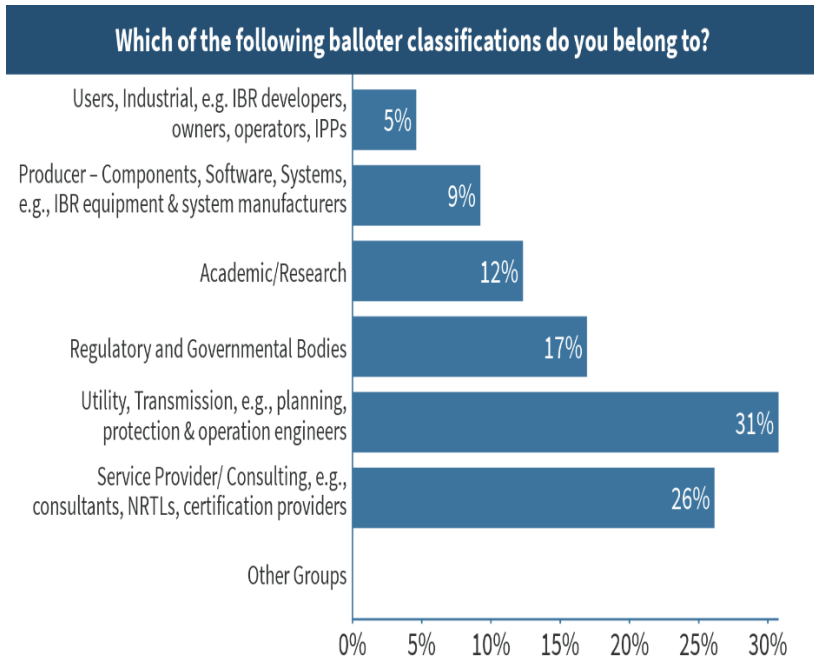
...some too stringent & not taking advantage of new capability



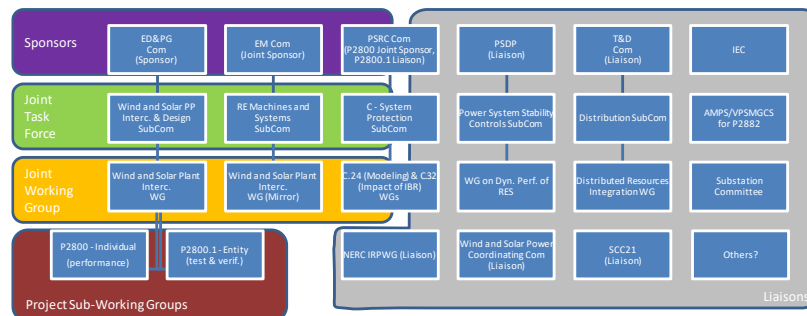
Source: <https://www.natf.net/>

Approximately 300 Interested Parties and 175+ WG Members

**>99%
WG Approval**



Broad Collaboration & Coordination



- 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

IEEE 2800 Objective: Filling Gaps in North American Interconnection Standards

		Performance	Test & Verification & Model Validation
FERC / NERC?	Transmission	• FERC Orders • NERC Reliability Standards & Guidelines	• NERC compliance monitoring & enforcement
NARUC / State PUCs?	Sub-Transmission	• Not available	• Not available
	Distribution (for DER)	• IEEE Std 1547-2018 ✓	• IEEE 1547.1-2020 ✓ • UL 1741 (SB) • IEEE ICAP

