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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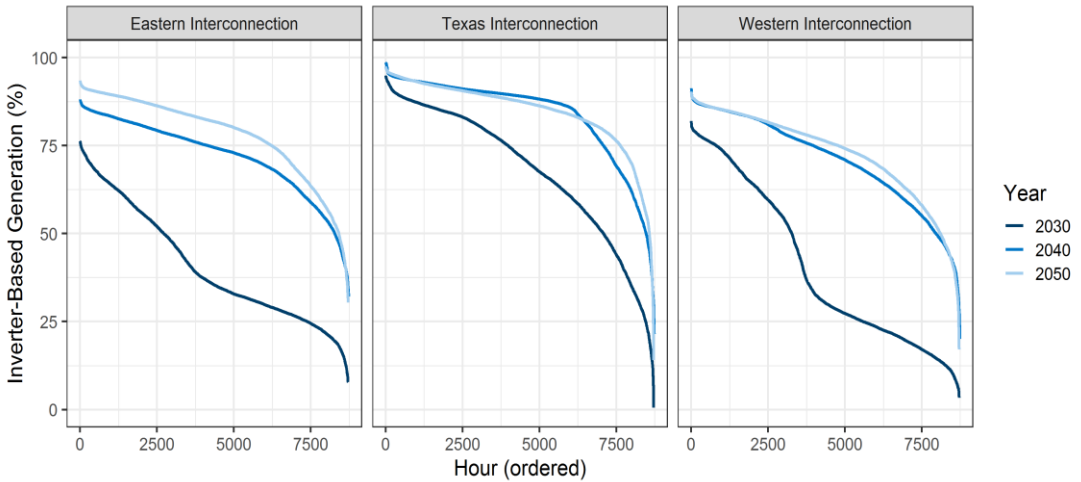
- Agencies/bodies can have independent discussions outside of IEEE SA
- If a body wants to pursue “requiring” IEEE 2800 via rulings or placing the standard on their respective approved lists for use, that is up to them
- If the individual WG Chair or WG members wish to have discussions with FERC, DOE, 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.

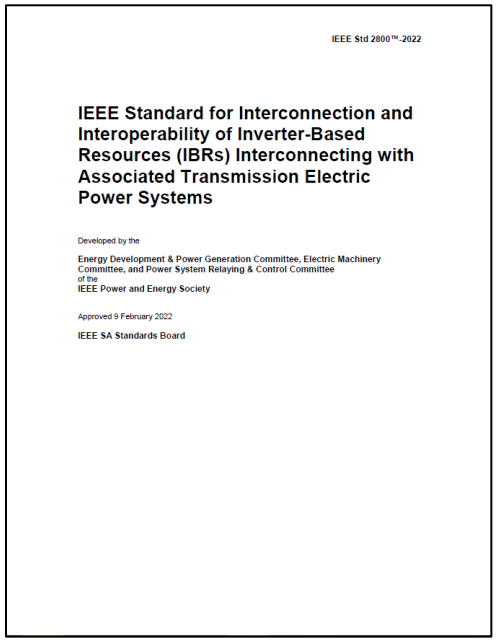


Data from 2021 DOE/NREL Solar Futures Study: https://www.nrel.gov/analysis/solar-futures.html

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**


IEEE Std 2800™-2022

IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

Developed by the

Energy Development & Power Generation Committee, Electric Machinery Committee, and Power System Relaying & Control Committee of the IEEE Power and Energy Society

