# IEEE P2800.2 Subgroup 3
# **Design evaluations**

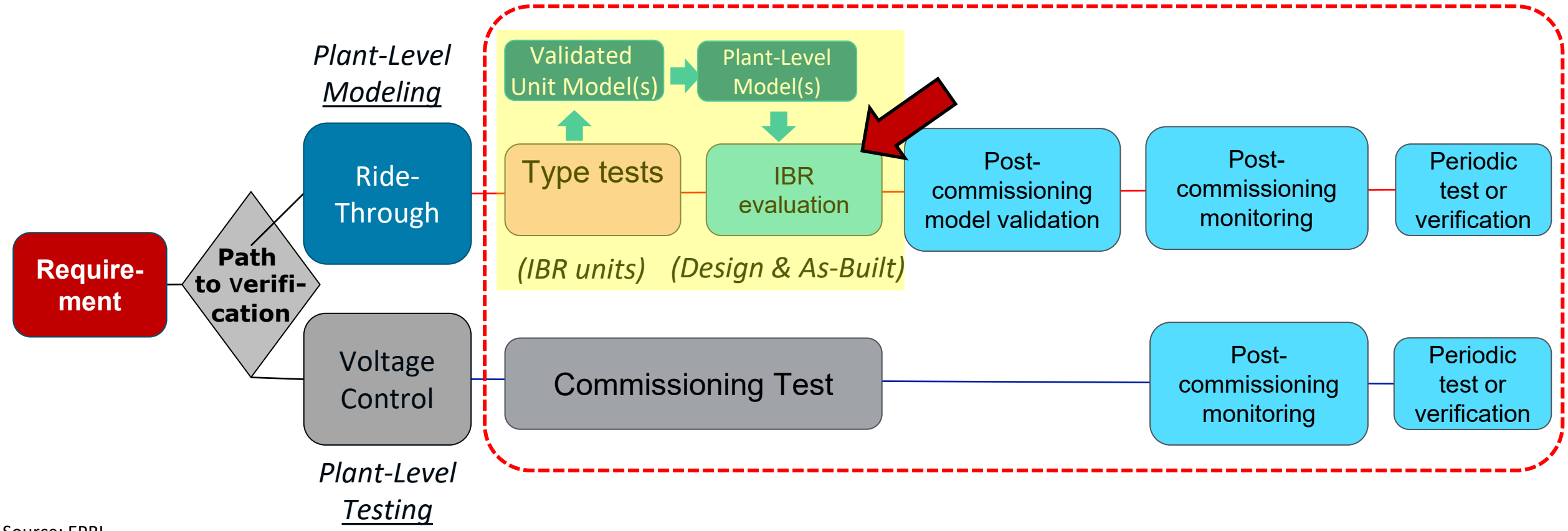

**Vice Chair: Jens Boemer**

**Subgroup Chairs: Andrew Isaacs, Alex Shattuck**


IEEE P2800.2 Working Group Meeting
February 17, 2022

# 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

# Related IEEE Standard Association activities?

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

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

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

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

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

# Related NERC and IEC activities?

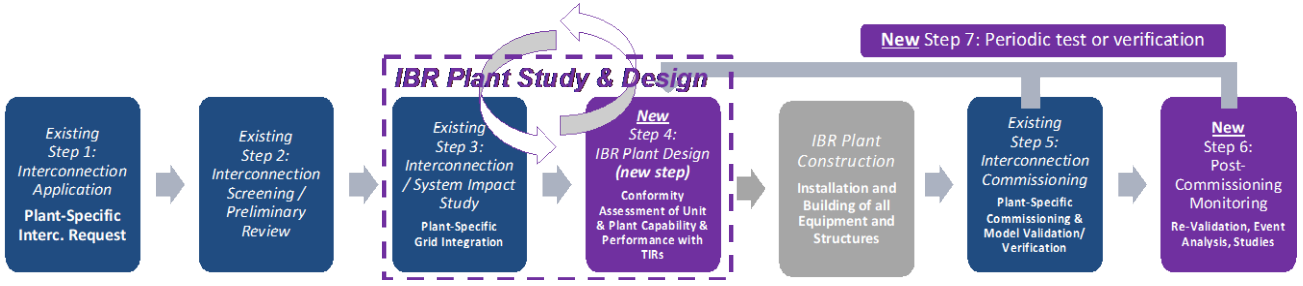
**NERC IRPWG SubGroup Work Item #8:**
**Improvement of Interconnection Studies and Process**

Scope:

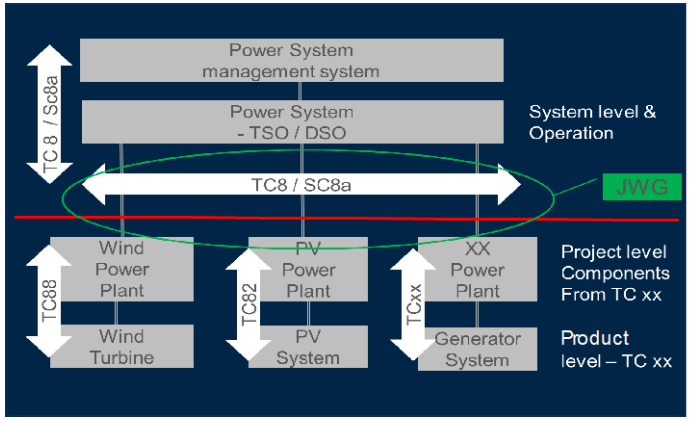
- Address challenges associated with the interconnection study process
- Use of models in feasibility study, system impact study, and facilities study
- Recommend adequate test and verification of IBR plant-level capability & performance

Logistics:

- bi-weekly meetings Thursdays in uneven weeks, 1:00p-2:00p ET / 10:00a-11:00a PT, irpwg_intstudy@nerc.com
- P2800.2 Liaisons: Alex Shattuck (axsha@vestas.com) and Jens Boemer (jboemer@epri.com)

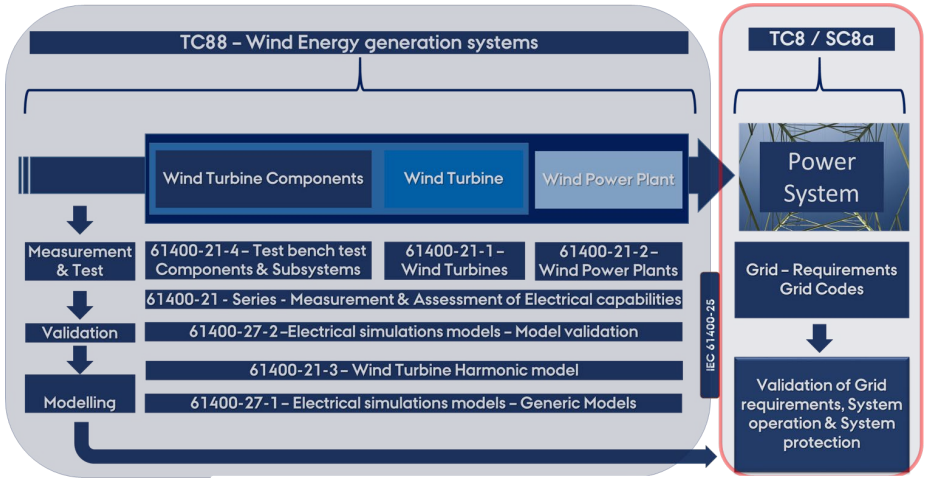



**IEC TS 63102:2021 Grid Code Compliance Assessment Methods For Grid Connection Of Wind And PV Power Plants**




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

# Possible Interconnection Procedures Improvements

**New** Step 7: Periodic test or verification

**IBR Plant Study & Design**

## Existing Step 1: Interconnection Application
**Plant-Specific Interc. Request**

- Submit **appropriate models*** configured to match standards and/or TO's minimum performance
- Specify **model 'acceptance criteria'**

* Such models should be as adequate as possible based on the information available at the time

## Existing Step 2: Interconnection Screening / Preliminary Review

Possible **screening criteria** may include:

- Steady state deliverability
- Grid strength metrics (both conventional and advanced)
- Dynamic assessment with appropriate model configured to represent common or technical minimum performance

➔ **Outcomes:**

- Either **Permission to proceed** into IBR Plant Study & Design
- Or **Request for re-submission of more detailed appropriate models**, as needed, if found necessary under the screening

## Existing Step 3: Interconnection / System Impact Study
**Plant-Specific Grid Integration**

- Study system impact **using latest available, adequate, site-specific** equipment models and parameters
- As Step 3 and Step 4 progress, update the models for IBR units, supplemental IBR devices, and the IBR plant as design choices are made
- Changes in the design could trigger either
  - a "reset in the inter-connection queue position", or
  - a "restudy of the IBR plant design"?

