IEEE 2800-2022 Adoption

A Preliminary Detailed Gap Assessment of ERCOT's Nodal Protocols and Nodal Operating Guides relate to IEEE 2800-2022

ERCOT Inverter-Based Resources Task Force (IBRTF)

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July 8, 2022

Classification: Public

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- The views expressed in the presentation do not necessarily represent the views of the **DOE or the U.S. Government**.

This assessment is ongoing. We explicitly encourage stakeholders to provide feedback!

Introduction & Refresher

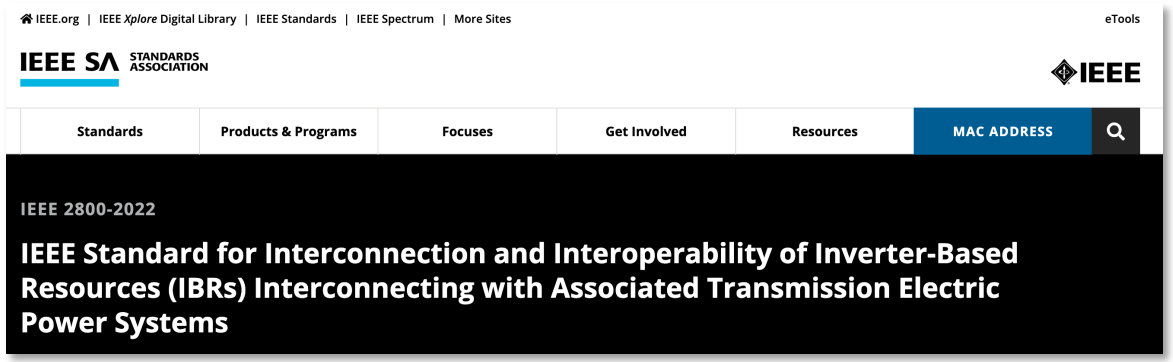
Meetings to Date with IEEE 2800-2022 Scope

Date	Scope	Presentation
Mar 18, 2022 - IBRTF Meeting by Webex Only	General Overview	Posted
Apr 08, 2022 - IBRTF Meeting by Webex Only	Voltage Ride-Through, Reactive Power, and Voltage Support	Posted
May 23, 2022 - IBRTF Meeting by Webex Only	Primary Frequency Response, Fast Frequency Response, Frequency Ride-Through, RoCoF Ride-Through, etc.	Posted
June 10, 2022	No update on IEEE 2800	
July 8, 2022 – IBRTF Meeting by Webex Only	Modeling Requirements Conformity Assessment: OEM equipment readiness, self-certification, etc.	Posted
TBD	Requirements in Scope of Transmission Service Provider (TSP) and not of ERCOT Other Requirements of IEEE 2800 by Mutual Agreement (Optional)	

Recap on discussion from May 23, 2022

- Capability vs. utilization (configuration of performance)
- Make fast frequency response capability a mandatory requirement?
- Coordination of protection inside the IBR plant as important as the capability of the IBR units

Resources and Media



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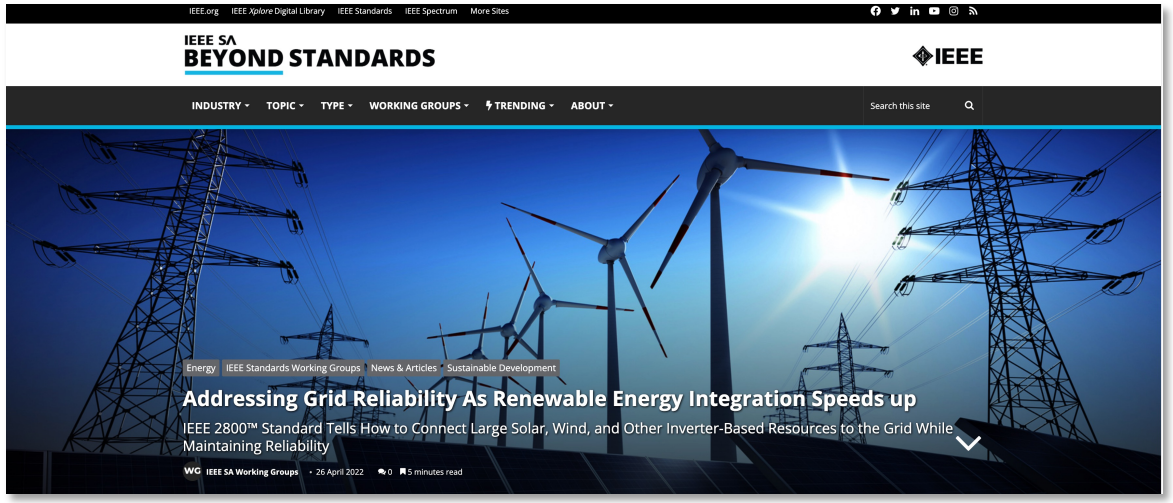
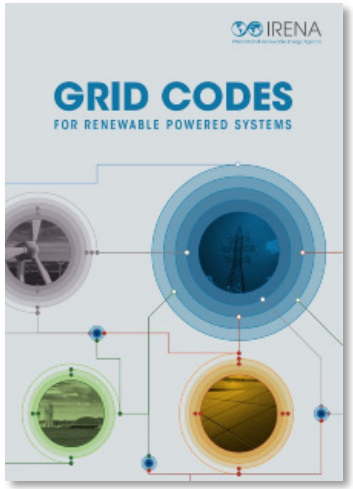


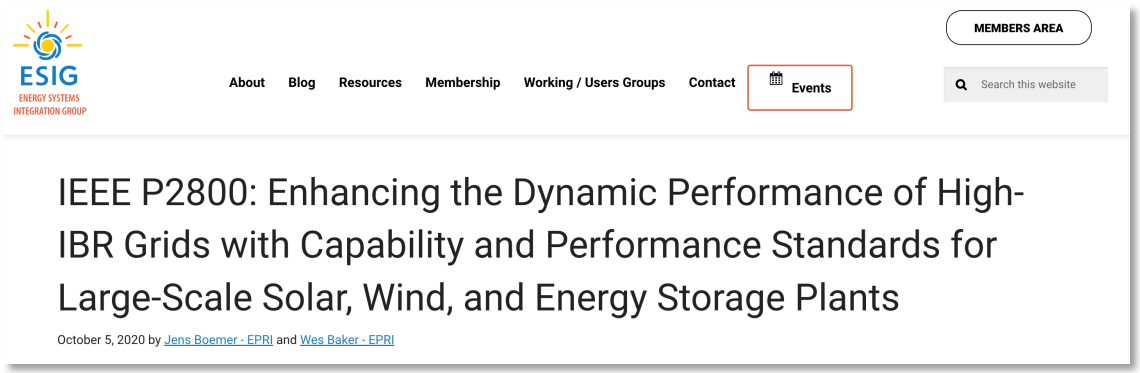
https://beyondstandards.ieee.org/addressing-grid-reliability-as-renewable-energy-integration-speeds-up/



"Grid Codes for Renewable Powered Systems" report by the International Renewable Energy Agency, published April 2022; pages 87-88:

"[IEEE 2800] will be [a] regional grid cod[e] for North America, with the main area of applicability being the United States, but [is] designed to go beyond this scope. [It] can clearly be recommended as [an] optio[n] for internationally standardised technical requirements for generators."

https://www.irena.org/publications/2022/Apr/Grid-codes-for-renewable-powered-systems



https://www.esig.energy/ieee-p2800-enhancing-the-dynamic-performance-of-high-ibr-grids/

Webinar Recording Available:
https://engagestandards.ieee.org/IEEE-2800-Update-Registration-LP.html

IEEE 2800-2022 Industry Webinars

Date	Event
Monday, May 2, 2022	Joint IEEE–ESIG–PSERC–CURENT **Webinar** for Subject Matter Experts & Academia • Speakers: **Jens C. Boemer (WG Chair)** (slide deck) (recording)
Tuesday, May 3, 2022	Joint NERC–NATF–NAGF–EPRI **Webinar** for Transmission Owners/Planners/Operators/Engineers • Speakers: **Manish Patel (WG Vice-Chair)** (slide deck) (recording)
Tuesday, May 31, 2022	Joint SEIA–ACP **(formerly AWEA) Webinar** for OEMs & Developers • Speakers: **Mahesh Morjaria (WG Vice-Chair)** (slide deck) (recording)

https://sagroups.ieee.org/2800/resources/

Related EPRI Webinars

Session	Date	Access Level	Topic
1	4/12/2022	Member Only	IEEE 2800-2022 part 1
2	4/27/2022	Member Only	IEEE 2800-2022 part 2
3	5/17/2022	Member Only	IEEE 2800-2022 part 3
4	5/26/2022	Public	Project Overview and Status Update on Model Development, Improvement, and Validation https://www.epri.com/research/programs/027570/events/7036D11A-3C86-4D64-8FA2-0B45988FFF63

PV-MOD Project Website at https://www.epri.com/pvmod

Recent News: FERC NOPR RM22-14 on Improvements to Generator Interconnection Procedures and Agreements

- Press release available here.
- Key areas of reforms:
  - Implement a first-ready, first-served cluster study process
  - Improve interconnection queue processing speed
  - **Incorporate technological advancements into the interconnection process**
  - **Update modeling and performance requirements for system reliability**

➢ Comments are due 130 days (~4 months) from publication in Federal Register : ~October 24, 2022

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NEWS RELEASES

FERC Proposes Interconnection Reforms to Address Queue Backlogs

June 16, 2022

Docket No. RM22-14
Items E-1 | Staff Presentation

FERC today issued a proposed rule focused on expediting the current process for connecting new electric generation facilities to the grid. The notice of proposed rulemaking (NOPR) aims to address significant current backlogs in the interconnection queues by improving interconnection procedures, providing greater certainty and preventing undue discrimination against new generation.