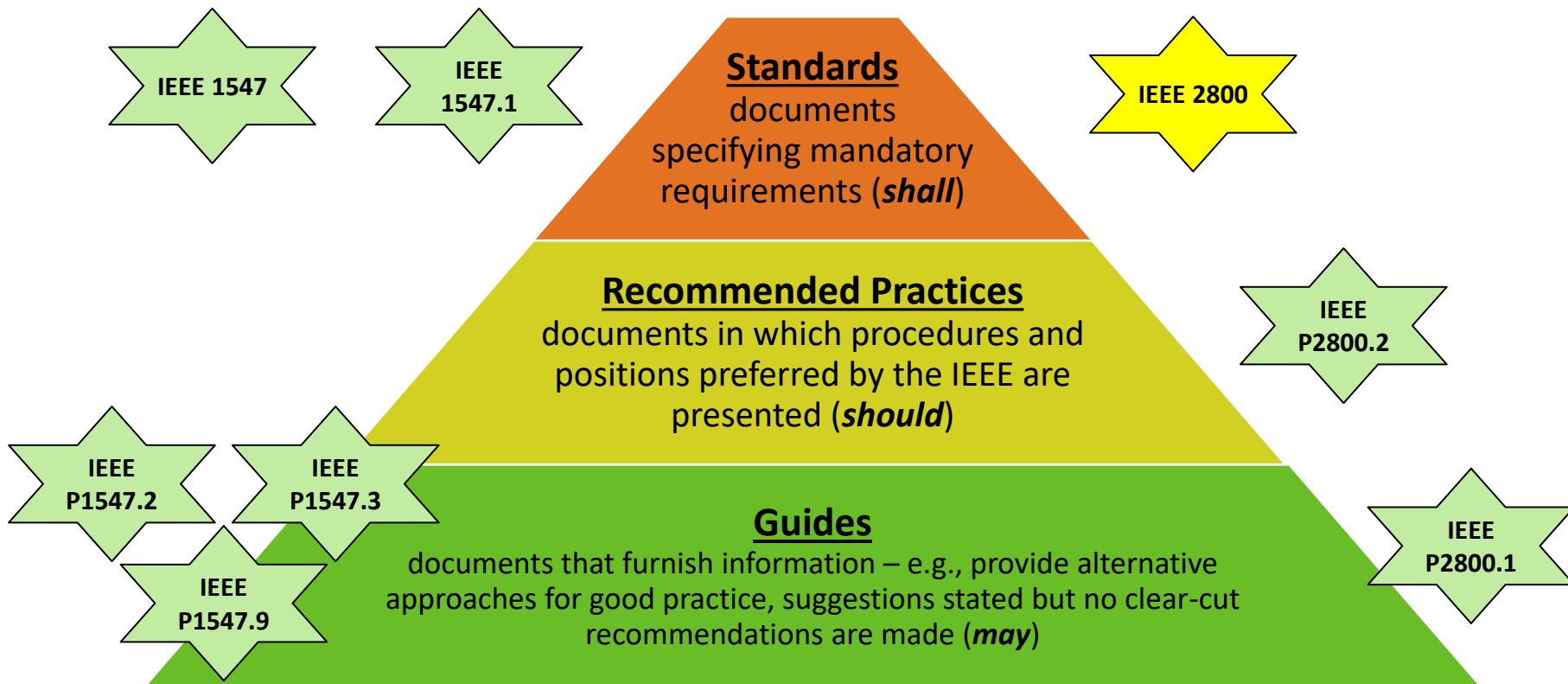
**IEEE
2800-2022**

**IEEE
P2800.2**

DER: Distributed Energy Resource

When adopted by the appropriate authority (e.g., transmission owners/operators, NERC, FERC, distribution utilities), IEEE standards become mandatory

IEEE Standards Classification



What to expect from IEEE 2800?

■ Provides Value

- widely-accepted, unified technical minimum requirements for IBRs
- simplifies and speeds-up technical interconnection negotiations
- flexibility for IBR developers and OEMs → not an equipment/plant design standard

■ Specifies

- performance and functional capabilities but not utilization, services, or markets
- functional default settings and ranges of available settings
- performance monitoring and model validation
- types of verifications means, but not detailed procedures (→ *IEEE P2800.2*)

■ Scope

- All transmission and sub-transmission connected wind, solar, energy storage and HVDC-VSC

What not to expect from IEEE 2800?

■ Specifications for grid-forming IBRs

- 2800 applies to all IBRs (including grid-forming ones), but was designed with conventional grid-following IBRs in mind

■ Definition of an interconnection process

- This is up to transmission system owners and their stakeholders and regulators
- 2800 may be used as part of such a process

■ Procedures to verify that IBRs comply with requirements

- Procedures are currently being developed in IEEE P2800.2
- 2800 adoption is *not* contingent on P2800.2

Capability versus Utilization

Capability:

“Ability to Perform” – Required by 2800

- Functions
- Ranges of available settings
- Minimum performance specifications



Examples

- Frequency Response
 - Frequency Droop Response
 - Ramp rate limitations
- 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

