IEEE P2800.2 3rd Working Group Meeting

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

August 23-25, 2022

Some content derived from IEEE P2800 WG and Jens Boemer, P2800 WG Chair

Please record your attendance

- Please record your attendance at:

  https://imat.ieee.org/attendance

  https://imat.ieee.org/sp17300043/attendance-log?p=4048500005&t=656400043

- **Meeting attendance determines eligibility for WG voting membership**
  - Credit for attendance will be given to those who attend at least 2 of 3 days this week

- In lieu of verbal roll call, **please type your name and affiliation in the chat window**
  - IEEE affiliation FAQs: http://standards.ieee.org/faqs/affiliation.html

Acknowledgements and disclaimers

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

- Draft standard disclaimer:
  - 2800 and P2800.2 are unapproved drafts of proposed IEEE Standards. As such, the documents are subject to change, any draft requirements and figures shown in this presentation may change.

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

Agenda

- Day 1
  - Call to order and welcome
  - Roll call and declaration of affiliation (via chat window)
  - P2800.2 Working Group policies and procedures
  - IEEE patent and copyright policies
  - Approval of agenda and past minutes
  - IEEE 2800-2022 update
  - P2800.2 overview
  - Subgroup 1: General Requirements
  - Subgroup 2: Type Tests
- Day 2
  - Subgroup 3: Design Evaluations
  - Subgroup 4: Commissioning Tests and As-built Evaluations
- Day 3
  - Subgroup 4: Commissioning Tests and As-built Evaluations (continued)
  - Subgroup 5: Post Commissioning Model Validation, Monitoring, and Periodic Evaluations
  - Power Quality Task Force
  - Summary and next steps

Working Group Policies and Procedures

- We plan to use the same P&Ps as the P2800 WG, as previously approved by the sponsor, available here: https://sagroups.ieee.org/2800/wp-content/uploads/sites/336/2020/08/EDPGC-Sponsored-WG-P-and-PV2Jan2020_IEEE-P2800-WG.pdf
  - Introduced at previous WG meetings
- Given 108 WG members total, we have a quorum if 26 members or more are present

IEEE patent policy and legal notices

- IEEE Patent Policy
  - https://development.standards.ieee.org/myproject/Public/mytools/mob/slideset.pdf
  - Call for potentially essential patents
- IEEE Copyright Policy:
  - https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/copyright-policy-WG-meetings.potx
- IEEE Participant Behavior:
  - https://standards.ieee.org/wp-content/uploads/import/documents/other/Participant-Behavior-Individual-Method.pdf

Status of IEEE 2800-2022

- Officially approved by IEEE-SA Standards Board Feb 9, 2022. 94% ballot approval. **Published April 22, 2022**.
- Harmonizes interconnection requirements for large solar, wind, and storage plants (and other inverter-based resources)
- A consensus-based standard developed by over ~175 Working Group participants from utilities, system operators, transmission planners, & OEMs over 2+ years
- IEEE standards are **voluntary until adopted by an appropriate entity**. Such entities are encouraged to consider adoption of 2800 to the extent feasible even before IEEE P2800.2 is complete.

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 at https://standards.ieee.org/ieee/2800/10453/

Last meeting's minutes

- The minutes of the last WG meeting (February 2022) were posted on iMeet Central shortly after the meeting
- WG members were notified of an opportunity to review the minutes upon posting and were reminded when the agenda for this meeting was sent
- **Call for comments/approval of last meeting minutes**

P2800.2 Overview (from PAR)

- Title:
  - Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems
- Scope:
  - Define **recommended practices** for test and **verification procedures to confirm plant-level conformance** of IBRs interconnecting with bulk power systems in compliance with IEEE Std 2800
  - Applies to IBRs in transmission and sub-transmission systems
  - May also apply to isolated IBRs interconnected to an AC transmission system via dedicated voltage source converter high-voltage direct current (VSC-HVDC) transmission facilities, e.g., offshore wind farms
  - Specifications for the equipment, conditions, tests, modeling methods, and other verification procedures that should be used to demonstrate conformance with IEEE 2800
- Includes:
  - **Type tests** (unit level, not full compliance)
  - **Design evaluation**, including modeling
  - **As-built evaluation** and **commissioning tests**
  - **Post-commissioning model validation, monitoring, periodic tests**, and **periodic verifications**
- Recommended practice: Uses “should” language, not “shall” language.
  - In recognition that prescribing uniform procedures across all IBR types and utility locations would be very challenging

IEEE P2800.2 Scope

- 2800-2022 contains performance requirements for IBRs, and a table of methods to verify each requirement
  - Details of verification methods not included
- P2800.2 will recommend details of verification methods

- Include procedure for each "R"
- Likely for each "D" as well
- If an appropriate procedure exists elsewhere, can refer to that

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)							

P2800.2 Key Questions

- How specific should procedures be? How prescriptive?
  - Keep in mind "should", not "shall"
- Will procedures include quantitative pass-fail criteria? Or rely on expert judgement? A combination?
  - Subgroups to propose
- Can one test procedure cover multiple requirements?
  - Yes. Subgroups to consider
- For some requirements, will we offer multiple different verification methods?
  - Probably yes. Which ones? (Subgroups to propose)
- Many other subgroup-specific questions

P2800.2 – Paradigm shift?

- Note that:
  - Key interconnection requirement conformity assessment steps occur *before* commissioning
  - Validated models that accurately represent plant performance likely needed, probably before commissioning (but exactly when is to be determined by the WG)
- Is that a change from your current process?

- Why?
  - Once an IBR is commissioned, it can be costly to fix any issues. Power system is changing fast.
- Is this going to be easy?
  - Probably not
- But if we do a good job, P2800.2 (along with other ongoing industry efforts) can:
  - Offer a standardized industry-wide practice for IBR conformance assessment
  - Minimize future need for costly retrofits
  - Help ensure the near-future, highly renewable grid is at least as reliable as today's
    - I.e., avoid continued incidents like Odessa and Blue Cut disturbances, but potentially much bigger

P2800.2 – Relationship to the IBR interconnection process

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

- Proposal to WG: In P2800.2, our job is (only) to **write procedures to verify that IBRs conform to IEEE 2800**
  - Important discussions related to interconnection that do not relate to *IEEE 2800 conformance verification* can take place *primarily outside* P2800.2
  - By providing standardized procedures, we are taking a major step to improve the interconnection process (without trying to fix everything)
- **Does WG agree?**

P2800.2 – How urgent is it?

- Just finished major effort to write, ballot, and publish IEEE 2800
  - Entities are considering when to adopt
  - Some elements of 2800 are urgently needed to address BPS reliability events
- P2800.2 is expected to take ~3 years to write, ballot, and publish (plus more time for products to be tested and deployed)
  - 2800 and P2800.2 leadership have proposed that 2800 could be adopted prior to the publication of P2800.2.
    - Existing methods and self-attestation can be used to verify compliance
  - ESIG interconnection workshop: Presenters indicated that most (but not all) 2800 requirements can be adopted before .2 is published
- Conclusion: **P2800.2 appears to be needed to facilitate full adoption of 2800, so our work is urgent**
  - Adoption of key 2800 requirements is still encouraged prior to .2 publication!

IEEE P2800.2 Subgroup Scopes

SG 1

Overall document and general requirements

SG 2 | **SG 3** | **SG 4** | **SG 5**

Excerpt of 2800 Table 20:

Verification Methods Matrix

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

PQ Task Force

IEEE PES Power & Energy Society®

IEEE P2800.2 Initial Structure and Leaders

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

Vice Chair: Lead subgroup and coordinate with other subgroups

Subgroup Chair(s): Facilitate subgroup calls

Draft specific verification procedures with subgroup input

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

Chair	Andy Hoke Andy.Hoke@nrel.gov
Secretary	Manish Patel mpatel@southernco.com
Vice Chair	Bob Cummings
Vice Chair	Mahesh Morjaria

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

Lead overall WG

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

Provide input to subgroups on PQ requirements verification

Subgroup 1 – Overall document: Scope

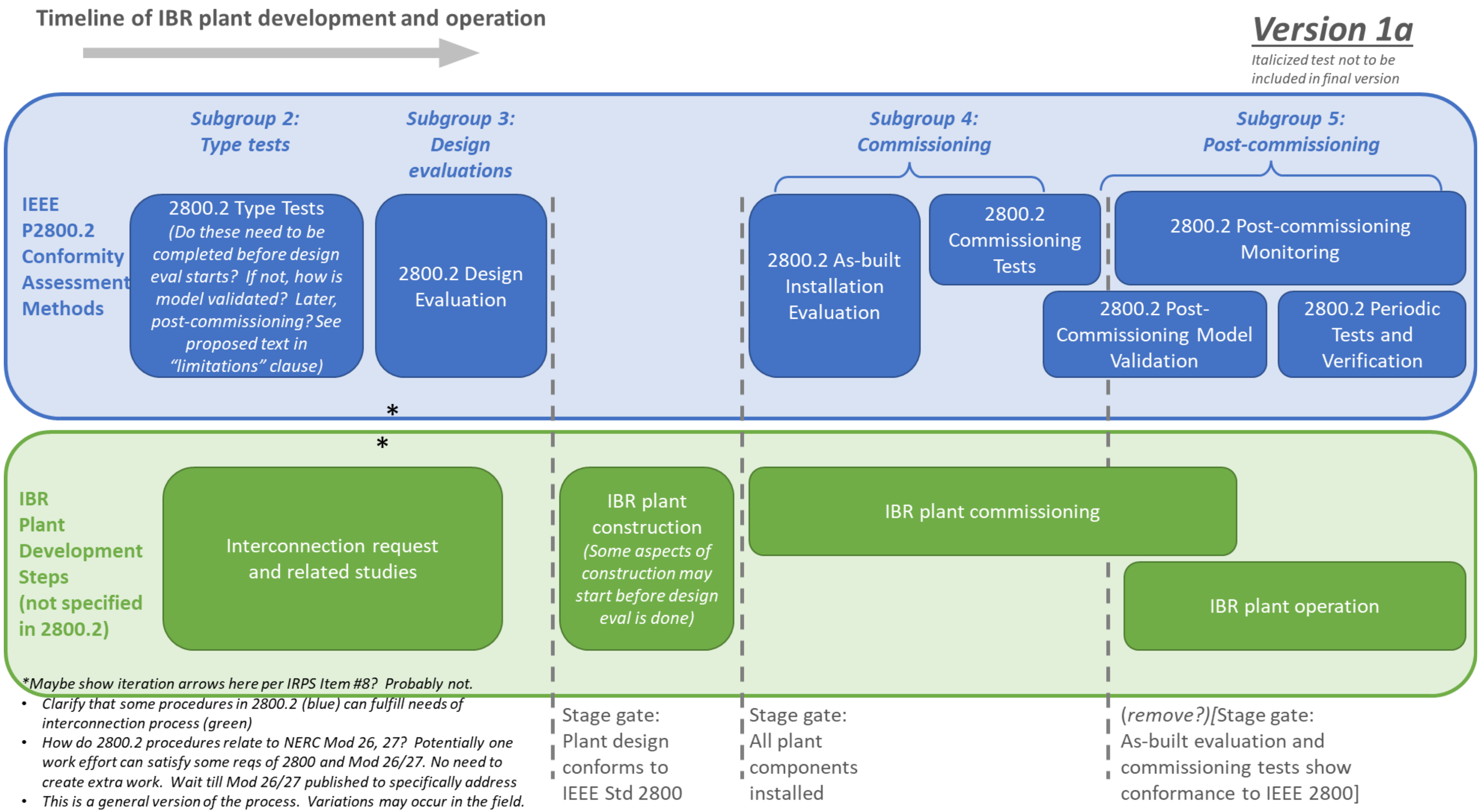
- Scope
  - Normative and informative references
  - Definitions and acronyms
  - Introductory material
  - General requirements
  - Any other items that do not fall under other subgroups
- Items not in scope
  - Topics not related to 2800 requirements verification

Subgroup 1 draft material – Overview

- Introduction and summary of clauses
- Scope and purpose taken directly from PAR
- Reference to IEEE 2800 as “essential to understand”
- Relationship to interconnection process

  “While this recommended practice does not define an IBR interconnection process, many of the procedures defined here can be used as part of an IBR interconnection process…”

Subgroup 1 draft material – Overview



- *Clarify that some procedures in 2800.2 (blue) can fulfill needs of interconnection process (green)*
- *How do 2800.2 procedures relate to NERC Mod 26, 27? Potentially one work effort can satisfy some reqs of 2800 and Mod 26/27. No need to create extra work. Wait till Mod 26/27 published to specifically address*
- *This is a general version of the process. Variations may occur in the field.*

General remarks (paraphrased)

- Applicable to IBRs on transmission and sub-transmission
- Scope and purpose taken directly from PAR
- Contains test and verification procedures for 2800
- Certain IBRs, e.g. type III wind, have different procedures
- Alternate means of compliance verification allowed upon mutual agreement
- Validated models may not always be available at start of 2800 verification process
- Generator sign convention

Limitations (paraphrased)

- Personnel safety not covered
- Does not define a certification or interconnection process
- IEEE 2800 takes precedence in case of conflict with .2
- Not intended/appropriate for distribution
- Exceptions allowed for emerging technologies (e.g. grid-forming) if needed
- Some equipment ion plant is subject to other standards
- Does not specify reqs for interconnection studies, but study could include procedures from .2
- Does not specify verification procedures for power oscillation damping controls
- Does not apply to non-IBR part of hybrid plant
- Alternate procedures allowed when a sync machine is used as a supplemental IBR device

Limitations (paraphrased)

- Does not contain verification procedures for IBR self-protection (except to verify that protection does not interfere with 2800 compliance)
- Does not provide guidance on IBR parameter selection
- Does directly address high-IBR operation challenges
- Does not provide guidance on utilization of IBR capabilities
- Does not recommend procedures for verification of secure communications
  - May include some references on this. **Should it?**
- Does attempt to verify performance in extreme conditions outside plant design basis

IEEE P2800.2 Flow Chart

- Show separate slide deck with *draft* flow chart
- Does WG see value in including flow chart (assuming we can come to consensus on details)?

Terminology clarification

- **Model validation:*** the process of comparing measurements (from lab or field) with simulation results to assess whether a model response adequately mimics the measured response for the same disturbance and external power system conditions
- **Conformity Assessment:*** the process of comparing IBR unit and/or plant capability or performance with specified requirements to assess whether the IBR unit/plant complies with applicable standards or requirements
  - **Verification:** The process of comparing measurement results to required response or measured results to the simulation results while for the purpose of conducting conformity assessment. Also used in the context of comparing the equipment and settings in the field with what's in the models (e.g. during "as-built" assessment)
- *Definitions derived from NERC IRPS

Next steps

- Incorporate definitions as they arise in other subgroups
- Address topics that cut across multiple subgroups
- Develop any general content needed (Clause 4)
- Coordinate flow chart revisions

Subgroup 1 – Overall document: Logistics

- Plan
  - Biweekly meetings, Mondays, 10am Mountain Time
- Leads
  - Andy Hoke (andy.hoke@nrel.gov)
  - Manish Patel (mpatel@southernco.com)
- How to get involved, join listserv, send an email message to listserv@listserv.ieee.org
  - In first line of email body, write: ***SUBSCRIBE*** STDS-P2800-2-SG1 <***Your Name***>
  - For example, "SUBSCRIBE STDS-P2800-2-SG1 Andy Hoke"

10 minute break – Back 15 minutes past hour

- Subgroup 3 (Design Evaluation) continues next

- Reminder: record your attendance in iMat:
  - https://imat.ieee.org/sp17300043/attendance-log?p=4048500005&t=656400043

Subgroup 2

- Discussion led by Steve Wurmlinger

Agenda – Wednesday and Thursday

- Day 1
  - Call to order and welcome
  - Roll call and declaration of affiliation (via chat window)
  - P2800.2 Working Group policies and procedures
  - IEEE patent and copyright policies
  - Approval of agenda and past minutes
  - IEEE 2800-2022 update
  - P2800.2 overview
  - Subgroup 1: General Requirements
  - Subgroup 2: Type Tests
- Day 2 (tomorrow)
  - Subgroup 3: Design Evaluations
  - Subgroup 4: Commissioning Tests and As-built Evaluations
- Day 3
  - Subgroup 4: Commissioning Tests and As-built Evaluations (continued)
  - Subgroup 5: Post Commissioning Model Validation, Monitoring, and Periodic Evaluations
  - Power Quality Task Force
  - Summary and next steps

Subgroup 3 – Design Evaluations

Subgroup 4 – Commissioning and As-Built

Welcome to Day 3 of IEEE P2800.2 WG meeting

- Please record your attendance at:

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  or

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- Day 3
  - Subgroup 4: Commissioning Tests and As-built Evaluations (continued)
  - Subgroup 5: Post Commissioning Model Validation, Monitoring, and Periodic Evaluations
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  - Summary and next steps

Subgroup 4 – Commissioning and as-built evaluations

- Discussion continued from Day 2

Subgroup 5 – Post-Commissioning Model Validation, Performance Monitoring, and Periodic Tests

10 minute break – Back 20 minutes past hour

- Power Quality Task Force is next
- Reminder: record your attendance in iMat:
  - https://imat.ieee.org/sp17300043/attendance-log?p=4048500005&t=656400043

Power Quality Task Force

Excerpt of 2800 Table 20:

Verification Methods Matrix

SG 2 | SG 3 | SG 4 | SG 5

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		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*
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8.4.1 Limitation of cumulative instantaneous over-voltage	POM	R	R	R	NR	NR	R	NR	NR
8.4.2 Limitation of over-voltage over one fundamental frequency period	POM	D	R	R	NR	NR	R	NR	NR

PQ Task Force

Wrap-up and Next Steps

- Please join any subgroup or task force aligned with your interest/knowledge
  - Join listserv, and send a note to the lead so they are aware
- Consider volunteering to draft procedures/content in that subgroup – that's how we move this forward

To get involved in IEEE P2800.2:

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

Related international standards update

- Two FGW (German interconnection-related documents) are now available to WG on iMeet site, for use (only) in P2800.2 development. (Thank you Jens for arranging!)
  - FGW TG 8 - Certification of the electrical characteristics of power generating units and systems in low-, medium-, high- and extra-high voltage grids – Rev 9 (01.02.2019) / EN
  - FGW TG 9 - Determination of high frequency emissions from renewable power generating units – Rev 1 (18.04.2016) / EN
  - FGW TG 3 and TG4 coming soon when latest English versions become available

- Request from IEEE for various IEC standards is pending.

- If you identify a standard we should refer to, notify the appropriate subgroup/task force lead.

IEEE P2800.2 Email Listservs

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

Future P2800.2 meetings

- **Next meeting (tentatively, pending confirmation): December 6-8, 2022**
- 3-4 per year
- Currently still online only
- Will consider in-person meetings with remote option if conditions allow
  - Anyone want to host at their organization? Need meeting room for ~100 people

- Jan 2022 — WG Kickoff
- Jan 2022 — P2800.2 leaders outline content
- Feb 2022 — WG meeting to align on overall outline
- Q2-Q3 2022 — Subgroup meetings to draft procedures
- Aug 2022 — WG meeting to review and coordinate
- Q4 2022 — Subgroup meetings to draft procedures
- Dec 2022 — WG meeting to review and coordinate
- …

Pattern of 2-3 months of SG meetings followed by WG meeting repeats...

- …
- Q4 2023 — Final WG meeting
- Q1 2024 — Balloting
- Q2-Q3 2024 — Recirculation
- Late 2024 — Publication?

