Post-Commissioning Monitoring Aspects of IEEE 2800.2 – NASPI Webinar

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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Resources

ESIG i2X FIRST website: https://www.esig.energy/i2x-first-forum/

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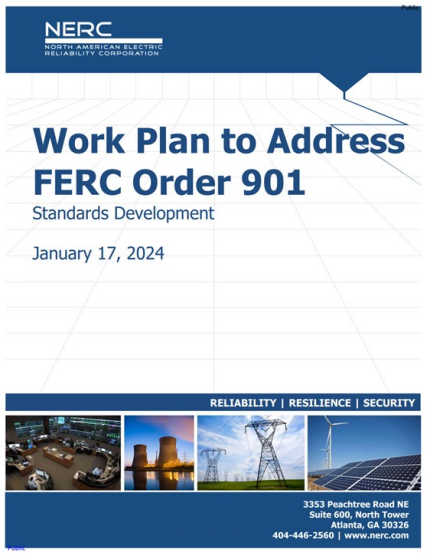
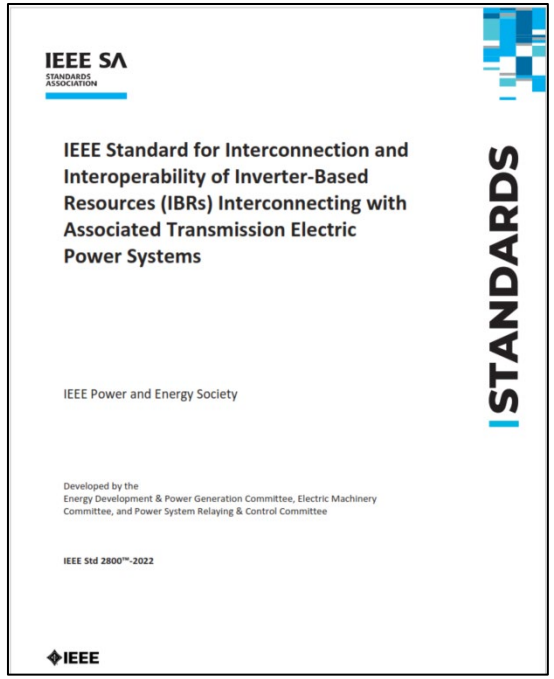


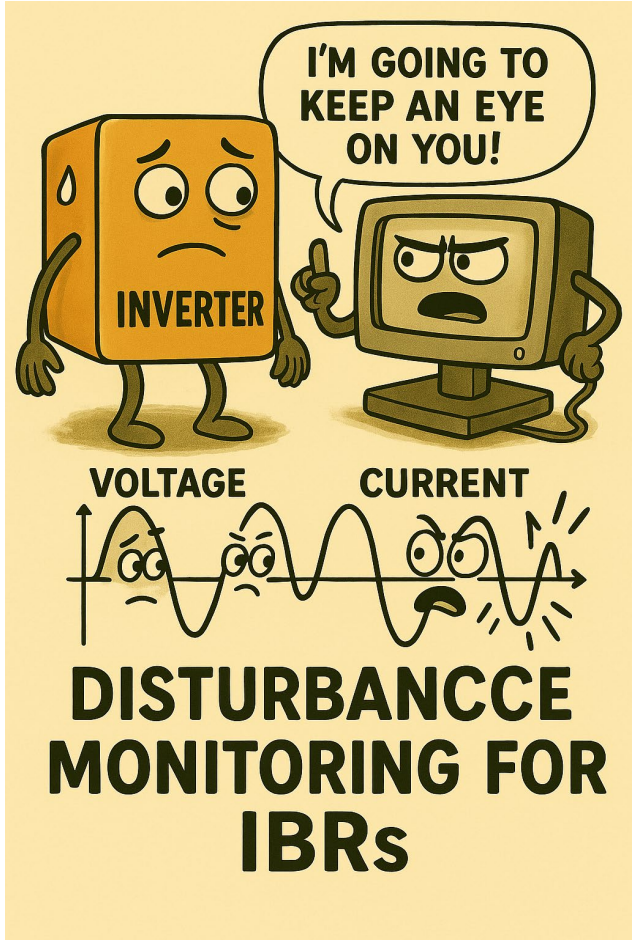
https://www.nerc.com/pa/Stand/Pages/Default.aspx