➔ **this could inform the definition of "material modification" per FERC LGIP/LGIA :**

## **New** Step 4: IBR Plant Design **(new step)**
**Conformity Assessment of Unit & Plant Capability & Performance with TIRs**

- Assess IBR plant-level conformity with RTO/ISO/TP's TIRs **using adequate, site-specific** equipment models and parameters
- **Design freeze** for Interconnection Agreement (IA)
  - Any changes to the IBR or supplemental units require repeat of Steps 3 and 4

➔ **Outcomes:**

- Either **Permission to proceed** into IBR plant construction
- Or **Request for re-design** to mitigate system impact and/or meet conformity
- Preliminary MOD 026/027 IBR plant small- and large-signal disturbance model verification

## IBR Plant Construction
**Installation and Building of all Equipment and Structures**

- Once the IBR plant is built, an "as-built" plant-level evaluation (see IEEE P2800 & 1547-2018) could show that what is installed matches what was studied/ designed.
  - Any changes to the IBR or supplemental units require repeat of Steps 3 and 4

## Existing Step 5: Interconnection Commissioning
**Plant-Specific Commissioning & Model Validation/ Verification**

- Perform a (limited) set of field tests to validate/verify IBR plant model.
  - Likely limited to small-signal disturbances.

➔ **Final MOD 026/027 IBR plant small-signal disturbance model verification**

## **New** Step 6: Post-Commissioning Monitoring
**Re-Validation, Event Analysis, Studies**

- Collect field data to validate/verify IBR plant model.
  - Especially for large-signal disturbances.

➔ **Continuous MOD 026/027 IBR plant large-signal disturbance model verification**

**Guiding Principle**

Open and timely communication

Legend

| | |
|---|---|
| Blue | existing process |
| Purple | proposed modifications |
| TIRs | technical interconnection requirements |

Source: EPRI/NERC

# 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)

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

# 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
  - (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: Logistics

- Plan
  - Biweekly meetings, 1.5-2 hours
  - TBD – Thursdays in uneven weeks, 1:00p-2:00p ET / 10:00a-11:00a PT?
    - Combine/merge with NERC IRPWG SubGroup #8 (at some point in future)?
    - Alternating Thursdays may conflict with IRPWG monthly meetings and NERC SAR adjustment meetings
  - Starting sometime in March 2022?

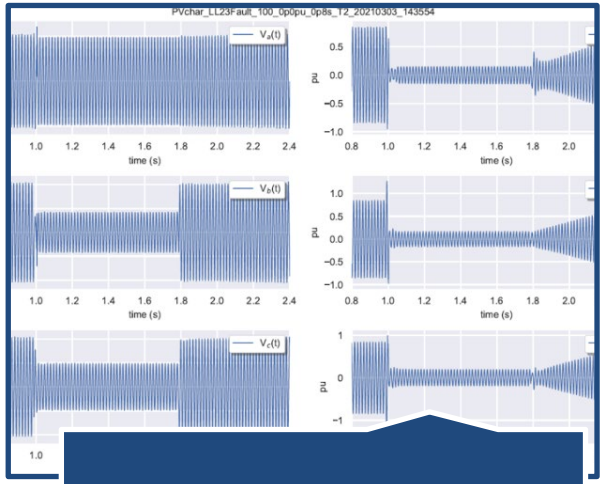
- Leads
  - Jens Boemer (jboemer@epri.com)
  - Andrew Isaacs (ai@electranix.com)
  - Alex Shattuck (axsha@vestas.com)

- How to get involved
  - Join listserv (see slide x)

# EXAMPLE USE OF MODELING FOR PLANT PERFORMANCE ASSESSMENT

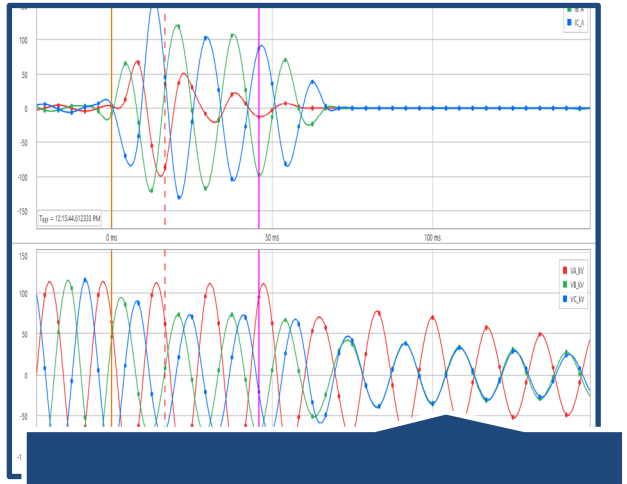
# Simulation Examples Based on EPRI's Inverter-Based Resource Characterization and Modeling Research

