

Introduction to Design Evaluation



ESIG

ENERGY SYSTEMS
INTEGRATION GROUP

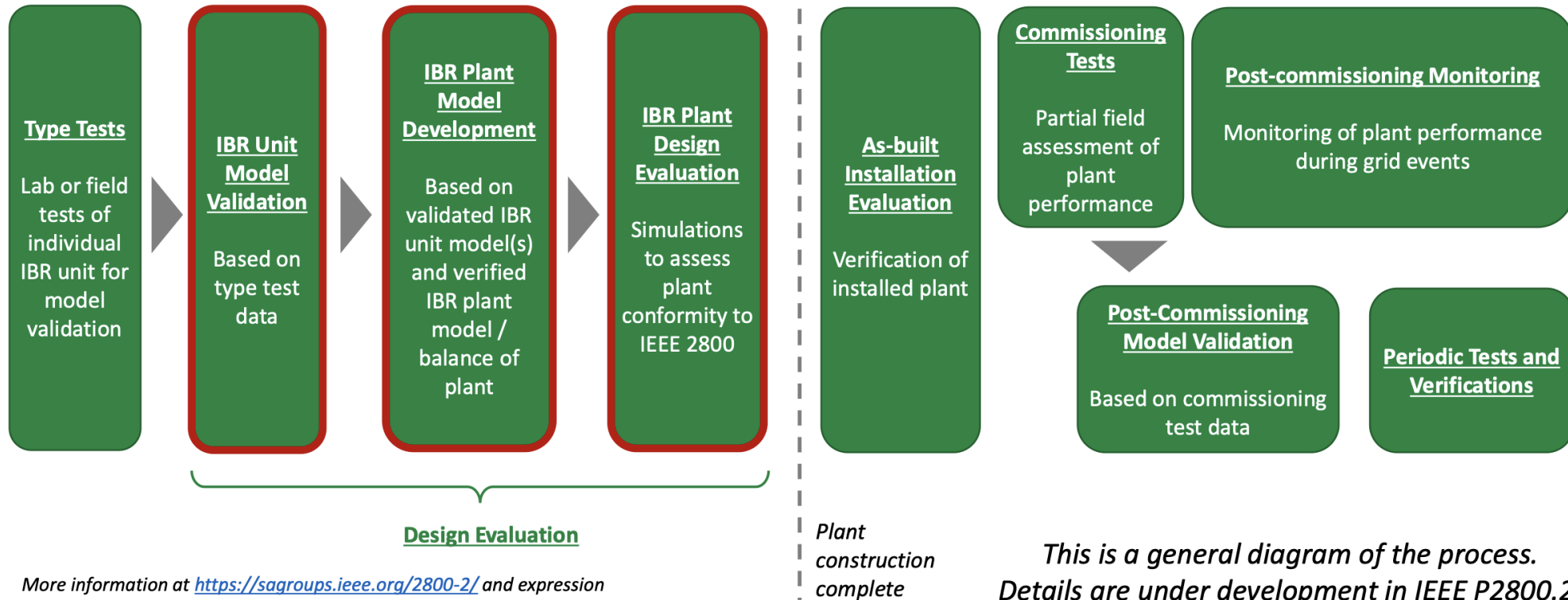
Design Evaluation: Introduction



- Design evaluation is a term with specific meanings in specific contexts
- **Generally:** Design evaluation is exactly what it sounds like, confirming that the site as designed and modeled conforms with the performance requirements at the point of interconnection
- Requires **validated** equipment and **verified** plant models
- **Disclaimer:**
 - I have been heavily involved at a leadership level in the P2800.2 process and have many (many) opinions on design evaluation and validation/verification
 - Some of these opinions differ from the consensus language in the currently approved P2800.2 draft

Design Evaluation: Introduction

Overview of conformity assessment steps in IEEE P2800.2, *Recommended Practice for Test and Verification Procedures for IBRs Interconnecting with Bulk Power Systems*