At the end of 2021, there were more than 1,400 gigawatts of generation and storage waiting in interconnection queues throughout the country. This is more than triple the total volume just five years ago. Projects now face an average timeline of more than three years to get connected to the grid. As the resource mix rapidly changes, the Commission's policies must keep pace. Today's NOPR proposes reforms to ensure that interconnection customers can access the grid in a reliable, efficient, transparent and timely manner.

> "Today's unanimous action addresses the urgent need to update, expedite and streamline our processes to interconnect new resources to the grid," FERC Chairman Rich Glick said. "We are witnessing unprecedent demand for new resources seeking to interconnect to the transmission grid, and queue delays are hindering customers' access to new, low-cost generation."

The proposed rule includes several key areas of reforms.

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Latest News

HEADLINES

FERC Staff Issues the Final Environmental Impact Statement for the MP66-69 Compression Relocation and Modification Amendment and the MP33 Compressor Station Modification Amendment Project (Docket Nos. CP21-1-000 and CP21-458-000)

June 24, 2022

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**

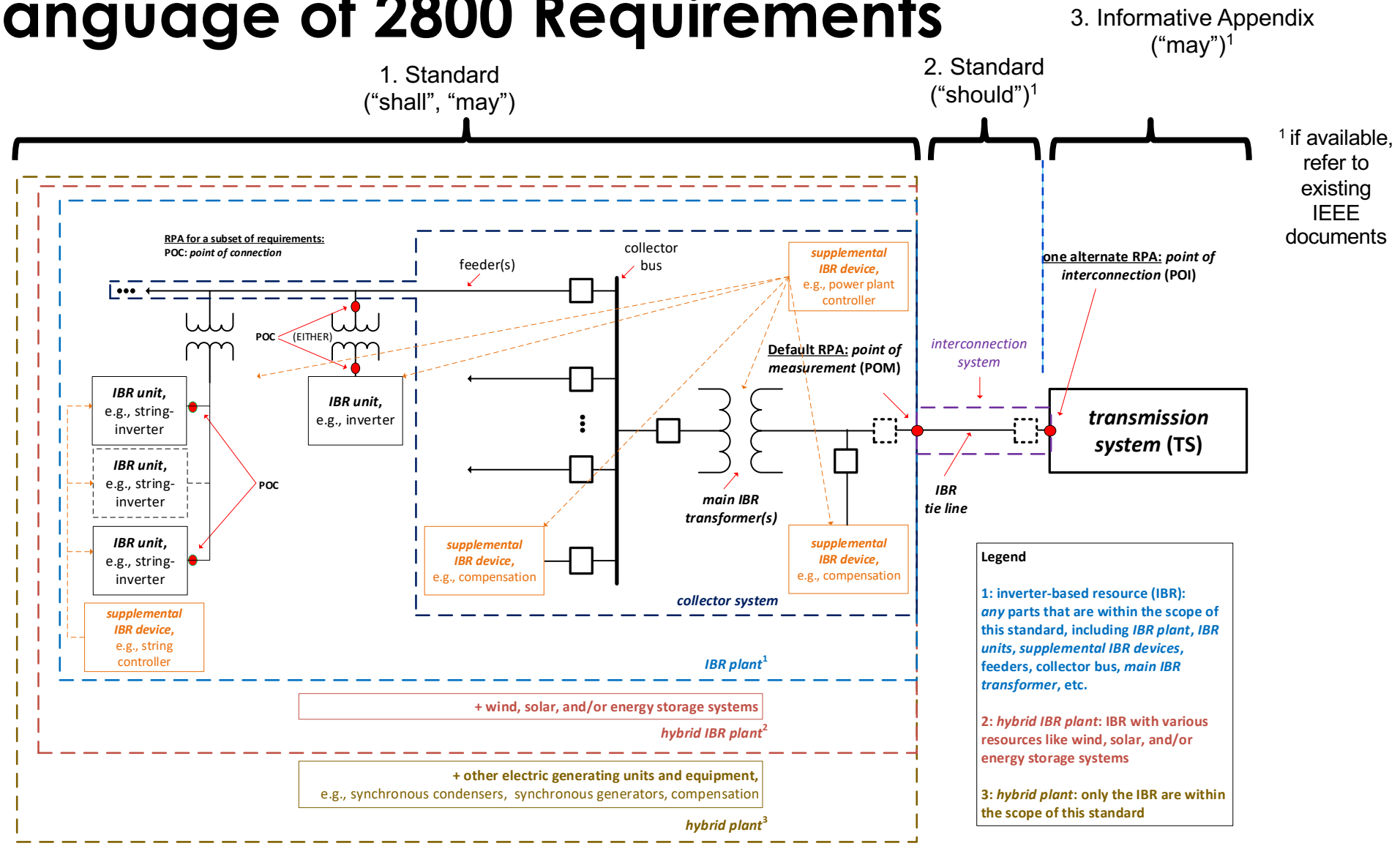
Available from IEEE at https://standards.ieee.org/project/2800.html and via IEEExplore: https://ieeexplore.ieee.org/document/9762253/

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

Scope and Language of 2800 Requirements

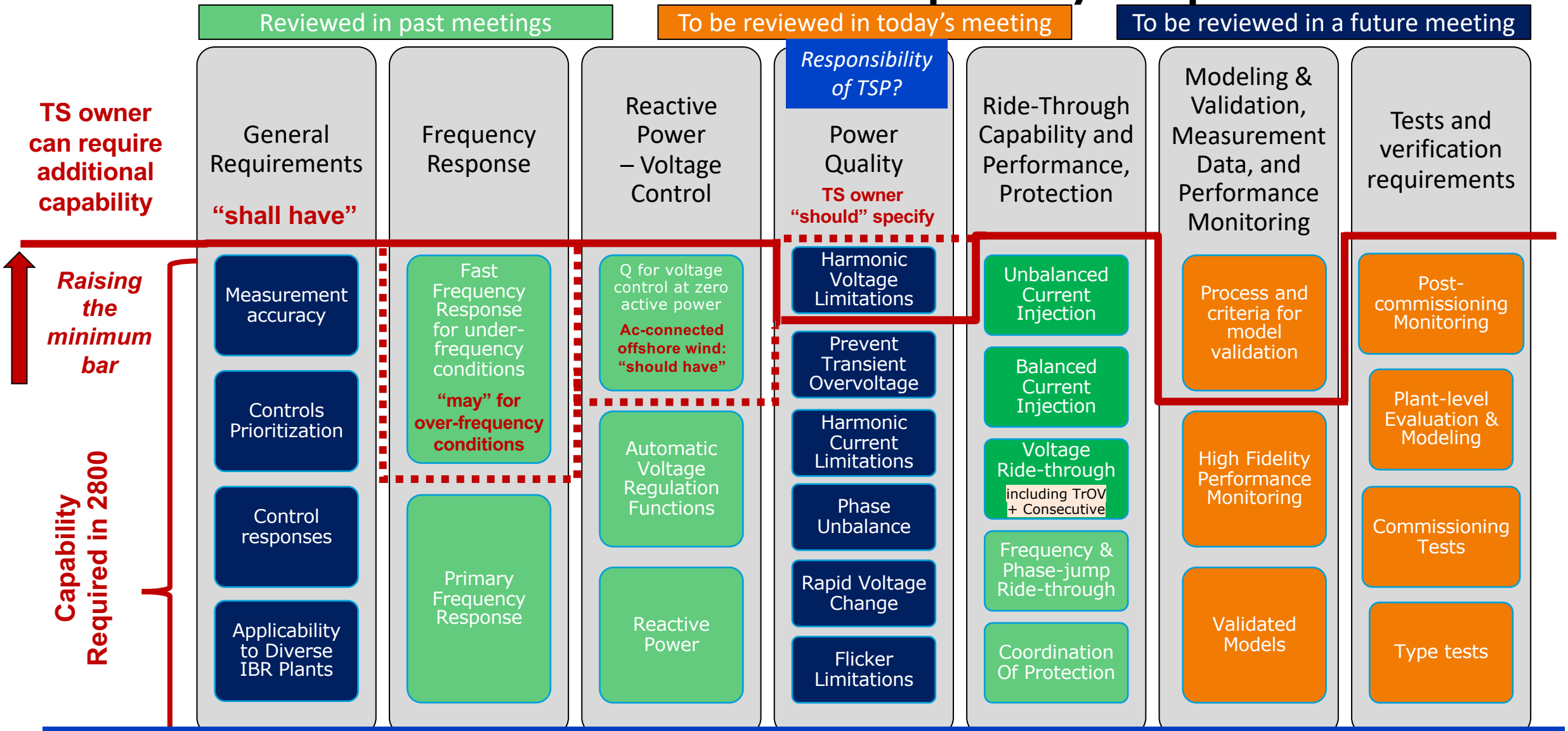
Important Terms

- *point of connection* (POC)
  - *IBR unit* terminals
- *point of measurement* (POM)
  - *IBR plant*
- *point of interconnection* (POI)
  - *interconnection system*
  - *IBR tie line*
- *transmission system* (TS)
  - Transmission
  - Sub-transmission
- *supplemental IBR device*
  - Compensation
  - Plant controller
  - Etc.