Future dates are tentative

Anticipated Timeline

	Jan 2019-Dec 2020	Q2-Q4 2021	Q2 2022	Current Phase Q2-Q4 2022	2023	2024	2025	2026 and Beyond
2800	WG Drafting in Parallel Subgroups	Balloting and Recirculation	Publication					
P2800.2 Conformance verification			Kick-off and Directional Alignment	WG Drafting in Parallel Subgroups	WG Drafting in Parallel Subgroups	Balloting	Publication	
Related activities	IEEE 1547.1 is published	NERC IRPWG Guidelines		FERC GI NOPR IEEE 1547 Revision Kickoff?	Potential 2800 Adoption	Potential 2800 Adoption		Potential P2800.2 Adoption

IEEE P2800.2 Subgroup 2
Type Tests

Subgroup Vice Chair: Stephen Wurmlinger
Subgroup Chairs(s): Pramod Ghimire, Michael Ropp

IEEE P2800.2 Working Group Meeting
August 23, 2022

Subgroup 2 members

74 members in IEEE listserv

IEEE Listserv address
STDS-P2800-2-SG2@listserv.ieee.org

- Aboutaleb Haddadi
- Alex Shattuck
- Alyssa Jenkins
- Amin Banaje
- Amir Abiri Jahromi
- Amir Kazemi
- Andres Cardozo
- Andrew Isaacs
- Andy Hoke
- Antti Eerola
- Ben Hui
- Bo Gong
- Bob Cumming
- Brad Marszalkowski
- Breno Freitas
- Chris Milan
- Ciaran Roberts
- Curtiss Fox
- David Narang
- David Roop
- Divya Kurthakoti
- Durga Gautam
- Eddy Lim
- Edris Agheb
- Eugen Starshchich
- Fernando Aramirez
- Francisco Gafaro
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- Pramod Ghimire
- Rajat Majumder
- Reigh Walling
- Reza Salehi
- Ritwik Chowdhury
- Roberto Favela
- Sachin Soni
- Saurabh Vyas
- Sergey Kynev
- Siddharth Pant
- Stephen Wurmlinger
- Sudip Manandhar
- Syed Ahmed
- Taylor Hill
- Wenzong Wang
- Xingxin Tian
- Zhibo Wang
- Ziang Zhang

Agenda

- Overview of IEEE 2800 – 2022 Type Tests
- Subgroup 2 worksheet review
- Questions/ comments for each clause

Scope

Scope

- Develop type test methods that determine IBR unit's ability to perform as defined in IEEE 2800-2022, (Table 20 - Verification methods matrix) at the POC and provide information for plant level conformity verification.
- Normative and informative references
- Identification and specification of the quantities to be measured for the performance of the IBR unit
- Testing procedures for quantifying the performance
- Criteria/ results for assessing compliance / conformity

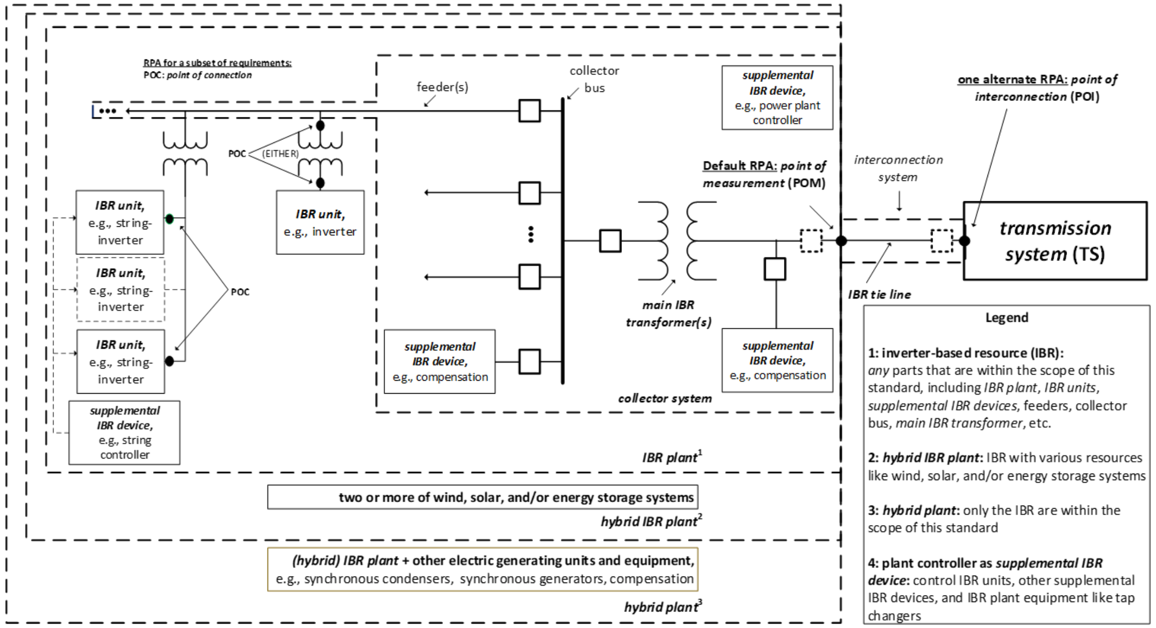
Items not in Scope

- Each of the different requirements in Table 20 that have "NR" under Type Test

Type Tests

- Definition in IEEE 2800 is adopted from IEEE1547-2018

  A test of one or more devices manufactured to a certain design to demonstrate, or provide information that can be used to verify, that the design meets the requirements specified in this standard.



Ref: IEEE 2800-2022

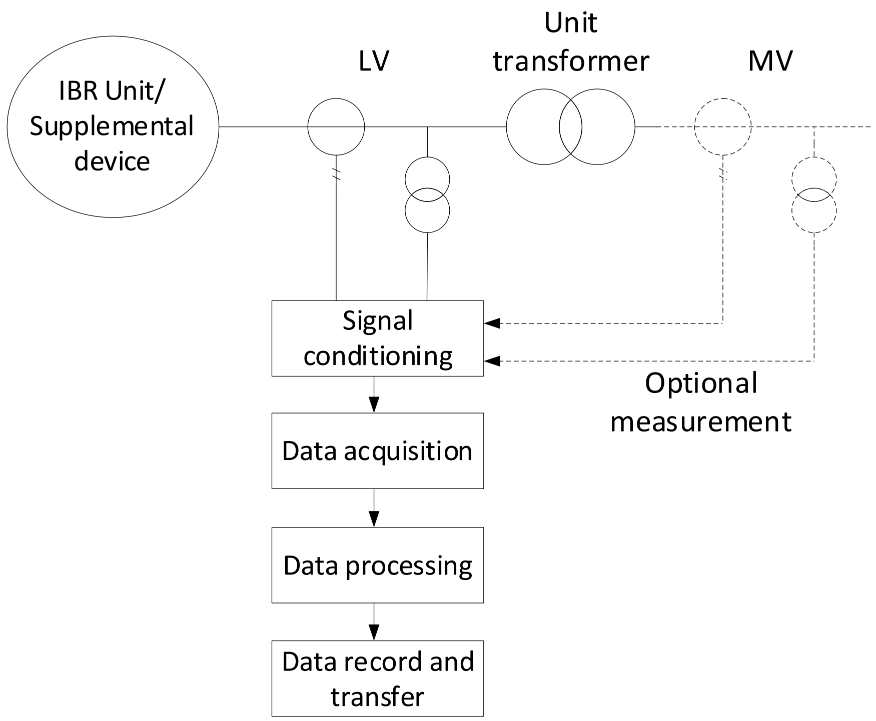
Some important remarks from Type Tests IEEE 2800 - 2022.

- A type test may be performed on one device or a combination of devices.
- Type tests shall be performed on IBR units as well as supplemental IBR devices.
- Where a supplemental IBR device is used to meet a requirement of this standard as specified in Table 20 – Verification method matrix , the type test for such device in combination with other information on this device shall provide such information to render possible verification during the design evaluation.
- IBR units and supplemental IBR devices that are too large or have power ratings too high to be practically type tested may demonstrate through other means.
- Type tests shall be performed on a representative IBR devices or subsystem, either in field, laboratory or on equipment in the field.
- Type test results from an IBR unit within product family of the same design including hardware and software, shall be allowed to be representative of other IBR units within same product family with different power ratings provided the hardware and software designs are appropriately scaled but not otherwise different between models.
- In order to cover the requirements applicable at the POM, type tests and subsequent verification steps that use type test results as input shall take into account differences in conditions between POC and POM; and shall consider the aggregate behavior of the multi-IBR unit and supplemental IBR device.

Ref: IEEE 2800-2022

What it includes in Type test?

- IBR Unit/ Unit level supplementary devices
- Measurement instrument, such as CT’s, PT’s
- Measurement equipment/ computer for signal recording and data logging
- Type test could be at laboratory test, prototype field, …



3rd WG meeting agenda

- Worksheet used by Subgroup 2 to draft sections

- Table 20 of base standard and functions identified as “R” or “D” in the type test column were used to create list of functions requiring type test procedure
- Use of the worksheet – to go through each function and identify questions, comments and direction we are taking. Also if any resources we should be reviewing. Then use these notes to draft actual wording for the document.
- Layout of type test section will be:
  - Type test section summary will be based on 12.2.2 of the base standard plus other notes made in the worksheet
  - For each function, will have
    - A general section which will include:
      - Explain whether testing applies for IBR unit at POC or POM or some other location
      - Explain purpose of the testing: verify capability, verify performance and/or data
    - Equipment requirements – test equipment and EUT
    - Test procedure
    - Test criteria/ Test results

IEEE P2800.2 Subgroup 3
Design evaluations

Vice Chair: Jens Boemer
Subgroup Chairs: Andrew Isaacs, Alex Shattuck

IEEE P2800.2 WG Meeting
August 24, 2022
11:00am – 2:00pm ET | 8:00am – 11:00am PT

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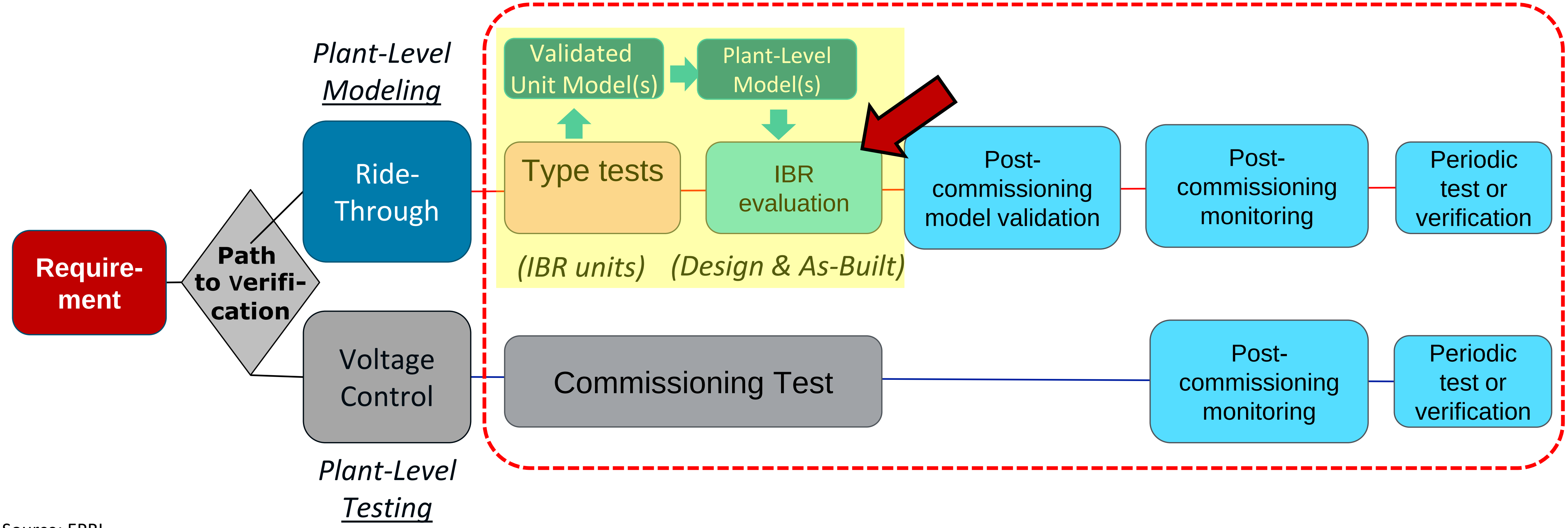
Scope of SG3 within Clause 12 (Test and Verification) Framework

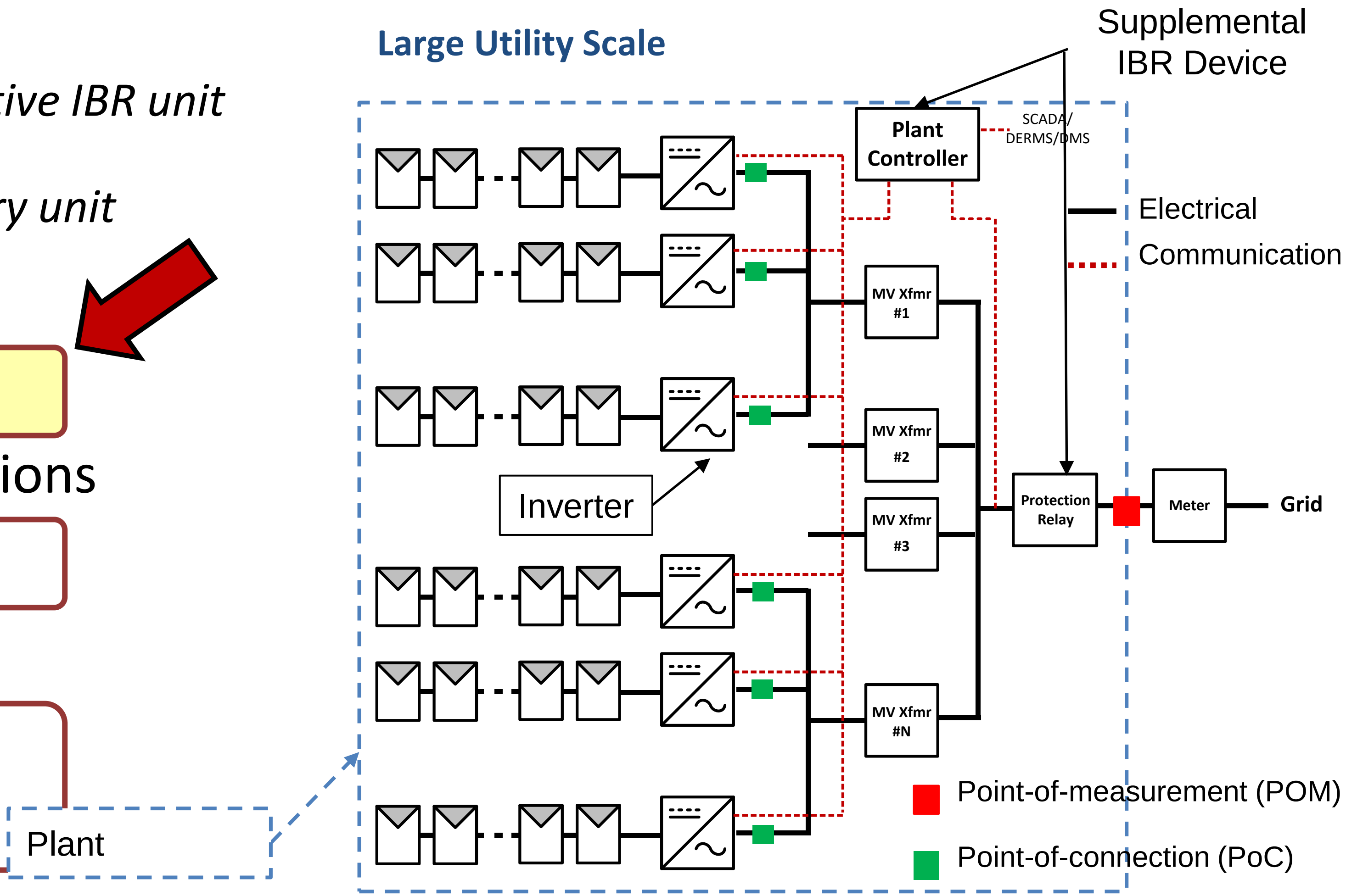
What's the requirement? → **Where's the reference point of applicability (RPA)?** → **Required path to verification** → **Category of test and verification needed**



Source: EPRI

IEEE 2800-2022 Test and Verification Methods – P2800.2 SG3 Scope

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



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

Source: EPRI

Subgroup 3 – Design evaluations: Logistics

- **Kicked-off May 5, 2022**
  - Biweekly meetings, 1-1.5 hours
    - Starting with ~1 hour meetings for time being
  - Thursdays in even weeks, 1:05p-1:50p ET / 10:05a-10:50a PT
    - May occasionally conflict with IRPS monthly meetings and NERC SAR adjustment meetings

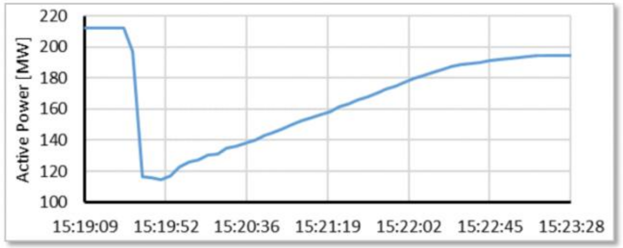
- **Use of the SG3 listserver for meeting invitations and discussion**
  - **To join the SG3 listserv, send an email message to listserv@listserv.ieee.org**
  - **In first line of email body, write: SUBSCRIBE STDS-P2800-2-SG3 <Your Name>**
  - For example, "SUBSCRIBE STDS-P2800-2-SG3 Andy Hoke"
  - Subject line of e-mail does not matter (can keep empty or put in anything)
  - This triggers the listserver to send an e-mail with a link
  - ➢ ***Need to click on link in e-mail to confirm to be added to listserver!***
  - **Place STDS-P2800-2-SG3@LISTSERV.IEEE.ORG into blind copy (BCC)**
  - This avoids unintentional replies to the sender and all Subgroup 3 members
  - Recipients may intentionally decide to reply to the listserver and all its members as they see fit

- **iMeetCentral Workspace**
  - https://ieee-sa.imeetcentral.com/p/ZgAAAAAA3egB
  - Copy of IEEE 2800-2022 for the purpose of P2800.2 standards development at https://ieee-sa.imeetcentral.com/p/aQAAAAAE7KAd
  - If you have trouble accessing iMeetCentral, please verify that you acknowledged the IEEE Privacy Policy at https://engagestandards.ieee.org/IEEE-SA-Privacy-Policy-Acceptance.html

Recent NERC/WECC Event Analysis and Engineering

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Plant Controller Interactions Persist



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

<u>Example: Plant with Legacy Inverters</u>

- 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

- 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

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 <u>and</u> IBR plant controller (= “supplemental IBR device”)**

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

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ERCOT Status Update for Odessa Disturbance

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

ercot

PUBLIC

2

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

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	‡	
	Fast Frequency Response / Inertial Response: Overfrequency FFR	√	
	Return to Service (Enter Service)	‡	
	Black Start	√	
Dynamic Voltage Support	Dynamic Voltage Support / Current Injection during VRT: Balanced	‡	
	Dynamic Voltage Support / Current Injection during VRT: 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

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 13, 2022


HOME > NEWS EVENTS > NEWS > FERC PROPOSES INTERCONNECTION REFORMS TO ADDRESS QUEUE BACKLOGS

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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.

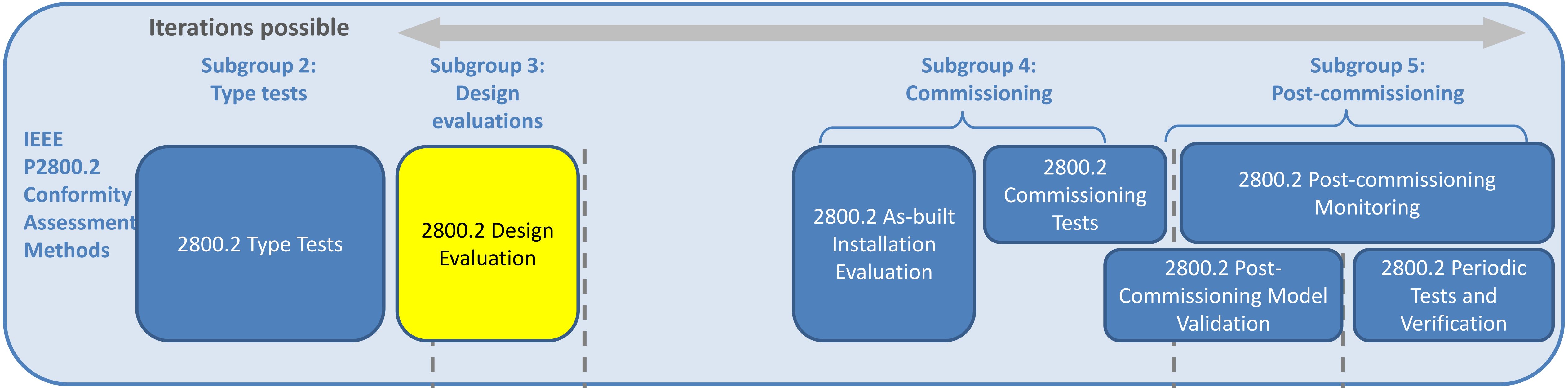
Contact Information

Mary O'Driscoll
Director, Media Relations
Telephone: 202-502-8680
Email: mediadl@ferc.gov

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

Version 1c



SG2: recommend procedures for <u>how to produce</u> measurements in type tests that may be used to validate **equipment models**

SG3: recommend procedures for **equipment and plant model** <u>sufficiency validation / model quality verification</u>

SG3: recommend procedures for <u>how to use</u> these validated **equipment models** in the IBR design evaluation with the objective to assess plant-level conformity and to freeze the final design with real equipment before purchase requests are made and ground is moved in the field.