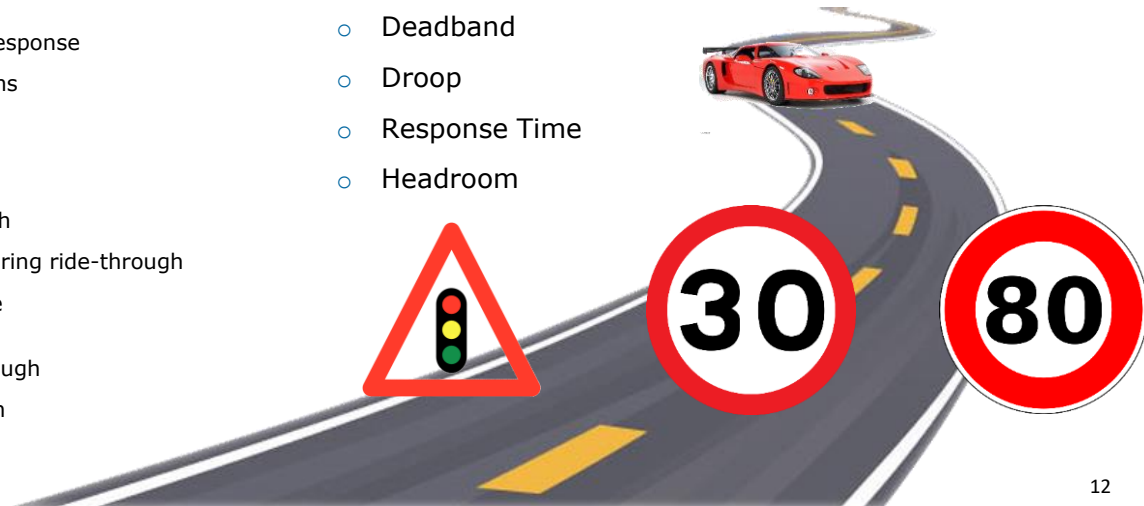
Utilization of Capability:

“Delivery of Performance” – Largely outside 2800 scope

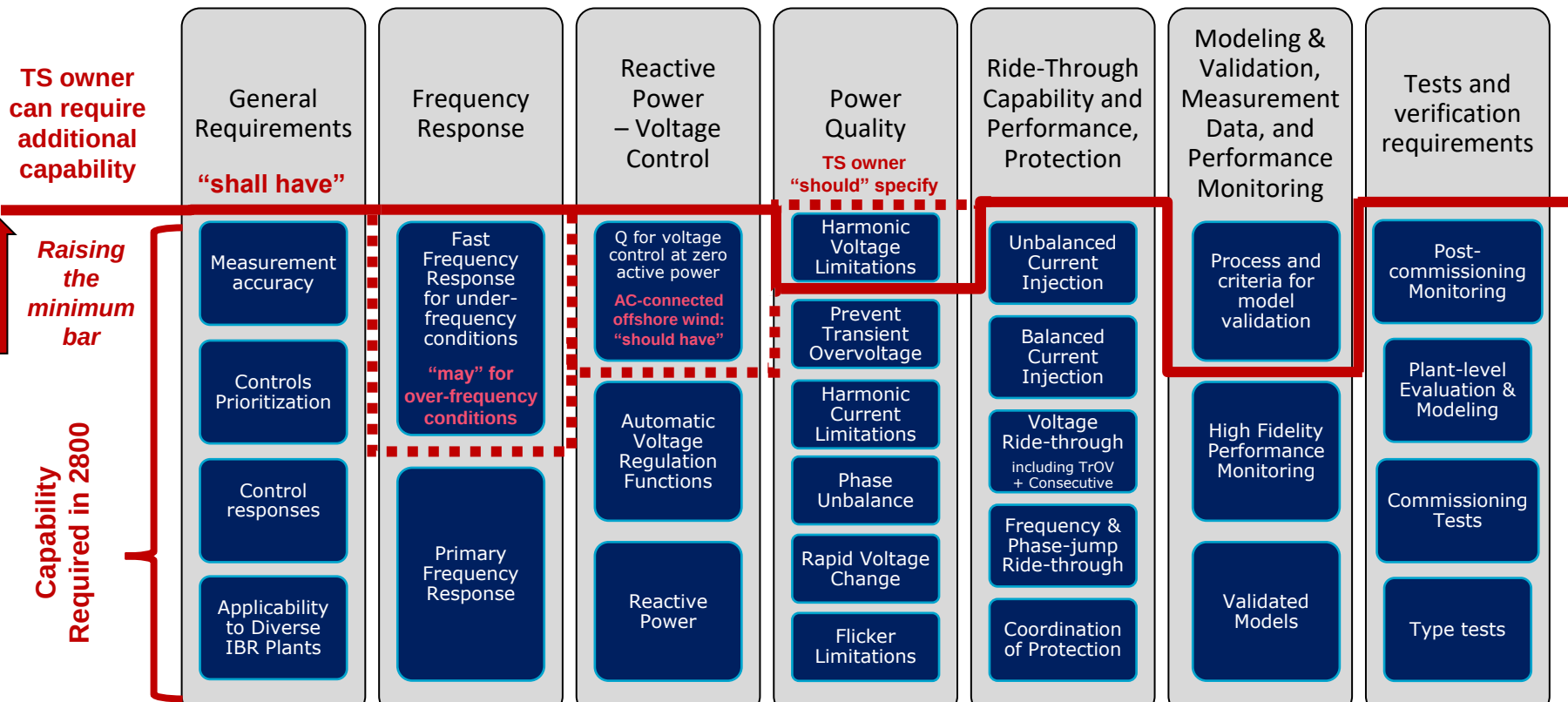
- Enable/disable functions
- Functional settings / configured parameters
- Operate accordingly (e.g., maintain headroom, if applicable)