ERCOT > IEEE 2800: adopt and exceed 2800 with POI as RPA?

IEEE 2800-2022 Technical Minimum Capability Requirements



Detailed Gap Assessment

Objective and Approach

Objective

Inform strategic decision on IEEE 2800 adoption method:

- General reference ('wholesale adoption')
- Detailed reference ('piecemeal adoption – per reference')
- Full specification ('piecemeal adoption – own language')

Approach

Answer the following questions for where ERCOT and IEEE 2800 both specify requirements:

i. Where IEEE 2800 are more specific or more stringent than ERCOT requirements ("<"), e.g.,
   - longer ride-through capability, or
   - detailed functional specification versus non-prescriptive specification as for dynamic voltage support / short circuit current injection during fault

ii. Where ERCOT requirements and P2800 already align in stringency and level of specificity ("~")

iii. Where ERCOT requirements exceed IEEE 2800 either in stringency or specificity (">")

iv. Analysis not yet completed or clarifying questions

Comparison Basis and Remarks

ERCOT

1. **ERCOT Nodal Protocols (NPs)** – applicable Sections available at https://www.ercot.com/mktrules/nprotocols/current and published on or prior to February 11, 2022.

   The [Nodal] Protocols outline the procedures and processes used by ERCOT and Market Participants for the orderly functioning of the ERCOT system and nodal market.

2. **Nodal Operating Guides (NOGs)** – applicable Sections available at https://www.ercot.com/mktrules/guides/noperating/current and published on or prior to March 1, 2022

   The Nodal Operating Guides, which supplement the Protocols, describe the working relationship between ERCOT and the entities within the ERCOT Region that interact with ERCOT on a minute-to-minute basis to ensure the reliability and security of the ERCOT System.

3. **Planning Guide (PG)** – applicable Sections available at https://www.ercot.com/mktrules/guides/planning/current and published on or prior to `January 1, 2022

   The Planning Guide, which supplements the ERCOT protocols, provides ERCOT stakeholders and market participants with information and documentation concerning the ERCOT transmission planning process.

4. **Model Quality Guide (MQG)** – applicable Sections available at https://www.ercot.com/services/rq/integration and published on or prior to April 20, 2021

   Assists REs/IEs submit stability models per Planning Guide Section 6.2, including the new Model Quality Testing requirements. Also includes the UDM Model Guideline and PSCAD Model Guideline.

IEEE 2800-2022

- IEEE P2800 Draft 6.3 (December 2021)

Remarks on ERCOT documents:

- Both NPs and NOGs are mandatory.
- NPs are broad in scope and tend to high level.
- NOGs tend to be narrower in scope and provide guidance on more practical/ operational aspects.
- The language in NPs and NOGs should not be in conflict; if it is in conflict, it should be pointed out as a finding.
- Some requirements only apply to resources providing ancillary services (AS); this would be explicitly stated, or it is obvious from the Section of the NPs.
  - For example, where an entire section is on Responsive Reserve (RRS) qualification or performance.

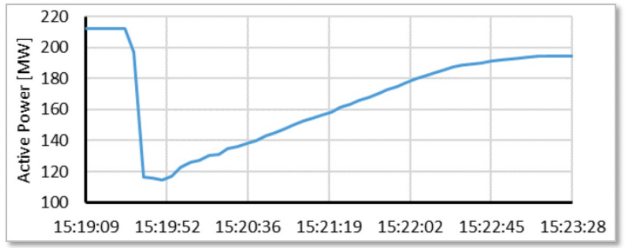
Question: shall comparison be relative to current language or approved revisions (grey boxes)?

Recent NERC/WECC Event Analysis and Engineering

Example Findings

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Plant Controller Interactions Persist



Example: Plant with Legacy Inverters

- Momentary cessation settings:
  - Voltage threshold: 0.875 pu
  - Delay to recover: 1.020 sec
  - Recovery ramp rate: 8.2%/sec
- Expect recovery to pre-disturbance in about 13-14 seconds
- Plant requires about 4 minutes to restore output

Fault Occurs
⇩
Voltage Drops
⇩
Inverters Enter Momentary Cessation
⇩
Plant Controller Pauses Control
⇩
Fault Clears
⇩
Voltage Recovers
⇩
Plant Controller Regains Control
⇩
Plant Controller Limits Inverter Recovery

- Systemic issue seen across many facilities – big and small, old and new

19 RELIABILITY | RESILIENCE | SECURITY

- Momentary cessation occurs above 10% pu voltage
- Plant controller slows restore output after fault beyond 1 s

IEEE 2800-2022 Conformity Assessment

Function Set	Advanced Functions Capability		IEEE 2800-2022	Conformity Assessment
Bulk System Reliability & Frequency Support	Frequency Ride-Through (FRT)		‡	
	Rate-of-Change-of-Frequency (ROCOF) Ride-Through		‡	
	Voltage Ride-Through (VRT)		‡	Pass
	Transient Overvoltage Ride-Through		‡	
	Consecutive Voltage Dip Ride-Through		‡	
	Restore Output After Voltage Ride-Through		‡	Fail
	Voltage Phase Angle Jump Ride-Through		‡	
	Frequency Droop / Frequency-Watt		‡	
	Fast Frequency Response / Inertial Response	Underfrequency FFR	‡	
		Overfrequency FFR	√	
	Return to Service (Enter Service)		‡	
	Black Start		√	
Dynamic Voltage Support	**Dynamic Voltage Support / Current Injection during VRT**	**Balanced**	‡	Fail
		Unbalanced	‡	Fail
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		√	

IEEE 2800-2022 requirements apply to the IBR plant*

- IBR units and IBR plant controller (= “supplemental IBR device”)

* with exception of ‘current injection during VRT’ which applies to IBR unit

ERCOT Status Update for Odessa Disturbance

Example Findings

Overview of Recent Action Items

- ERCOT recently had follow up conference calls with REs of 6 solar farms that tripped during Odessa Disturbance
  - Inverter overvoltage (2)
  - Inverter underfrequency (1)
  - Momentary cessation and slow recovery (1)
  - Feeder breaker overvoltage (1)
  - Feeder breaker underfrequency (1)
- Call with OEM rep for momentary cessation and delayed reactive injection
- Sent out emails to all plants with TMEIC inverters to verify loss of synchronism protection disabled

- Two plants tripped in post-fault period
- Plant owners are currently reviewing mitigation with OEM

IEEE 2800-2022 Conformity Assessment

Function Set	Advanced Functions Capability		IEEE 2800-2022	Conformity Assessment
Bulk System Reliability & Frequency Support	Frequency Ride-Through (FRT)		‡	
	Rate-of-Change-of-Frequency (ROCOF) Ride-Through		‡	
	Voltage Ride-Through (VRT)		‡	Pass
	Transient Overvoltage Ride-Through		‡	Fail
	Consecutive Voltage Dip Ride-Through		‡	
	Restore Output After Voltage Ride-Through		‡	
	Voltage Phase Angle Jump Ride-Through		‡	
	Frequency Droop / Frequency-Watt		‡	
	Fast Frequency Response / Inertial Response	Underfrequency FFR	‡	
		Overfrequency FFR	√	
	Return to Service (Enter Service)		‡	
	Black Start		√	
Dynamic Voltage Support	Dynamic Voltage Support / Current Injection during VRT	Balanced	‡	
		Unbalanced	‡	
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		√	

IEEE 2800-2022 requirements apply to the IBR plant*

- IBR units and IBR plant controller (= “supplemental IBR device”)

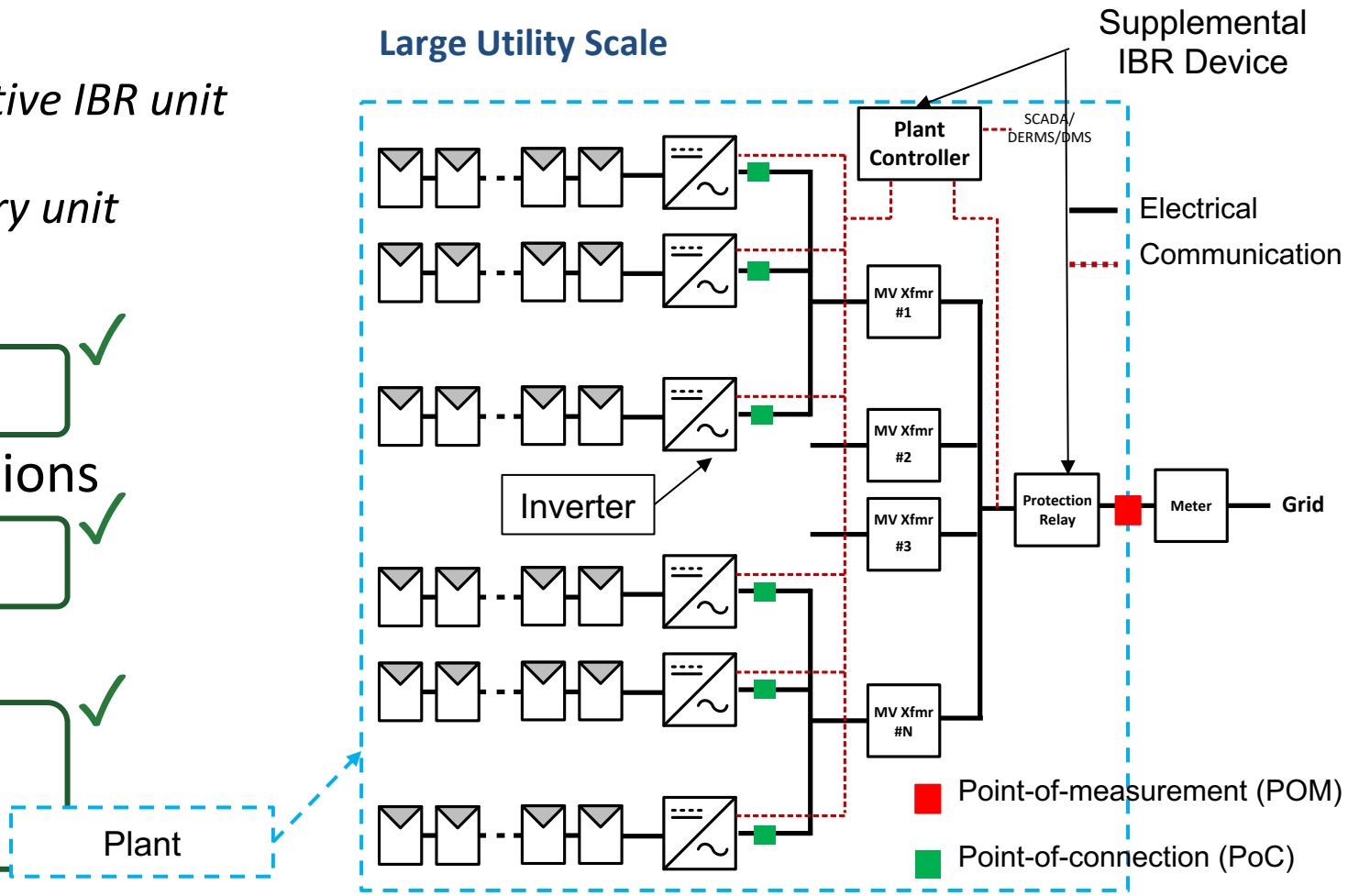
* with exception of ‘current injection during VRT’ which applies to IBR unit