## Resource characterization



Laboratory testing

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

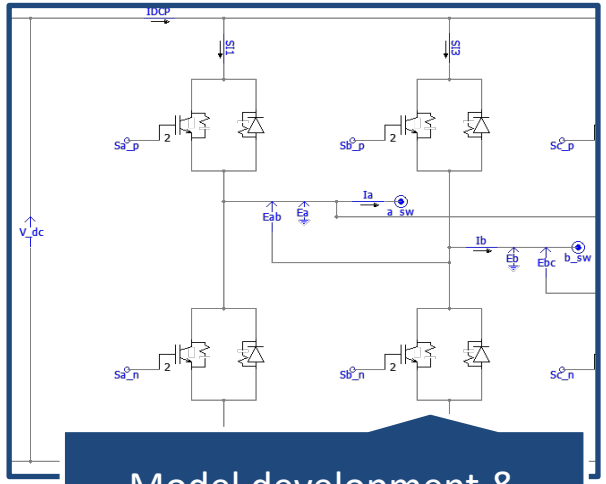


Field data collection and analysis

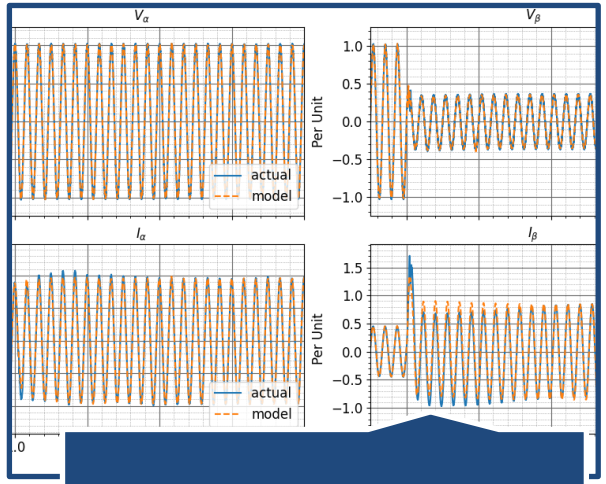
Data from system events

- 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

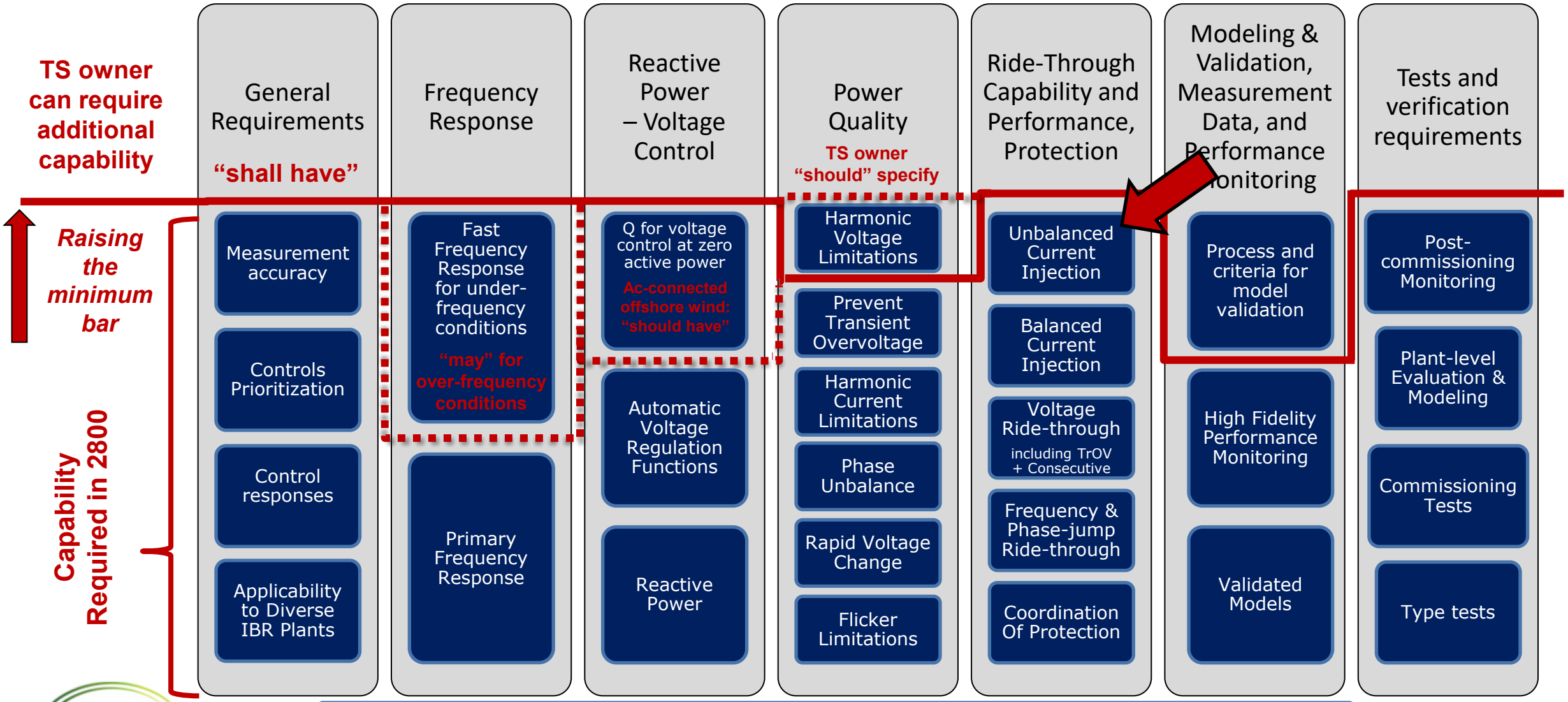
This work is, in part, supported by the U.S. Department of Energy, Solar Energy Technologies Office under Award Number DE-EE0009019 *Adaptive Protection and Validated MODels to Enable Deployment of High Penetrations of Solar PV (PV-MOD)*. https://www.epri.com/pvmod