Approved 9 February 2022

IEEE SA Standards Board

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

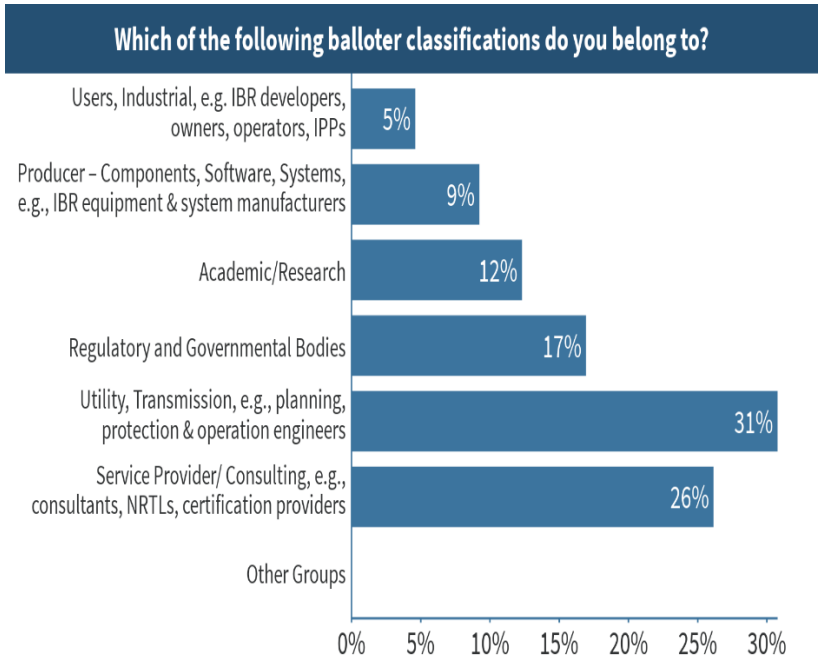
- Requirements may not be balanced

  …some too stringent & not taking advantage of new capability

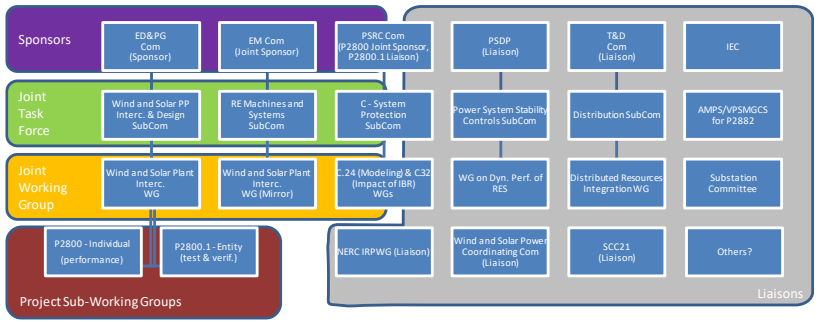
Source: https://www.natf.net/