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

Outline

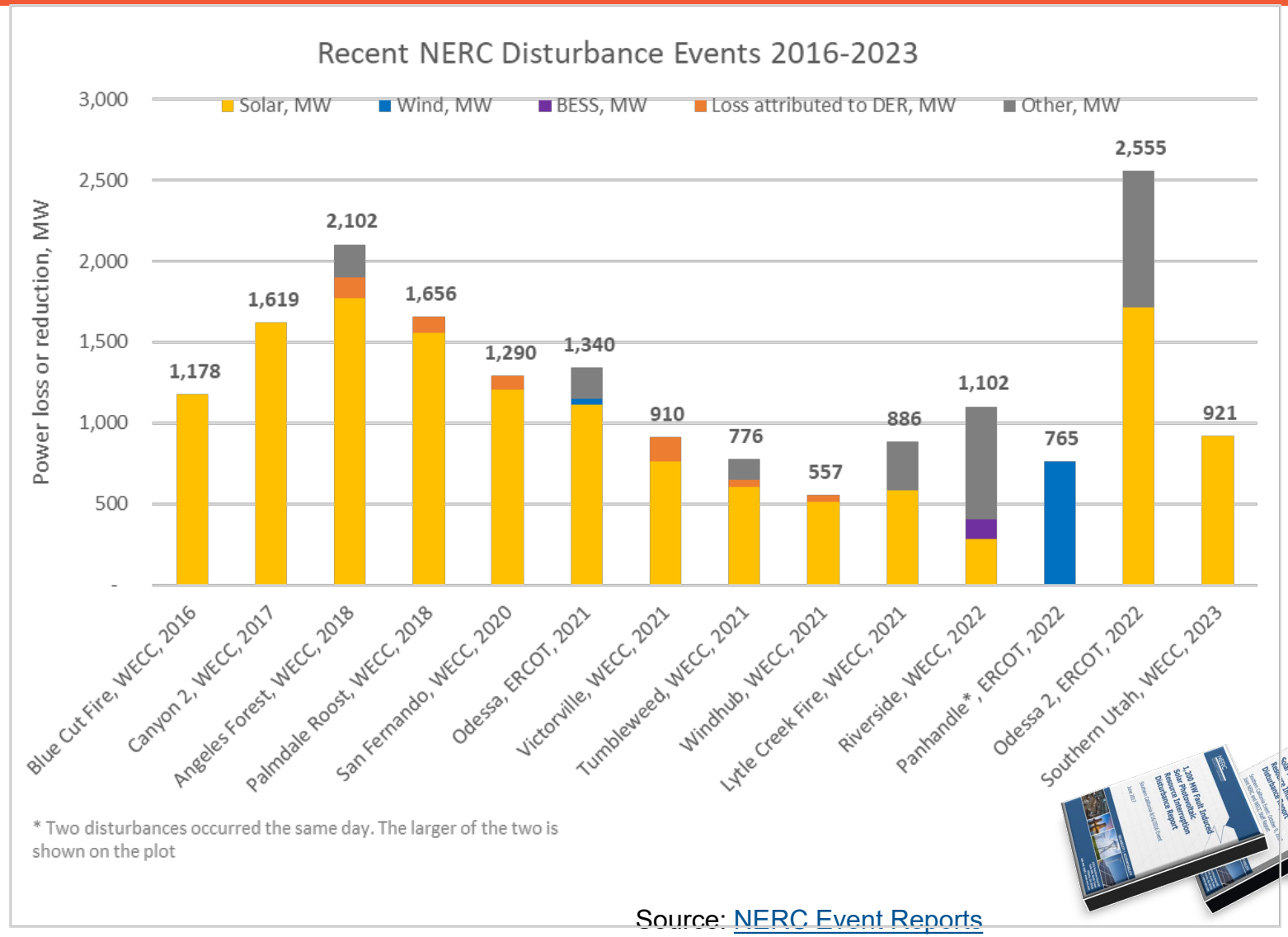
- Why is Post-Commissioning Monitoring Important
- Interconnection Process and Lack of Model Validation
- Post Commissioning Assessment – General Need
- Relevant Standards (IEEE 2800 and NERC PRC-028, PRC-030)
- IEEE 2800.2 and Post Commissioning Assessment



Quote and an illustration shamelessly stolen from Manish Patel's NERC IRPS Presentation on 06/26/2025 (he might have used AI to generate it ☺):

Disturbance monitoring: Because guessing what went wrong is only fun in murder mysteries—not in power systems.