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

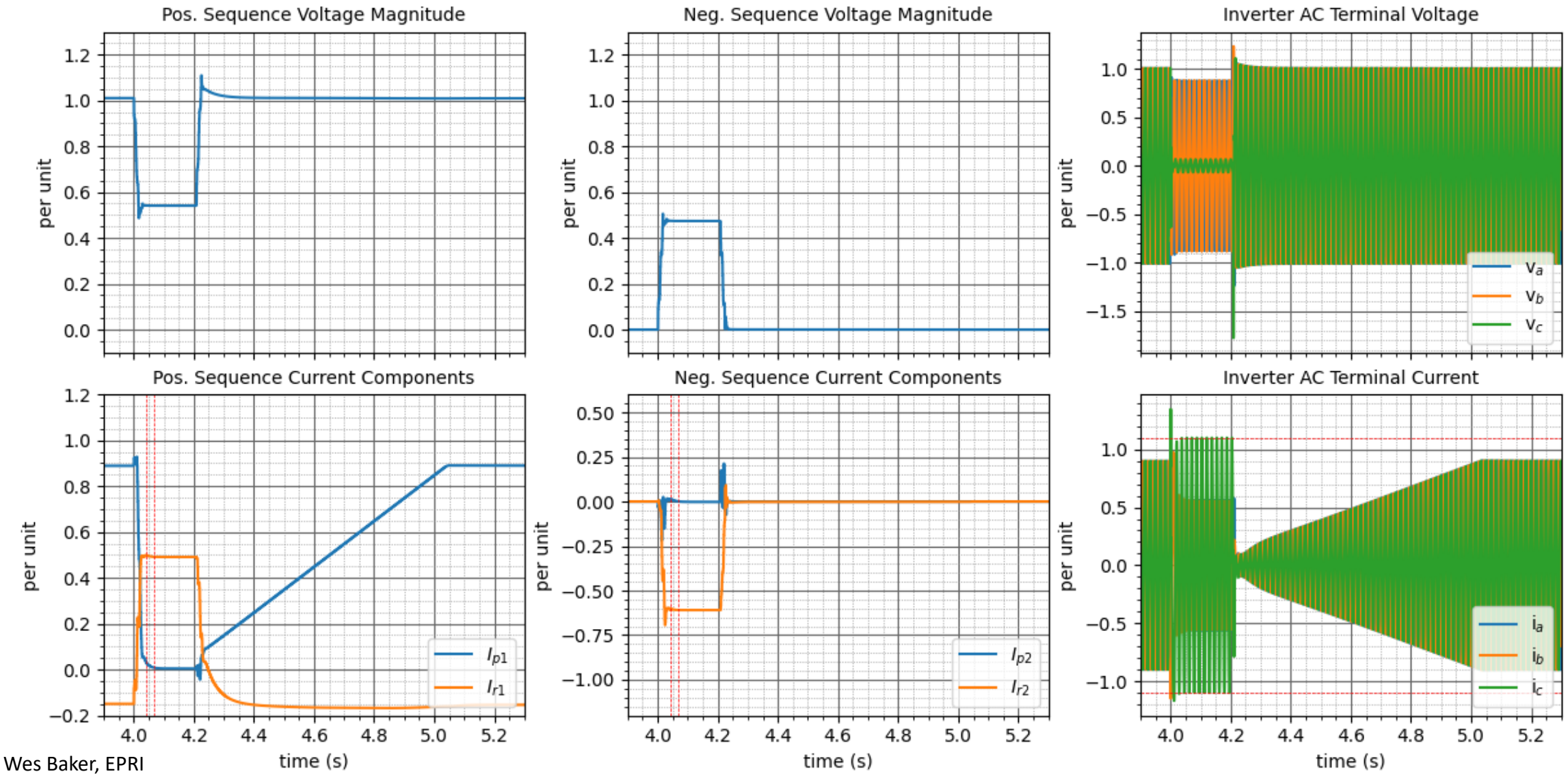



***Utilization*** of these capabilities is outside the purview of 2800

IEEE PES Power & Energy Society®

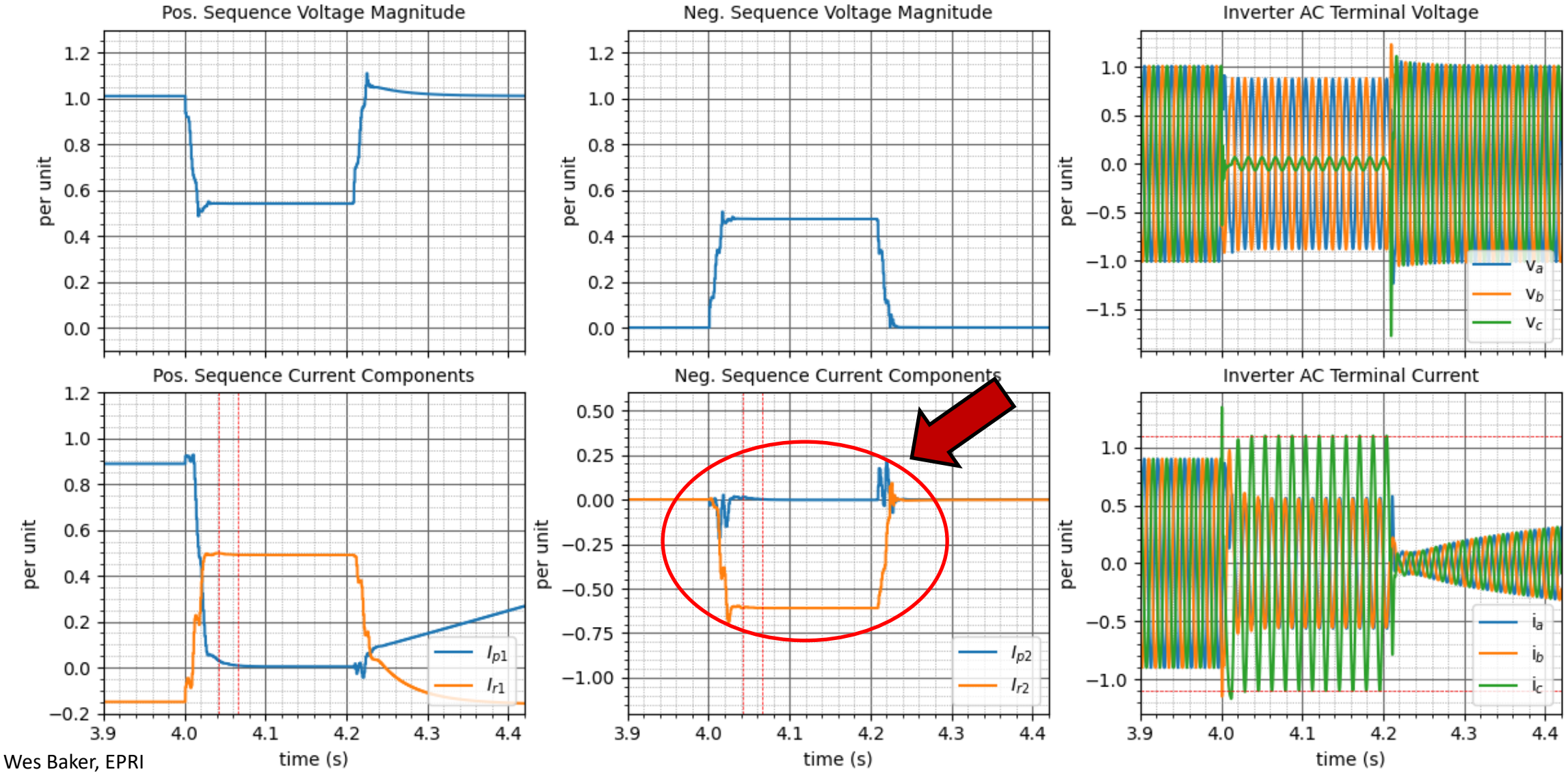
IEEE

# Example 1a: 2800 compliant



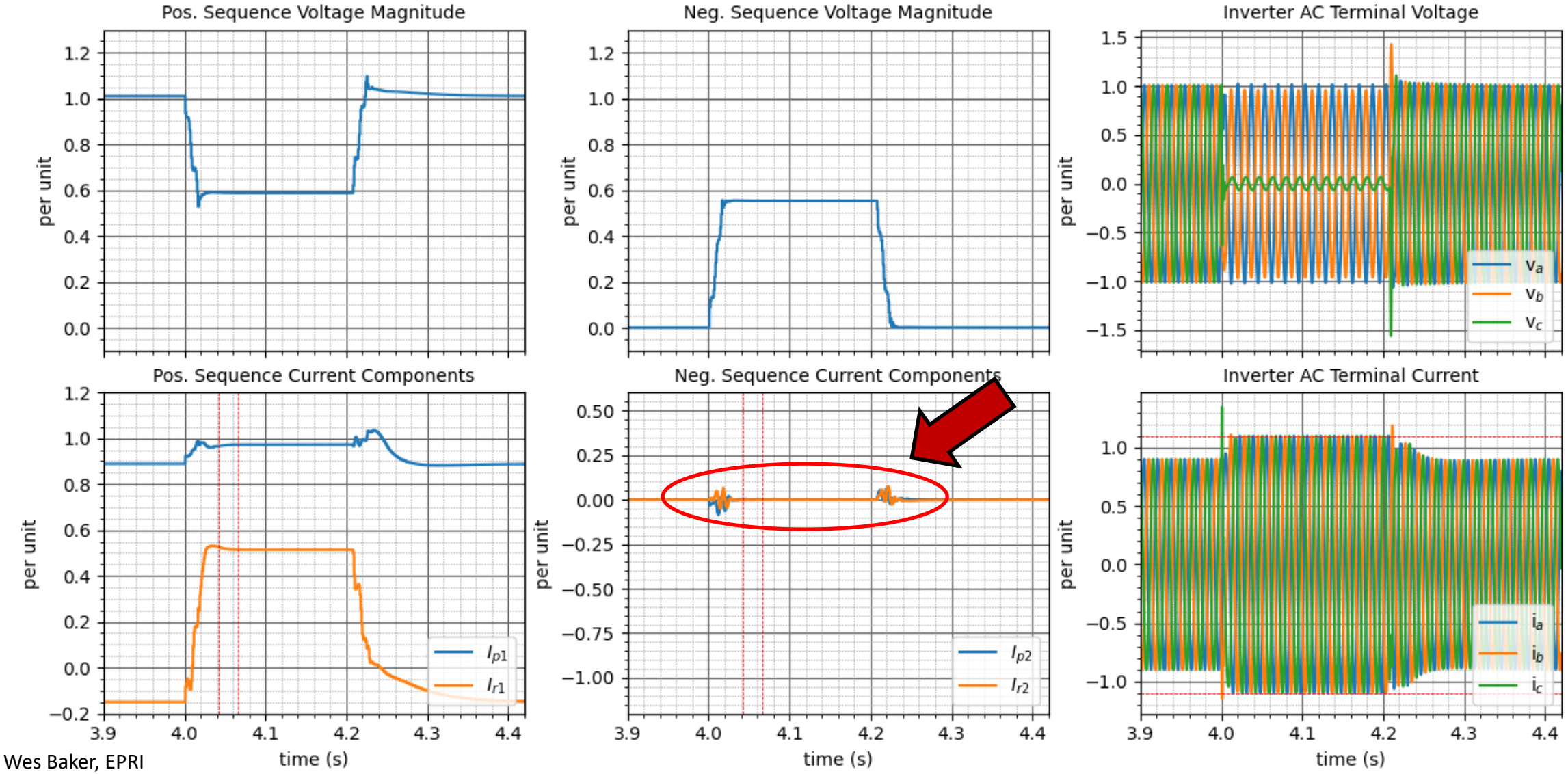

Source: Wes Baker, EPRI

# Example 1a: 2800 compliant (zoom)



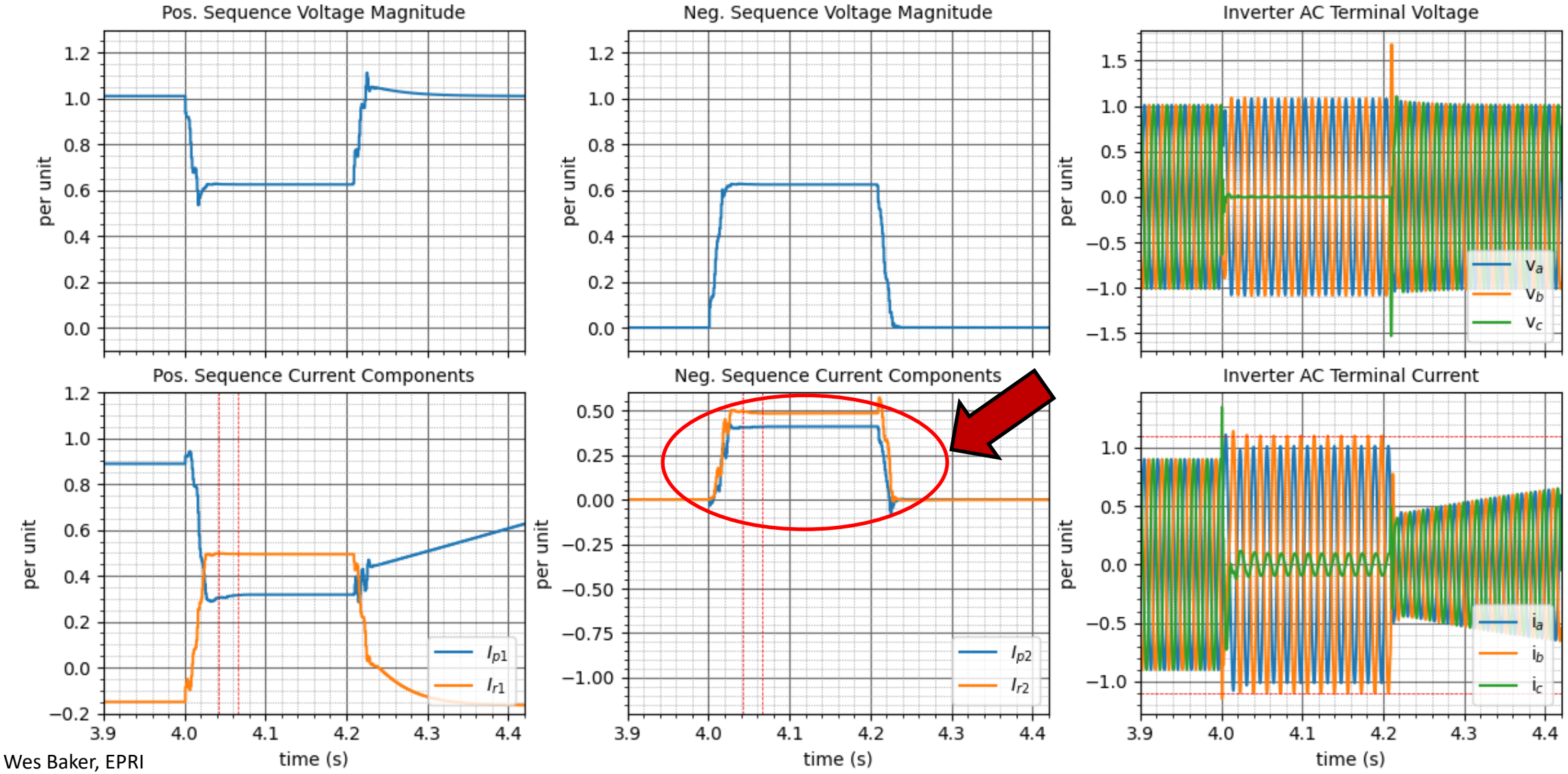

Source: Wes Baker, EPRI

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




Source: Wes Baker, EPRI

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




Source: Wes Baker, EPRI

# BACKUP

# 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***

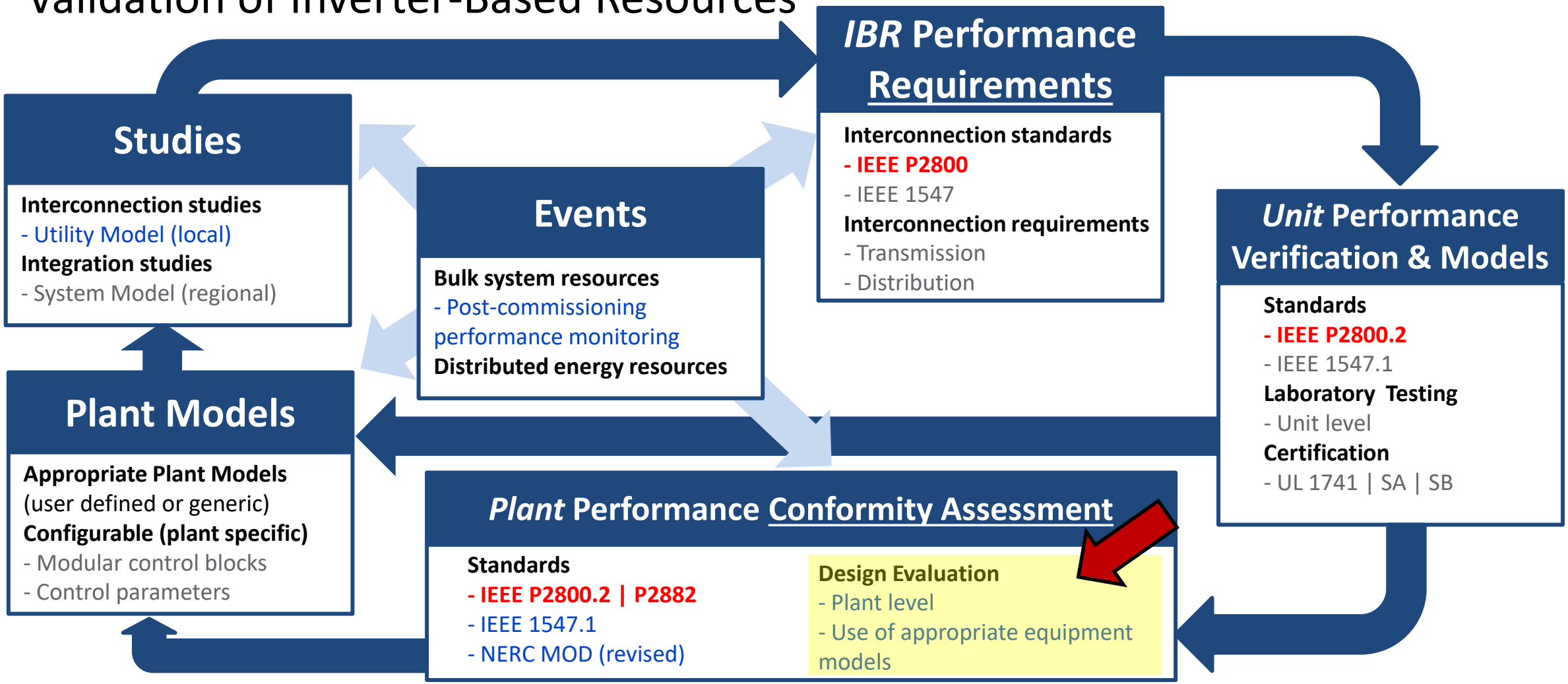
| Requirement | RPA at which requirement applies | *IBR unit*-level tests (at the POC) | *IBR plant*-level verifications (at the RPA) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Type tests* | Design evaluation (including modeling for most require-ments) | As-built installation evaluation | 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

# Continuation Plant-Level Model Development, Improvement, and Validation of Inverter-Based Resources




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