Approximately 300 Interested Parties and 175+ WG Members

>99% WG Approval

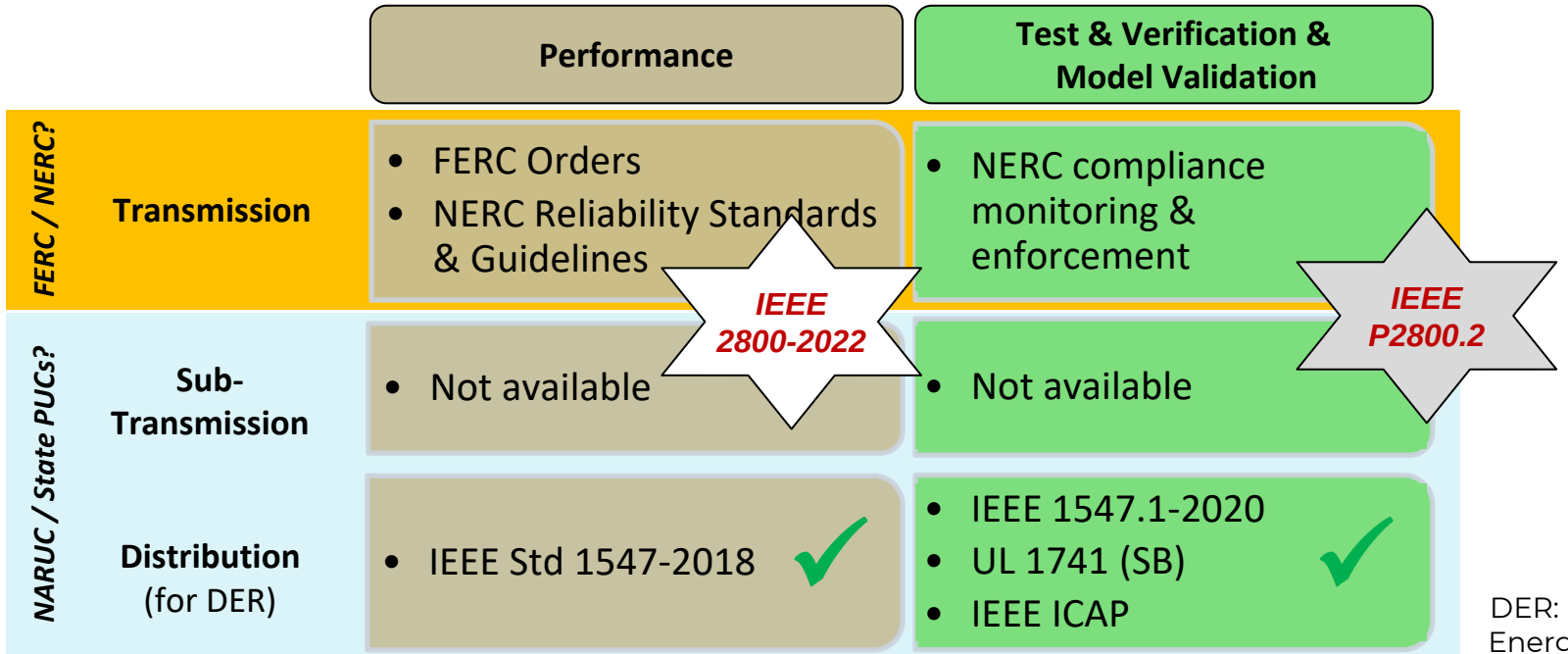


Broad Collaboration & Coordination



- 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

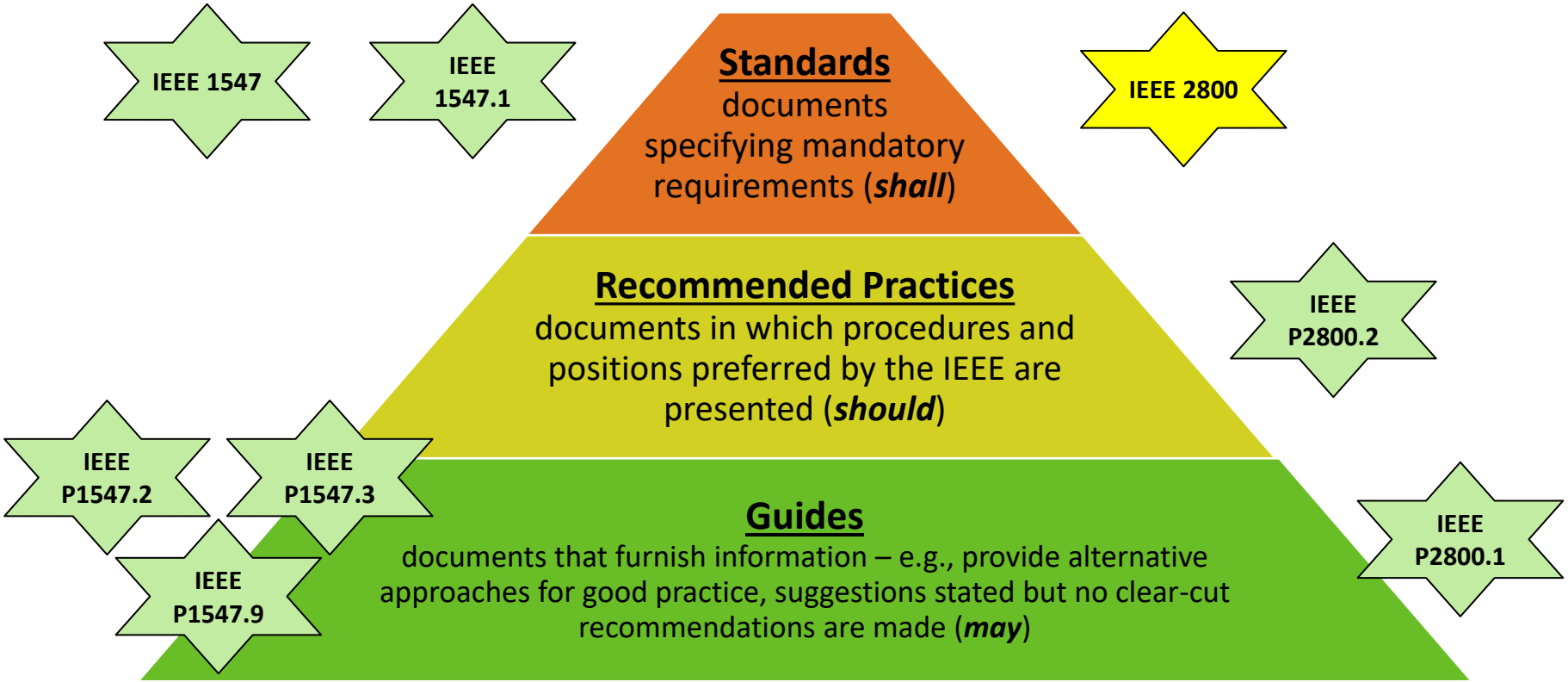
IEEE 2800 Objective: Filling Gaps in North American Interconnection Standards