NERC Disturbance Events – Importance of Model Accuracy

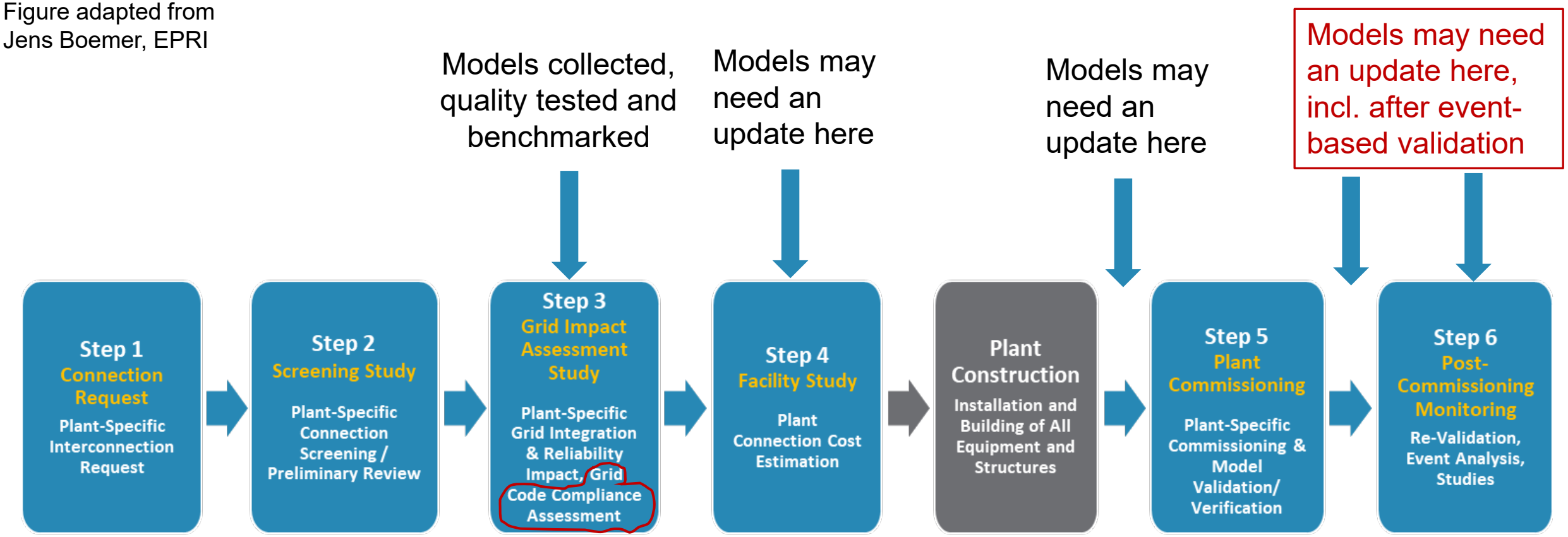


Source: NERC Event Reports

- None of the events showed up in studies & IBR Plant models
- Post-event analysis revealed:
  - Lack of event data and
  - Non-conformity of IBR plants with applicable interconnection requirements

IBR Plant Models are NOT Validated and IBR Plant Conformity MAY NOT be Assessed (and CANNOT be Fully Assessed) during Interconnection