Examples

- Deadband
- Droop
- Response Time
- Headroom



IEEE 2800-2022 Technical Minimum Capability Requirements



Utilization of these capabilities is outside the purview of 2800

Voltage And Reactive Power Control Modes

The *IBR plant* shall provide the following mutually exclusive modes of reactive power control functions:

- RPA voltage control mode
- Power factor control mode
- Reactive power set point control mode

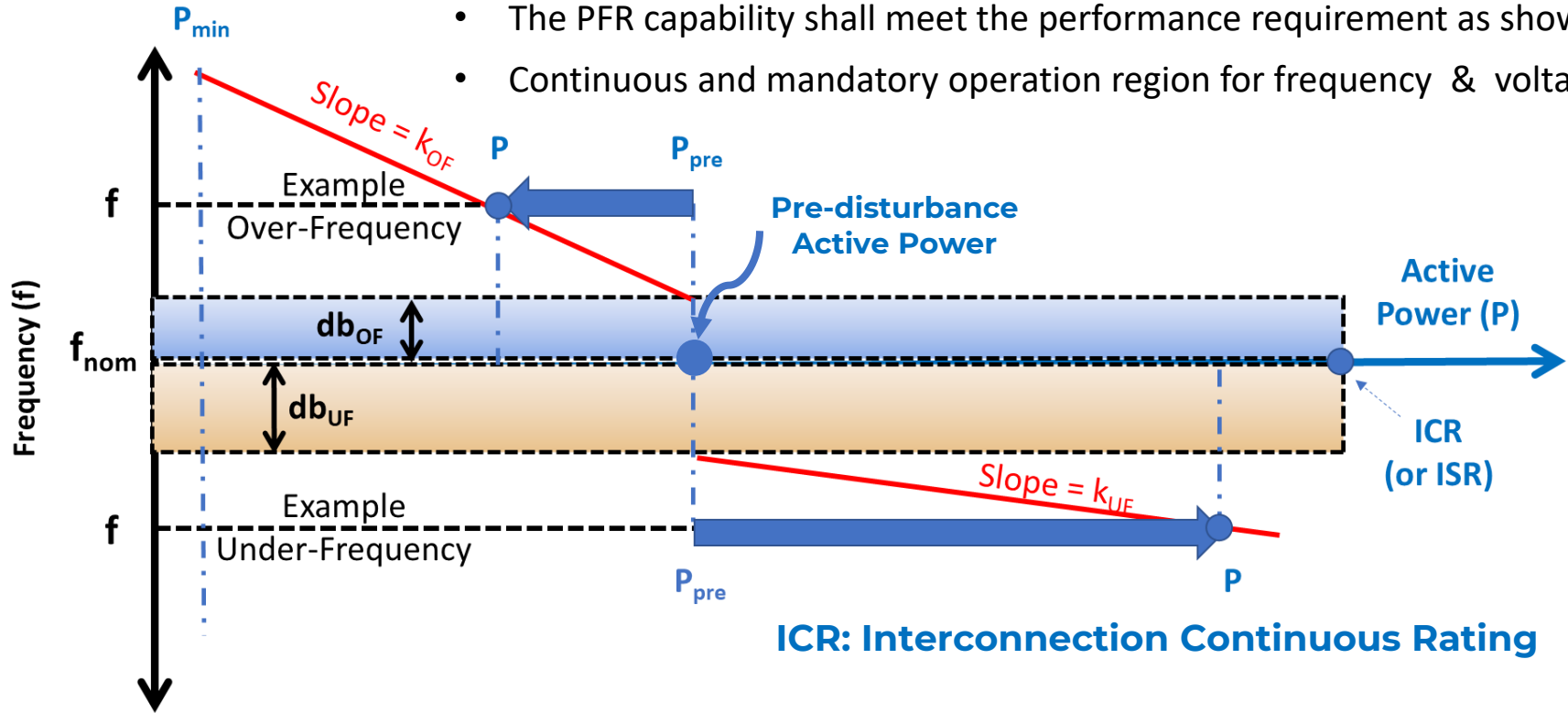
RPA voltage control

- Closed-loop automatic voltage control mode to regulate the voltage at the RPA
- Stable response & any oscillations shall be positively damped (> 0.3 damping ratio)
- Capable of reactive power droop to ensure a stable and coordinated response