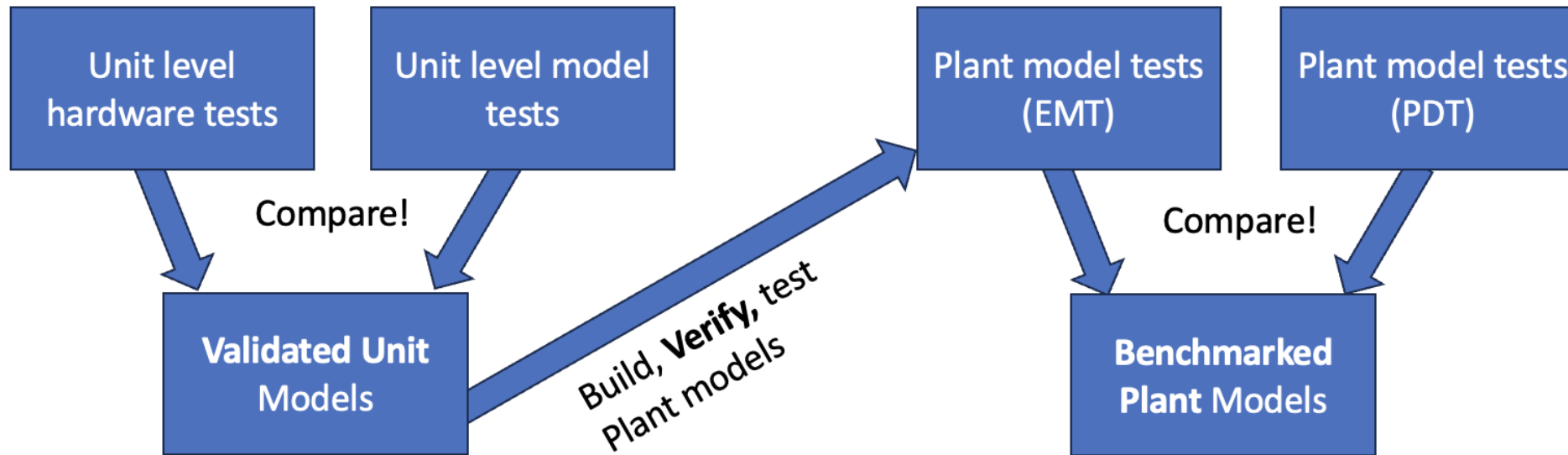


More information at <https://sagroups.ieee.org/2800-2/> and expression of interest to participate [here](#).

Plant construction complete

*This is a general diagram of the process.
Details are under development in IEEE P2800.2.
Some variations permitted.*

IBR Unit Model Validation



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What will be validated? (models compared against type tests)

1. Voltage and reactive power control modes – Clause 5.7.4
2. Primary Frequency response – Clause 5.9.4
3. Fast Frequency response – Clause 5.9.4
4. Voltage disturbance ride through – Clause 5.11.4 to 5.11.8
5. Frequency disturbance ride through – Clause 5.13
6. Limitation of overvoltage over one fundamental frequency period – Clause 5.14.4
7. PPC Testing – Clause 5.17
8. Frequency Scanning
9. Protections – Clause 5.15
 - a. Frequency protection
 - b. ROCOF protection
 - c. Voltage protection
 - d. AC overcurrent protection
 - e. Unintentional islanding protection

IBR Unit Model Validation Challenges



- **How do you evaluate what is an “acceptable” match?**
 - This topic delayed IEEE P2800.2 by months (sorry)
 - Incredibly difficult to gain consensus
- **Different manufacturers have different modeling standards**
 - Some manufacturers have highly detailed and mapped models, others may not have the same level of accuracy
- **Intent of IEEE standards**
 - Some manufacturers have trouble committing to accuracy percentages
 - How is error calculated
 - Fear that requirements will be copy/pasted with no nuance
- **Is the difference in performance real or due to measurement errors in the test bench?**
 - While measurement errors should be minimized, IEEE 2800-2022 measurement tolerances add up

IBR Unit Model Validation Challenge #1



- **Quantitative vs Qualitative** (single most contentious issue in the design evaluation subgroup)
- **Quantitative**
 - **Pro:**
 - Can standardize model quality
 - Helps automate screening
 - Informs engineering judgement
 - **Con:**
 - Poorly determined error bands can let bad models through and overly constrain good models
 - If there is no qualitative component, it is very easy to fall into automation traps