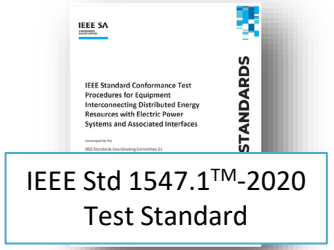
This work is, in part, supported by the North American Electric Reliability Corporation (NERC) under EPRI contract 20011165 *Inverter-Based Resources Dynamic Response Characterization for Bulk Power System Protection, Planning, and Power Quality.*

Source: EPRI

# PLANT PERFORMANCE CONFORMITY ASSESSMENT

# IEEE 1547/2800 Test and Verification Methods

1. Type Tests – *performed on representative DER / IBR unit or DER system*
2. Production Tests – *performed on every unit*
3. DER / IBR Evaluations
   a. Design Evaluation (desk study)
   b. As-built Installation Evaluation (on-site)
4. Commissioning Tests and Verifications
5. Periodic Interconnection Tests



IEEE Std 1547.1™-2020
Test Standard

New Concept for **facility-level verifications** of DER / IBR composites that are not 'certified systems'

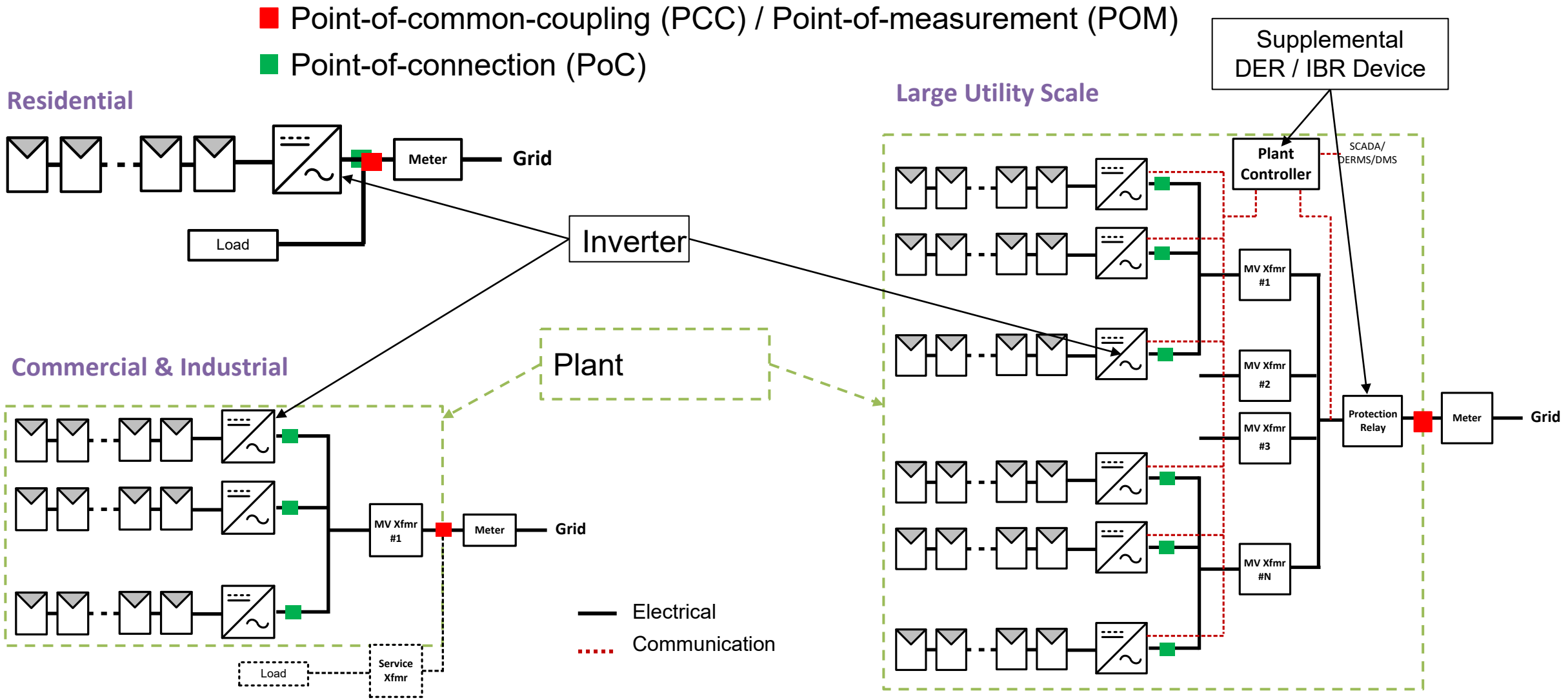
- **Not the focus of existing processes.**
- Normally incorporated in utilities technical review and approval process.
- May / Shall include modeling and simulation if detailed DER / IBR evaluation is needed.
- Include both certification compliance and impact study, e.g., load flow, short circuit, etc.