SG5: recommend procedures for <u>how to validate</u> **plant models** performance

- Immediately after commissioning
  - maybe by use of commissioning tests for small-signal disturbances and steady state plant performance
  - maybe by use model benchmarking against the equipment models used in the IBR design evaluation for large-signal disturbances plant performance
- over the plant's lifetime in periodic intervals after commissioning
  - maybe by use of post-commissioning monitoring for small-signal (SCADA?) and large-signal (DFT?) disturbances plant performance

- Outside P2800.2, maybe in MOD 026/027 etc.: requirements for <u>which models be used</u> and model acceptance criteria, possibly with reference to IEEE 2800/2800.2 plant models as the preferred choice.
- Both **equipment models** and **plant models** could be RMS, EMT, short-circuit, and frequency-domain models as subject for which requirement from IEEE 2800-2022 conformity is assessed.

Source: Andy Hoke, P2800.2 WG Chairs, SG1, *modified by SG3*

Stage gate:
Validated IBR unit and supplemental IBR device models

Stage gate:
Plant design + *settings* conform to IEEE 2800
(and maybe SIS?)

Stage gate:
Plant components + settings match frozen plant design

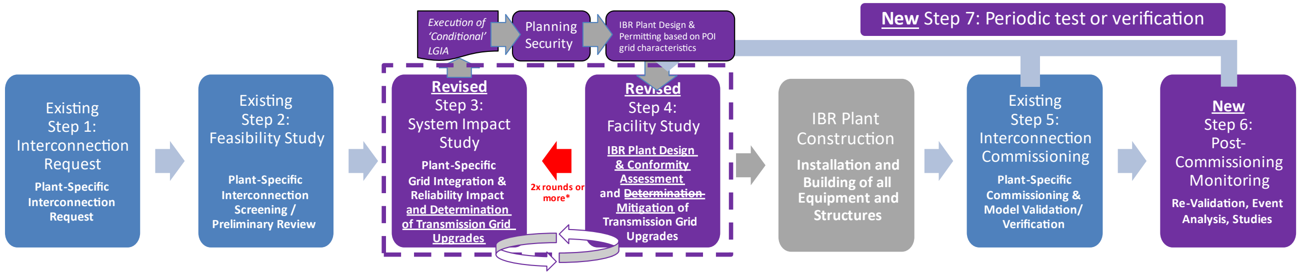
Stage gate:
As-built evaluation, commissioning tests, and model benchmarking show conformance to IEEE 2800

Related NERC and IEC activities?

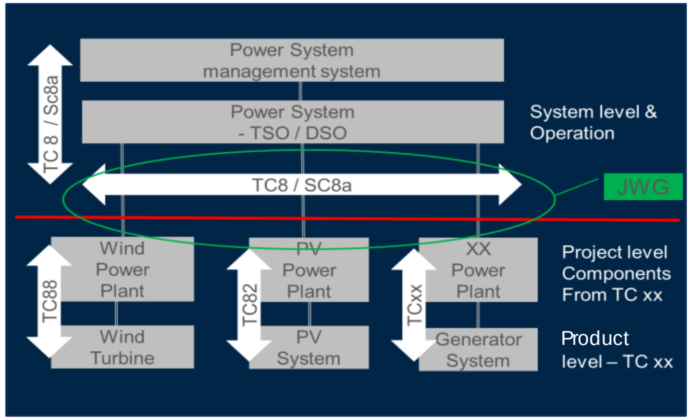
NERC IRPWG SubGroup Work Item #8:
Improvement of Interconnection Process and Related Studies

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

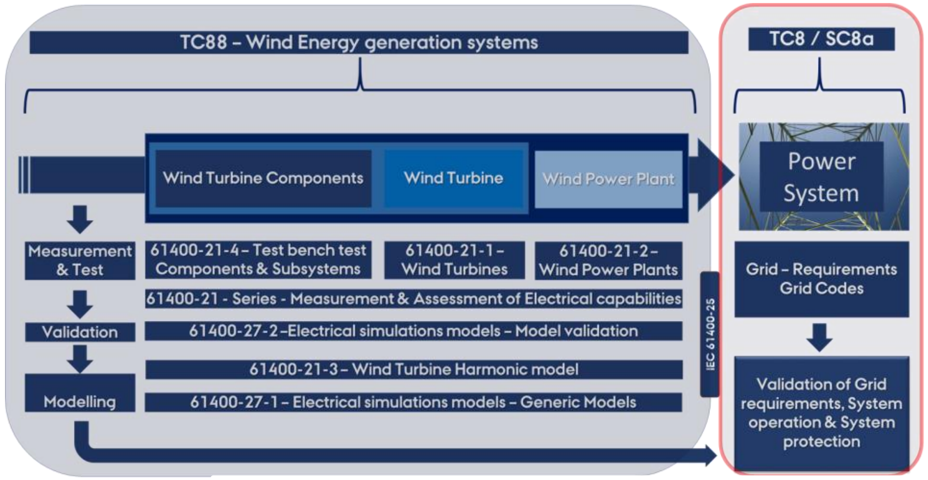
Logistics:
- No meetings for time being while leads are drafting document, irps_intstudy@nerc.com
- P2800.2 Liaisons: Alex Shattuck (axsha@vestas.com) and Jens Boemer (jboemer@epri.com)



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 has different scope compared to P2800.2.**

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

Subgroup 3 – Design evaluations: Scope

- Scope
  - Normative and informative references
  - Definitions and acronyms
  - Verification procedures and criteria
    - Pre-commissioning modeling and model validation
    - Plant-level performance conformity assessment
  - Verification signals, success metrics, and accuracies
  - (Placeholder)

Scope document for Subgroup 3 on the P2800.2 website

- https://sagroups.ieee.org/2800-2/wp-content/uploads/sites/478/2022/02/Subgroup-3-Scope-IBR-design-evaluation_v3.pdf

- Items not in scope
  - Post-commissioning modeling and model validation
  - System impact studies (using transmission system model) ➔ SG3 dependency / interfacing?
  - Power quality voltage harmonic limit pre-commissioning verification? ➔ PQ Subgroup
  - (Placeholder)

Subgroup 3 – Design evaluations: Key questions

"Thornier" Questions

- Inverter level model validation: What is our benchmark for success?
  - Qualitative: engineering judgement, expert opinion
  - Quantitative etc.
  - (Placeholder)
- Can we agree that manufacturer specific EMT models will be required?
  - average or switching models?
  - (Placeholder)
- Will HIL be required?
  - For components only?
  - Inverter and PPC separate?
  - (Placeholder)

"Easier" Questions

- What is the quality requirement for EMT models
  - 2800 Appendix G has a good start on this
  - very good (tested) resources available
  - Lumped or detailed model?
  - (Placeholder)
- What is the process for testing plant models?
  - Resources are available from utilities ahead of this standard
  - (Placeholder)
- External grid representation
  - Using single-machine infinite or weak bus?
  - (Placeholder)

Subgroup 3 – Design evaluations: General questions

- To what extent, and how should we aim for the *IBR plant* design to comply with 2800 prior to commissioning while not complicating the process but minimizing the burden on all involved?
  - Process standardization, automation, tool development?
  - (Placeholder)
- When evaluating whether an *IBR plant* design complies with 2800, what are consensus verification signals, success metrics, and accuracies?
  - Active power (P) and current (Ip) | Reactive power (Q) and current (Iq) | +,-,0-sequence components | (Placeholder)
  - Qualitative: trend with "high" and "low" accuracy
  - Quantitative: Root mean square error (RMSE), Maximum error (MXE), Mean error (ME), Mean absolute error (MAE) with xx% and yy% accuracy | (Placeholder)
- Coordination between Subgroups?
  - How could the need and scope of *commissioning tests* depend on *design evaluations*?

Conformity Assessment

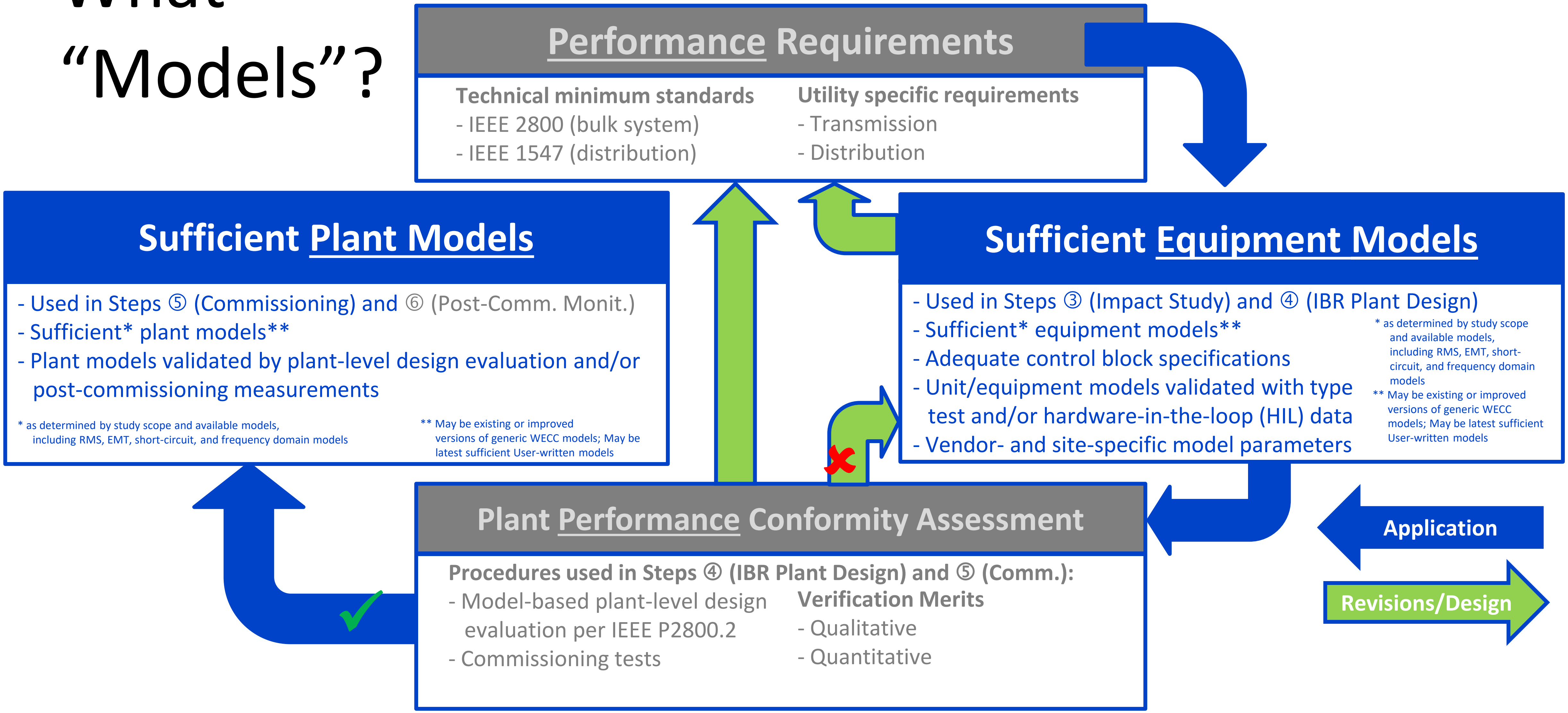
Testing
(process of setting up and executing relevant trials/experiments)

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 and/or IEEE P2882
** Already specified in IEEE 2800-2022

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

What “Models”?



Source: EPRI - Continuous and Iterative Improvement of IBR Performance Requirements, Plant-Level Modeling, and Model Validation. [Online] https://www.epri.com/pvmod

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

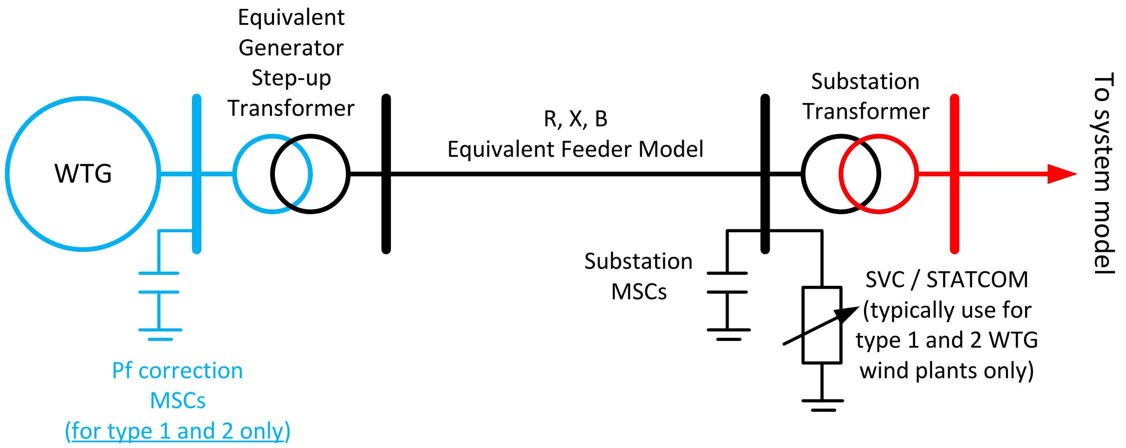
Cause of observed behavior	**Simulation domain limitation**	**Most of today's model incorrectly parameterized**	**Most of today's model do not represent**	
Unbalanced conditions		✓		Future model can represent as capability exists in simulation domain
Sub-cycle ac over voltage		✓		
Sub-cycle ac over current		✓		
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			✓	

(b) EMT simulation domain

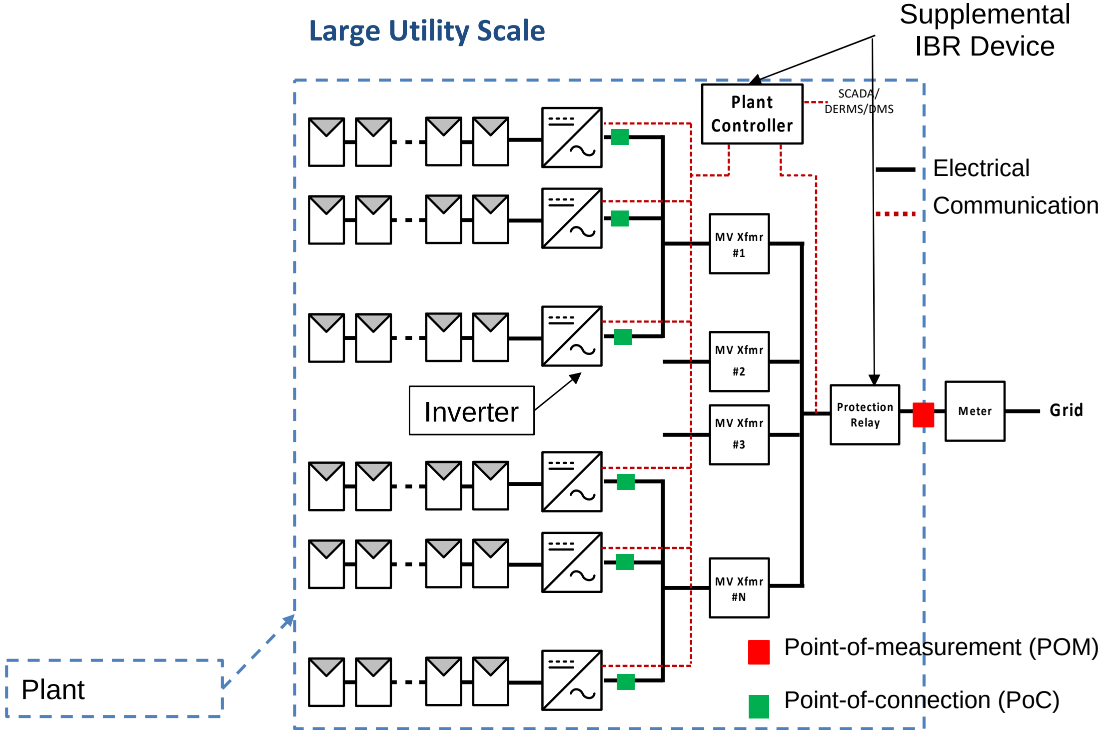
Source: EPRI (2022)

Type of Models

Lumped Plant Model
using Equivalent Plant Model



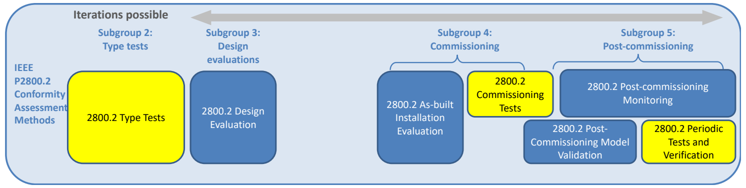
Detailed Plant Model
using Equipment Models

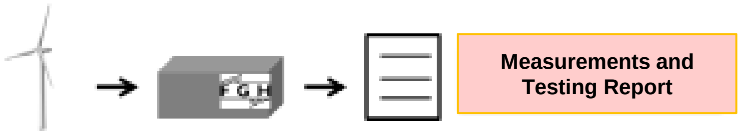


- Outside P2800.2, maybe in MOD 026/027 etc.: requirements for which models be used and model acceptance criteria, possibly with reference to IEEE 2800/2800.2 plant models as the preferred choice.
- Both **equipment models** and **plant models** could be RMS, EMT, short-circuit, and frequency-domain models as subject for which requirement from IEEE 2800-2022 conformity is assessed.

Definitions

Test and ***Testing***



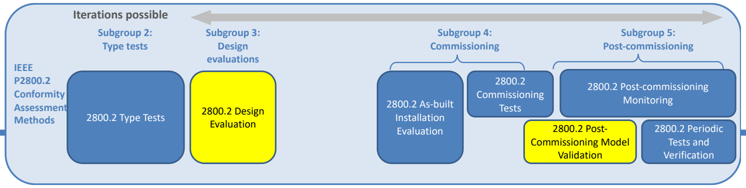


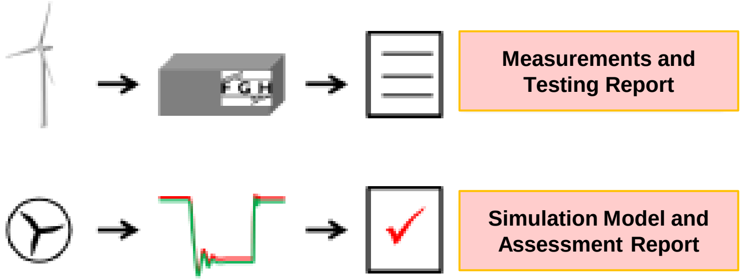
Test and ***Testing*** should be used as a verb and action noun respectively when describing a process of setting up and executing relevant trials/experiments, for the purpose of conducting **conformity assessment** or **model validation**.

Source: NERC MOD 026/027

Definitions

Model Sufficiency Validation





The dynamic process of **comparing measurements[1] with simulation results[2]** for the assessment whether a model response adequately mimics the measured response for the same event/disturbance and external power system conditions.