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

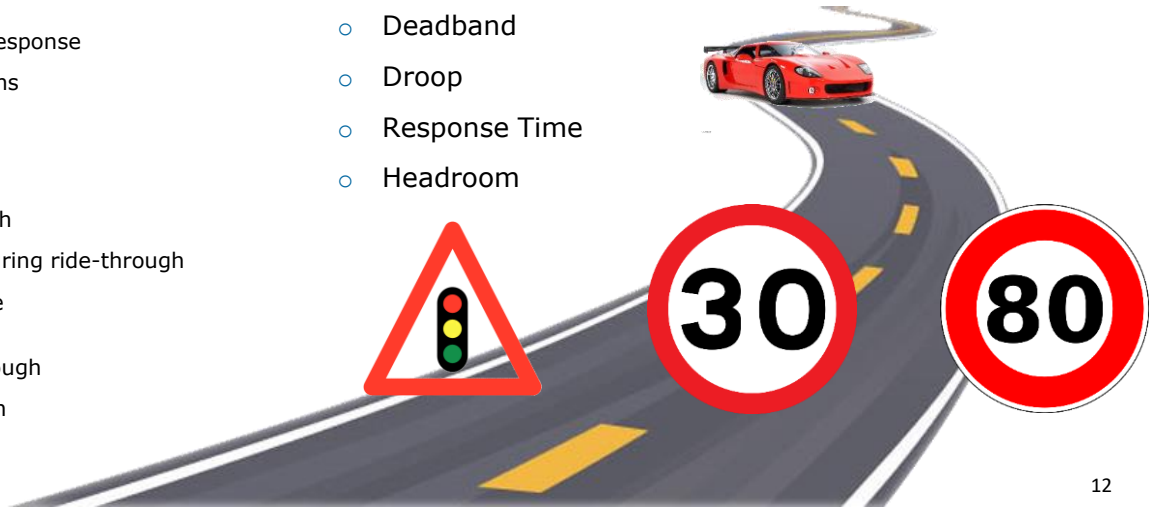
- Frequency Response
  - Frequency Droop Response
  - Ramp rate limitations
- Ride-Through
  - Voltage ride-through
  - Current injection during ride-through
  - Consecutive voltage ride-through
  - Frequency ride-through
  - ROCOF ride-through
  - Phase angle jump ride-through

Utilization of Capability:
"Delivery of Performance" – Largely outside 2800 scope

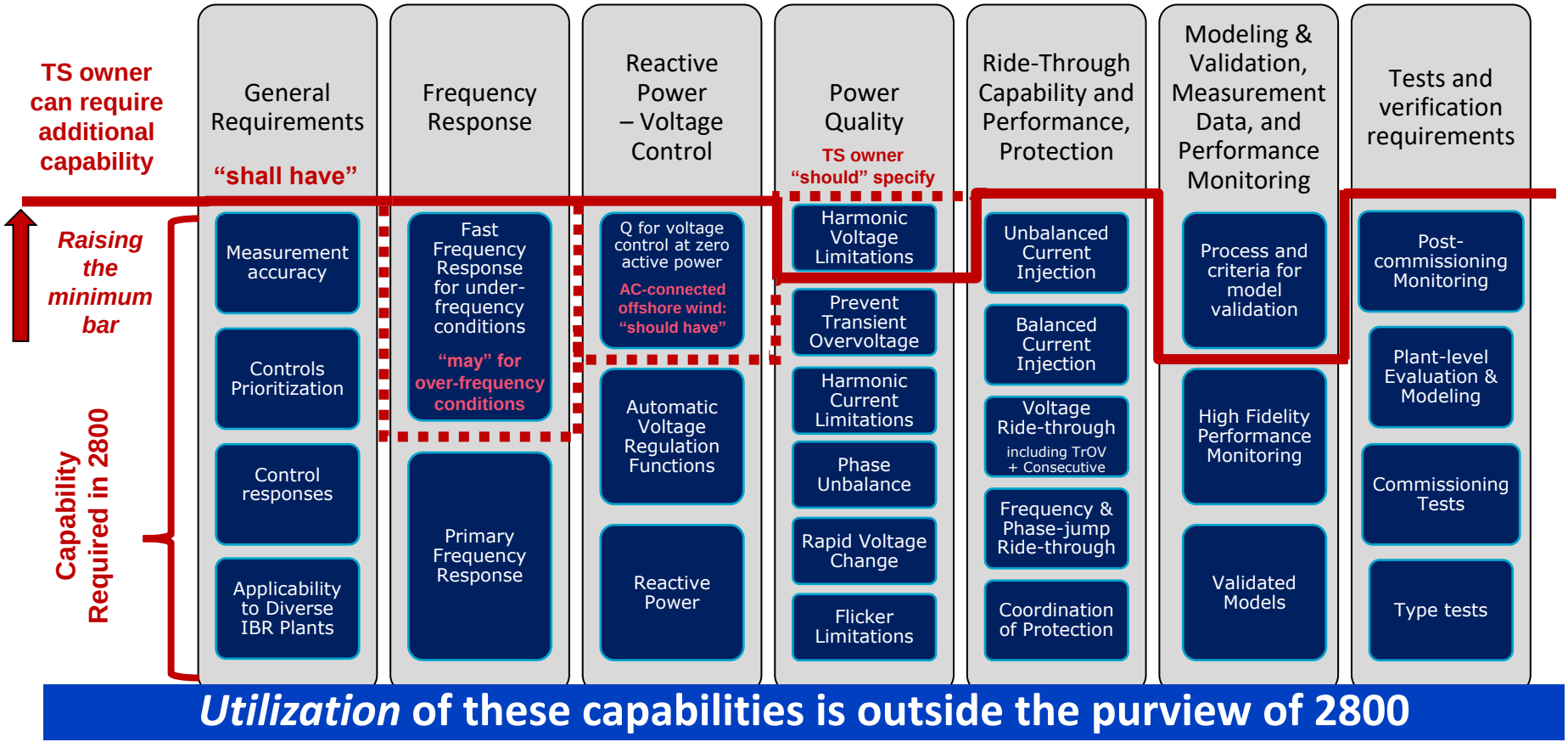
- Enable/disable functions
- Functional settings / configured parameters
- Operate accordingly (e.g., maintain headroom, if applicable)