Parameter	Performance Target	Notes
Reaction Time	<200 ms	
Maximum Step Response Time	As Required by TS Operator	range between 1 s and 30 s
Damping	Damping ratio of 0.3 or better	

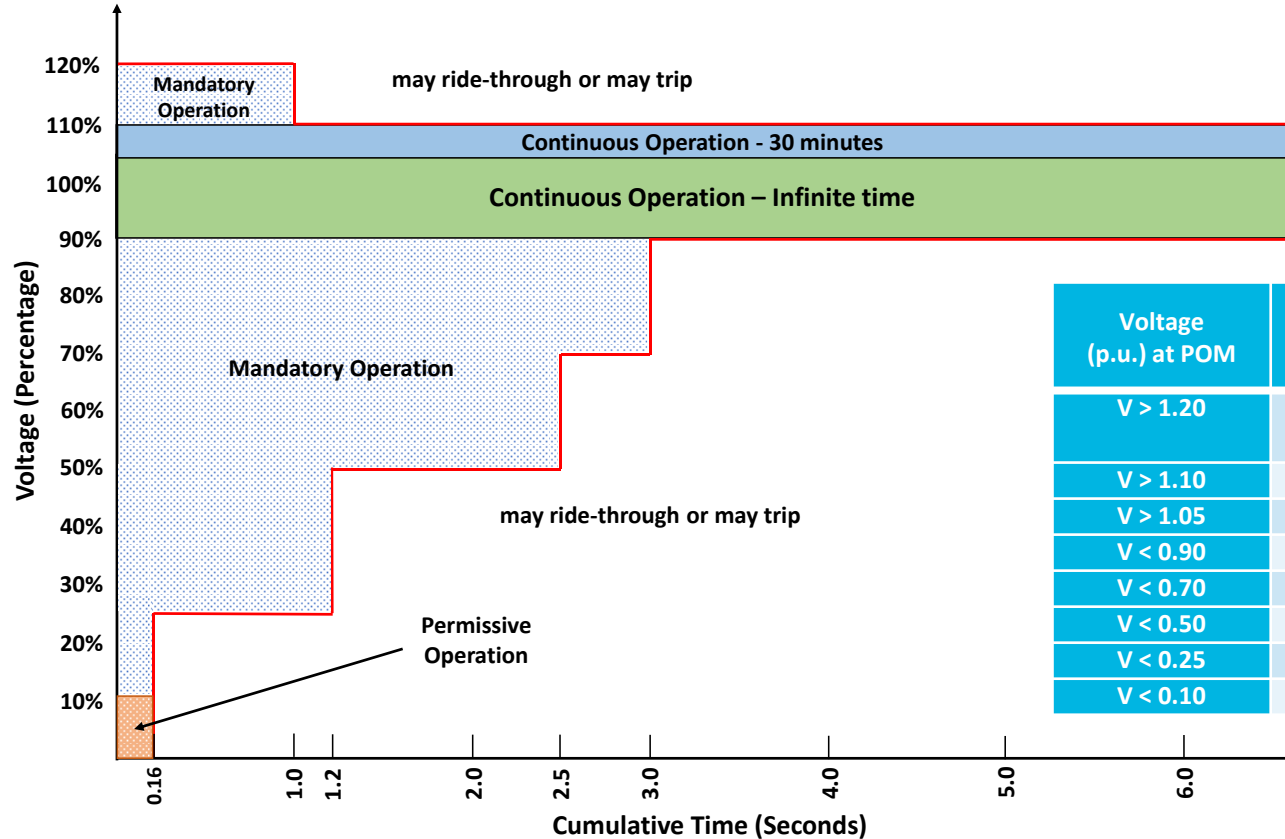
Primary Frequency Response (PFR) Capability of an IBR at RPA

- The PFR capability shall meet the performance requirement as shown
- Continuous and mandatory operation region for frequency & voltage.