Figure adapted from Jens Boemer, EPRI

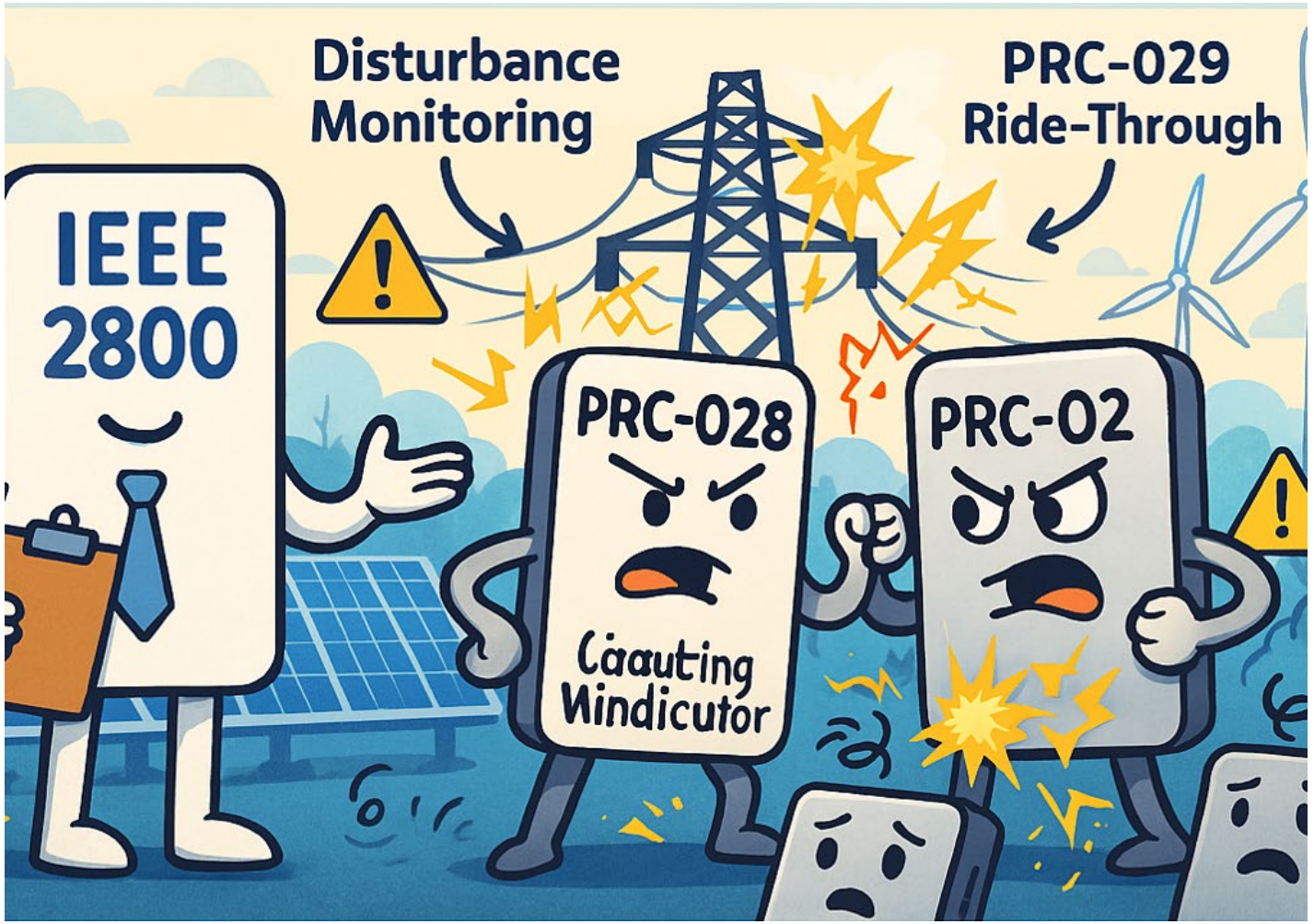


* Every time a plant model is updated, quality testing, validation/benchmarking steps are repeated, and some relevant studies may need to be repeated depending on the model change

Post-Commissioning Assessment

- It is not feasible to fully assess conformity with some requirements of IEEE 2800 through IBR unit type tests, model-based IBR plant design evaluation, and commissioning tests;
- Post commissioning monitoring may provide an opportunity to fully assess IBR plant conformity to those requirements when relevant large-signal grid events occur.
- The purpose of post-commissioning monitoring is to verify, to the extent possible, that the IBR plant continues to meet the connection requirements over its lifetime.
- Post-commissioning monitoring is also an opportunity to
  - validate the IBR plant models for conditions outside of the normal operation region and
  - capture any unintended changes in an IBR plant since commissioning.

Random Thoughts: IEEE 2800, PRC-028, PRC-029, PRC-030, and Chaos



Disclaimer: Shamelessly stolen from Manish Patel's NERC IRPS Presentation on 06/26/2025 (who might have used AI to generate it ☺)

Summary of IEEE 2800 Standard

- The standard **harmonizes** Interconnection Requirements for Large Solar, Wind and Storage Plants
- It is a **consensus-based** standard developed by over ~175 Working Group participants from utilities, system operators, transmission planners, & OEMs over 2 years
- It has successfully passed the IEEE SA ballot among 466 SA balloters **(>94% approval**, >90% response rate)
- **Published on April 22, 2022 (Earth Day)**

Clause 11: Measurement data for performance monitoring and validation (Table 19)