IBR Unit Model Validation Challenge #1

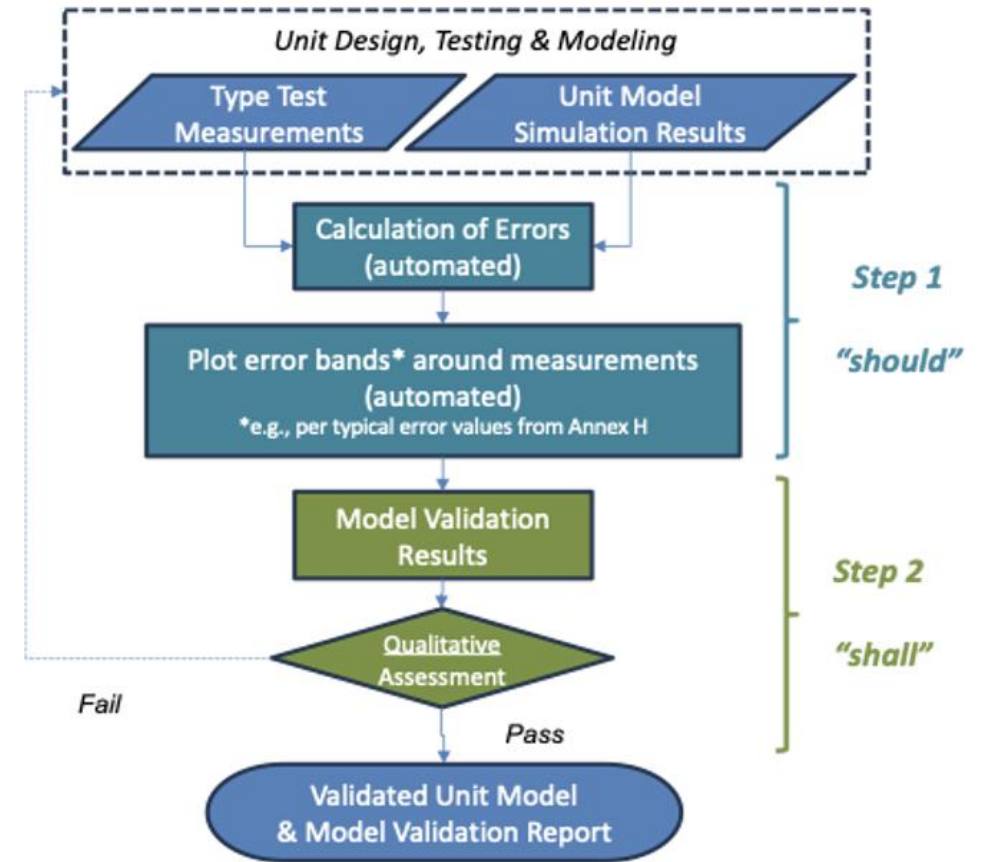


- **Quantitative vs Qualitative** (single most contentious issue in the design evaluation subgroup)
- **Qualitative**
 - **Pro:**
 - Experienced engineers have more freedom to assess model performance and ask nuanced questions
 - If done well, can effectively identify important errors
 - **Con:**
 - There aren't enough experienced engineers to do this work
 - Hard to automate, can lead to fatigue
 - Doesn't help standardize model accuracy, can lead to variance in "acceptable" performance