Only having a certified unit (e.g., inverter) ≠ facility on-site is IEEE 1547 / 2800 compliant

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

Source: EPRI

# Inverter vs Plant and PoC vs PCC



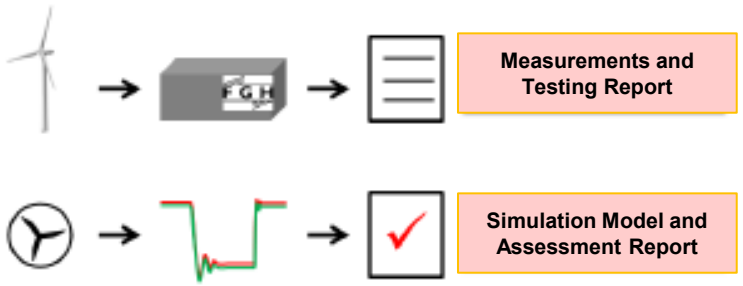

*DER Plant-Level Performance Verification and Commissioning Guideline: First Edition.* Technical Update. EPRI. Palo Alto, CA: December 2020. 3002019420

Source: EPRI

For larger-scale DER and large-scale IBR, plant controller can be critical to meet the IEEE 1547-2018 / 2800 requirements at PCC / POM.

# Differences between “Validation/Verification” and “Conformity Assessment”

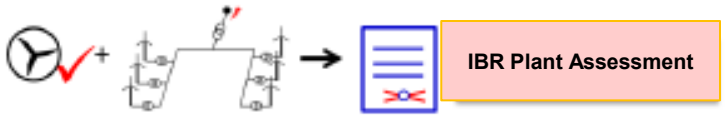
## Model Adequacy Validation/Verification




The 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*, or from field measurements for *IBR plants*
[2] obtained from an *IBR unit* model, or from an *IBR plant* model that is appropriately configured

## Conformity Assessment of Unit & Plant-level Capability and Performance with Technical Requirements




The 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]
- pre-commissioning plant-level design evaluation using 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: EPRI/NERC

# NERC MOD 026/027 Revision

**Status:** Ongoing

**Developed working definitions for “Validation” and “Verification”**

1. Standard-Only Definition:

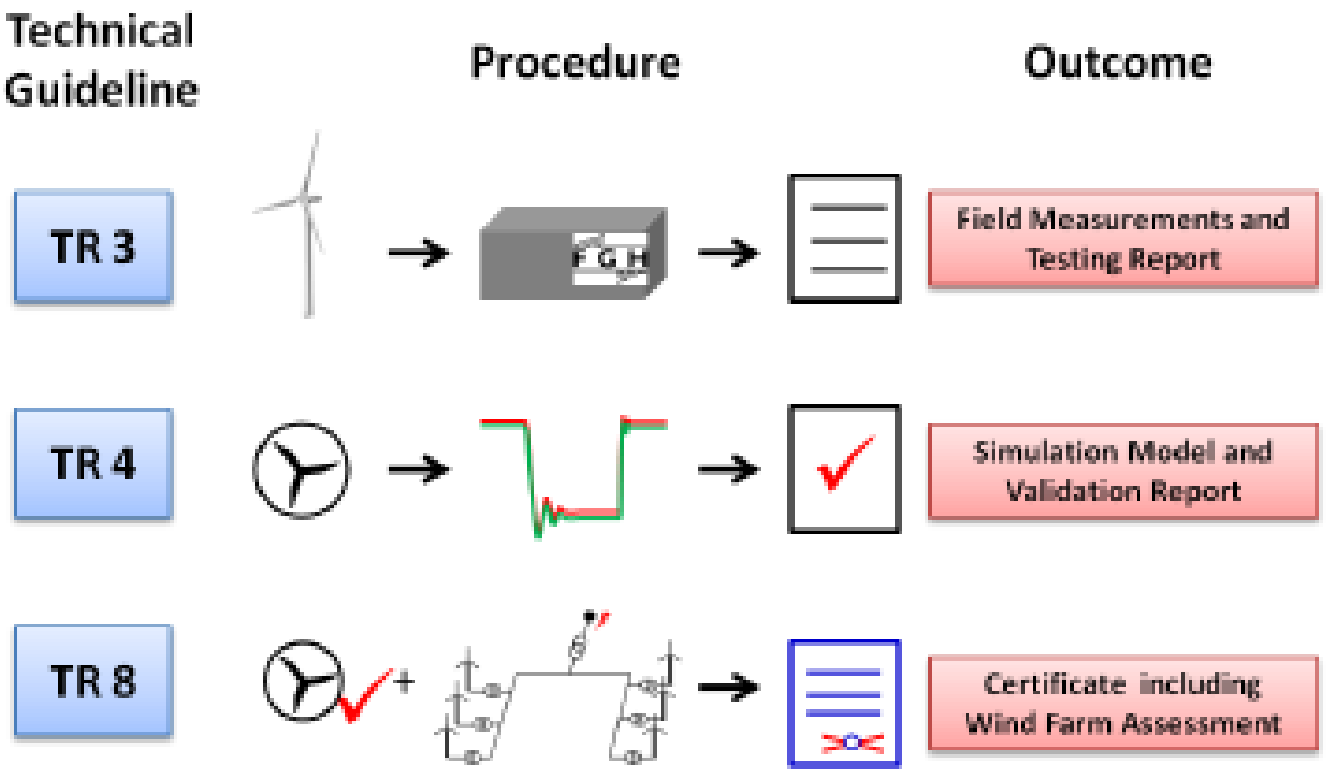
**1.1. Verification** - the static method of checking documents and files, and comparing them to a model parameters, model structure, or equipment settings.

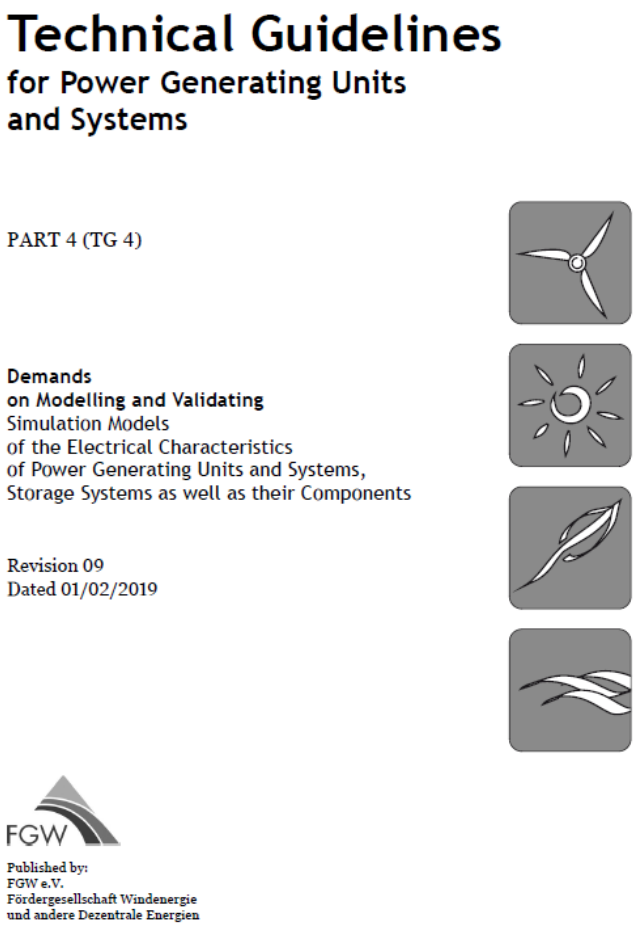
**1.2. Validation** - the dynamic process of testing or monitoring the in-service equipment behavior, and then using the testing or monitoring result and comparing them to the model simulated response.