Focus Today:
Modeling Requirements, Plant-Level Verification

IEEE 2800-2022 Test and Verification Methods

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

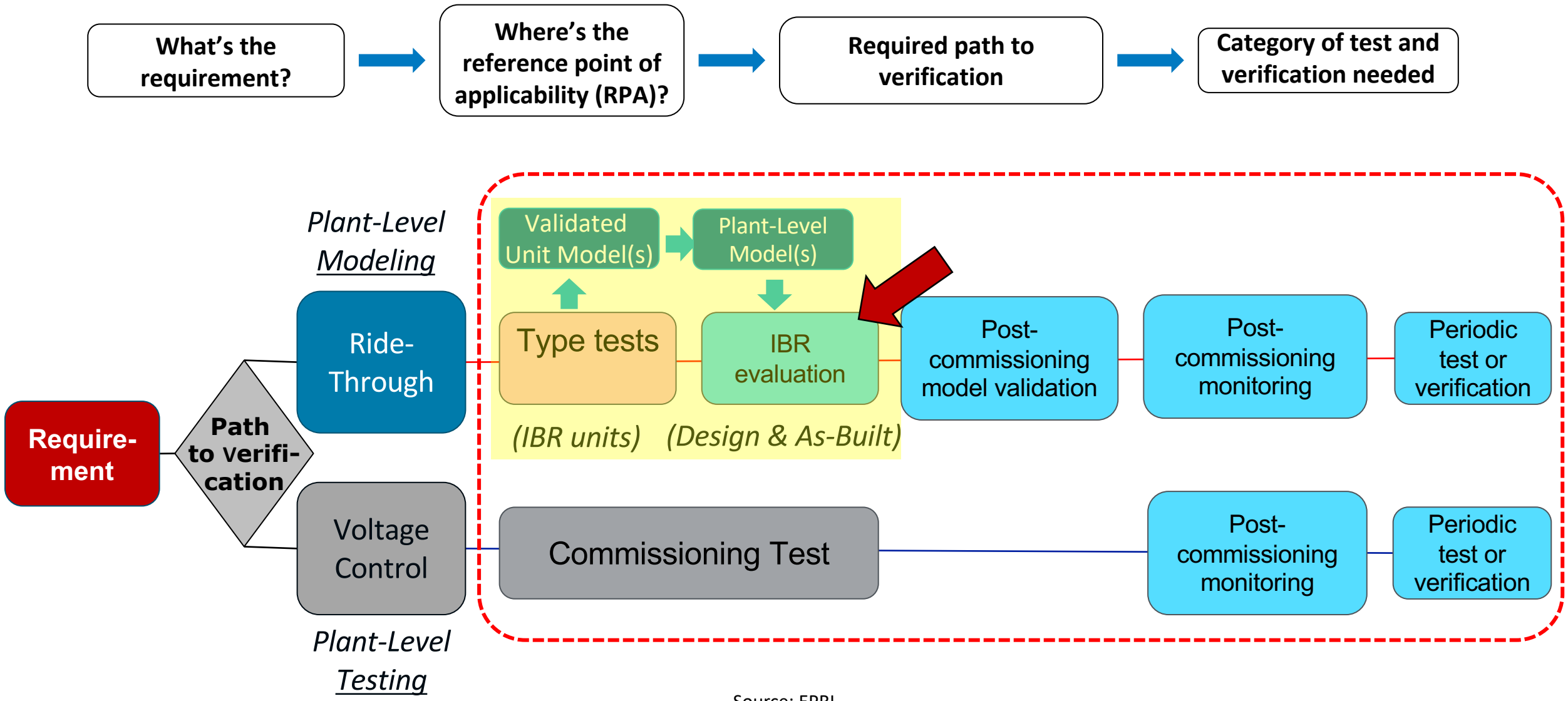
1. Type Tests – *performed on representative IBR unit*
2. Production Tests – *performed on every unit*
3. Pre-Commissioning Verifications
   a. Design Evaluation (desk study) ✓
4. Commissioning Tests and Verifications
   a. As-built Installation Evaluation (on-site) ✓
5. Post-Commissioning Verifications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



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

ERCOT > IEEE 2800: adopt and exceed 2800 with POI as RPA?