IBR Unit Model Validation Recommendations



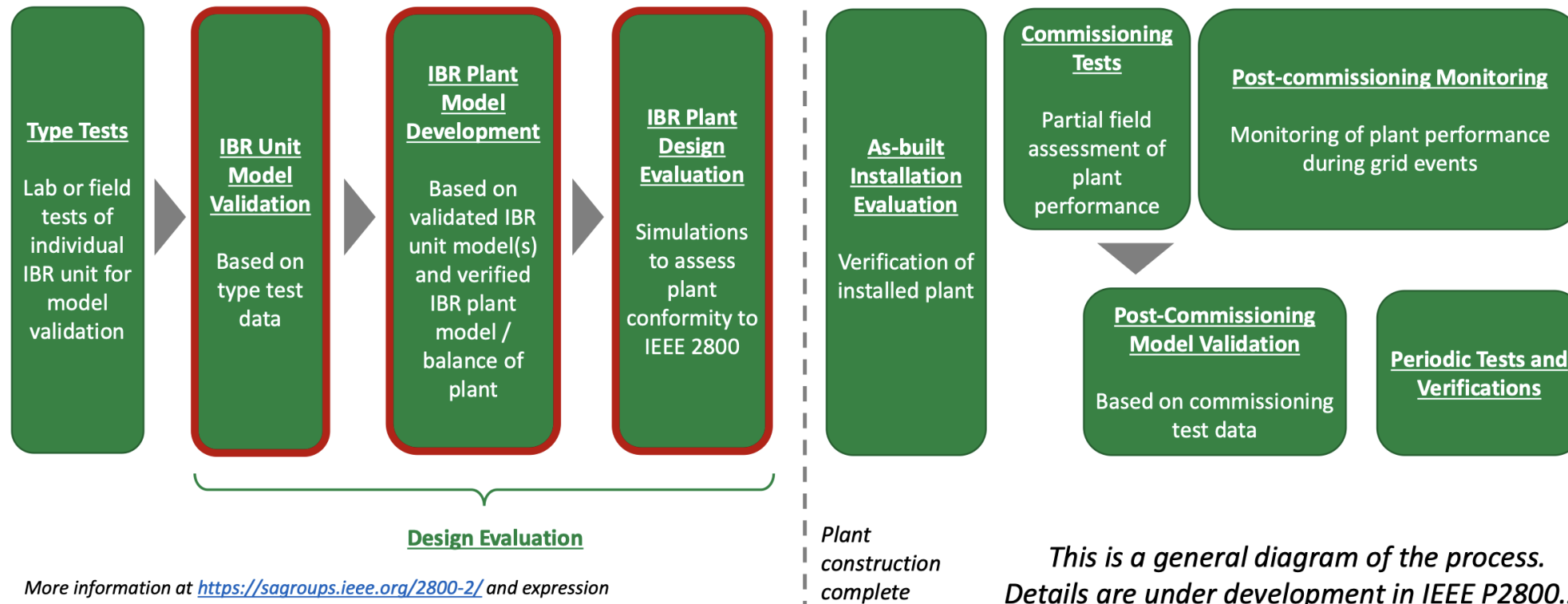
- **Push this work to the manufacturer**
 - Create a validation report that:
 - Uses both quantitative and qualitative methods
 - Engineering review for any differences outside of determined bands
 - And other oddities
- **Lowers burden on other industry stakeholders**
 - Other stakeholders would review the validation report
 - Validation reports are done only by the equipment-level experts



Source: IEEE ©2024

IBR Plant Design Evaluation

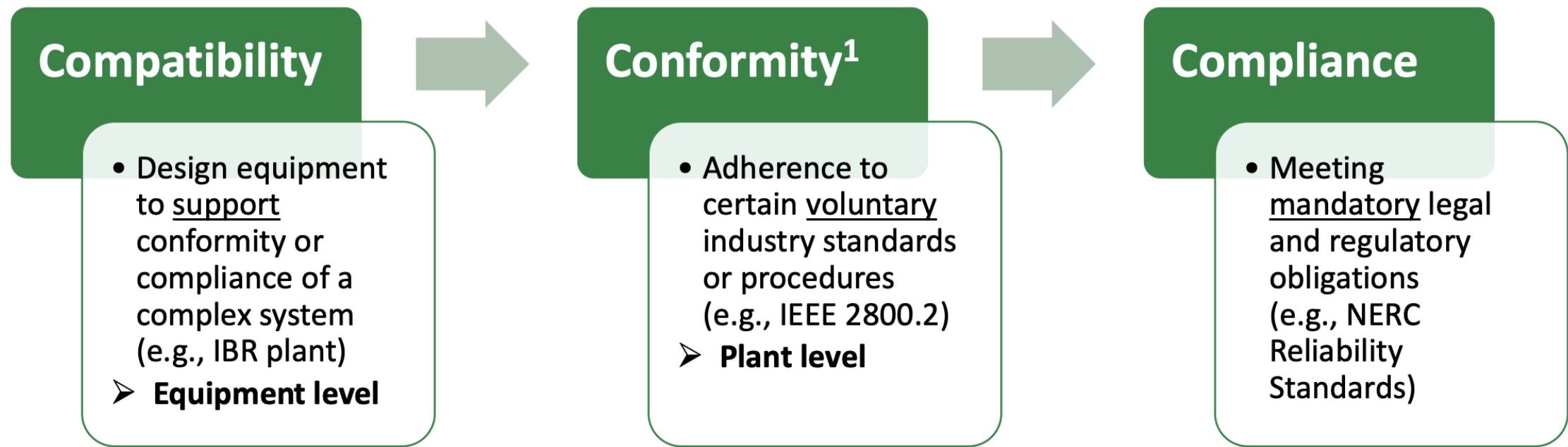
Overview of conformity assessment steps in IEEE P2800.2, Recommended Practice for Test and Verification Procedures for IBRs Interconnecting with Bulk Power Systems