Similar to IEEE 1547-2018 Requirements

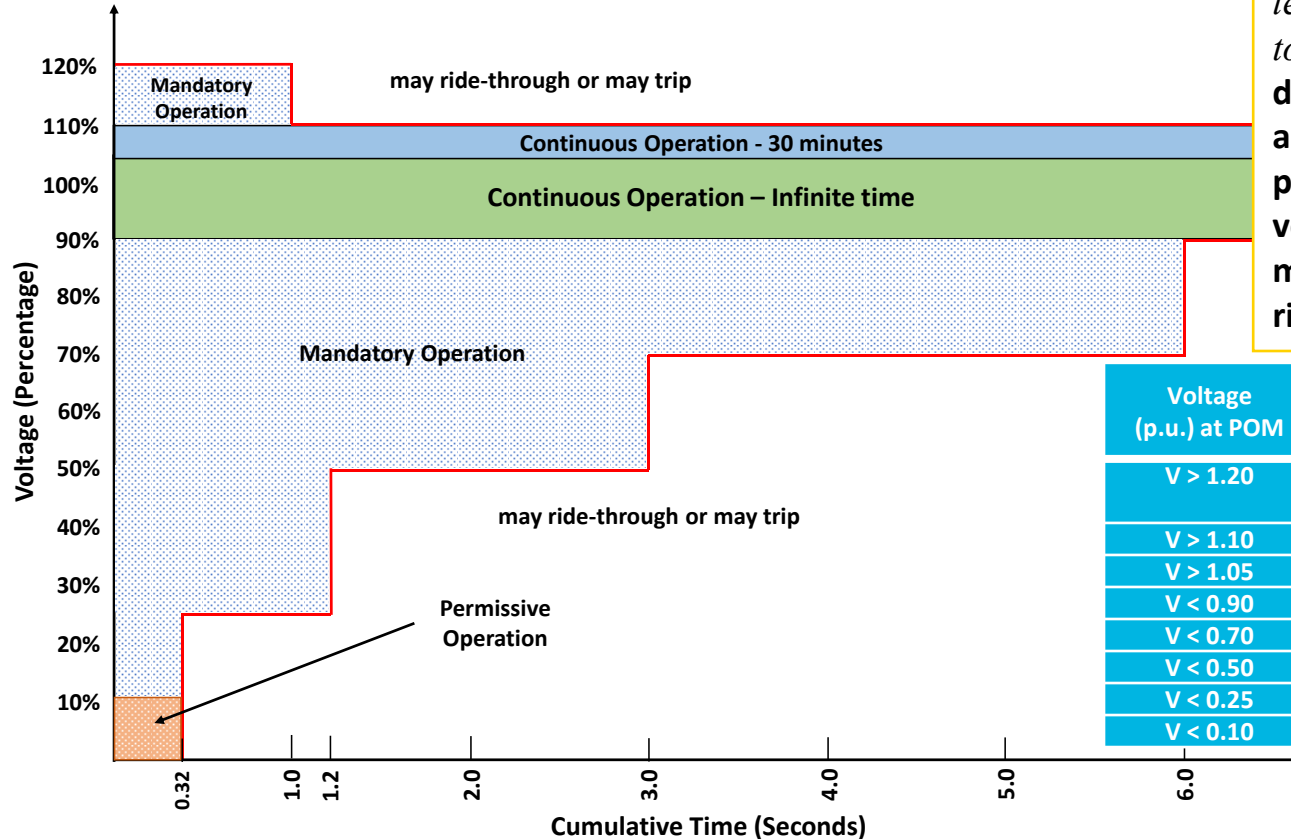
Voltage ride-through capability – Plants with aux. load limitations, i.e., wind plant



Voltage (p.u.) at POM	Operating mode/response	Minimum ride-through time (s) (design criteria)
$V > 1.20$	May Ride-Through or May Trip	NA
$V > 1.10$	Mandatory Operation	1.0
$V > 1.05$	Continuous Operation	1800
$V < 0.90$	Mandatory Operation	3.00
$V < 0.70$	Mandatory Operation	2.50
$V < 0.50$	Mandatory Operation	1.20
$V < 0.25$	Mandatory Operation	0.16
$V < 0.10$	Permissive Operation	0.16