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

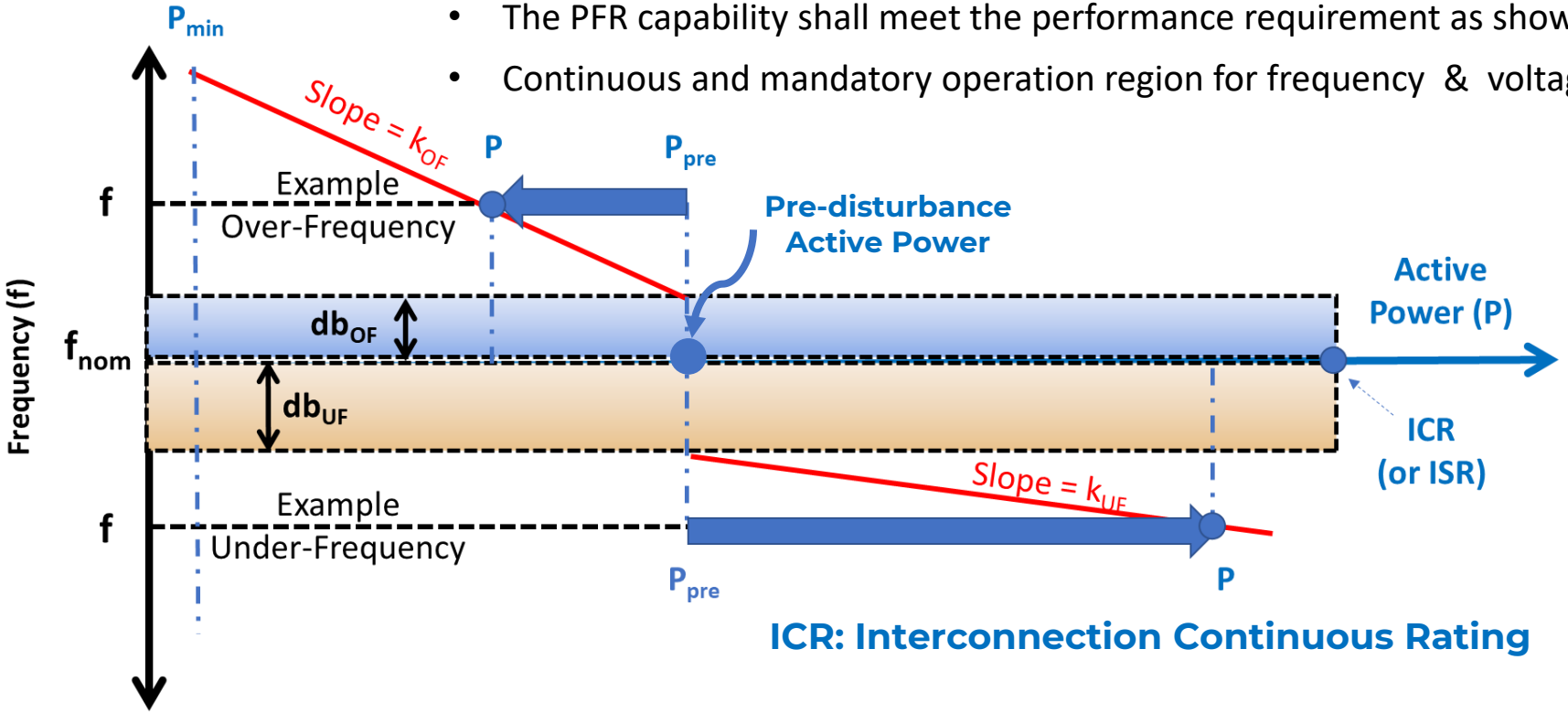
<u>RPA voltage control</u>