**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

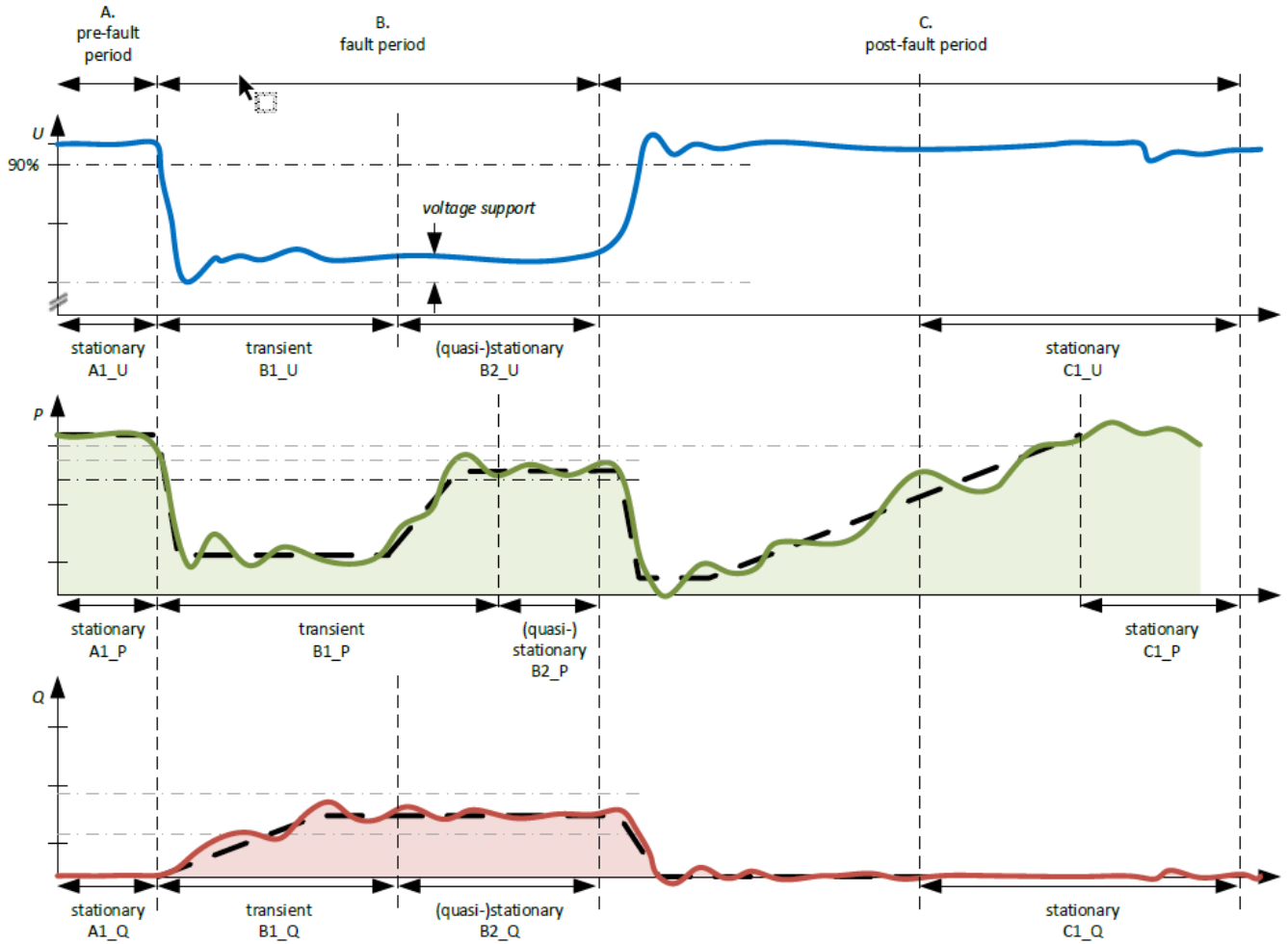
# Performance Verification Example: Germany




Source: EPRI

# Model Validation 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

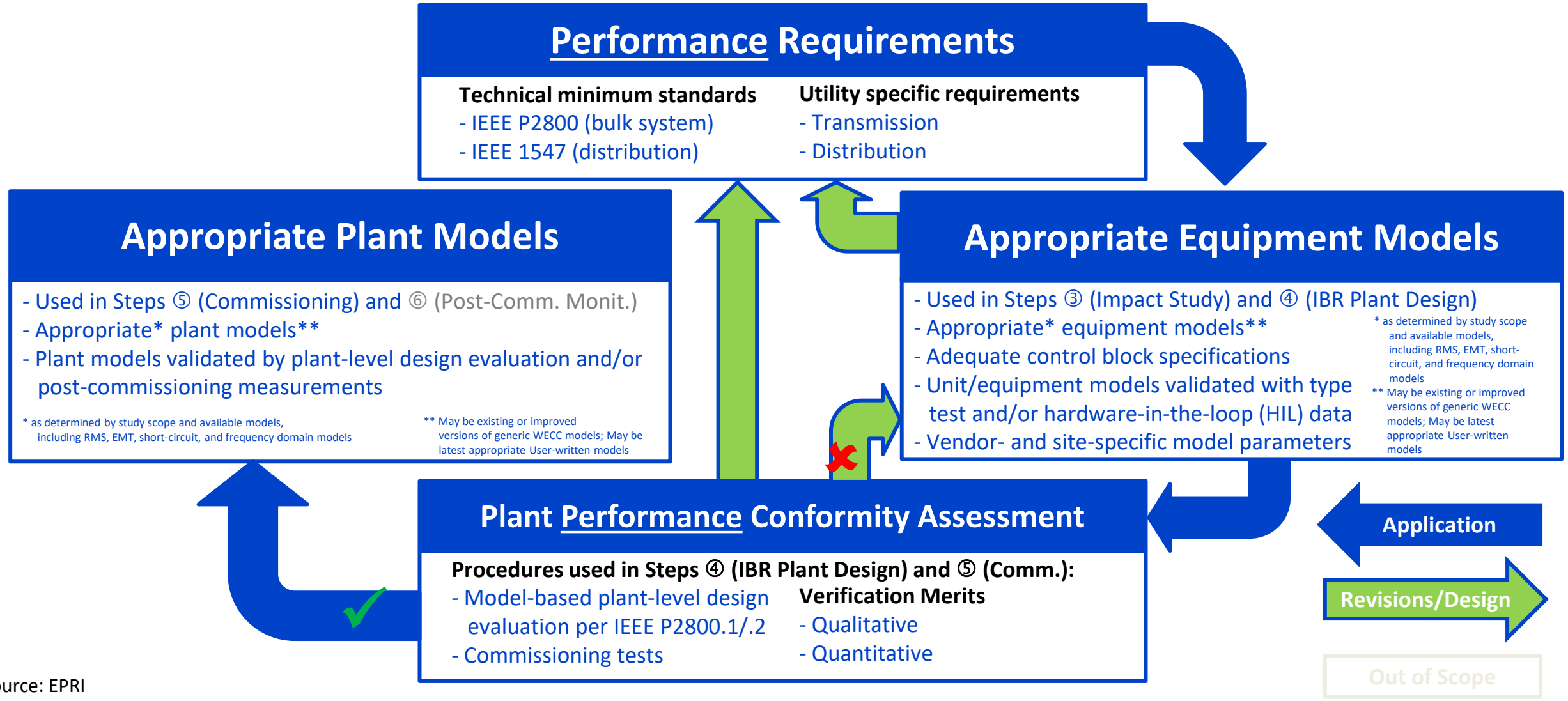
Revision 09
Dated 01/02/2019

FGW

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

Source: EPRI

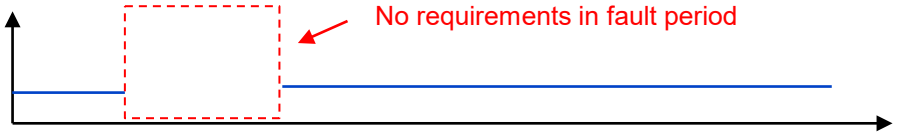
# Continuous and Iterative Improvement of IBR Performance Requirements, Plant-Level Modeling, and Model Validation