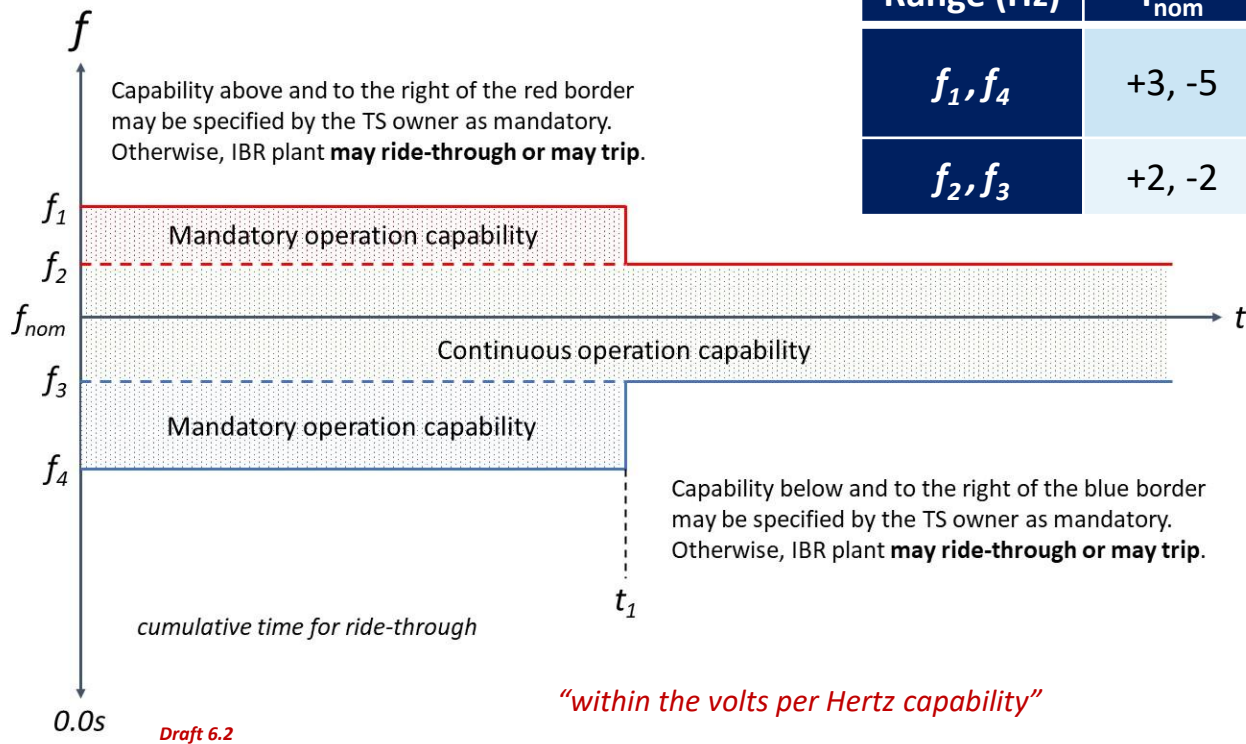
Voltage ride-through capability – Plants without aux. load limitations, e.g., solar plant

Note: June 16 NOPR clause 9.7.3 conflicts with 2800 by requiring “*real power production at pre-disturbance levels*” and “*dynamic reactive power to maintain facility’s voltage schedule*” during voltage ride-through. 2800 allows for either active or reactive power priority and prioritizes dynamic voltage support rather than maintenance of a schedule when in ride-through conditions.



Voltage (p.u.) at POM	Operating mode/response	Minimum ride-through time (s) (design criteria)
$V > 1.20$	May Ride-Through or May Trip	NA
$V > 1.10$	Mandatory Operation	1.0
$V > 1.05$	Continuous Operation	1800
$V < 0.90$	Mandatory Operation	6.00
$V < 0.70$	Mandatory Operation	3.00
$V < 0.50$	Mandatory Operation	1.20
$V < 0.25$	Mandatory Operation	0.32
$V < 0.10$	Permissive Operation	0.32

Frequency Ride-Through *Capability*



Frequency Range (Hz)	% from f_{nom}	Minimum Time (s) Design Criteria	Operation
f_1, f_4	+3, -5	299.0 (t_1)	Mandatory
f_2, f_3	+2, -2	∞	Continuous