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

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

Source: IEEE 2800,SEIA-ACP Joint Webinar, May 2022

IEEE 2800-2022 Adoption Efforts

IEEE 2800-2022 Adoption—Detailed Inventory

Company	Phase (if applicable)	Adoption Approach (End)	Retroactive Application on Legacy IBRs	Reference Point of Applicability (RPA)	Performance and Capability?	Clause 1: Overview	Clause 2: Normative references	Clause 3: Definitions, acronyms, abbreviations	Clause 4: General requirements	Clause 5: Reactive power—voltage control	Clause 6: Active power—frequency response	Clause 7: Response to TS abnormal conditions	Clause 8: Power quality	Clause 9: Protection	Clause 10: Modeling data	Clause 11: Measurement data	Clause 12: Test and verification	Grid-forming Requirements
Ameren IL		Hybrid Reference Customization &	✕	POI	✓	○	○	○	○	◗	○	○	○	○	○	○	○	○
Ameren Transmission Company of Illinois (ATXI)	Interim Phase 1 (ahead of MISO)	Detailed Reference & Customization	✕	POI	✓	○	○	○	○	○	○	●	○	○	●	○		
	Phase 1 (aligned with MISO)	Hybrid Reference Customization &	✕	POI	✓	○	○	○	●	○	○	●	○	○	○	○		
Bonneville Power Administration (BPA)		Detailed Reference & Customization	✕	POI	✓	○	○	◗	●	●	●	●	◗	◗	●	◗		
Duke Energy		Hybrid Reference Customization &	✕	POI	✓	○	○	◗	◕	●	●	●	◕	●	●	●	◗	○
ERCOT	Phase 1	Hybrid Reference Customization &	✓	POI	✓	○	○	○	◔	●	○	●	○	●	◔	◔	◔	
	Phase 2	Hybrid Reference Customization &	✓	POI	✕	○	○	○	○	○	○	○	○	○	○	◗	○	○
HECO	Stage 3 Hawaii RFP	Hybrid Reference Customization &	✕	POI	✓	○	○	○	◔	●	◕	◗	●	●	●	●	○	
ISO-NE		Detailed Reference & Customization	✕	POM	✓	○	○	●	◕	◕	◕	◕	○	○	○	○	○	○
MISO	Phase 1	Detailed Reference & Customization	✕	POM	✓	○	○	○	◗	○	○	◕	○	○	◔	○	○	
	Phase 2	Detailed Reference & Customization	✕	POM	✓	○	○	○	◗	◕	◕	◕	○	○	◔	◕	○	
NYSRC		Detailed Reference & Customization	✕	POI	✓													
North American Electric Reliability Corporation (NERC)	Milestone 2	Full Specification & Customization	✓	POM	✓	○	○	◔	○	○	○	◕ PRC-029	○		○	◕ PRC-028	◔ PRC-030	○
Natural Resources Department of Canada	SREPs Program	General Reference	✕	POI	✓	○	○	○	○	○	◗	○	○	○	○	○	○	○
San Diego Gas & Electric Co.		Hybrid Reference Customization &	✕	POI	✓	○	○	○	○	◗	◗	◗	◔	◗	◗	◕	◔	○
SaskPower		Hybrid Reference Customization &	✕	POI	✓	○	○	○	○	◕	●	◕	○	○	○	○	○	○
Southern California Edison (SCE)	Phase 1	Detailed Reference & Customization	✕	POI	✓	●	●	●	●	◗	◗	●	●	●	○	○		
Southern Company	Phase 1	Detailed Reference & Customization	✕	POI	✓	○	○	○	◗	●	●	●	◗	●		◕		○
	Phase 2	Detailed Reference & Customization	✕	POI	✓	○	○	◕	◗	●	●	●	◗	●	●	◕	◔	○
	Phase 3	Detailed Reference & Customization	✕	POI	✕	○	○	◕	○	○	○	○	○	○	●	○	◕	○
SPP	Phase1	Detailed Reference & Customization	✕	POM	✓	○	○	○	◗	○	○	◕	○	○	○	●	○	
SRP	Phase 1	Hybrid Reference Customization &	✕	POI	✓	○	○	●	●	●	●	◕	◕	●	●	●	●	○
Tennessee Valley Authority (TVA)	Phase 1	Hybrid Reference Customization &	✕	POM	✓	●	○	●	●	●	◕	●	◕	●	●	●	○	○

Legend: ○ – not adopted | ◔ , ◗ , ◕ , ● – various adoption degrees | ◔ , ◗ , ◕ , ● – various degrees of own specs