Source: EPRI

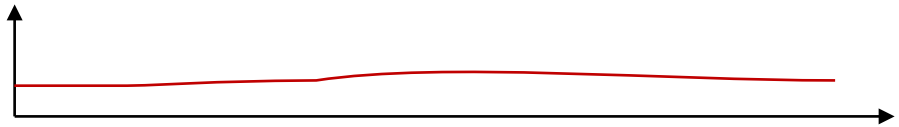
# Revision 0: Voltage Ride-Through Requirements
# Plant with VRT but no reactive current injection during fault

## Performance Requirements

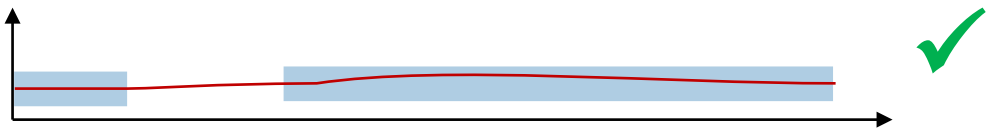



## Appropriate Plant Models

## Appropriate Equipment Models



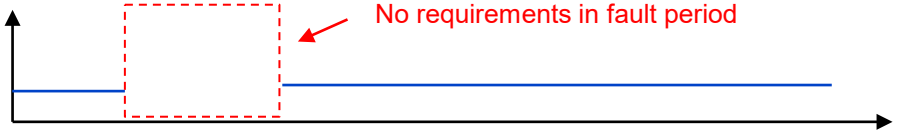
## Plant Performance Verification



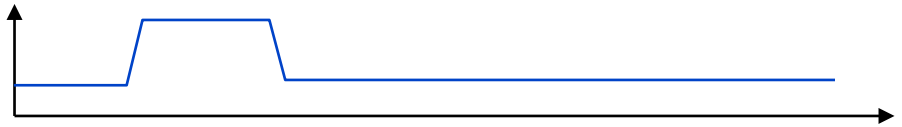
Source: EPRI

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

## Performance Requirements




## Appropriate Plant Models



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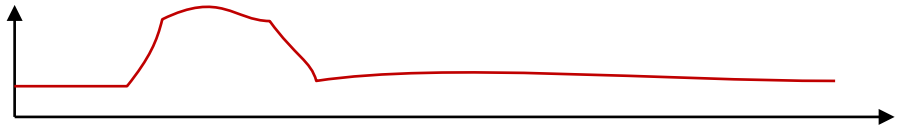
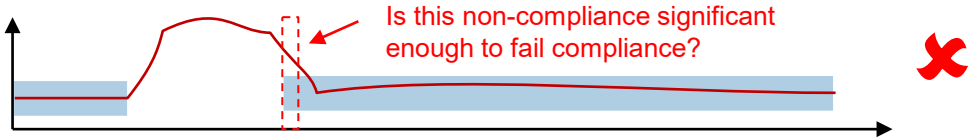


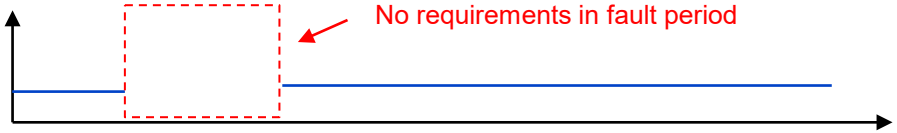
## Plant Performance Verification



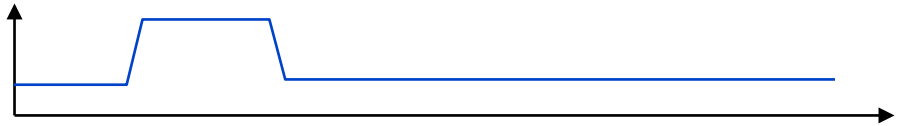

Source: EPRI

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

## Performance Requirements




## Appropriate Plant Models



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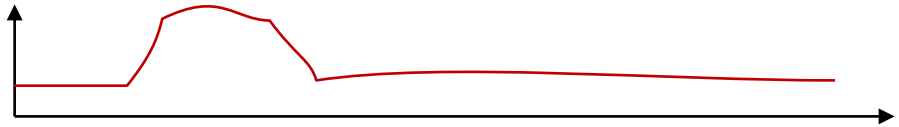
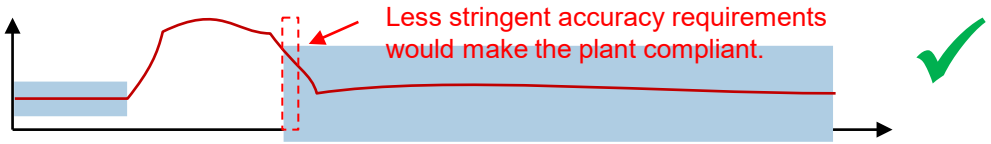


## Plant Performance Verification

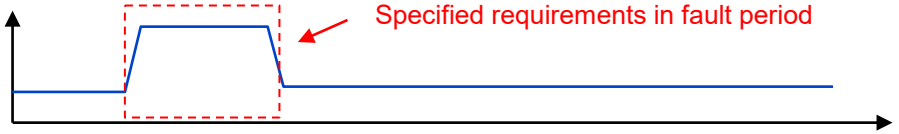



Source: EPRI

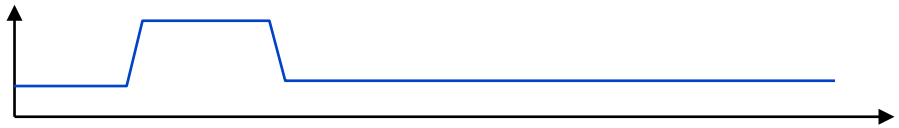
# Revision 1: Voltage Ride-Through Requirements

## Plant with VRT and reactive current injection during fault

### Performance Requirements




### Appropriate Plant Models



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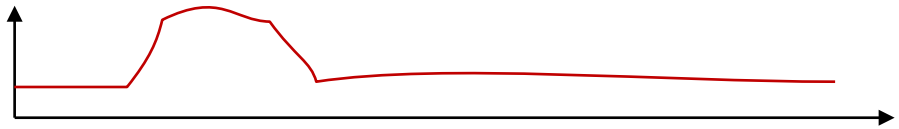
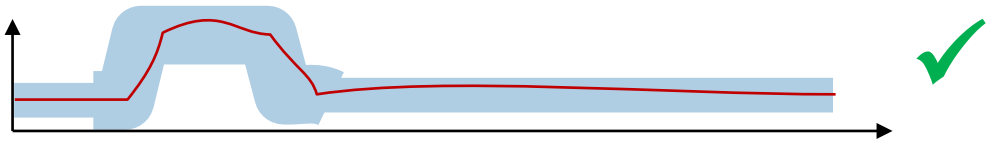


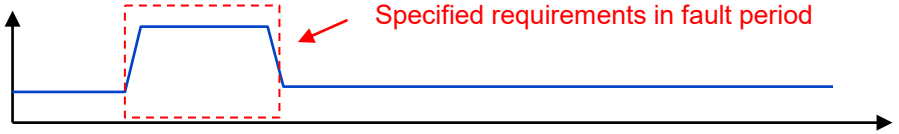
### Plant Performance Verification



Source: EPRI

# Revision 1: Voltage Ride-Through Requirements
# Plant with VRT but no reactive current injection during fault

## Performance Requirements

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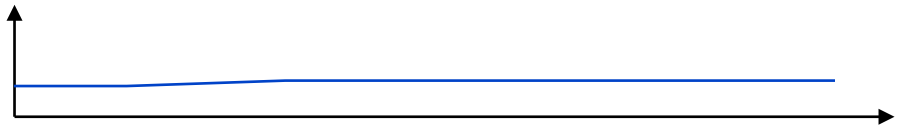

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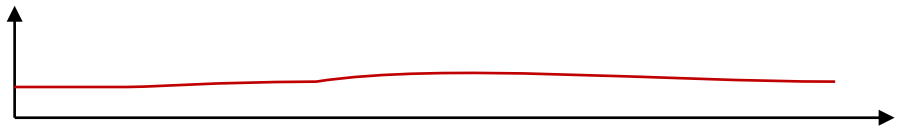
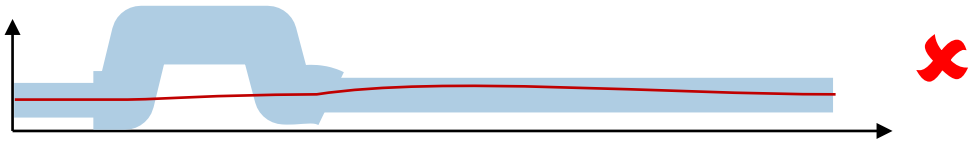


## Plant Performance Verification



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)

  } used in IEC 61400-27-1

**Example Accuracy Assessment**

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