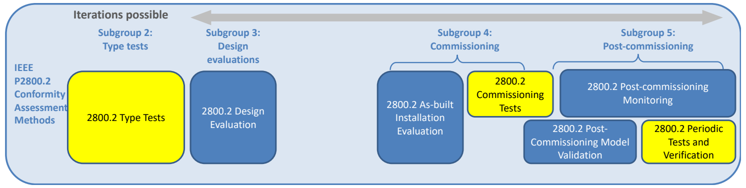
Footnotes

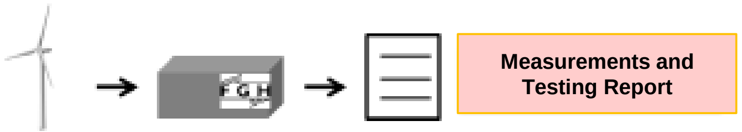
[1] obtained from type tests in the laboratory for *IBR units*, from field measurements for *IBR plants,*

[2] obtained from an *IBR unit* model, or from an *IBR plant* model that is appropriately configured

Source: EPRI/NERC IRPS

Test and *Testing*





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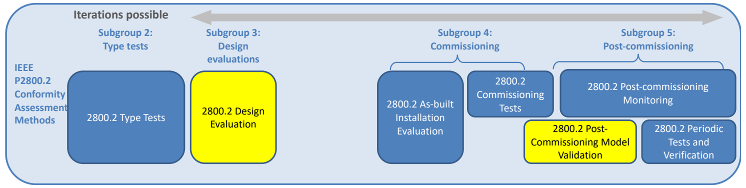
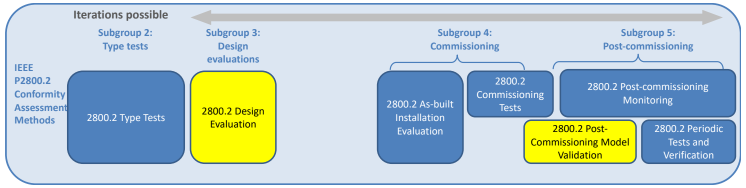
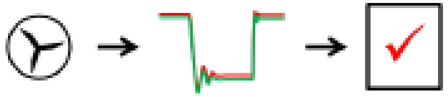


=?

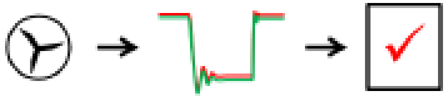
Model Benchmarking



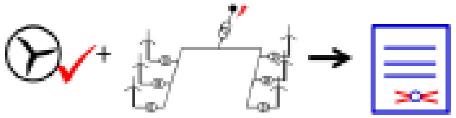
Measurements and Testing Report



Simulation Model and Assessment Report



IBR Unit Model Benchmarking Report



IBR Plant Model Benchmarking Report

The dynamic process of **comparing measurements[1] with simulation results[2]** for the assessment whether a model response adequately mimics the measured response for the same event/disturbance and external power system conditions.

Footnotes

[1] obtained from type tests in the laboratory for *IBR units*, from field measurements for *IBR plants,*

[2] obtained from an *IBR unit* model, or from an *IBR plant* model that is appropriately configured

Source: EPRI/NERC IRPS

The dynamic process of **comparing simulation results** from two models for the assessment whether a response from one model[1] adequately mimics the response from the other model[1] for the same disturbance and external power system conditions.

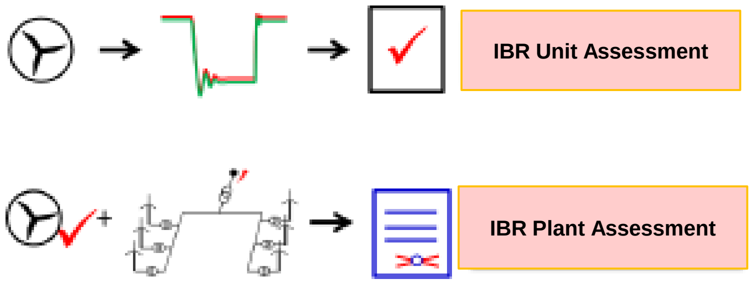
Footnotes

[1] an IBR unit model, or an IBR plant model that is appropriately configured

Source: NERC MOD 026/027

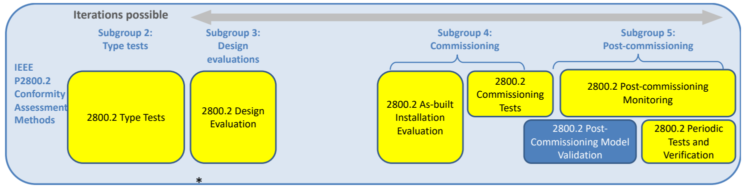
Definitions

Verify and *verification*

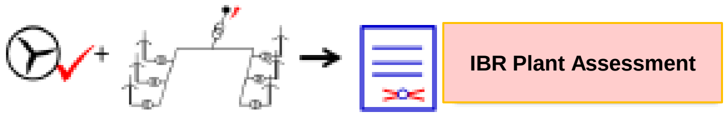


Verify and ***verification*** should be used as a verb and action noun respectively when describing a static process of e.g. comparing measurement results to required response or measured results to the simulation results for the purpose of conducting **conformity assessment**. It can also be used in the context of comparing the equipment and settings in the field with what's in the models (during e.g. "as-built" assessment).

Conformity Assessment



(of Unit & Plant-level Capability and Performance with Technical Requirements)



The static process of comparing IBR unit and/or[1] plant capability or performance with specified requirements for the assessment whether the IBR unit/plant complies with applicable standards or requirements[2], by use of

- type testing of IBR unit, plant-controller, and other supplemental IBR devices, [1]
- Control-hardware-in-the-loop-simulation testing and/or Real-Time Digital Simulator testing
- pre-commissioning plant-level design evaluation using simulations with adequate and validated models, and/or
- post-commissioning field measurements.

Footnotes
[1] as applicable, subject to whether technical requirements apply to *IBR unit* or *IBR plant*
[2] may include NERC, IEEE, IEC, other standards, and requirements

Source: NERC IRPS, MOD 026/027 and P2800.2 Officers

NERC MOD 026/027 Revision

Status: Ongoing

Developed working definitions for "Validation" and "Verification"

1. Standard-Only Definition:

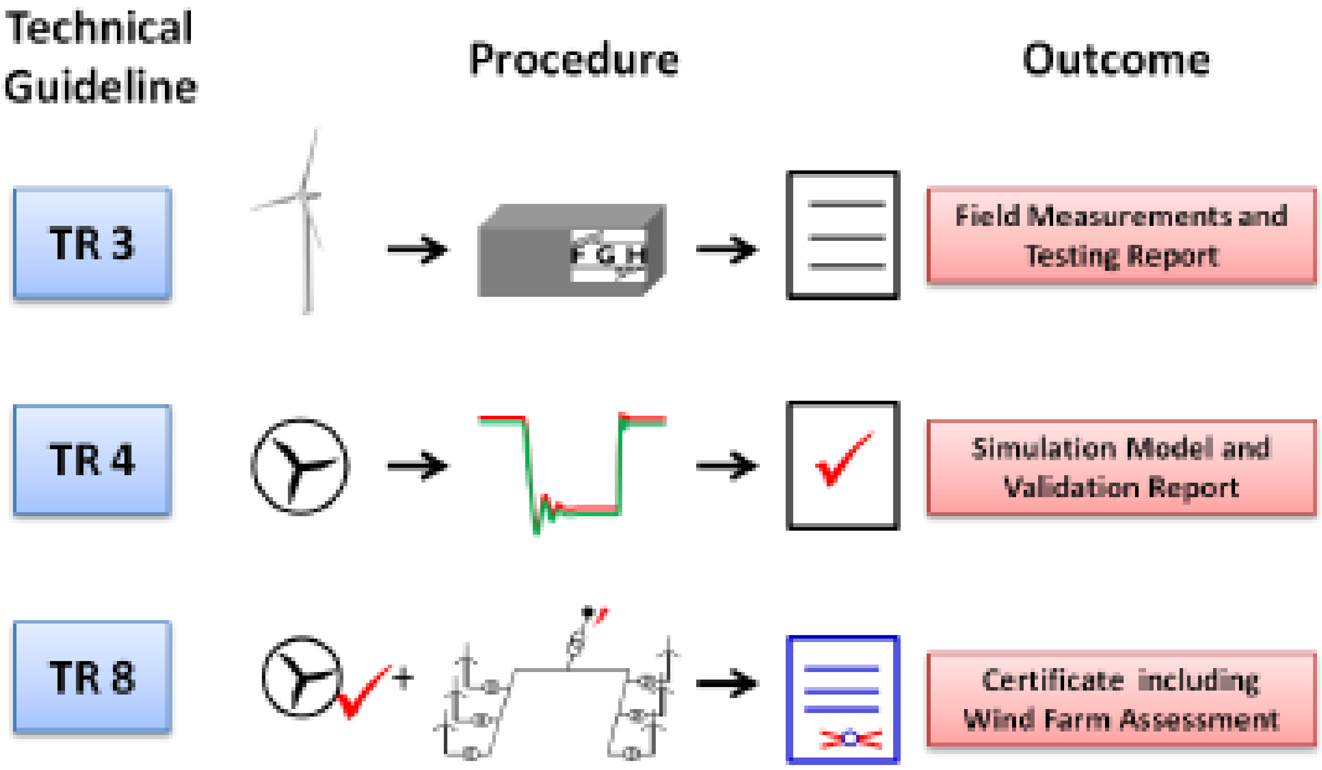
1.1. Verification - the static method of checking documents and files, and comparing them to a model parameters, model structure, or equipment settings.

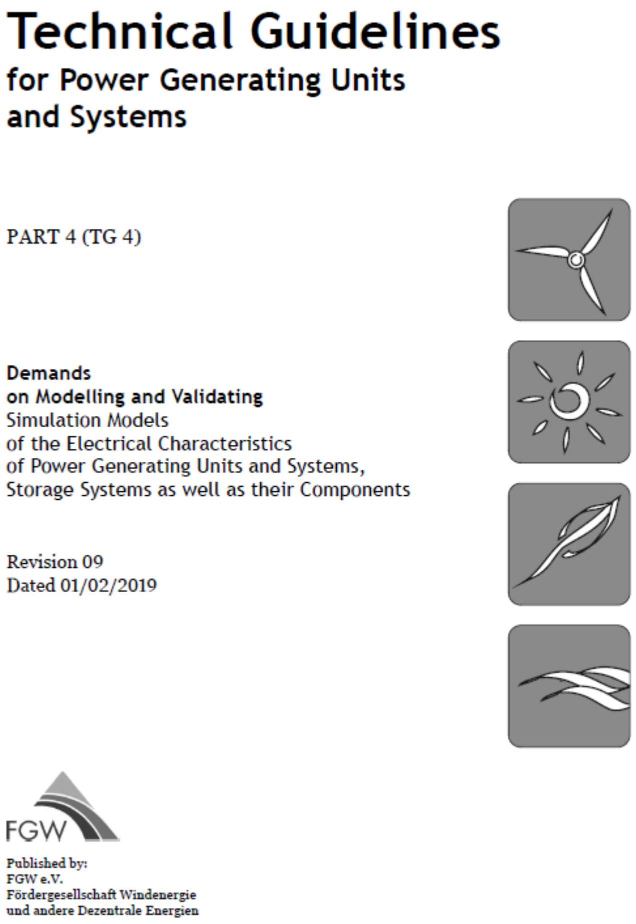
1.2. Validation - the dynamic process of testing or monitoring the in-service equipment behavior, and then using the testing or monitoring result and comparing them to the model simulated response.

1.3. Verified model – the contents of a verified model are defined in Requirements R2-R6, and can include the activities of verification and/or validation

Source:
E-Mail from Brad Marszalkowski, 2/10/2022

Performance Verification Example: Germany




Technical Guidelines
for Power Generating Units and Systems

PART 4 (TG 4)

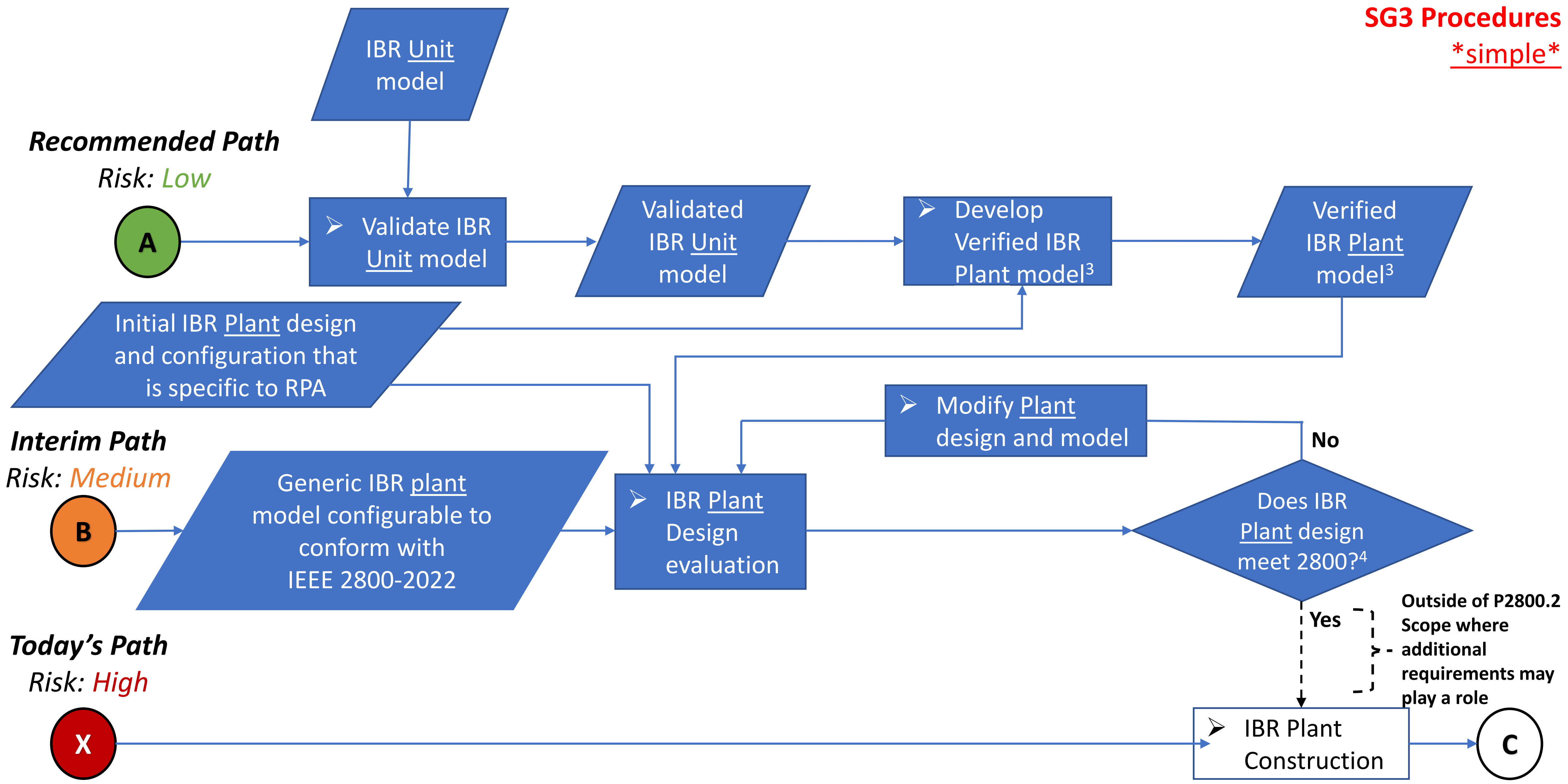
Demands
on Modelling and Validating
Simulation Models
of the Electrical Characteristics
of Power Generating Units and Systems,
Storage Systems as well as their Components

Revision 09
Dated 01/02/2019

FGW

Published by:
FGW e.V.
Fördergesellschaft Windenergie
und andere Dezentrale Energien

Source: EPRI



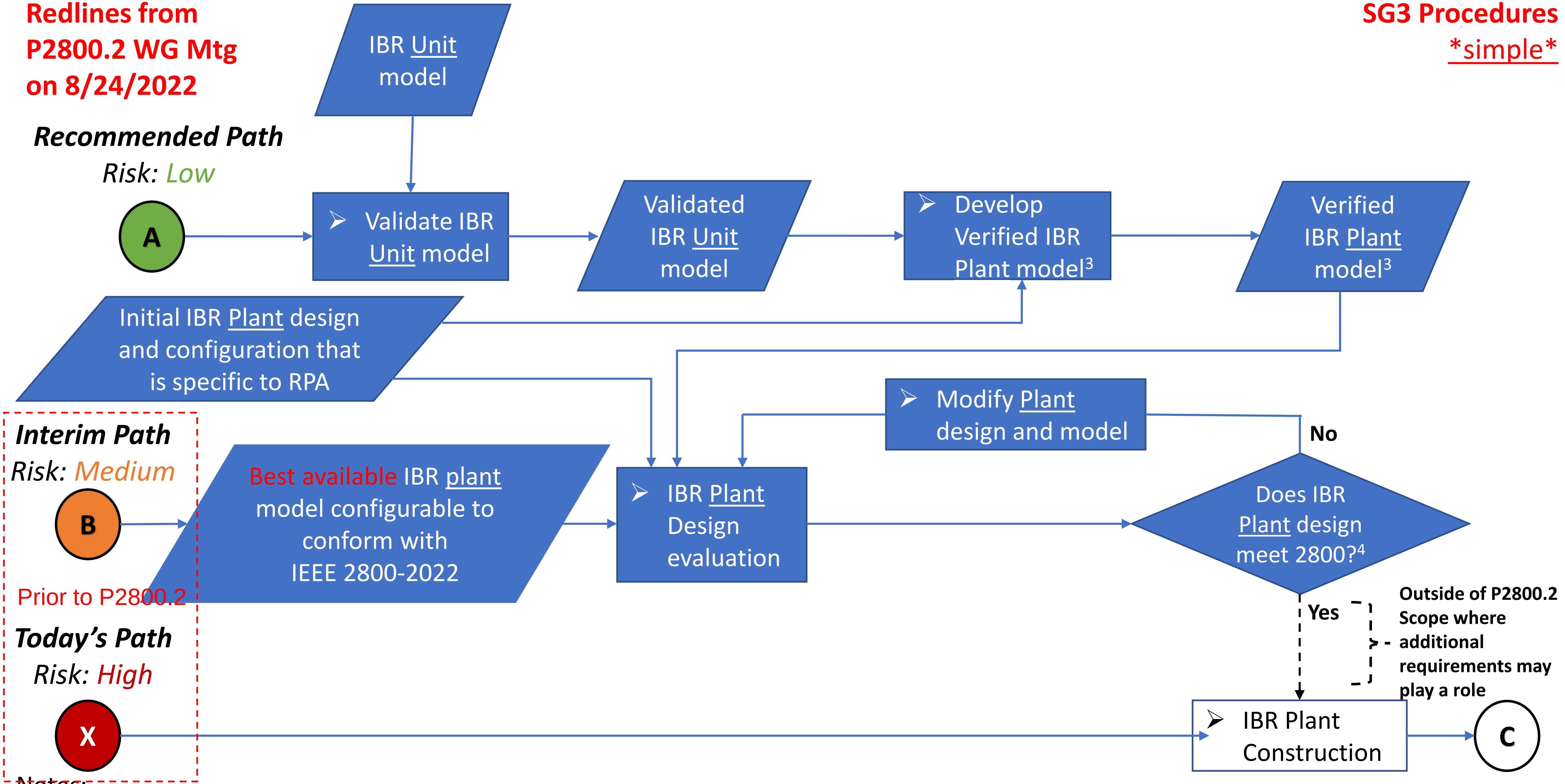
Notes:

3. Verified IBR Plant model developed using IBR plant design and validated IBR Unit Model. The plant model in this step is not validated.