- 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	

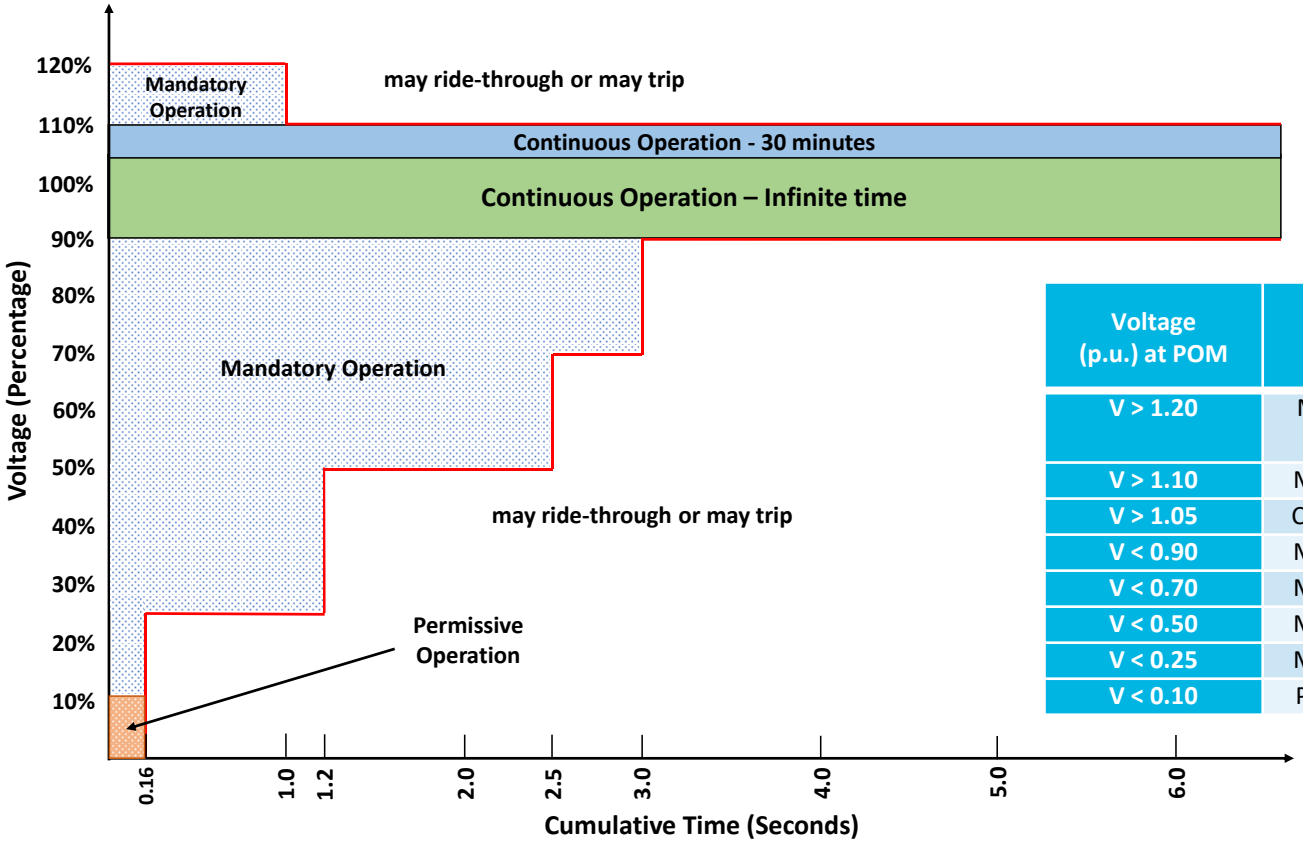
Primary Frequency Response (PFR) Capability of an IBR at RPA