Clause 12 (Test and Verification) Framework

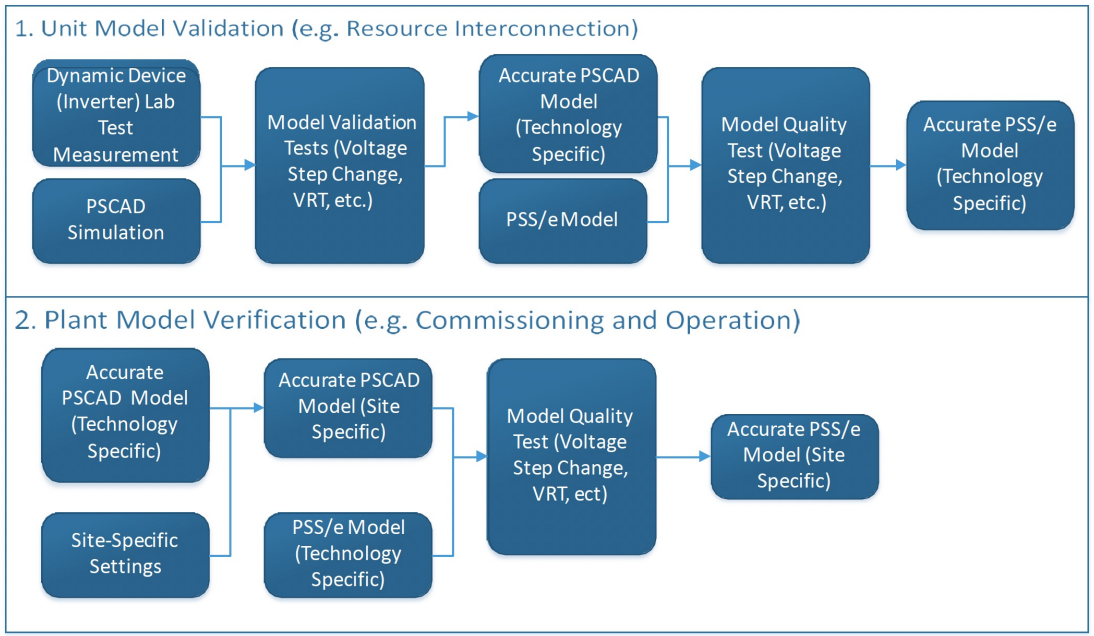


Source: EPRI

Use of Validated Models as a Centerpiece of Plant-Level Conformity Assessment

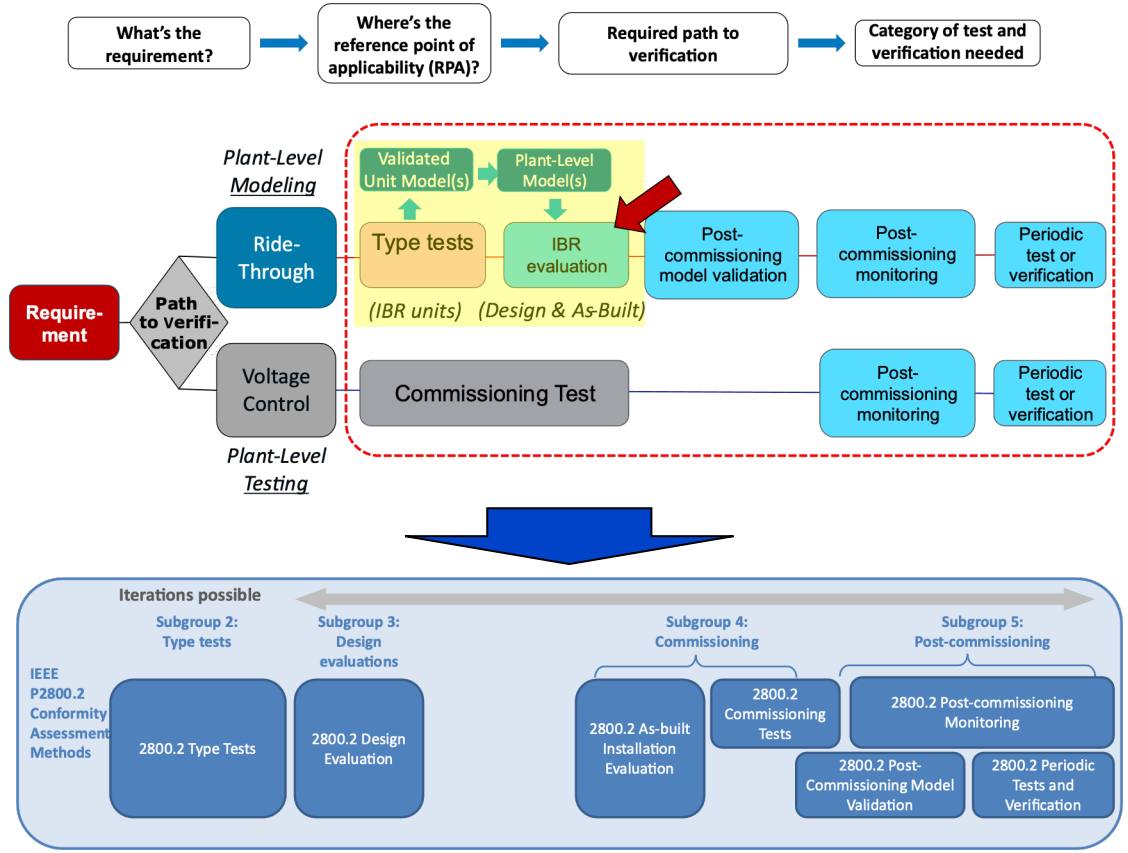
ERCOT

Model Validation and Verification Concept
Implemented with PGRR-075 and PGRR-085



PUBLIC ercot https://www.ercot.com/files/docs/2022/03/18/7_PGRR085_IBRTF_MAR22.pdf 5

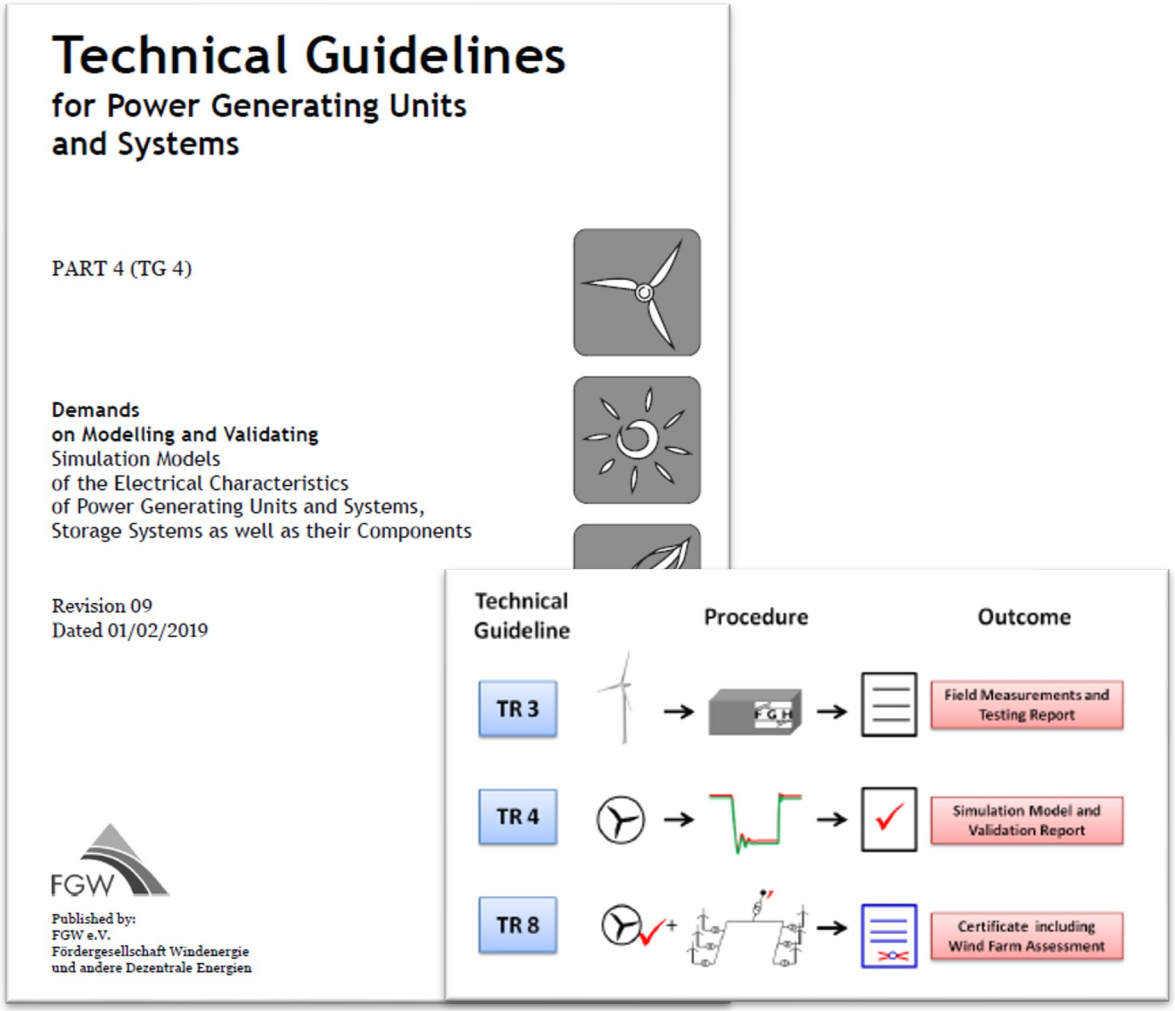
IEEE 2800 – Clause 12. Test and verification requirements



Ongoing drafting of Test and Verification Procedures in IEEE P2800.2
https://sagroups.ieee.org/2800-2/

Learning from International Experience

Performance Verification Example: Germany



EPRI Comments

- Very detailed and specific to the German regulatory context:
  - requires a 3rd party assessment and certification
  - may not be transferable to the U.S.

- Could inform possible stakeholder responsibilities:
  - IBR developer:
    - should be responsible for the sufficient design of the *IBR plant*
    - should provide sufficient documentary evidence about IBR design to evaluate plant conformity with technical requirements
  - TS owner/TS operator:
    - could be responsible for sufficient design evaluation of the IBR plant that verify whether the *IBR plant* design is sufficient to conform with IEEE 2800
    - may delegate the execution of the design evaluation procedures
  - Third party:
    - may execute the *design evaluation* procedures

Review of IEEE 2800-2022

IEEE 2800-2022: Clause 3.1 (Definitions)

interconnection study: a study conducted during the interconnection process

NOTE 1—An *interconnection study* may be conducted by the *TS owner*/*TS operator*, the *IBR owner*, or a third party and may require coordination between parties, subject to regulatory context.

NOTE 2—An *interconnecting study* may include verification of requirements with this standard.

verification entity: A test or verification entity responsible for performing or observing type tests, inverter-based resources (IBR) evaluations, commissioning tests, post-commissioning test/verification, or overseeing production testing programs to verify conformance of the IBR to the standard. (Adapted from IEEE Std 1547™ -2018)

NOTE 1—Verification entities can be a *TS owner*, *TS operator*, *IBR operator*, *IBR owner*, *IBR developer*, *IBR unit* manufacturer or third party testing agency, depending on the test or verification performed.

NOTE 1—In the U.S., the verification entity for type tests may be a Nationally Recognized Testing Laboratory, another independent third party, or the *IBR unit* manufacturer.

IEEE 2800-2022: Clause 12.2 (Definitions of verification methods)

12.2.1 General

All IBR interconnection and interoperability requirements of this standard shall be verified by a combination of the following methods as specified in this clause: *type tests,* IBR evaluations, commissioning tests, and operational evaluation.[145]

[145] Development of dedicated type test procedures complementing this standard is recommended. Existing type test procedures such as IEEE Std 1547.1-2020 [B49], IEC 61400-21-1 [B39], FGW TR3 [B26], FGW TR4 [B27], FGW TR8 [B28], IEC 62927 [B43], IEEE Std 115 [B48], IEC 60034-4-1 [B32], or IEC TS 60034-16-3 [B44] may or may not be appropriate to verify compliance with this standard. Certification of equipment, for example under UL 1741 SA, SB, or CRD PCS ([B111], [B112], [B110]) is outside the scope of this standard.

12.2.3 Design Evaluation [*not* 12.2.4 As-Built Installation Evaluation]

The design evaluation (desk study) is an engineering evaluation during the interconnection and plant commissioning process to verify that the *IBR plant*, as designed, or the *IBR unit(s)*, as applicable, meet the interconnection and interoperability requirements of this standard. […]

IEEE 2800-2022: Clause 12.2 (Definitions of verification methods)

12.2.3 Design Evaluation (cont.)

[…] The *IBR plant* design evaluation may be performed by the *IBR owner*, *TS operator*, *TS owner*, third party consultants and/or jointly by these parties. The design evaluation often includes modeling and simulation of the *IBR plant*, its *IBR unit(s)*, and *supplemental IBR device(s)*, and the interactions with the TS. This evaluation does not include testing. However, reports derived from test results may be consulted in the design evaluation, and the model verification may be informed by the results from *type tests* if available. The design evaluation may also determine other verification steps that may be required such as commissioning testing or post-commissioning monitoring. – The details of interconnection review process vary among *TS owners*/*TS operators* and may be dependent on regional regulatory requirements.