4. Passes IBR Plant design evaluation steps listed as R or D in Design Evaluation column of IEEE 2800 Table 20

Redlines from P2800.2 WG Mtg on 8/24/2022

SG3 Procedures *simple*



Notes:

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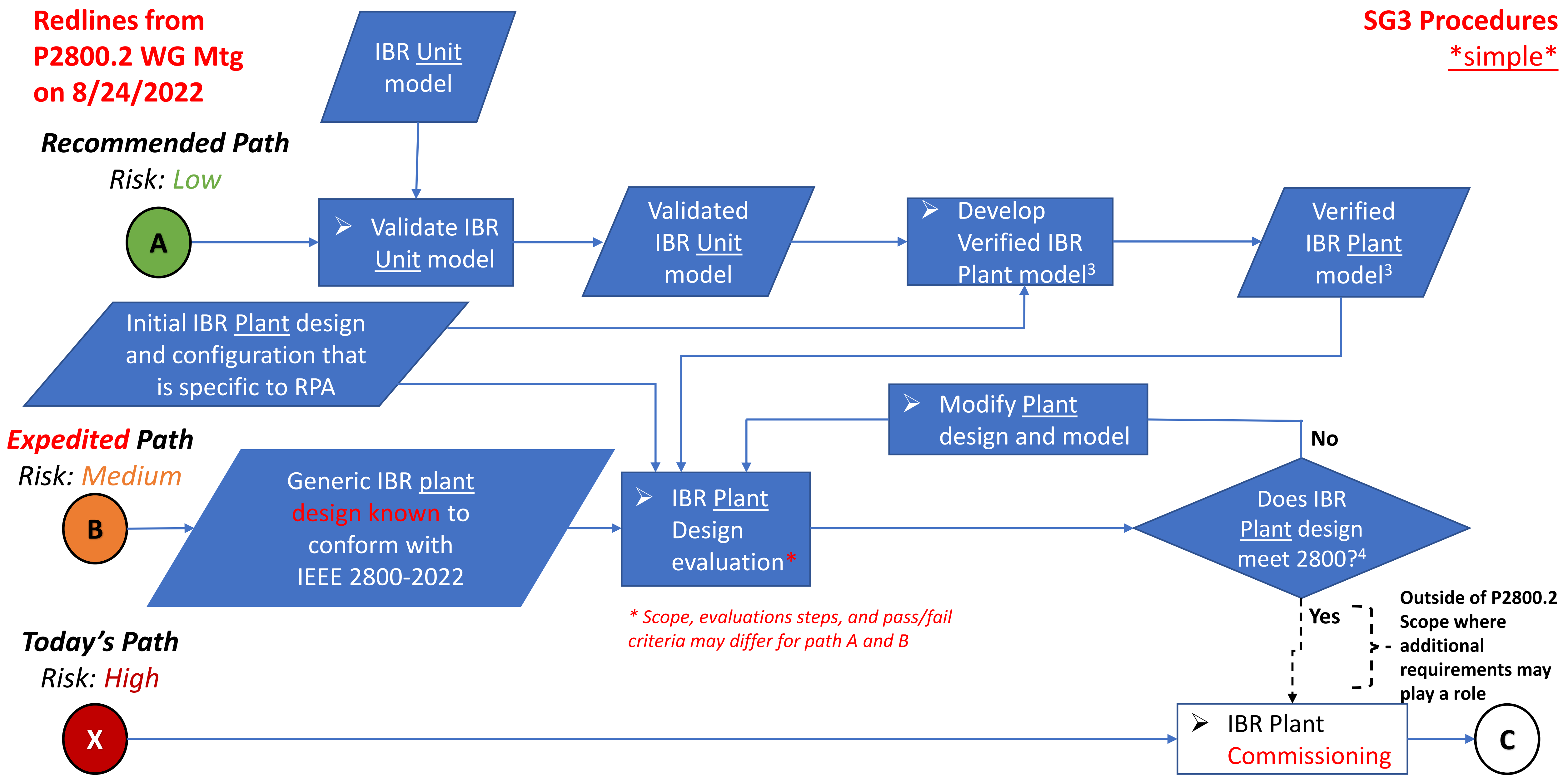
4. Passes IBR Plant design evaluation steps listed as R or D in Design Evaluation column of IEEE 2800 Table 20



Notes:

3. Verified IBR Plant model developed using IBR plant design and validated IBR Unit Model. The plant model in this step is not validated.

4. Passes IBR Plant design evaluation steps listed as R or D in Design Evaluation column of IEEE 2800 Table 20

Possible Pass/Fail Criteria*

*for early WG discussion, not yet vetted by SubGroup 3

Recommended Path - Risk: Low

➢ *Use of validated IBR unit and verified IBR plant models!*

- For IBR unit and supplemental IBR devices
  - Model sufficiency criteria
    - 2800 Appendix G has a good start on this
    - Checklist, attestation, etc.
  - Model verification
    - Is the IBR unit model sufficiently configured to represent the expected performance of the IBR units in the field?
    - Any model that is not a "real-code" model should be validated using the measurements from the *type test* of the *IBR unit*.
  - Acceptable tolerances for model validation
    - Qualitative: engineering judgement, expert opinion
    - Quantitative etc.
- For IBR plant models
  - Lumped vs. detailed
  - Are all "relevant" protective elements included?

Expedited Path - Risk: Medium

➢ *No use of modeling? Only based on a "design checklist"?*

- Has the IBR unit performance conformity been assessed in a type test and satisfies some minimum requirements?
  - ➢ *Would require SubGroup 2 to specify performance conformity tests and pass/fail criteria in addition to only the provision of measurements!*
- Is the IBR unit firmware appropriate to meet the standard's requirements?
  - Or is it firmware for UL 1741 / IEEE 1547 performance requirements
- Have all IBR plant protection elements settings been verified to conform with ride-through requirements?

Comment from P2800.2 WG Mtg on 8/24/2022:
*While the WG recognizes that the industry in the U.S. cannot jump from path X to A immediately, even if FERC LGIP timelines were loosened up. But **there seemed to be preliminary consensus** that the goal should be to get to path A. Thus, path B should stay as an interim approach for early adoption of IEEE 2800-2022, prior to the publication of IEEE 2800-2022, and NOT included in P2800.2 as an Expedited Path.*

Possible Justification For Alternate Paths

*for early WG discussion, not yet vetted by SubGroup 3

- Performing any simulations with models that are not validated/verified seems like a waste of time and resources
- In cases where the plant design is fairly standard and the grid is fairly strong, modeling may not be needed to ensure sufficient reliability
- If expert resources are not available to conduct the studies, a reasonable amount of verification steps that do not involve modeling could be better than no verification at all; this could include, for example:
  - a proof of sufficient level of IBR unit ride-through conformity,
  - a feeder protection settings review, and
  - a review of plant controller parameters
- …

BACKUP

Clause 12, Table 20 —Verification methods matrix

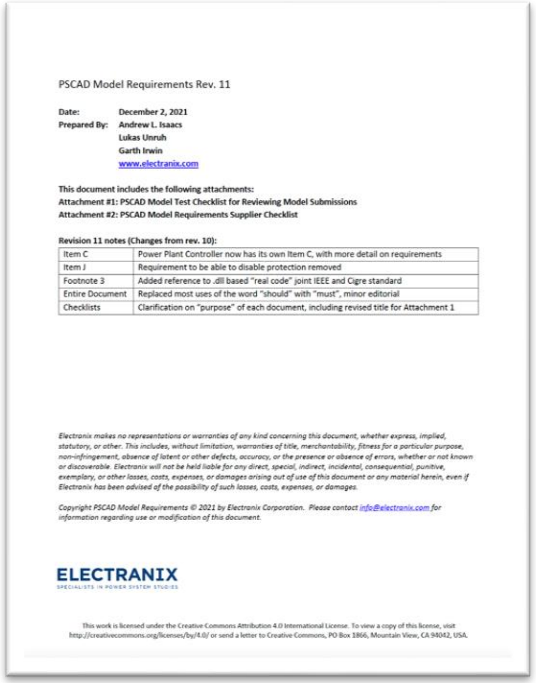
Requirement	RPA at which requirement applies	*IBR unit*-level tests (at the POC)	*IBR plant*-level verifications (at the RPA)						
		Type tests	Design evaluation (including modeling for most requirements)	As-built installation evaluation	Commissioning tests	Post-commissioning model validation	Post-commissioning monitoring	Periodic tests	Periodic verification
		Responsible entity							
		IBR unit or *supplemental IBR device* manufacturer[a]	*IBR developer /TS owner/ TS operator*[a]	*IBR developer /TS owner/ TS operator*[a]	*IBR developer/ TS owner/ TS operator*[a]	*IBR developer/ IBR operator/ TS owner/ TS operator*[a]	*IBR operator/ TS owner/ TS operator*[a]	*IBR operator/ TS owner/ TS operator*[a]	*IBR operator/ TS owner/ TS operator*[a]
Clause 5 Reactive power—voltage control requirements within the continuous operation region									
5.1 Reactive power capability	POM	R	R	R	R	R	D	D	D
5.2 Voltage and reactive power control modes	POM	D	R	R	R	R	D	D	D
Clause 6 Active-power—frequency response requirements									
6.1 Primary frequency response (PFR)	POC and POM	NR	R	R	R	R	D	D	D
6.2 Fast frequency response (FFR)	POC and POM	R	R	R	R	R	D	D	D
Clause 7 Response to TS abnormal conditions									
7.2.2 Voltage disturbance ride-through requirements	POC and POM	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							

Verification Matrix – Example “Preferred” Use of Models

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 requirements)	As-built installation evaluation	Commissioning tests	Post-commissioning model validation	Post-commissioning monitoring	Periodic tests	Periodic verification
		Responsible entity							
		IBR unit or supplemental IBR device manufacturer[a]	*IBR developer /TS owner/ TS operator*[a]	*IBR developer /TS owner/ TS operator*[a]	*IBR developer/ TS owner/ TS operator*[a]	*IBR developer/ IBR operator/ TS owner/ TS operator*[a]	*IBR operator/ TS owner/ TS operator*[a]	*IBR operator/ TS owner/ TS operator*[a]	*IBR operator/ TS owner/ TS operator*[a]
Clause 5 Reactive power—voltage control requirements within the continuous operation region									
5.1 Reactive power capability	POM	R	**Steady state simulation** + **detailed** plant model	R	R	R	D	D	D
5.2 Voltage and reactive power control modes	POM	D	Dynamic **positive sequence** simulation + **detailed** plant model	Cmps DE vs. as-built equipment/ settings	R	Dynamic **positive sequence** simulation + **lumped** plant model	D	D	D
Clause 6 Active-power—frequency response requirements									
6.1 Primary frequency response (PFR)	POC and POM	NR	Dynamic **positive sequence** simulation + **detailed** plant model	R	R	Dynamic **positive sequence** simulation + **lumped** plant model	D	D	D
6.2 Fast frequency response (FFR)	POC and POM	R	Dynamic **positive sequence** simulation + **detailed** plant model	R	R	Dynamic **positive sequence** simulation + **lumped** plant model	D	D	D
Clause 7 Response to TS abnormal conditions									
7.2.2 Voltage disturbance ride-through requirements	POC and POM	R	**EMT** simulation + **detailed** plant model	R	NR	Dynamic **positive sequence** simulation + **lumped** plant model	R	D	D
7.2.3 Transient overvoltage ride-through requirements	POM	R	**EMT** simulation + **detailed** plant model	R	NR	Dynamic **positive sequence** simulation + **lumped** plant model	R	D	D
7.3.2 Frequency disturbance ride-through requirements	POM	R	**EMT** simulation + **detailed** plant model	R	NR	Dynamic **positive sequence** simulation + **lumped** plant model	R	D	D
7.4 Return to service after IBR plant trip	POM	Refer to line entries for 4.10							

Review of Existing Model Quality Tests

PSCAD Model Requirements Rev. 11


PSCAD Model Requirements Rev. 11

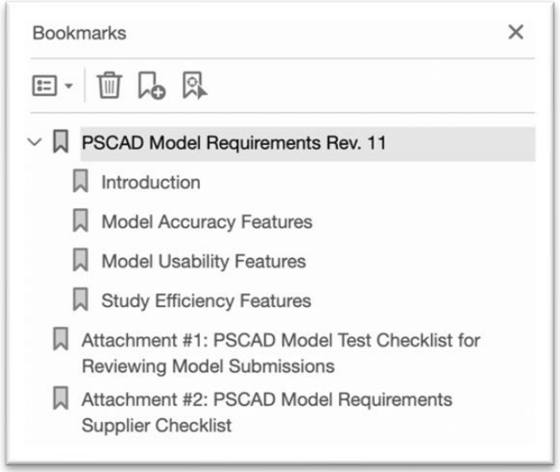
Date: December 2, 2021
Prepared By: Andrew L. Isaacs
Lukas Unruh
Garth Irwin
www.electranix.com

This document includes the following attachments:
Attachment #1: PSCAD Model Test Checklist for Reviewing Model Submissions
Attachment #2: PSCAD Model Requirements Supplier Checklist

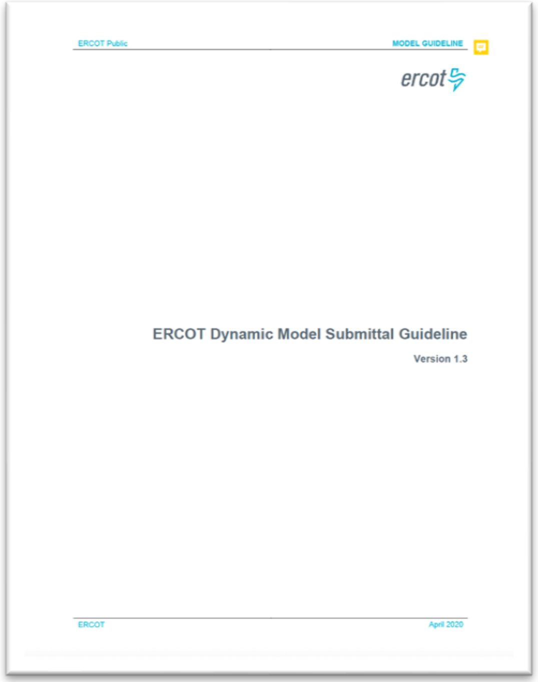
Revision 11 notes (Changes from rev. 10):

Item C	Power Plant Controller now has its own Item C, with more detail on requirements
Item J	Requirement to be able to disable protection removed
Footnote 3	Added reference to .dll based "real code" joint IEEE and Cigre standard
Entire Document	Replaced most uses of the word "should" with "must", minor editorial
Checklists	Clarification on "purpose" of each document, including revised title for Attachment 1

ELECTRANIX
SPECIALISTS IN POWER SYSTEM STUDIES



ERCOT Dynamic Model Submittal Guideline - Version 1.3


ERCOT Public — MODEL GUIDELINE

ercot

ERCOT Dynamic Model Submittal Guideline
Version 1.3

ERCOT — April 2020

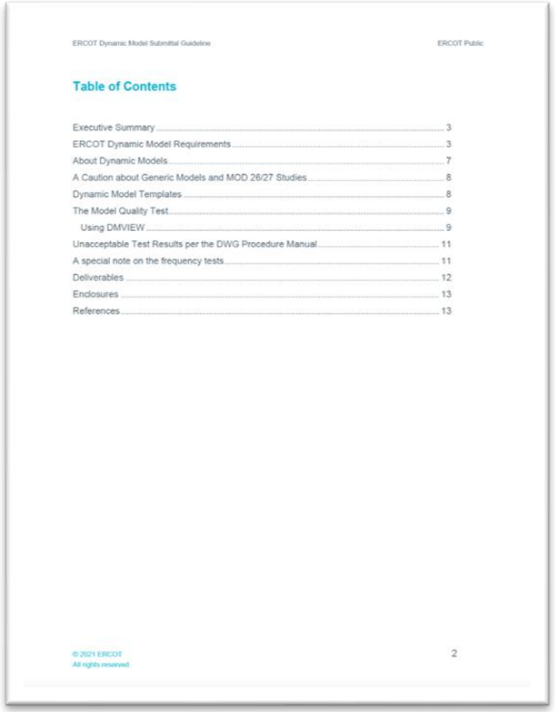

ERCOT Dynamic Model Submittal Guideline — ERCOT Public

Table of Contents

2

IEEE 2800-2022 Technical Minimum Capability Requirements

TS owner can require additional capability

Raising the minimum bar

Capability Required in 2800

General Requirements
"shall have"
- Measurement accuracy
- Controls Prioritization
- Control responses
- Applicability to Diverse IBR Plants

Frequency Response
- Fast Frequency Response for under-frequency conditions
  "may" for over-frequency conditions
- Primary Frequency Response

Reactive Power – Voltage Control
- Q for voltage control at zero active power
  Ac-connected offshore wind: "should have"
- Automatic Voltage Regulation Functions
- Reactive Power

Power Quality
TS owner "should" specify
- Harmonic Voltage Limitations
- Prevent Transient Overvoltage
- Harmonic Current Limitations
- Phase Unbalance
- Rapid Voltage Change
- Flicker Limitations

Ride-Through Capability and Performance, Protection
- Unbalanced Current Injection
- Balanced Current Injection
- Voltage Ride-through including TrOV + Consecutive
- Frequency & Phase-jump Ride-through
- Coordination Of Protection

Modeling & Validation, Measurement Data, and Performance Monitoring
- Process and criteria for model validation
- High Fidelity Performance Monitoring
- Validated Models

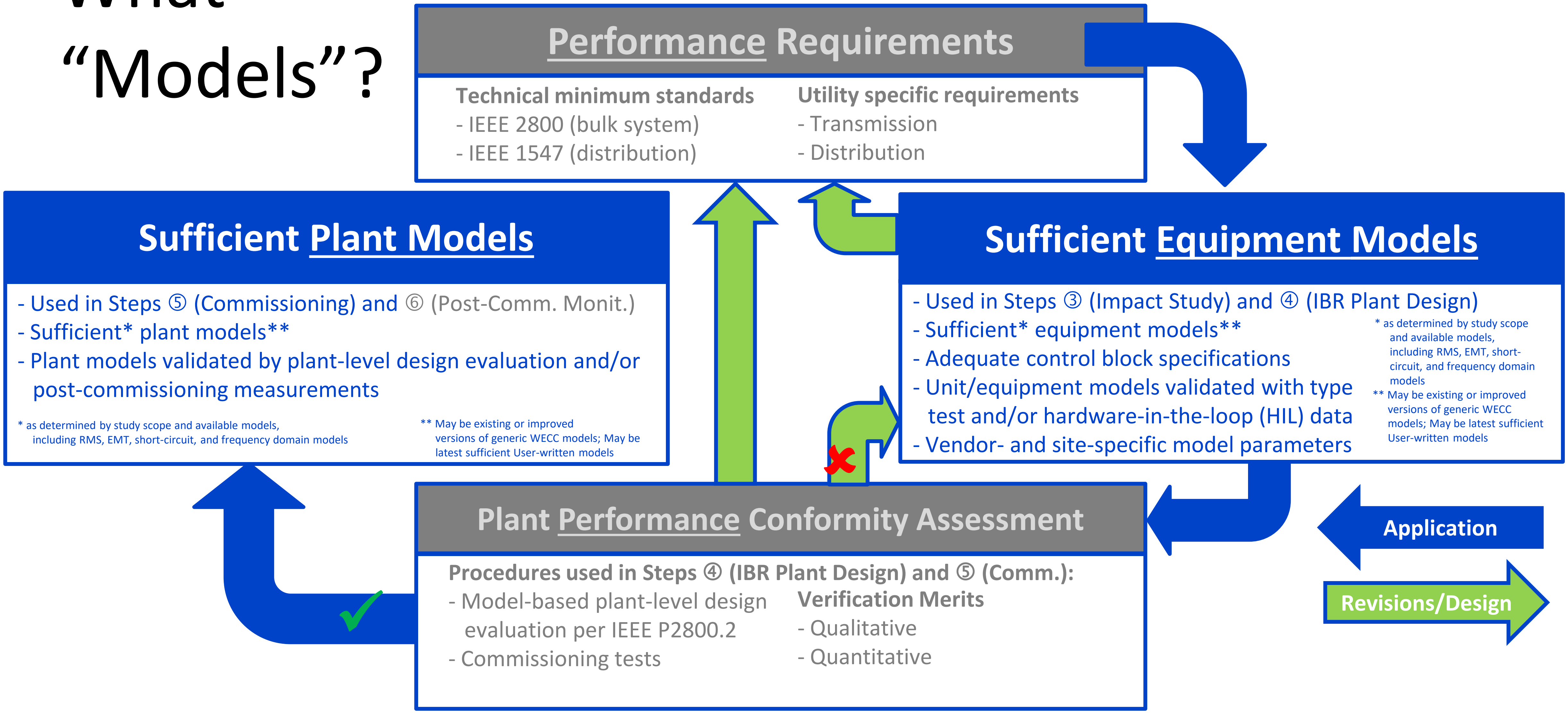
Tests and verification requirements
- Post-commissioning Monitoring
- Plant-level Evaluation & Modeling
- Commissioning Tests
- Type tests

Utilization of these capabilities is outside the purview of 2800

IEEE PES Power & Energy Society®

IEEE

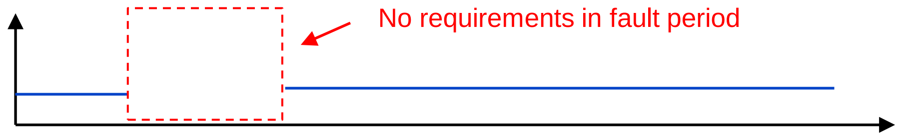
What “Models”?