Last Update: May 26, 2025

Please send feedback to jboemer@epri.com

Jens Boemer, EPRI (2025)

4

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ESIG i2X FIRST website: https://www.esig.energy/i2x-first-forum/

Presented by Jens Boemer (EPRI) at the i2X FIRST Season 2 Kick-Off meeting

NERC Order 901 and PRC-028 & PRC-030

Approved by FERC on 02/20/2025

New PRC-028

- Installation of disturbance monitoring equipment
- Share data on request

Approved by FERC on 07/24/2025

New PRC-029

- Performance based ride-through criteria
- Capability based ride-through criteria

Approved by FERC on 02/20/2025

New PRC-030

- Analysis of performance during a disturbance
- Triggers what is evaluated for ride-through performance

The WHY?

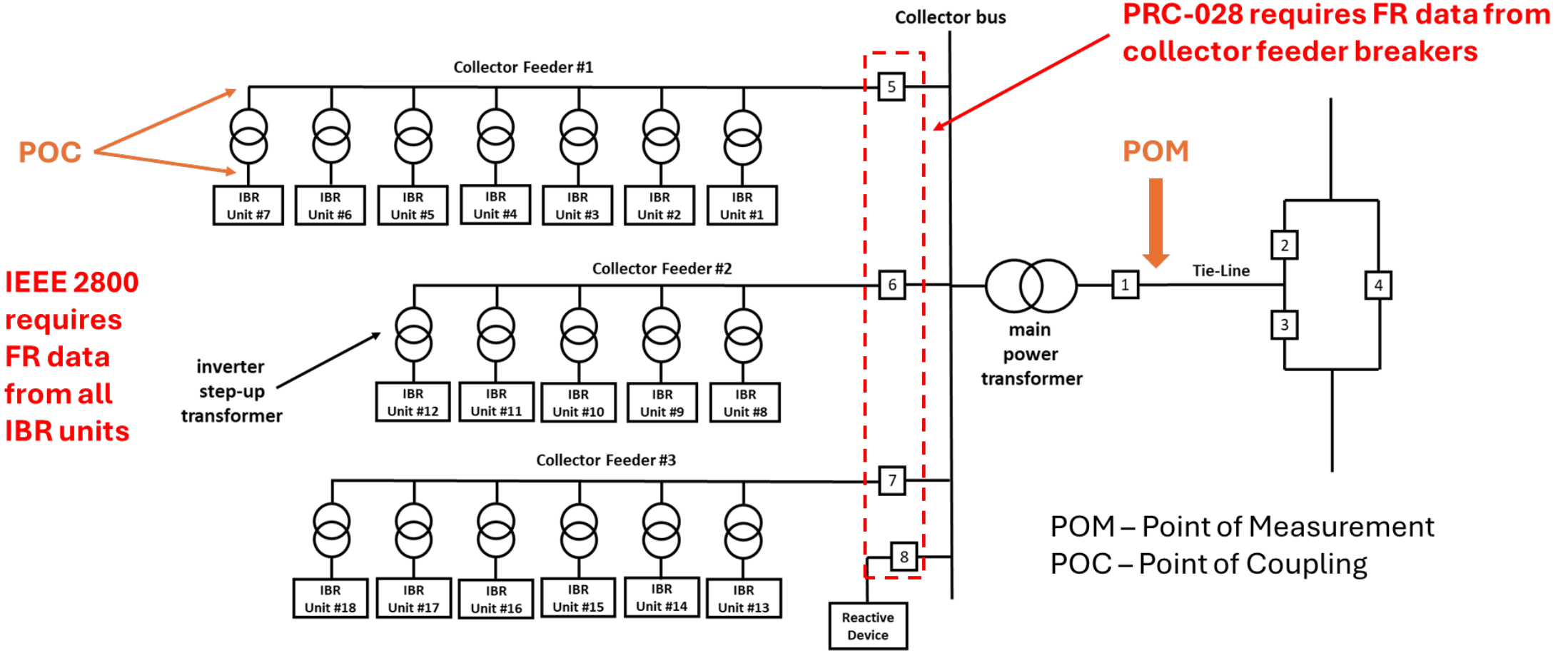
Source: [Reliability Standards Under Development]