In cases where a *supplemental IBR device* may be used to provide *IBR plant* or *IBR unit(s)* conformance with a subset of requirements of this standard, the design evaluation shall be specific to such requirement(s) along with any other *IBR plant* or *IBR unit* requirement(s) for which conformance to this standard may be impacted by that *supplemental IBR device*.

IEEE 2800-2022: Clause 12.3.2 (Verification methods matrix)

- IEEE 2800-2022 contains performance requirements for IBRs, and a table of methods to verify each requirement
  - ❖ Details of verification methods not included
- **Design evaluation** required per Table 20 (Verification methods matrix) for all IEEE 2800 requirements *except for*
  - 8.2.3 Flicker
- ***Dependent on agreement*** with TS operator/TS owner for
  - 8.3.2 Harmonic voltage distortion
  - 9.5 Unintentional Islanding Protection

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 2800-2022: Clause 12.3.2 (Verification methods matrix)

- The following evaluations ***depend on IBR [design and/or as-built] evaluations***

Requirement	RPA at which requirement applies	*IBR unit*-level tests (at the POC)	*IBR plant*-level verifications (at the RPA)						
		Type tests	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*
Clause 4 General interconnection technical specifications and performance requirements									
4.7 Prioritization of IBR Responses	POM	R *verify correct response*	R *check certification/ manual*	R *verify correct configuration of controls*	D	NR	R *verify correct performance*	D	NR
4.7 Prioritization of IBR Responses	POM	R *verify correct response*	R *check certification/ manual*	R *verify correct configuration of controls*	D	NR	R *verify correct performance*	D	NR
Clause 9 Protection									
9.2 Rate of Change of Frequency (ROCOF) Protection	POC and POM	D	R	R	D	R	R	D	D

IEEE 2800-2022: Appendix G (Recommendation for modeling data)

Annex G (informative) **Recommendation for modeling data**

- G.1 General
- G.2 Steady-state modeling data requirements
- G.3 Stability analysis dynamic modeling data requirements
- G.4 EMT dynamic modeling data requirements
- G.5 Power quality, Flicker and RVC modeling data requirements
- G.6 Short circuit modeling data requirements

Evolving Thoughts On Modeling-Based Plant-Level Conformity Assessment

Conformity Assessment

Testing
(process of setting up and executing relevant trials/experiments)

Model Validation (signal could be a measurement or a simulation result)* *Alternative:* **Model Acceptance Criteria / Model Sufficiency Validation****	**IBR Performance Verification** (does the signal performance meet requirements of IEEE 2800-2022?)	**Conformity Assessment**
Pass (valid)	Pass (conforms)	Pass (conforms)
Pass (valid)	Fail (does not conform)	Fail (does not conform)
Fail (invalid)	Pass (conforms)	Not conclusive: Fail (does not conform)
Fail (invalid)	Fail (does not conform)	Not conclusive: Fail (does not conform)

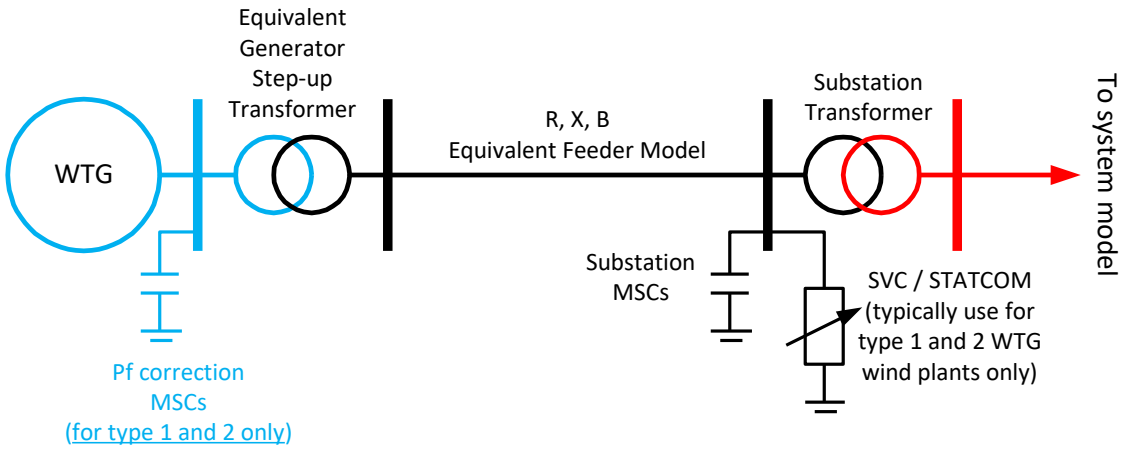
* Could refer to
IEC 61400-27-2
** Already specified

and/or
IEEE P2882
in IEEE 2800-2022

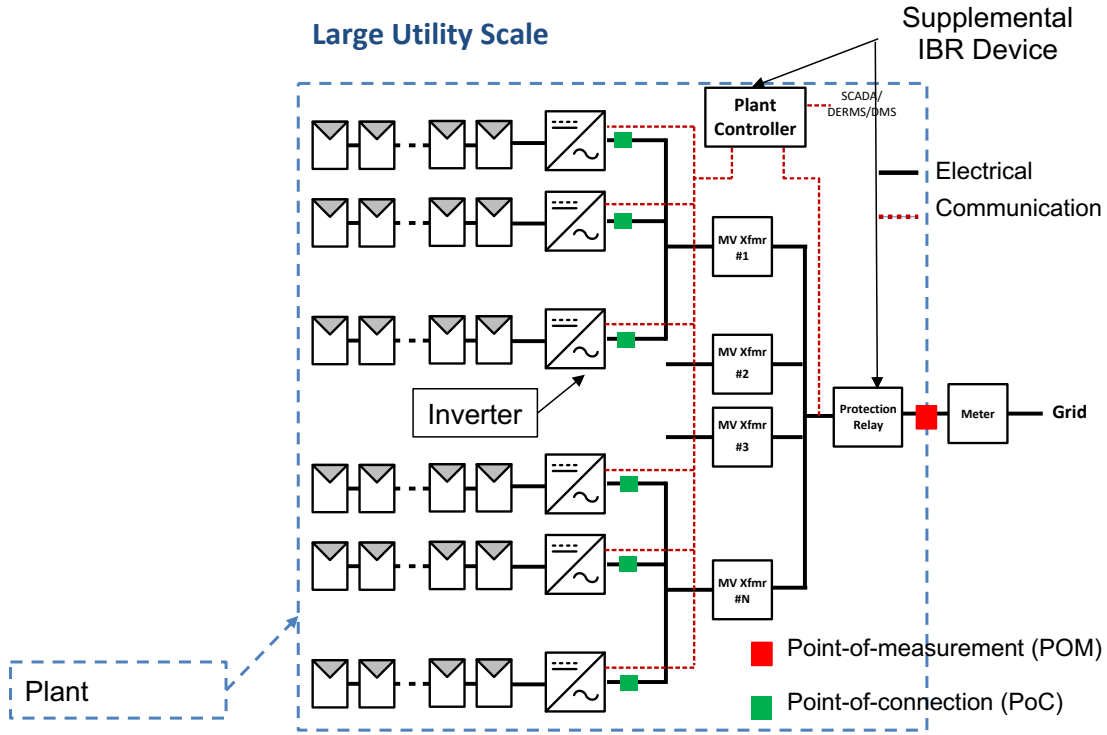
Model Benchmarking
(process of comparing simulation results from two models)

Type of Models

Lumped Plant Model
using Equivalent Plant Model



Detailed Plant Model
using Equipment Models



Both equipment models and plant models could be RMS, EMT, short-circuit, and frequency-domain models, subject to the specific requirement of IEEE 2800-2022 for which conformity is assessed.