Source: EPRI - Continuous and Iterative Improvement of IBR Performance Requirements, Plant-Level Modeling, and Model Validation. [Online] https://www.epri.com/pvmod

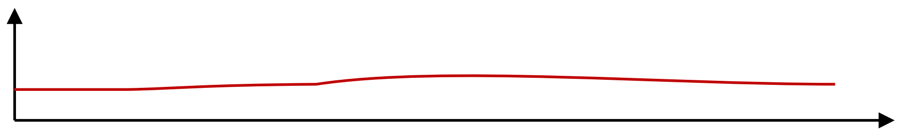
Revision 0: Voltage Ride-Through Requirements
Plant with VRT but no reactive current injection during fault

Performance Requirements

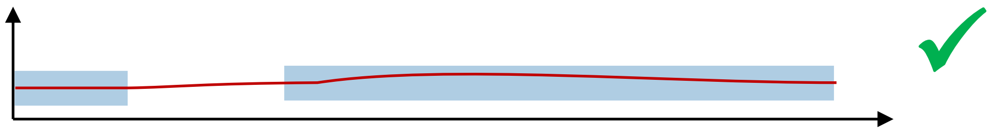


Sufficient Plant Models

Sufficient Equipment Models



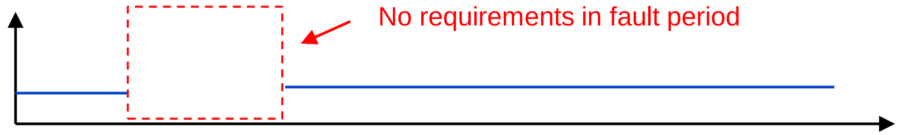
Plant Performance Verification



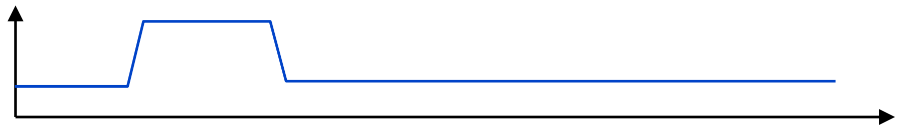
Source: EPRI

Revision 0: Voltage Ride-Through Requirements
Plant with VRT and reactive current injection during fault

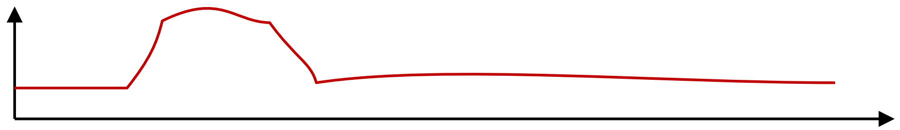
Performance Requirements



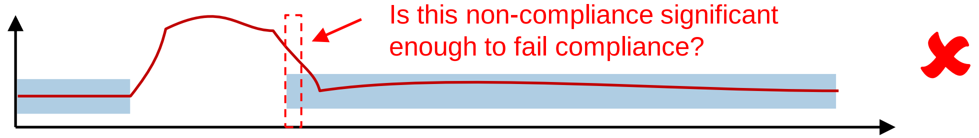
Sufficient Plant Models



Sufficient Equipment Models



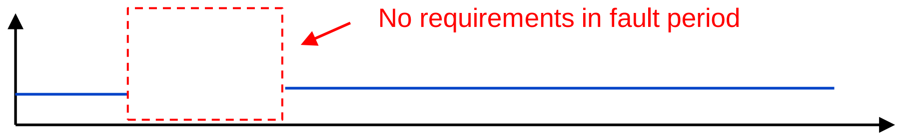
Plant Performance Verification



Source: EPRI

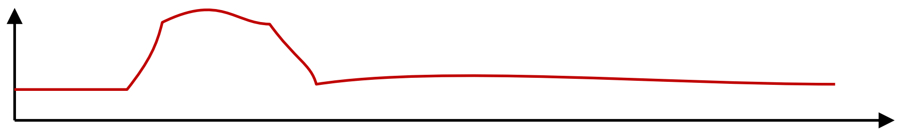
Revision 0: Voltage Ride-Through Requirements
Plant with VRT and reactive current injection during fault

Performance Requirements

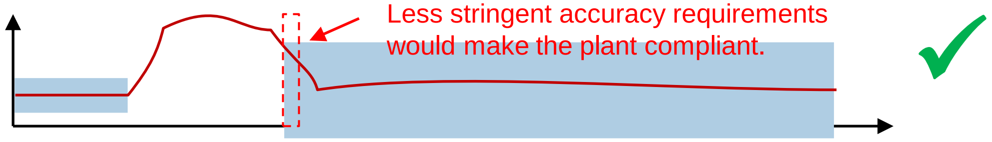


Sufficient Plant Models

Sufficient Equipment Models



Plant Performance Verification



Source: EPRI

Revision 1: Voltage Ride-Through Requirements
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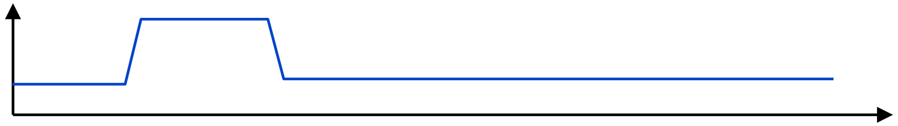
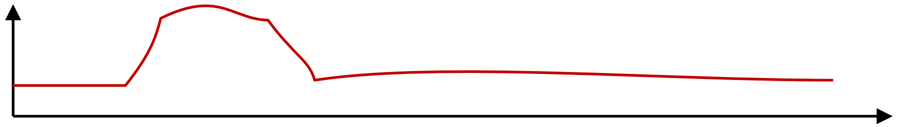
Performance Requirements

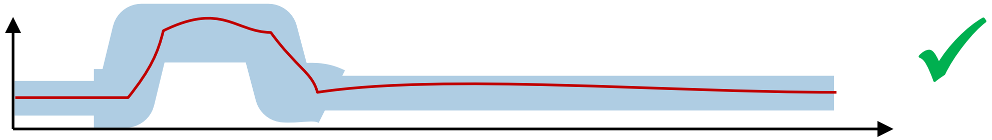
Sufficient Plant Models



Sufficient Equipment Models



Plant Performance Verification



Source: EPRI

Revision 1: Voltage Ride-Through Requirements
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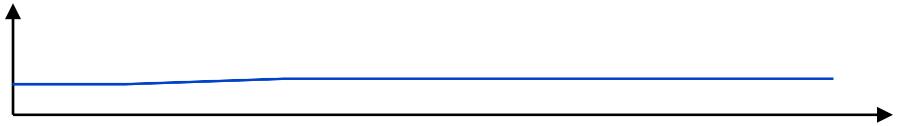
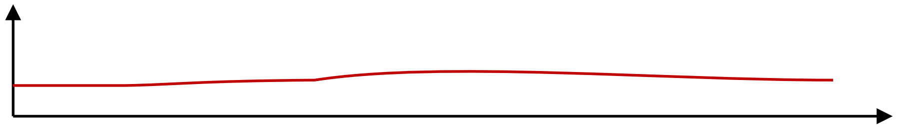
Performance Requirements

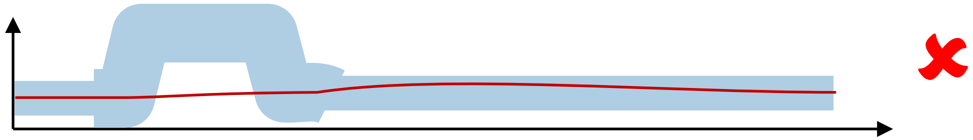
Sufficient Plant Models



Appropriate Equipment Models



Plant Performance Verification



Source: EPRI

Discussion: Possible Performance Verification & Model Validation

Phase	Purpose	Pre-fault	Fault period		Post-fault	
		Stationary	Transient	Quasi-stationary	Transient	Stationary
Interconnection / System Impact Study	Interconnection decision	[High]	[High]	[High]	[High]	[High]
IBR Plant Design	Plant performance verification	[High]	*	*	*	[High]
Post-Commissioning Modeling	Grid Compliance (MOD Stds)	[High]	[High]	[High]	[High]	[High]
	Transmission Planning Studies (long-term)	[High]	[Low]	[High]	[Low]	[High]

* Depends on performance requirements

Source: EPRI/NERC

Example Verification Signals

- Active power (P) and current (Ip)
- Reactive power (Q) and current (Iq)
- +,-,0-sequence components
- Others?

Example Verification Metrics

- Qualitative: trend
- Quantitative: Root mean square error (RMSE)
  - Maximum error (MXE)
  - Mean error (ME)
  - Mean absolute error (MAE)

  (MXE, ME, MAE: used in IEC 61400-27-1)

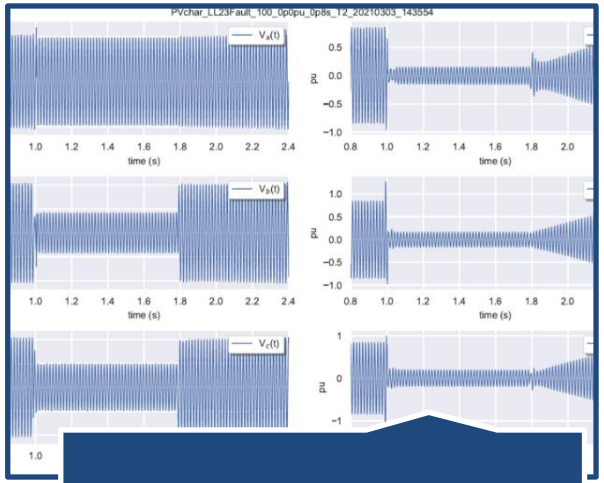
Example Accuracy Assessment

- Qualitative: “high” and “low”
- Quantitative: xx% and yy%
- Others?

EXAMPLE USE OF MODELING FOR PLANT PERFORMANCE ASSESSMENT

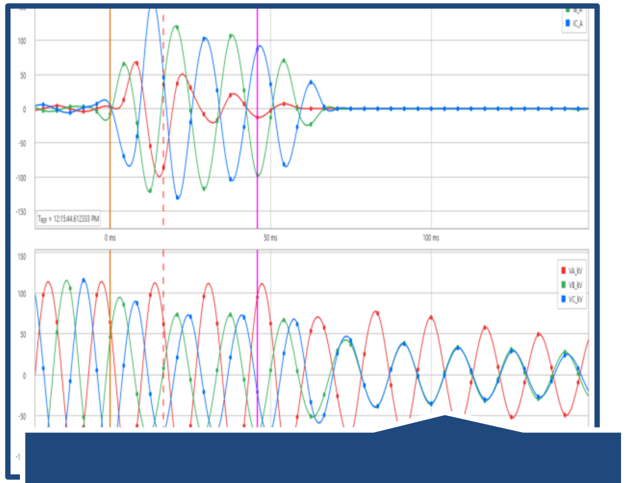
Simulation Examples Based on EPRI's Inverter-Based Resource Characterization and Modeling Research

Resource characterization



Laboratory testing

- kW to MW scale inverters
- LVRT response, P-f control, voltage phase angle shift, TROV, etc.

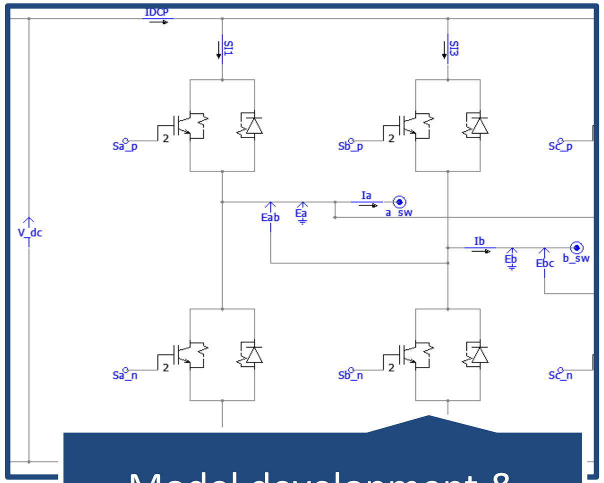


Field data collection and analysis

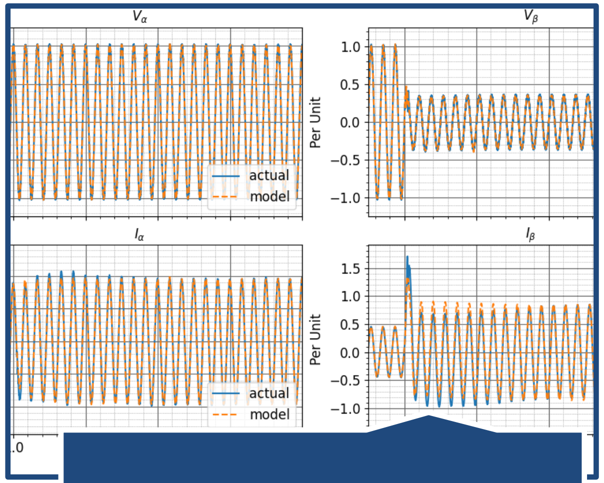
Data from system events

- Inverter level
- Plant level

Modeling



Model development & improvement



Model validation

- transient stability, EMT, short circuit, PQ, QSTS
- transmission connected PV plants, DER PV plants, individual PV inverters
- configurable for IEEE 2800 performance requirements
- generic models and OEM's user-defined models

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)*. https://www.epri.com/pvmod

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.*

Source: EPRI

IEEE 2800-2022 Technical Minimum Capability Requirements

TS owner can require additional capability

Raising the minimum bar

Capability Required in 2800

General Requirements

"shall have"

- Measurement accuracy
- Controls Prioritization
- Control responses
- Applicability to Diverse IBR Plants

Frequency Response

- Fast Frequency Response for under-frequency conditions **"may" for over-frequency conditions**
- Primary Frequency Response

Reactive Power – Voltage Control

- Q for voltage control at zero active power **Ac-connected offshore wind: "should have"**
- Automatic Voltage Regulation Functions
- Reactive Power

Power Quality

TS owner "should" specify

- Harmonic Voltage Limitations
- Prevent Transient Overvoltage
- Harmonic Current Limitations
- Phase Unbalance
- Rapid Voltage Change
- Flicker Limitations

Ride-Through Capability and Performance, Protection

- Unbalanced Current Injection
- Balanced Current Injection
- Voltage Ride-through including TrOV + Consecutive
- Frequency & Phase-jump Ride-through
- Coordination Of Protection

Modeling & Validation, Measurement Data, and Performance Monitoring

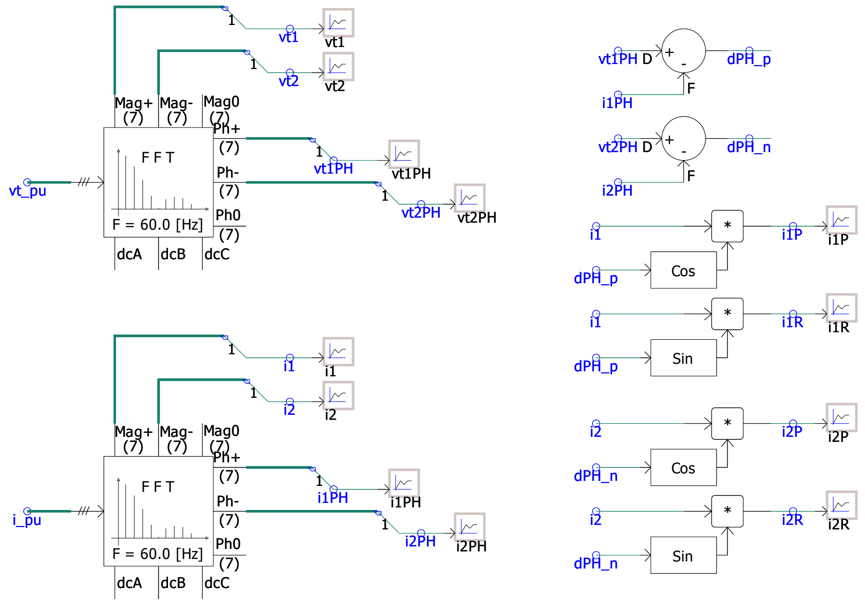
- Process and criteria for model validation
- High Fidelity Performance Monitoring
- Validated Models

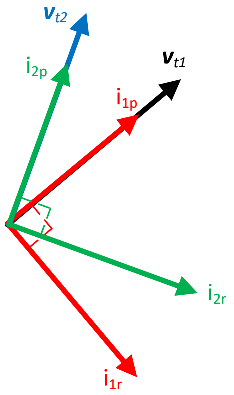
Tests and verification requirements

- Post-commissioning Monitoring
- Plant-level Evaluation & Modeling
- Commissioning Tests
- Type tests

Utilization of these capabilities is outside the purview of 2800

Nomenclature of fundamental frequency signals





Positive sequence fundamental frequency

$$i1P = |i1|\cos(\angle vt1PH - \angle i1PH)$$
$$i1R = |i1|\, sin(\angle vt1PH - \angle i1PH)$$

Negative sequence fundamental frequency

$$i2P = |i2|\cos(\angle vt2PH - \angle i2PH)$$
$$i2R = |i2|\, sin(\angle vt2PH - \angle i2PH)$$