ROCOF ride-through

- Shall not trip up 5.0 Hz/s
- Measured over 0.1 s window

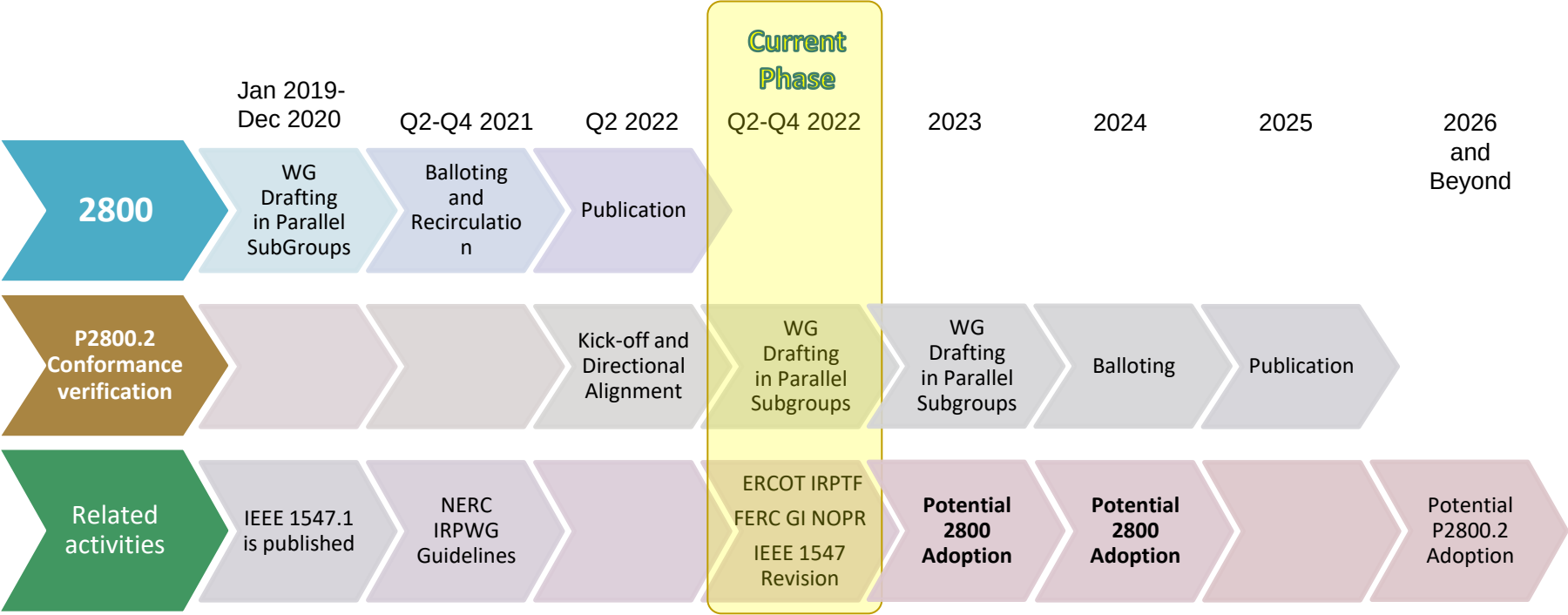
Similar to IEEE 1547-2018 Requirements

Modeling Data

- 2800 is an IBR capability & performance standard. Why include modeling data?
 - Some requirements cannot be verified with tests (type, production, commissioning etc.), i.e., voltage/frequency ride-through requirements
 - Studies (design evaluation) using models and simulations is necessary to verify that plant meets 2800 requirements
- Requirements to provide “verified models” to Transmission Entity (“shall” language)
 - Steady-state power flow, positive-sequence stability dynamic, EMT, short circuit, harmonics etc.
- Recommends details to be included in the model
- Guidance on how to develop “verified models” is not addressed

Note: June 16 NOPR Attachment A to Appendix 1 only requires EMT models “if Transmission Provider performs an electromagnetic transient study as part of the interconnection study.” EMT model may be needed for later studies even if not used at interconnection, at which point it may be too late to obtain one.

Anticipated Timeline, and What Comes Next?



IEEE P2800.2 Introduction

- Title: Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems
- WG formed January 2022;
- Recruiting participation from P2800 WG, NERC IRPS, 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
- See meeting slides etc on public website:
 - <https://sagroups.ieee.org/2800-2/>
- Contact andy.hoke@nrel.gov to get involved

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
Email Address: zhenyu.fan@gmail.com

3.3 Co-Stds Committee(s):

3.3.1 IEEE Power and Energy Society/Transmission and Distribution (PE/T&D)

Contact Information for Standards Representative:

Name: Daniel Sabin
Email Address: d.sabin@ieee.org

3.3.2 IEEE Power and Energy Society/Electric Machinery (PE/EM)

Contact Information for Standards Representative:

Name: Innocent Kamwa
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)

To get involved in IEEE P2800.2:

To join Working Group:

Attend any two meetings and request membership

Next meeting is August 23-25 (via web meeting)!

Join listserv to be notified of WG meetings (next slide)

WG member iMeet site: <https://ieee-sa.imeetcentral.com/p2800-2/home>

Public website: <https://sagroups.ieee.org/2800-2/>

To get involved in IEEE P2800.2:

- Overall listserv “P2800-2” will be used to communicate meeting dates, agendas, etc.
- Each subgroup and PQ task force now has a listserv – sign up to get involved
 - Overall WG listserv: 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**”

Summary

- **IEEE 2800 provides detailed consensus-based interconnection requirements for any non-synchronous generation connected above the distribution level**
 - Includes basic performance capabilities needed from all transmission-connected IBRs to maintain grid reliability in the fast-approaching high-IBR future
- **Adoption of IEEE 2800 can help preserve grid reliability while also smoothing interconnection by standardizing requirements**
 - The initial adoption period will certainly take effort from all stakeholders. This is a necessary effort as we transition to a power system with many non-synchronous resources (whether or not we have a national standard)
 - *A national standard can reduce effort* compared to an alternative where each balancing entity/control area invents its own approach to the high-IBR challenge
- **This won't be easy, but it will only get harder the longer we wait**

Questions? Want more info?

IEEE 2800

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IEEE P2800.2

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