Modeling Requirements

IEEE 2800 – Clause 10. Modeling data

- Some specified requirements **cannot** be verified based on tests (type, commissioning etc.)
- Verification of such requirements is **done using models and simulations**
- IBR owner is **required** to provide **verified models** to TS owner/operator such as, power flow, stability dynamic model, short-circuit, EMT, harmonics etc.
- Development of **verified models** is outside the scope of this standard; however, some guidance is provided.
- **Annex G** provides recommended practice for modeling data
  - i.e., details in each type of model

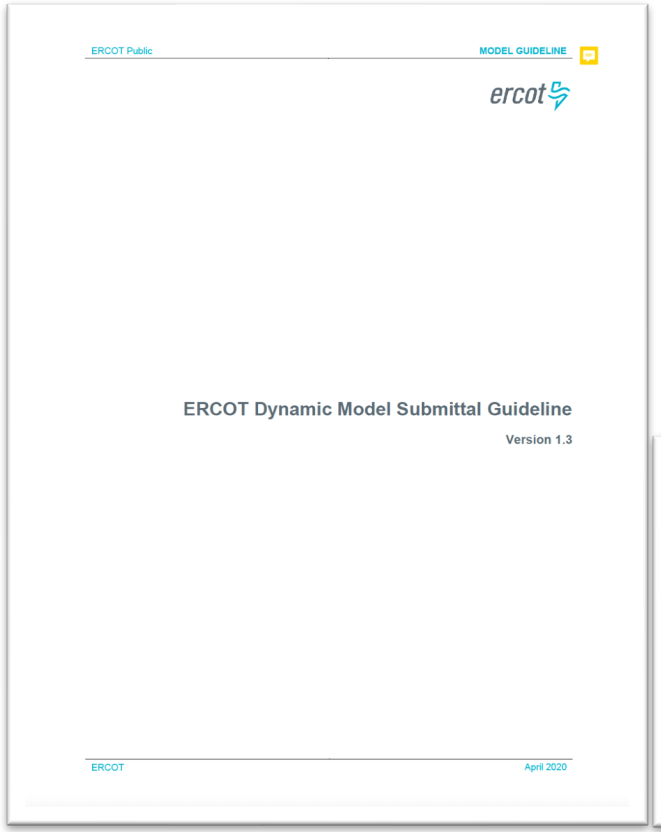
Modeling Requirements

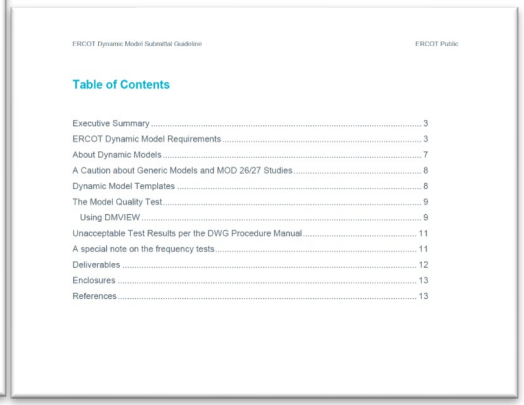
IEEE 2800 – Annex G. Recommendation for modeling data

- G.1 General
- **G.2 Steady-state modeling data requirements**
  - One-line electrical drawing of the entire *collector system*
  - Line parameters for transmission line between the *POM* and *POI*
  - Information on the substation transformer at *POM*
  - *IBR unit* original equipment manufacturer (OEM) data
  - IBR unit transformer data
  - For *energy storage systems*, the total energy capacity (MVAh), the maximum allowable charge/discharge rate, and the maximum/minimum absolute value of state of charge
- G.3 Stability analysis dynamic modeling data requirements
- G.4 EMT dynamic modeling data requirements
- G.5 Power quality, Flicker and RVC modeling data requirements
- G.6 Short circuit modeling data requirements

Modeling Requirements

ERCOT





http://www.ercot.com/services/rq/re

IEEE 2800 – Annex G. Recommendation for modeling data

- G.1 General
- G.2 Steady-state modeling data requirements
- **G.3 Stability analysis dynamic modeling data requirements**
  - OEM provided low/high voltage and low/high frequency ride-through capabilities of the *IBR units*
  - OEM provided parameters for the latest available generic models
  - If requested by *TS owner* or *TS operator,* OEM user-written model, parameters and documentation.
  - IBR developer provide data for SVC or STATCOM if available in the plant
- G.4 EMT dynamic modeling data requirements
- G.5 Power quality, Flicker and RVC modeling data requirements
- G.6 Short circuit modeling data requirements

ERCOT ~ IEEE 2800: Already fairly aligned?

Modeling Requirements

ERCOT

Summary of Dynamic Model Requirements

Requirement	Applicable Equipment	Required Tests[1]	When to Update	Responsible Entity	Language
Model Quality Test for PSS/e Model	All Resources and Dynamic Transmission Elements (system strength test is only required for inverter-based devices)	Flat start, small and large voltage disturbance, small frequency disturbance, and system strength tests	A new or updated model	Equipment owner (RE, IE or TSP)	PG 6.2(5)(c)
Model Quality Test for PSCAD Model	Inverter-based Resources (IBRs) and Dynamic Transmission Elements	All above tests plus phase angle jump test	A new or updated model	Equipment owner (RE, IE or TSP)	PG 6.2(5)(c)
Unit Model Validation for PSCAD Model[2]	Inverter-based Resources (IBRs)	Step change in voltage, large voltage disturbance, system strength, phase angle jump, and subsynchronous tests	A new PSCAD model provided after 3/1/21. (Validation tests should not need updating for model parameter updates on an existing model.)	Resource owner (RE or IE)	PG 6.2(5)(d)
Model Parameter Verification ("Verification Report")	All Resources and Dynamic Transmission Elements	Provide evidence that tunable model parameters match what is implemented in the field. Evidence can take the form of screenshots, nameplate photographs, signed manufacturer commissioning reports, etc.	1. Required within 30 days of COD (i.e., Part 3 approval), 2. 12 to 24 months after COD or 12-24 months after March 1, 2021 for existing resources, 3. A minimum of every 10 years. 4. Within 30 days of a change at the plant	Equipment owner (RE, IE or TSP)	PG 5.5, PG 6.2(5)(b)

(1) Detailed test information is available in the DWG Procedural Manual 3.1.5.

(2) Benchmark the PSCAD model against actual hardware measurements. This is not a site-specific test; the same report can be submitted for different projects whenever that the same inverter is used.

IEEE 2800 – Annex G. Recommendation for modeling data

- G.1 General
- G.2 Steady-state modeling data requirements
- G.3 Stability analysis dynamic modeling data requirements
- **G.4 EMT dynamic modeling data requirements**
  - The *TS operator/TS owner* may either require EMT models for all newly interconnecting inverter-based resources or may require these models on a case-by-case basis.
  - Includes a list of situations where these models should be required
  - Detailed EMT modeling requirements may be developed by *TS operator/TS owner* to help ensure consistent EMT models are provided
  - Includes recommendations for model features related to accuracy, usability, and efficiency
- G.5 Power quality, Flicker and RVC modeling data requirements
- G.6 Short circuit modeling data requirements

ERCOT ~ IEEE 2800: Already fairly aligned?

Modeling Requirements

ERCOT Dynamic Model Submittal Guideline

- For operational units, provides **evidence that the model incorporates site-specific settings** based on field evidence, screenshots, delivery reports, testing reports, etc.
- **User-Defined Models (UDM) are allowed** provided that "they are not unacceptable"
- The PSCAD model should **include all plant equipment and controllers** including switched shunts or dynamic reactive devices and the plant level controller
- **Model Quality Test** for PSS/E Model
- **User-Defined Models (UDM)** models often provide a more accurate response?
  - The cause of this problem is perhaps rooted in the fact that **generic models** are lower fidelity models and necessitate great care in choosing appropriate parameters? The expertise necessary to convert from a UDM model to a generic model usually requires involvement of the manufacturer and is sometimes not within the expertise of 3rd party consultants advertising MOD 26/27 services

EPRI Comments

- Overall, ERCOT's dynamic model submittal guideline leads the industry.
- To achieve a certain minimum model quality, an evolving list of questions that should be answered by OEMs regarding the accuracy and sufficiency of their UDMs is recommended.
  - One example are the PSCAD Model Requirements Rev. 11 available here.
- Plant equipment represented in the PSCAD model should include relay models and other protection equipment within the plant.
- A model quality test should also include a phase jump test.
- Not all user UDMs provide a more accurate response than generic models; it all depends on the specific model and its configuration (see next slide and EPRI white paper).
  - If not structured sufficiently and configured appropriately, a UDM may provide in inaccurate response also.

Opportunities for Improvements / Clarifications to ERCOT's Dynamic Model Submittal Guideline

Model limitation versus simulation domain limitation

- Present models in planning base cases (both positive sequence and EMT) have been unable to capture causes of inverter tripping
- Limitation of a model should not be confused with limitation of the simulation domain itself
- Future models (such as REGC_C and others) help bring about added capability that can be leveraged

Cause of observed behavior	Simulation domain limitation	Most of today's model incorrectly parameterized	Most of today's model do not represent	
Unbalanced conditions	✓			
Sub-cycle ac over voltage	✓			
Sub-cycle ac over current	✓			
Momentary cessation		✓		Future model can represent as capability exists in simulation domain
Error in frequency measurement		✓		
PLL loss of synchronism		✓		
Collector network level under frequency		✓		
Phase jump			✓	
dc reverse current			✓	
dc low voltage			✓	
Plant controller interactions			✓	

(a) Positive sequence simulation domain

Cause of observed behavior	Simulation domain limitation	Most of today's model incorrectly parameterized	Most of today's model do not represent	
Unbalanced conditions		✓		
Sub-cycle ac over voltage		✓		
Sub-cycle ac over current		✓		
Momentary cessation		✓		
Error in frequency measurement		✓		
PLL loss of synchronism		✓		
Collector network level under frequency		✓		
Phase jump			✓	
dc reverse current			✓	
dc low voltage			✓	
Plant controller interactions			✓	