Based on this nomenclature, during unbalanced faults, we expect:

positive sequence current lags positive sequence voltage

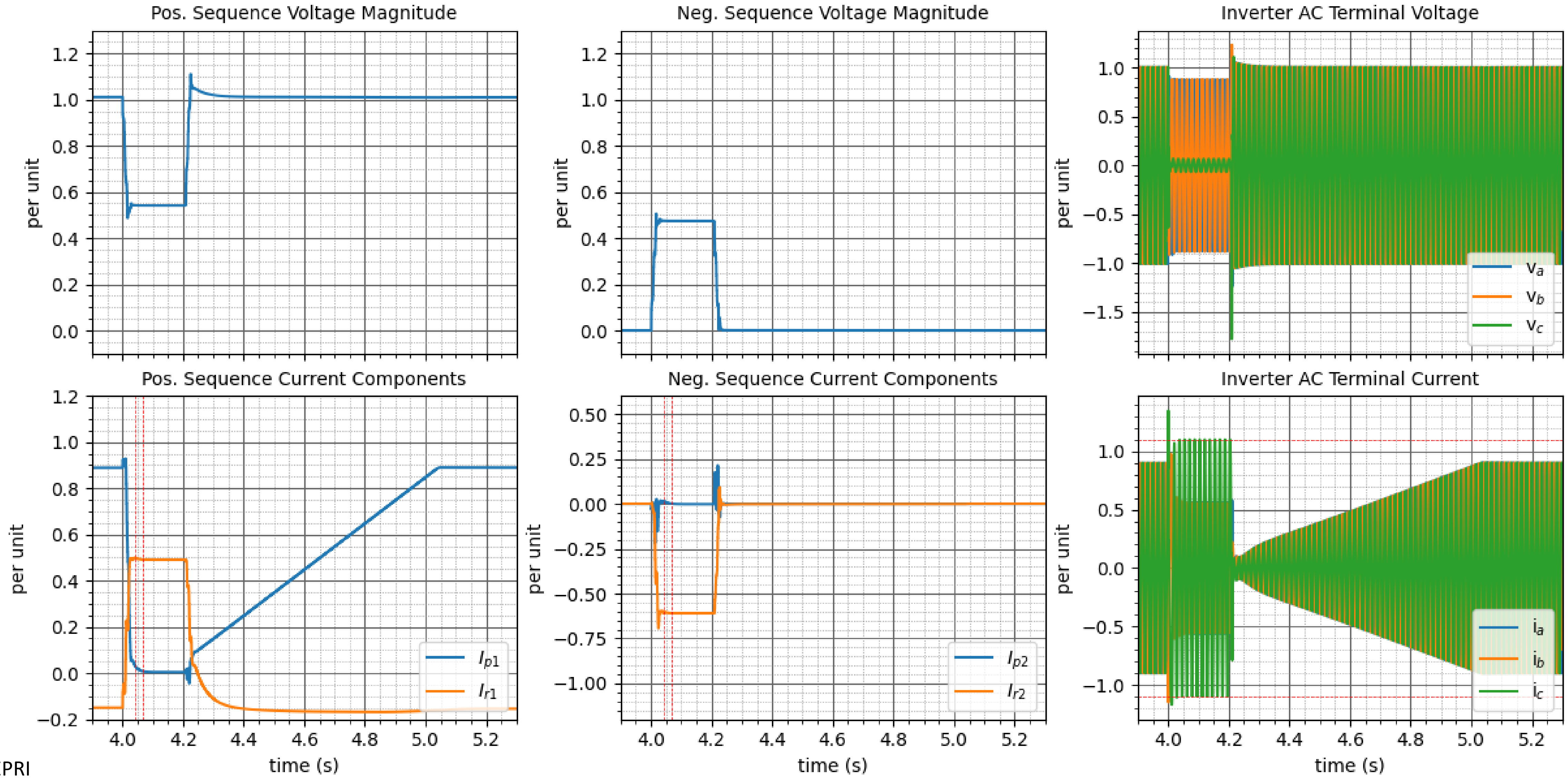
$$i1R > 0$$

negative sequence current leads negative sequence voltage

$$i2R < 0$$

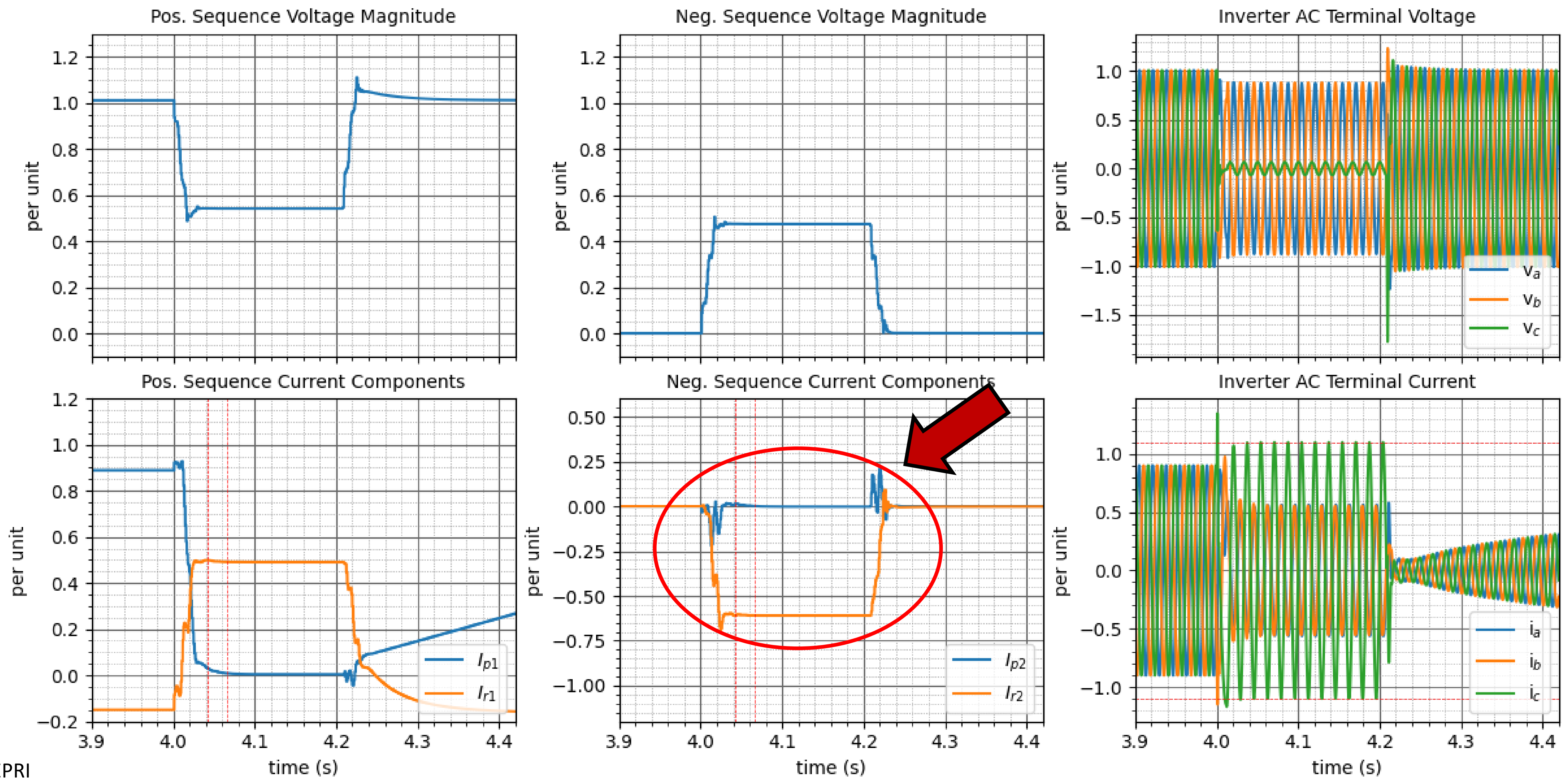
Source: EPRI, 2022

Example 1a: 2800 compliant



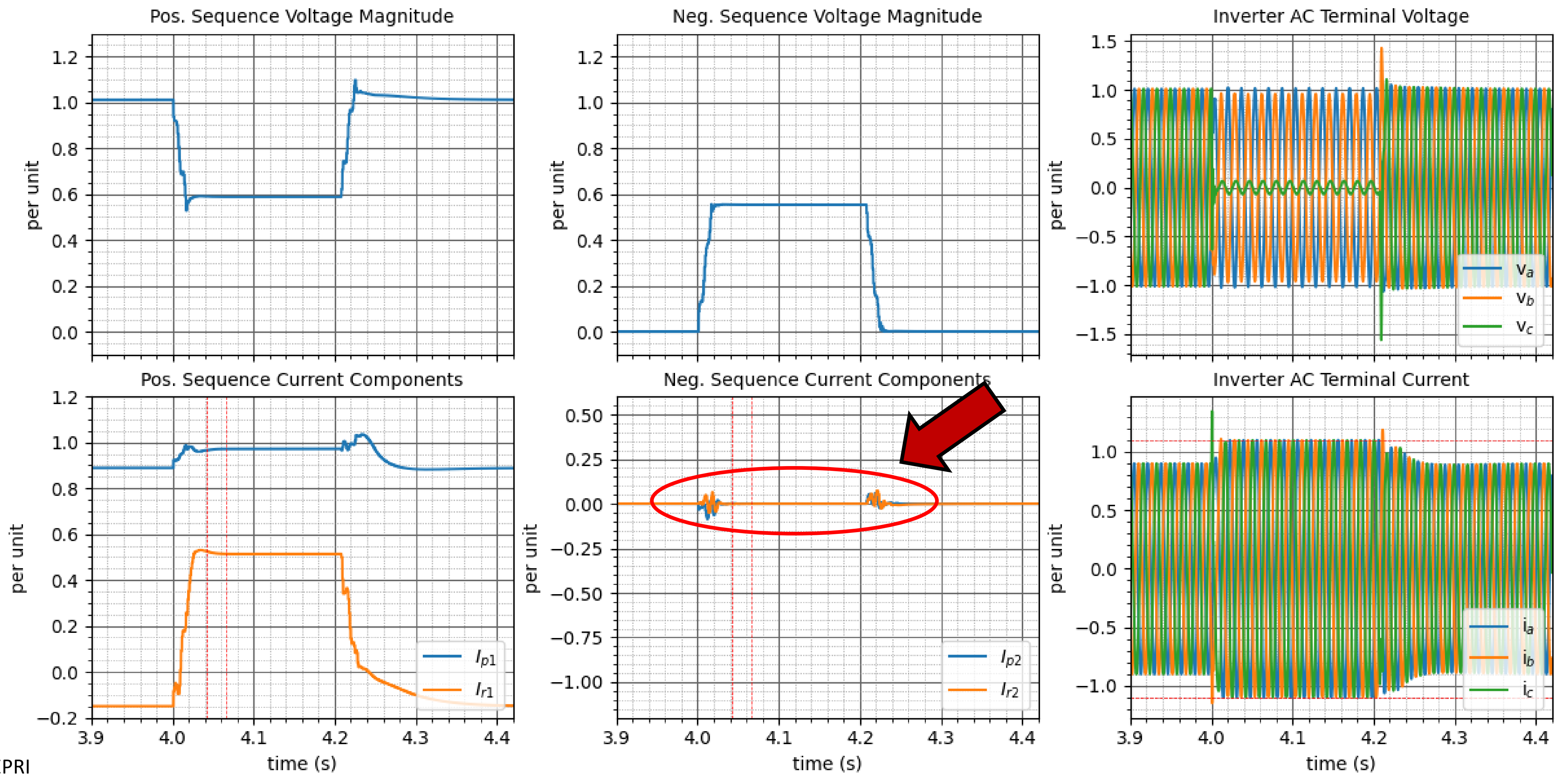
Source: EPRI

Example 1a: 2800 compliant (zoom)



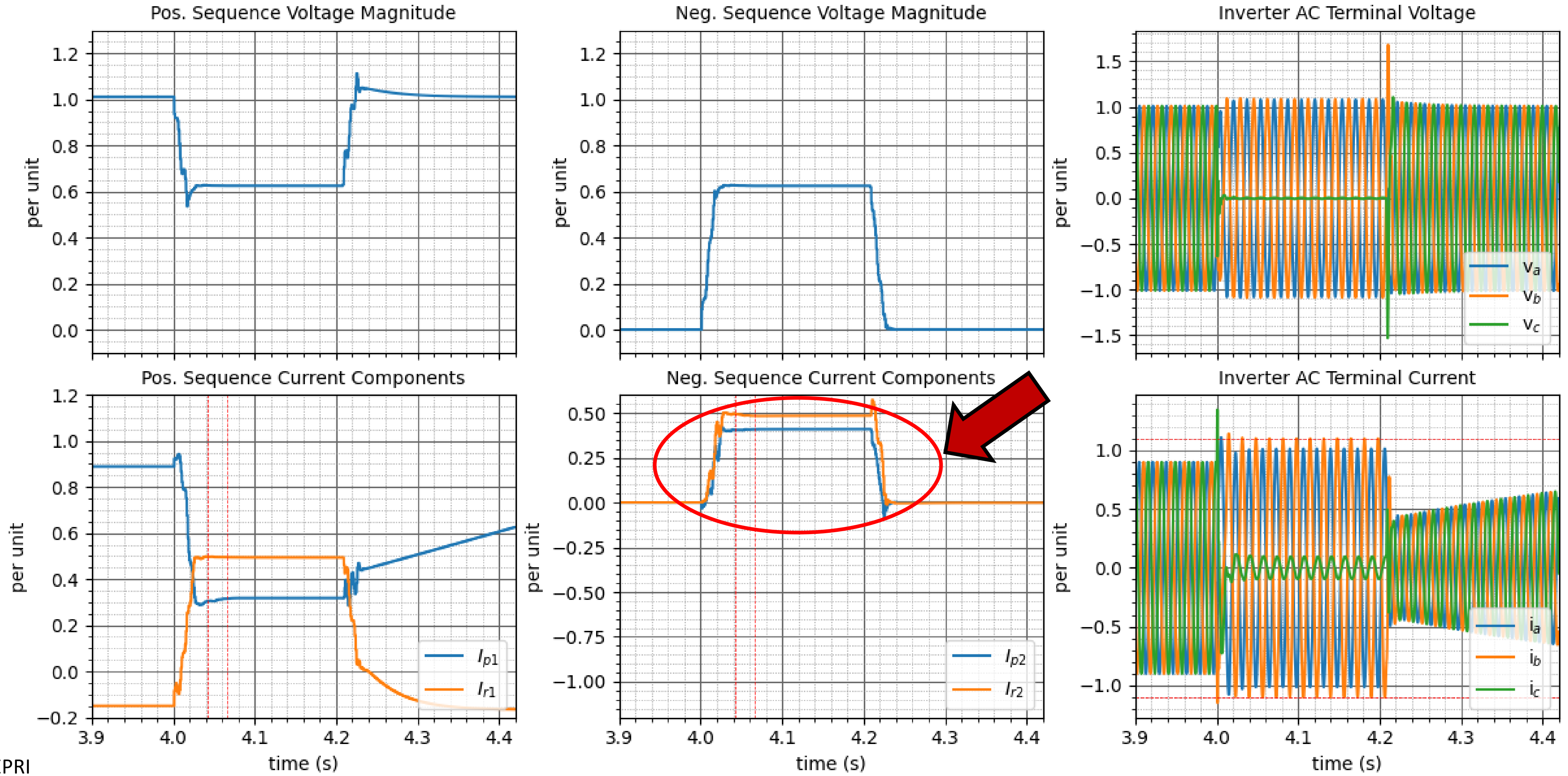
Source: EPRI

Example 1b: No V2 control (I2=0) (zoom)



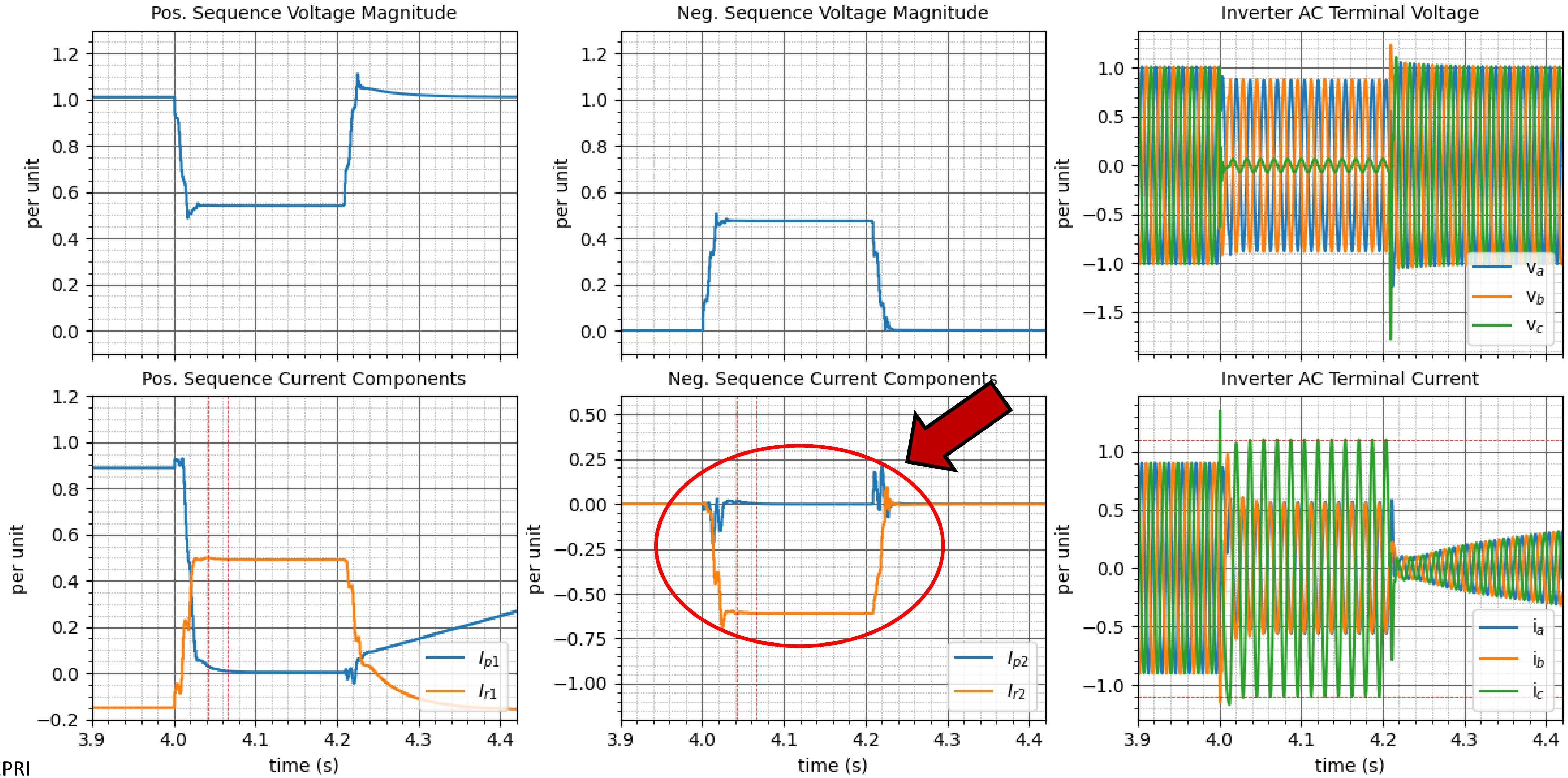
Source: EPRI

Example 1c: Incorrect V2 control (I2P <> 0 & I2R > 0) (zoom)



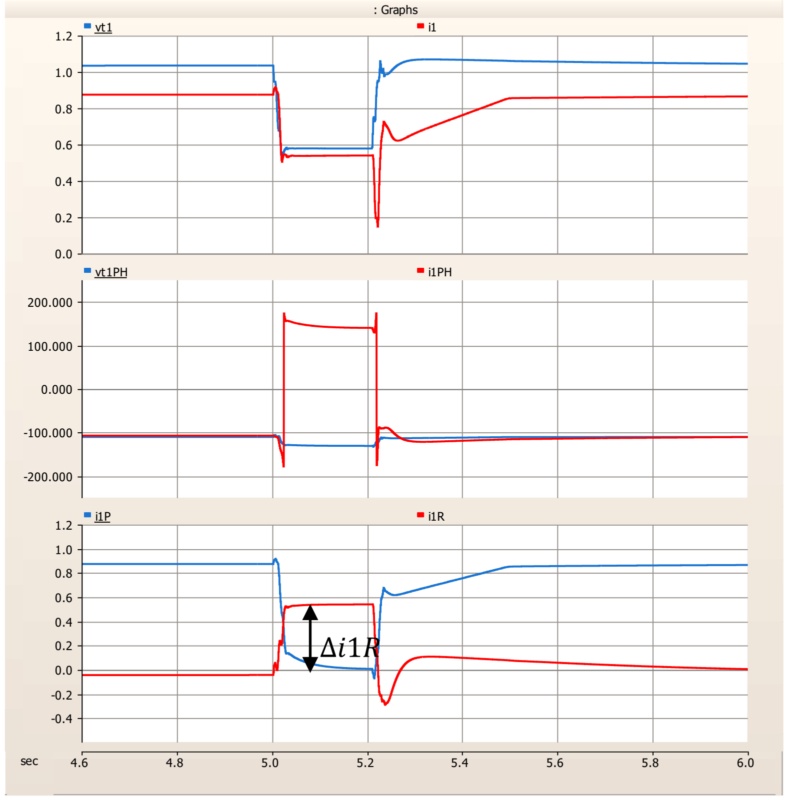
Source: EPRI

Example 1a: 2800 compliant (zoom)

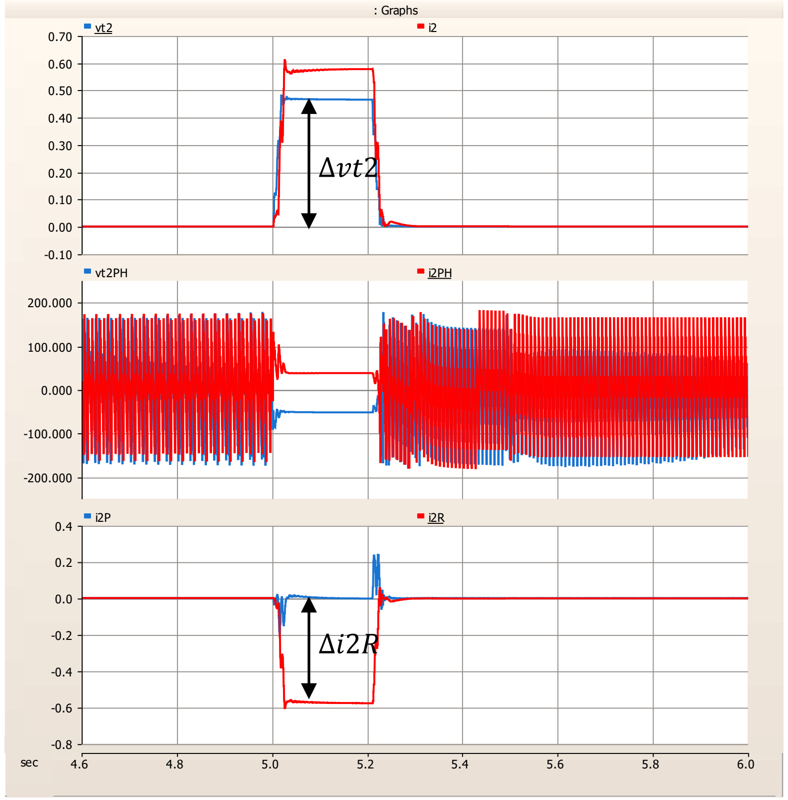


Source: EPRI

Inverter response to B-C fault at the 34.5 kV bus
Negative sequence current injection enabled (fault period)