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



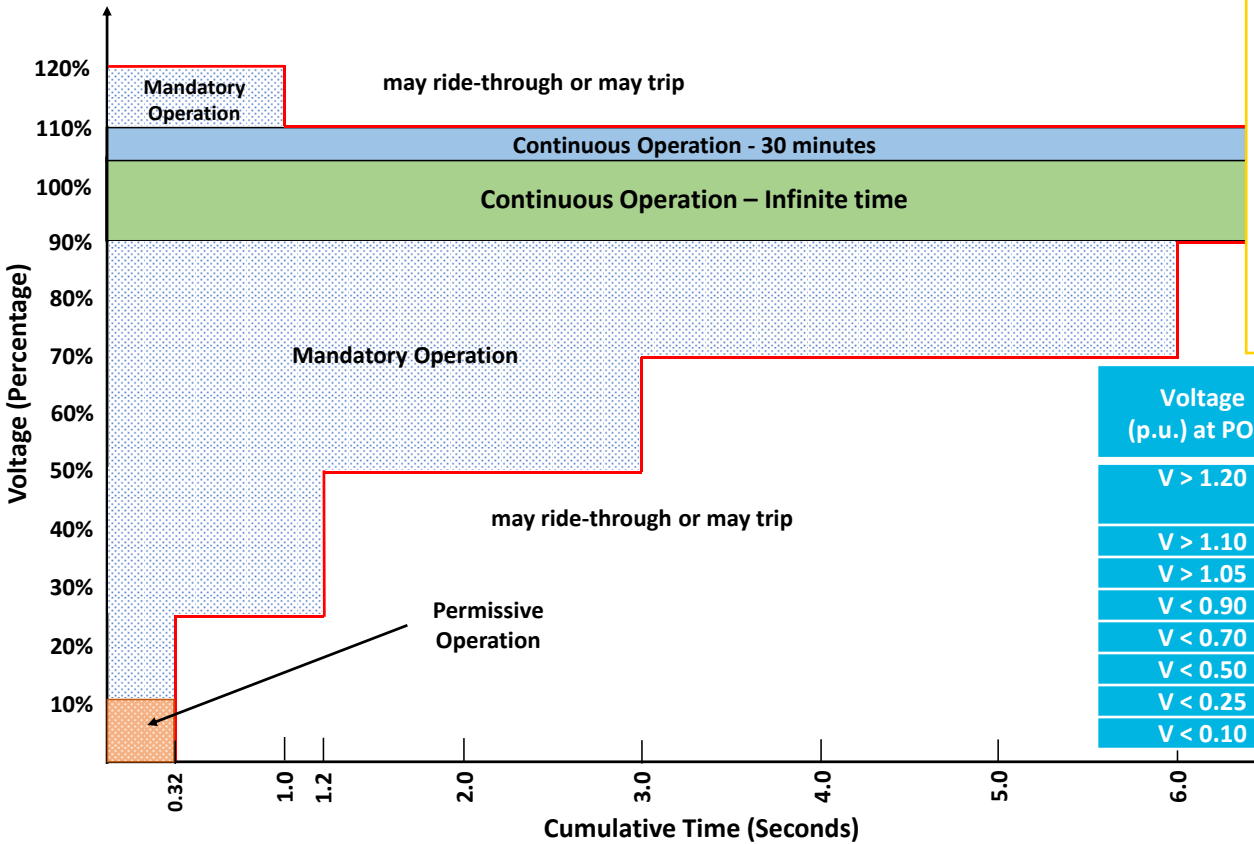
Similar to IEEE 1547-2018 Requirements

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

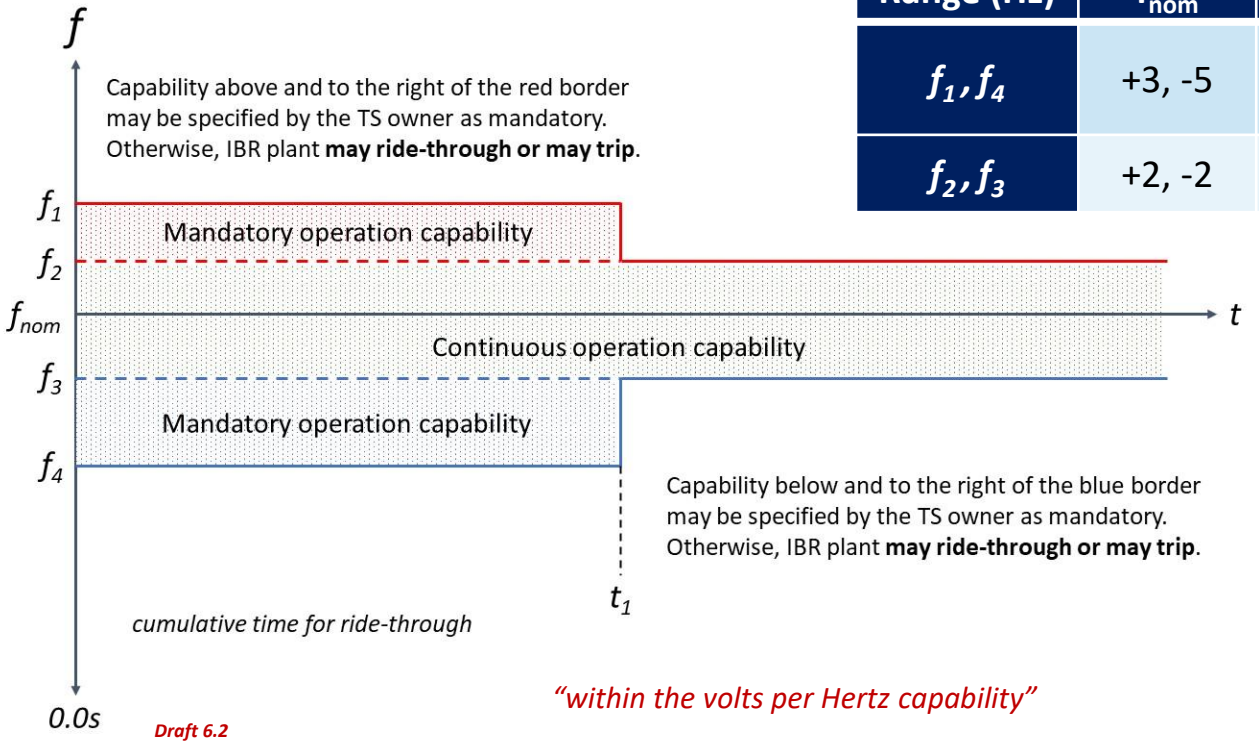


Note: June 16 NOPR clause 9.7.3 conflicts with 2800 by requiring *"real power production at pre-disturbance levels"* **and** *"dynamic reactive power to maintain facility's voltage schedule"* **during voltage ride-through. 2800 allows for either active or reactive power priority and prioritizes dynamic 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



Draft 6.2

"within the volts per Hertz capability"

ROCOF ride-through

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