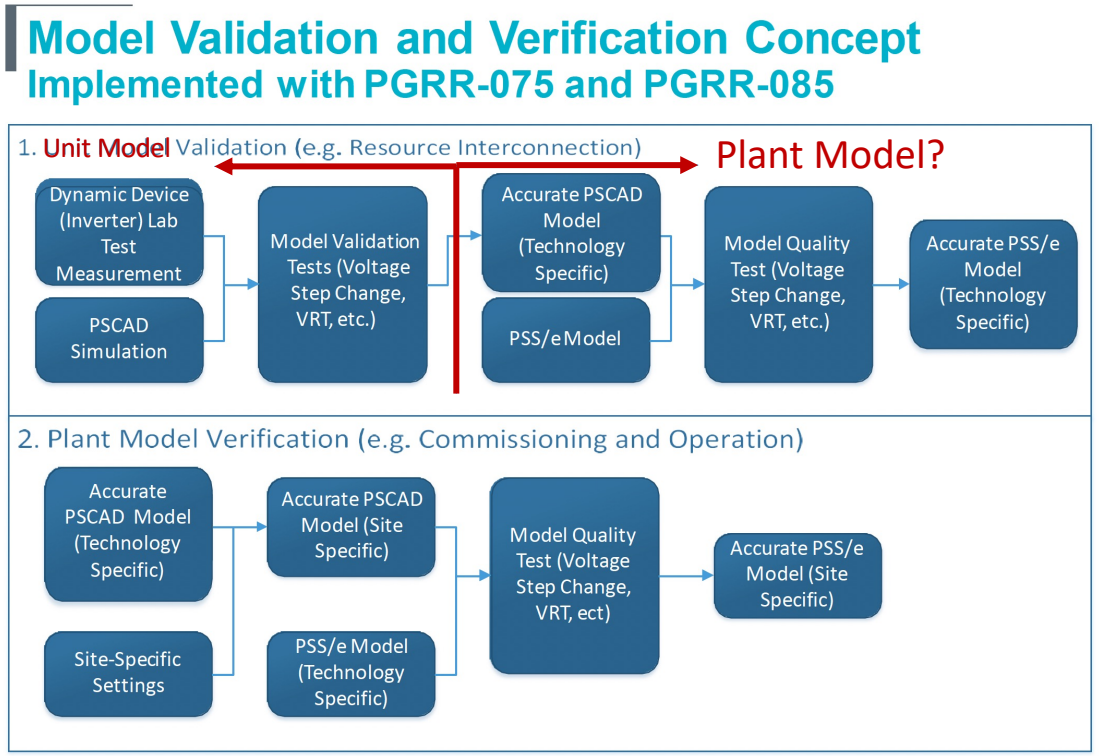
Future model can represent as capability exists in simulation domain

(b) EMT simulation domain

Differentiating between Applicability of Simulation Domains and Inverter Mathematical Models in these Domains. EPRI. Palo Alto, CA: 2022.3002025063. [Online] https://www.epri.com/research/products/000000003002025063

Use of Validated Models as a Centerpiece of Plant-Level Conformity Assessment

ERCOT



PUBLIC ercot https://www.ercot.com/files/docs/2022/03/18/7_PGRR085_IBRTF_MAR22.pdf 5

Observations

<u>During Resource Interconnection</u>

- Sophisticated, technology specific unit model *validation*
  - e.g., based on type tests measurements
- Limited pre-commissioning plant model validation?
  - could plant-level design evaluation help here?

➢ **Limited pre-commissioning plant-level conformity assessment during resource interconnection process?**

<u>During Commissioning and Operation</u>

- Sophisticated, site specific plant model *verification*
  - considering site specific settings and performance during operation

➢ **Leading post-commissioning plant-level conformity assessment during commissioning and operation**

ERCOT < IEEE 2800: Improve pre-commissioning plant-level conformity assessment?

Related NERC and IEC activities?

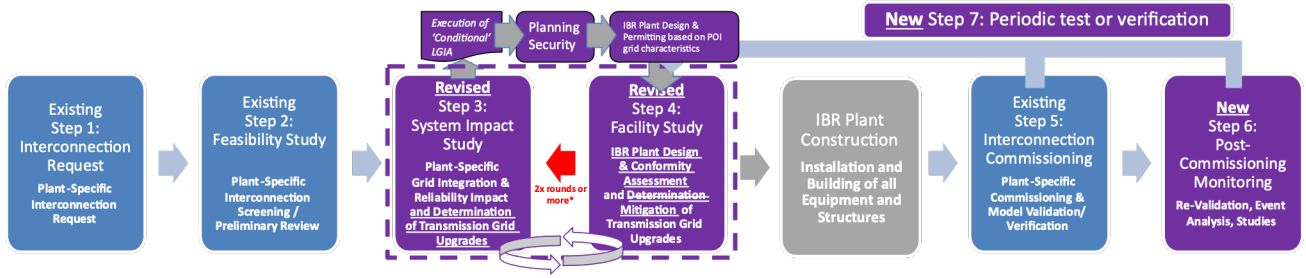
NERC IRPWG SubGroup Work Item #8: Improvement of Interconnection Process and Related Studies

Scope:

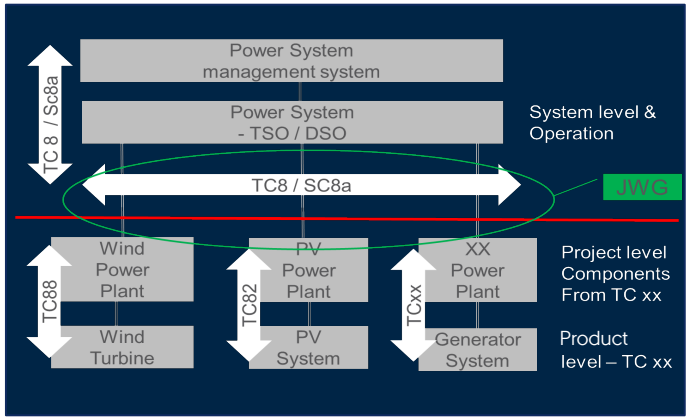
- Address challenges associated with the interconnection study process
- Use of models in feasibility study, system impact study, and facilities study
- Recommend adequate test and verification of IBR plant-level capability & performance

Logistics:

- No meetings for time being while leads are drafting document, irps_intstudy@nerc.com
- P2800.2 Liaisons: Alex Shattuck (axsha@vestas.com) and Jens Boemer (jboemer@epri.com)

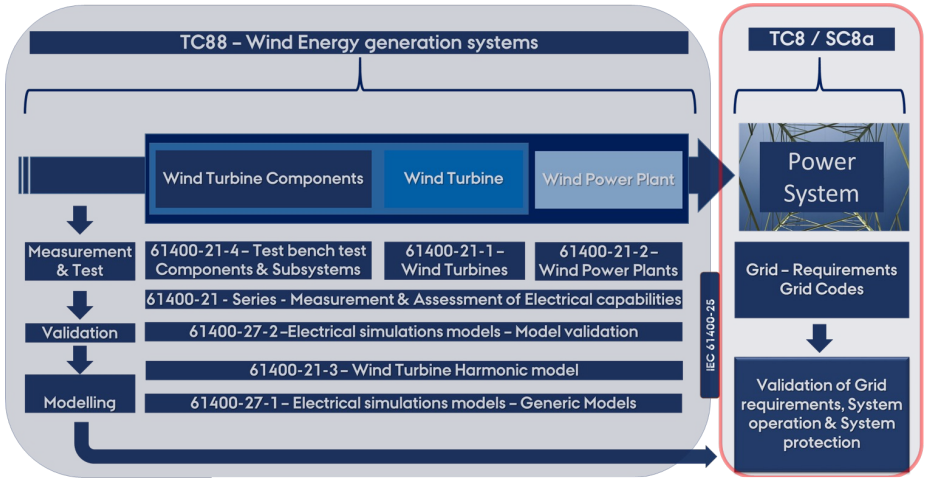


IEC TS 63102:2021 Grid Code Compliance Assessment Methods For Grid Connection Of Wind And PV Power Plants



TC 8/SC 8A/JWG 4

- IEC TS 63102:2021
- P2800.2 Liaison: Jason MacDowell (jason.macdowell@ge.com)
- Other tech reports in progress



Source: Björn Andresen, Aarhus University, Denmark

Related IEEE Standard Association activities?

P2800.2: Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems

- Type: recommended practice, individual project
- Sponsor(s): IEEE/PES/EDPG+EMC+PSRC+AMPS
- Tentative timeline: June 2023 (initial ballot), Dec 2023 (RevCom approval) – WG kick-off on January 18, 2022
- Scope: recommends leading practices for test and verification procedures that should be used to confirm plant-level conformance of IBRs interconnecting with BPSs under IEEE Std 2800.
  - complements the IEEE 2800 test and verification framework with specifications for the equipment, conditions, tests, modeling methods, and other verification procedures
  - may specify design and as-built evaluations procedures for verification of plant-level capabilities and performance
  - may also specify verification procedures for IBR plant-level generic models applied for different time frames including S/C models, RMS models, and EMT models

P2882: Guide for Validation of Software Models of Renewable and Conventional Generators for Power System Studies

- Type: guide, individual project
- Sponsor(s): IEEE/PES/AMPS+EMC+EDPG
- Tentative timeline: Dec 2021 (initial ballot), Dec 2022 (RevCom approval) – work is starting in 2022
- Scope: guidelines for the validation of software models for renewable and conventional generators used for power system studies.
  - … 'validation' is a procedure and set of acceptance criteria … to confirm that the models perform well numerically and provide the intended response(s).
  - does not cover … validation of generator software models against field measurements and other types of site or factory tests

➢ **This activity seems to have different scope compared to P2800.2.**

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 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-SG3 Jens Boemer”

https://sagroups.ieee.org/2800-2/

Discussion

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- Pre-commissioning plant-level conformity assessment practices are still evolving and could reflect a major change from status quo.
- IBR plant design evaluation and model quality check may include the dc part of the plant, especially in case of storage and hybrid plants.
- Engage in the broader consensus building by joining the respective IEEE P2800.2 Working Group and respective Subgroups outlined at https://sagroups.ieee.org/2800-2/subgroups/.

Together...Shaping the Future of Energy™