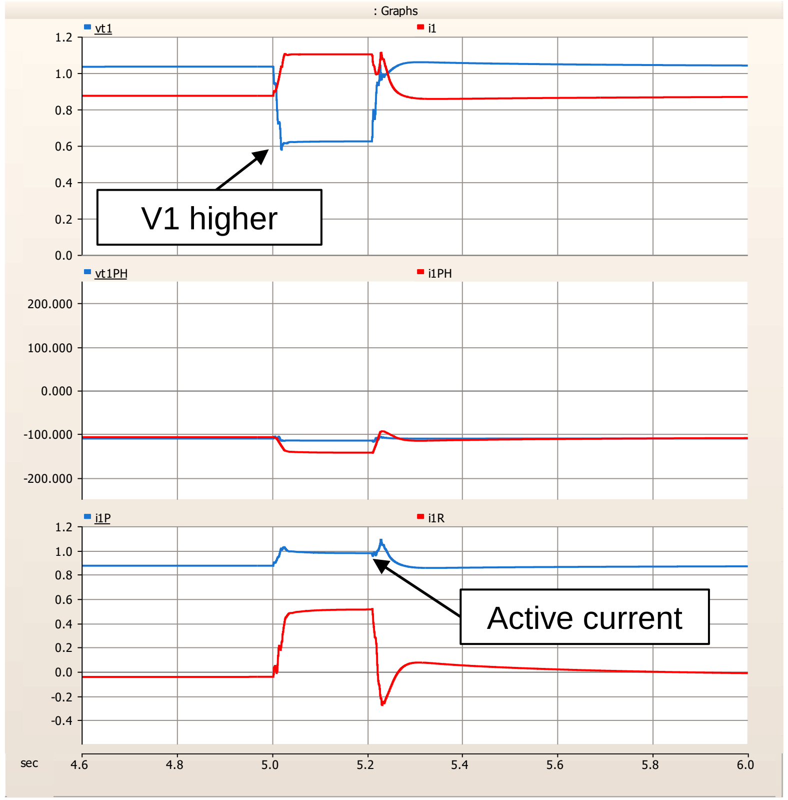
$k_{qv1} = 2.0$



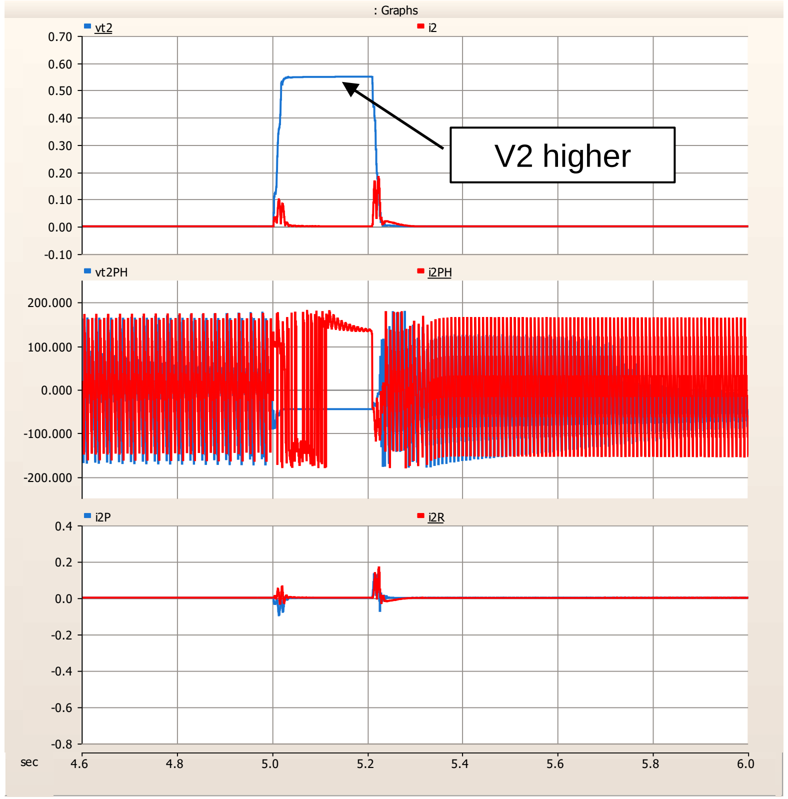
$k_{qv2} = 2.0$

Source: EPRI, 2022

Inverter response to B-C fault at the 34.5 kV bus
Negative sequence current injection disabled (fault period)



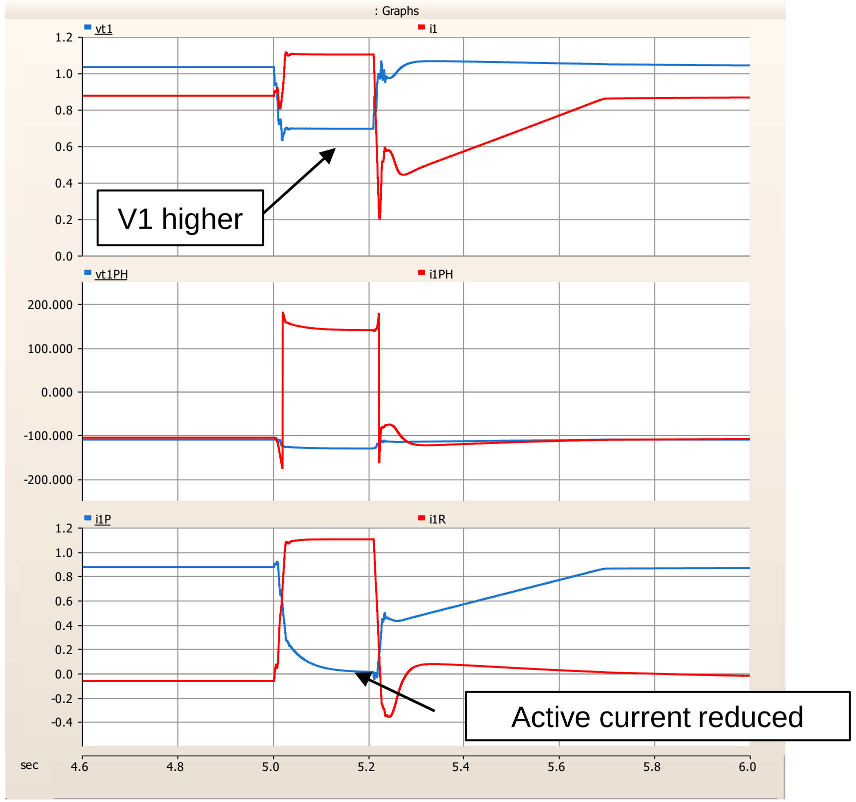
$k_{qv1} = 2.0$



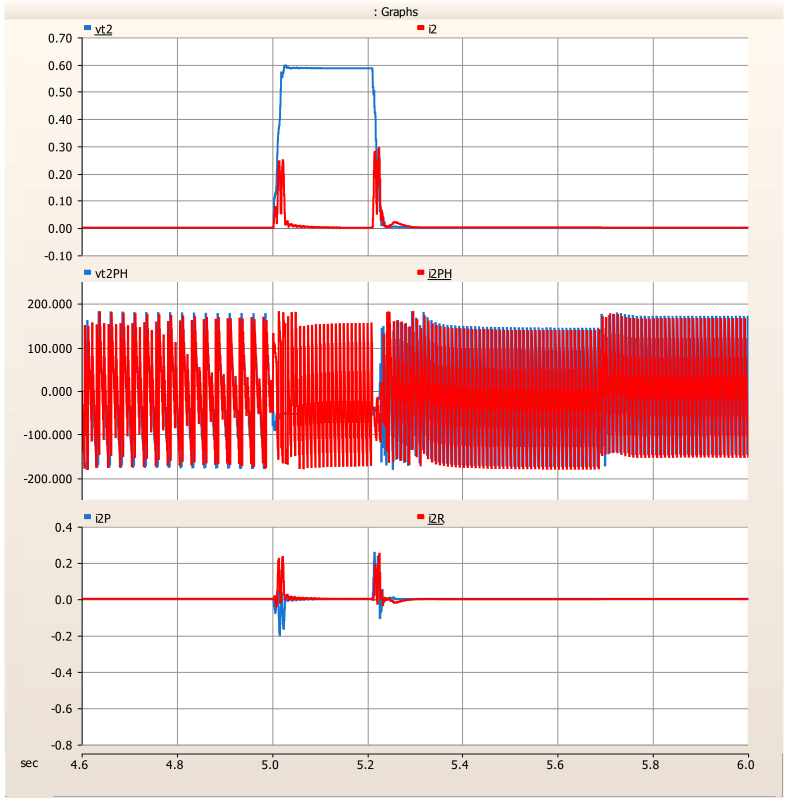
$k_{qv2} = 0.0$

Source: EPRI, 2022

Inverter response to B-C fault at the 34.5 kV bus
Negative sequence current injection disabled (fault period)



$k_{qv1} = 6.0$



$k_{qv2} = 0.0$

Source: EPRI, 2022

IEEE P2800.2std

Commissioning Test and As-built evaluation (Subgroup 4)

Project Management:

- First (SubGroup 4) SG4 meeting: April 20, 2022
  - Vice Chair: Divya Kurthakoti (dkuch@orsted.com)
  - Chair: Chris Milan (chrismilan@crestcura.com)
  - Chair: David Narang (david.narang@nrel.gov)
- Biweekly on Wednesday @ 12pm-1pm EST
- As of August 23, 2022: There are 77 subscribers for SG4
- To automatically enroll and participate please email to

STDS-P2800-2-SG4@LISTSERV.IEEE.ORG

General approach: SG4

- Went over each IEEE 2800std requirement that would require a test procedure to be written and within SG4 scope.
- Consensus within SG4 and outside on the following:
  1. SG4 scope focuses on commissioning tests.

     (Model validation utilizing commissioning tests are outside SG4 scope. Established a close coordination with SG5 to ensure that test results are in-line with model validation needs)
  2. Established a close coordination with PQ task force to provide draft language for section 8 of the IEEE 2800stds.
  3. For requirements where commissioning test may not be practically viable, a design review is suggested as the approach. Detailed language in the SG4 draft working document
  4. SG4 consensus that the following sections within the IEEE 2800std requires commissioning test procedures
     - 5.1 Reactive power capability
     - 5.2 Voltage and reactive power control modes
     - 6.1 Primary Frequency Response (PFR)
     - 6.2 Fast Frequency Response (FFR)
     - 7.4 Return to service after IBR plant trip

SG4 Ongoing Discussions: No consensus yet

- Draft language for the following has been received:
    - 5.1 Reactive power capability
    - 5.2 Voltage and reactive power control modes
    - 6.1 Primary Frequency Response (PFR)
    - 6.2 Fast Frequency Response (FFR)
- Open Issue(s) for broader discussion/decision:
  - Testing FFR capability for PV and storage plants: Does IEEE 2800std require control or energy testing? If its control, then there is no difference between PFR and FFR testing for PV and storage plants
  - Permit Service: there may be no permit service control logic function in large IBR plants. In such a case Permit to service may be interpreted as “human in the loop communication means to allow a plant to restore operation”
  - Automatic return to service control function

IEEE P2800.2std

Post-Commissioning

(Subgroup 5)

SG5 Project Management

- First SG5 meeting: April 8, 2022
- Leadership team:
  - Julia Matevosyan (julia@esig.energy)
  - Jason MacDowell (jason.macdowell@ge.com)
  - Brad Marszalkowski (bmarszalkowski@iso-ne.com)
- Biweekly on Tuesdays @ 2-3pm CST
- As of August 24, 2022: There are 73 subscribers for SG5 (17-20 calling in on regular basis, 5-7 actively participating)
- To automatically enroll and participate please email to

  STDS-P2800-2-SG5@LISTSERV.IEEE.ORG (**please also email Julia to get the meeting invites**)

SG5 Scope

- **Post-commissioning model validation**
- **Post-commissioning monitoring** (especially following TS events where the POM voltage and/or frequency deviate from the normal operating region).
- **Periodic tests**
- **Periodic verification** (including after any substantial changes to the IBR plant)

  These may include, but not limited to:
  - Functional software or firmware changes have been made on the IBR plant.
  - Any hardware component of the IBR plant has been modified in the field or has been replaced or repaired with parts that are not substitutive components compliant with this standard.
  - Protection settings have been changed after factory testing.
  - Protection functions have been adjusted after the initial commissioning process

Agreed on Pre-Amble: Post-Commissioning Model Validation and Verifications Assumptions

It is assumed that the following four steps have been successfully completed prior to this post-commissioning step:

- IBR unit-level type testing
- The design evaluation of the IBR plant incl. IEEE2800 conformity assessment
- The as-built installation evaluation of the IBR plant, and
- The commissioning tests for the IBR plant

Agreed on Pre-Amble: Post-Commissioning Model Validation and Verifications Scope

- Post-Commissioning Model Verification: verifying that the controls, protection settings and parameterization of the models, which govern the small and large-signal response of the plant, have not been materially changed, and documentation from the previous stages (design eval., as-built eval. and commission tests) provide clear evidence of this fact. If changes have been identified, evaluate implications on the plant performance/conformity with IEEE2800. – Currently reviewing Annex G of IEEE2800 to see if data and parameters listed there are sufficient for the verification
- Post-Commissioning Model Validation:
  a. perform an adequate set of field tests and measurements (refer to commissioning testing, SG4)
  b. post process the measured data ready for model validation work, and
  c. validate the steady state model and positive-sequence stability model of the IBR plant by comparing the simulated response to the measured field response of the plant to verify that the model adequately replicates the measured dynamic response of the plant for each test performed.

  Model validation of aspects which can be reasonably and safely tested in the field for the entire IBR plant:

  - a limited range of the reactive and real power capability of the plant.
  - the voltage and reactive power control modes and response (e.g. voltage and/or Q-ref step tests at the plant level),
  - the primary frequency response of the plant (e.g. frequency reference step tests),
  - the fast frequency response of the plant, to the extent possible (e.g. frequency reference step tests),

Agreed on Pre-Amble: Post-Commissioning Model Validation and Verifications Scope

- There is no need for additional field tests nor simulations to validate the large-signal performance of the IBR plant model at this stage.
- Aspects such as low/high voltage ride-through, low/high frequency ride-through, TOV protection, frequency protection, rate of change of frequency protection, AC overcurrent protection, unintentional islanding protection, voltage protection, interconnection system protection, etc. would have been fully studied and validated during the design evaluation and as-built installation evaluation.
- Moreover, it is impractical to test many of these aspects in the field.
- These aspects will be further validated during post-commissioning monitoring, specifically, following TS events where the POM voltage and/or frequency deviate from the normal operating region.
- There will be no need for additional IEEE2800 conformity assessment at this stage in the process. The above steps are sufficient to ensure that conformity achieved in the design stage and commissioning testing is still maintained.

Ongoing Discussion: Data Post-Processing and Passing Results

Post process the measured data ready for model validation work

Table 19 is specifying what format data is available. PMUs and DFR data can be used for stage testing for positive-sequence stability type of simulation, for higher speed validation need DFR data but that's during an event (post-commissioning monitoring/disturbances). During staged tests DFRs can be adjusted to capture small signal disturbance tests.

Direction on what constitutes passing results for the validation

Normally, engineering judgement is applied. In other countries more specific requirements with regards to absolute error integrated over given time and threshold for the error is identified. May be a hybrid combination of specified errors vs engineering judgement? We can add an appendix with examples to show how engineering judgement should be used (the examples will cover both Post commissioning model validation stage and post-commissioning monitoring stage, i.e. disturbance-based model validation). - We had a follow up discussion with leadership team but no final conclusion on this yet.

Ongoing Discussion: Initial Conditions Data and Model Validation

Initial conditions data for model validation

How the system looks like that we are interconnecting too? What are system conditions during commissioning test? Do we need to log this during commissioning testing to be able to validate the model, so that the model is validated for the grid condition at the time of test. SCR may be an appropriate parameter for that, should capture other plants in the area. For a known voltage step capture reactive power response and that would capture system strength in the area. Measured positive sequence frequency and voltage, we may also need information about how it was sampled. See Table 19.

For each function we are trying to validate is it sufficient to just have active, reactive power and voltage or do we need anything else? Data needed for model validation: not just outcome of the test but also input signals such as e.g. Voltage reference and Q commands from plant controller

- 5.1 Reactive Power Capability (model validation)
- 5.2 Voltage and Reactive Control (model validation)
- 6.1 Primary Frequency Response (model validation)
- 6.2 Fast Frequency Response (model validation) – Is this different from PFR in an IBR?

Power Quality Task Force (PQTF) Update

David Mueller

Eugen Starschich

August 25, 2022

Power Quality Task Force (PQTF)

- Scope:
  - Draft verification procedures for PQ-related requirements of 2800 where required by 2800 Table 20
  - Provide input to each subgroup on PQ requirements verification
- Leads:
  - Eugen Starschich
  - David Mueller
- Listserv: STDS-P2800-2-PQTF@LISTSERV.IEEE.ORG

IEEE P2800.2 Subgroup Scopes

SG 1

Overall document and general requirements

SG 2

SG 3

SG 4

SG 5

- Power Quality Task Force cuts horizontally across subgroups. Scope is to draft verification procedures for PQ-related requirements, as depicted at right.

Excerpt of 2800 Table 20:

Verification Methods Matrix

PQ Task Force

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

Overview of Power Quality Requirements

- 8.2.2 Rapid voltage changes
- 8.2.3 Flicker
- 8.3.1 Harmonic current distortion
- 8.3.2 Harmonic voltage distortion
- 8.4.1 Limitation of cumulative instantaneous over-voltage
- 8.4.2 Limitation of over-voltage over one fundamental frequency period POM

Harmonic voltage distortion

- Harmonic voltage limits are not common in the US market
- Definition of any harmonic limits requires more effort and goes beyond the scope of IEEE 2800.2
- Many observed instabilities in the AC network are due to harmonic voltage effects such as
  - Amplification of background harmonics
  - Negative IBR impedance → Creation of resonance network
- Should PQ group define testing requirements for such parameters?

SG2 – Type Testing (PQTF Inputs)

- Rapid voltage changes (NA)
- Flicker (NA)
- Harmonic current distortion
  - Must also include information needed for harmonics modeling (e.g. IBR Impedances)
- Limitation of cumulative instantaneous over-voltage (NA)
- Limitation of over-voltage over one fundamental frequency period POM (NA)

SG3 – Design Evaluation (PQTF Inputs)

- Rapid voltage changes
  - Some screening methodology for MPT energizing concerns
- Flicker (NA)
- Harmonic current distortion
  - Harmonics study likely
- Limitation of cumulative instantaneous over-voltage
  - Possibility of a study?
- Limitation of over-voltage over one fundamental frequency period POM
  - Possibility of a study?

SG4 – Commissioning (PQTF Inputs)

- Rapid voltage changes (NA)
  - Testing would not confirm worst case conditions
- Flicker (NA)
  - Not considered an issue for large plants, so not necessarily required
- Harmonic current distortion
  - TSO might also stipulate voltage distortion limits
  - Consideration of harmonics direction
  - Week long test is likely, CP95% of 10 minutes values according to IEEE 519
- Limitation of cumulative instantaneous over-voltage (NA)
- Limitation of over-voltage over one fundamental frequency period POM (NA)

SG5 – Post commissioning (PQTF Inputs)

- Rapid voltage changes **(need to confirm with monitoring)**
- Flicker **(need to confirm with monitoring)**
- Harmonic current distortion **(need to confirm with monitoring)**
- Limitation of cumulative instantaneous over-voltage **(need to confirm with monitoring)**
- Limitation of over-voltage over one fundamental frequency period POM **(need to confirm with monitoring)**

Power Quality Task Force (PQTF)

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