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This is a general diagram of the process. Details are under development in IEEE P2800.2. Some variations permitted.

Another Terminology Break



¹ The term “conformance” is depreciated and should not be used any longer.

Conformity does ensure grid stability!

Design Evaluation: Scope and Procedures



Requirement	RPA where requirement applies	Design evaluation	Procedure type	IBR Plant Representation Detail and Data ^a
Clause 4 General interconnection technical specifications and performance requirements				
4.2 Reference points of applicability (RPA)	POM (default)	R	IBR plant design documentation	Disaggregated single line diagram
4.4 Measurement accuracy	POC and POM	R	OEM documentation	IBR unit(s) and supplemental IBR device(s)
4.5 Operational measurement and communication capability	POM	R	OEM documentation	IBR unit(s) and supplemental IBR device(s)
4.6 Control capability requirements	POM	R	OEM Documentation	IBR unit(s) and supplemental IBR device(s)
4.6.1 Execution of mode or parameter changes	POM	R	OEM Documentation	IBR unit(s) and supplemental IBR device(s)
4.6.2 Ramping for control parameter change	POM	R	OEM Documentation	IBR unit(s) and supplemental IBR device(s)
4.7 Prioritization of IBR responses	POM	R	IBR plant design documentation	IBR unit(s) and supplemental IBR device(s)
4.8 Isolation device	POM	R	IBR plant design documentation	Disaggregated single line diagram
4.9 Inadvertent energization of the TS	POM and POC	R	Protocol Documentation between GO and TO	[TBD]
4.10 Enter service	POM	R	Protocol Documentation between GO and TO	IBR unit(s) and supplemental IBR device(s)
4.11 Interconnection integrity	POM	R	OEM documentation	IBR unit(s) and supplemental IBR device(s)
4.12 Integration with TS grounding	POM	R	IBR plant design documentation	Aggregated single line diagram

^[1] Refer to footnote 38 for examples of OEM documentation and to footnote 39 for examples of IBR plant design documentation.

^[2] In this version of the document, representing the IBR plant with a non-aggregated model may be limited to steady-state power flow and short-circuit, and [fundamental-frequency stability dynamic modeling] domains. The development and use of a non-aggregated IBR plant model in electromagnetic transient (EMT) modeling domain may be computational burdensome and time-consuming with limited benefits—a good compromise may be to use a partially aggregated EMT model in special cases and where justified. For more information about differentiating between applicability of simulation domains and inverter mathematical models in these domains refer to [B23].

Design Evaluation: Scope and Procedures



Requirement	RPA where requirement applies	Design evaluation	Procedure type	IBR Plant Representation Detail and Data ^a
<i>Clause 5 Reactive power—voltage control requirements within the continuous operation region</i>				
5.1 Reactive power capability	POM	R	IBR plant design documentation, OEM documentation and steady-state power flow or [positive-sequence] modeling	Aggregated model or Disaggregated model subject to [7.2.4.1]
5.2 Voltage and reactive power control modes	POM	R for capability	OEM documentation	IBR unit(s) and supplemental IBR device(s)
		R for performance of 5.2.2	Positive-sequence modeling or EMT modeling	Aggregated model
<i>Clause 6 Active-power—frequency response requirements</i>				
6.1 Primary frequency response (PFR)	POC and POM	R	Positive-sequence and EMT modeling	Aggregated model
6.2 Fast frequency response (FFR) ¹	POC and POM	R	Positive-sequence and EMT modeling	Aggregated model