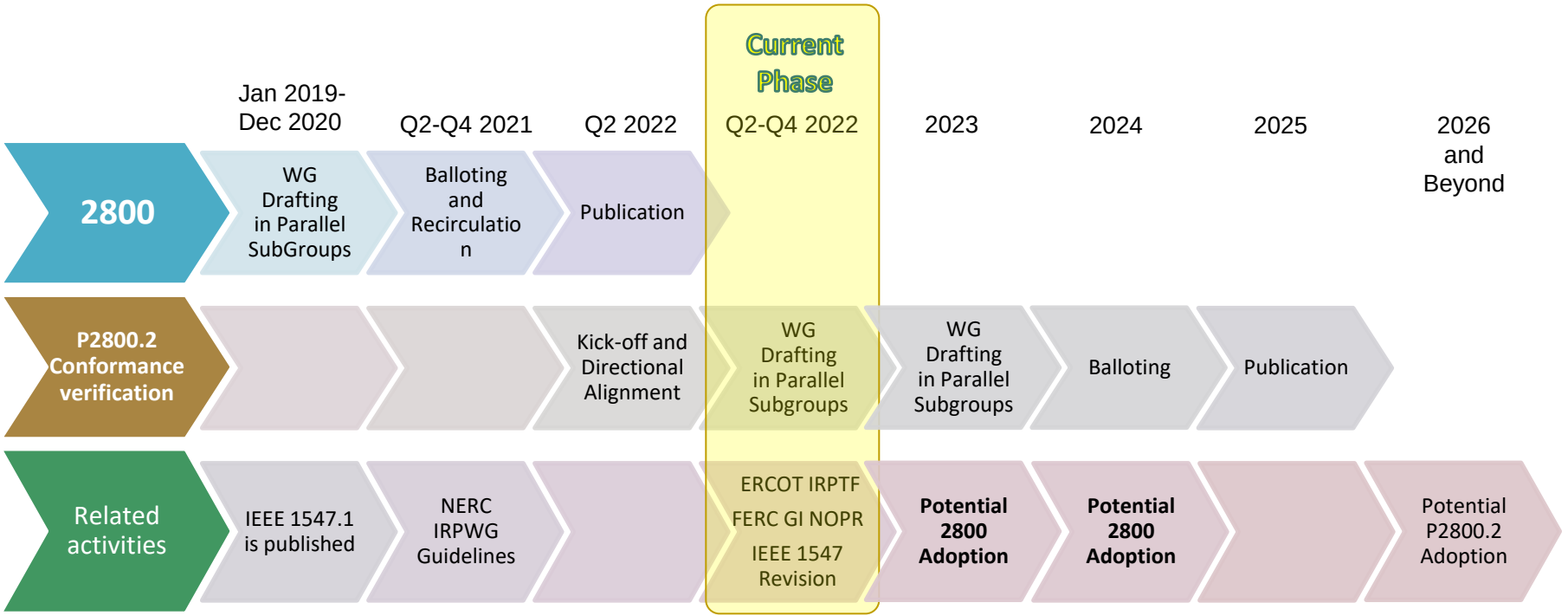
Similar to IEEE 1547-2018 Requirements

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 to 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

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:
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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:
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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)
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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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Additional information @

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