Design Evaluation: Scope and Procedures



Requirement	RPA where requirement applies	Design evaluation	Procedure type	IBR Plant Representation Detail and Data ^a
Clause 7 Response to TS abnormal conditions				
7.2.2 Voltage disturbance ride-through requirements	POC	R	OEM documentation on capability	IBR unit(s) and supplemental IBR device(s)
			EMT Modeling	
	POM	R	Positive-sequence and EMT modeling	Aggregated model
7.2.3 Transient overvoltage ride-through requirements	POM	R	IBR plant design documentation and OEM documentation	As appropriate
7.3.2 Frequency disturbance ride-through requirements	POM	R	Positive-sequence and EMT modeling	[Aggregated model]
7.4 Return to service after IBR plant trip	POM		Refer to line entries for 4.10	
Clause 8 Power quality				
8.1.2 Rapid voltage changes (RVC)	POM	R	[TBD]	[TBD]
8.1.3 Flicker	POM	NR	[TBD]	[TBD]
8.2.1 Harmonic current distortion	POM	R	[TBD]	[TBD]
8.2.2 Harmonic voltage distortion	POM	D	[EMT modeling or Frequency Domain]	[TBD]
8.3.1 Limitation of cumulative instantaneous overvoltage	POM	R	[TBD]	[TBD]
8.3.2 Limitation of overvoltage over one fundamental frequency period	POM	R	[TBD]	[TBD]

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Design Evaluation: Scope and Procedures



Requirement	RPA where requirement applies	Design evaluation	Procedure type	IBR Plant Representation Detail and Data ^a
<i>Clause 9 Protection</i>				
9.1 Frequency protection	POC and POM	R	Applicable <i>IBR plant</i> design documentation on [...], Applicable OEM documentation on [...], and validated <i>IBR unit</i> and <i>supplemental IBR device</i> models	<i>IBR unit(s)</i> and <i>supplemental IBR device(s)</i> , <i>collector system</i> , <i>main IBR transformer</i> , any other <i>IBR plant</i> equipment
9.2 Rate of change of frequency (ROCOF) protection	POC and POM	R		
9.3 Voltage protection	POC and POM	R		
9.4 AC overcurrent protection	POC and POM	R		
9.5 Unintentional islanding protection	POC and POM	D		<i>IBR unit(s)</i> and <i>supplemental IBR device(s)</i>
9.6 Interconnection system protection	POM	R		<i>main IBR transformer</i> , <i>intertie line</i>
<i>Clause 10 Modeling Data</i>				
10 Modeling data	POC and POM	R	OEM documentation	<i>IBR unit(s)</i> and <i>supplemental IBR device(s)</i> , <i>collector system</i> , <i>main IBR transformer</i> , any other <i>IBR plant</i> equipment

Verified Plant Models: EMT Reality



Simulation Domain / Model Detail	Non-aggregated model	Aggregated model		Notes ^a
		Partially aggregated model	Fully aggregated model	
steady-state power flow model	Yes ^a	n/a	Yes	In cases where aggregation provides limited benefit (for example battery systems with no substantial collector grid, or for very small plants), aggregated models may be used.
steady-state short-circuit model	Yes	n/a	Yes	
Fundamental-frequency phasor-domain (PDT) model (user-defined model and/or generic model)	[Maybe ^a]	Maybe ^a (maximize non-aggregation based on model limitations)	Yes	A non-aggregated stability model may inform proper coordination between IBR Unit protection, voltage protection, and voltage ride-through capability specified at the point of measure.. In cases where aggregation provides limited benefit (for example battery systems with no substantial collector grid, or for very small plants), aggregated models may be used.
electromagnetic transient (EMT) models	No ^a	Maybe ^a	Yes	Computing a non-aggregated EMT model may be overly burdensome and not add sufficient value in most cases.

^a Refer to subclause 7.2.4.1 for guidance on potential benefits and costs of aggregated and disaggregated IBR plant models.

Source:
IEEE

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Putting It All Together