Data Capture Requirements in IEEE 2800 vs NERC PRC-028

	IEEE 2800-2022 Clause 11 (Measurement Data for Performance Monitoring and Validation)	PRC-028 Disturbance Monitoring and Reporting Requirements for IBRs	Comments
	Forward looking standard	Applicable to existing and new IBRs (BES and non-BES)	
SCADA Data	**Yes**	**No**	
Plant Level SER Data	Yes	Yes	Requirements in PRC-028 may be brief but serves the purpose
IBR Unit Level SER Data	Yes	Yes	
Plant Level DFR & DDR Data	Yes	Yes	
IBR Unit Level DFR Data	**Yes**	**No**	In PRC-028, FR data from collector feeder breaker is required instead
IBR Unit Level DDR Data	No	No	
Measurement Accuracy	**Yes, except for IBR unit level data**	**No**	

Source: Manish Patel's NERC IPRS Presentation on 06/26/2025, see also DOE i2X FIRST 03/17/25 Workshop

FR Data – Unit Level in IEEE 2800 versus CF level in PRC-028



Source: Manish Patel's NERC IRPS Presentation on 06/26/2025, see also [DOE i2X FIRST 03/17/25 Workshop]

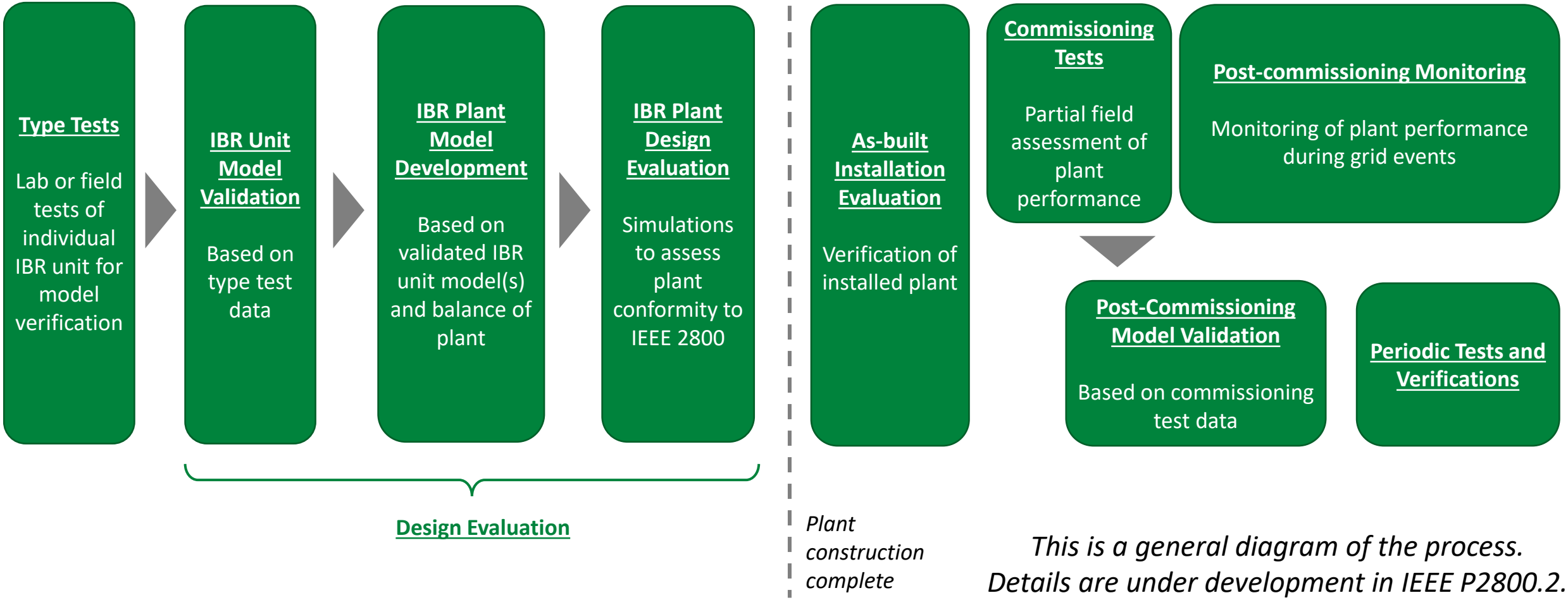
IEEE 2800 versus PRC-028 Time Synchronization

	IEEE 2800-2022 shall be synchronized to UTC with	PRC-028 shall be synchronized to UTC with
IBR Plant Level Monitoring	± 1 µs time accuracy	± 1 ms time accuracy
IBR Unit Level Monitoring	± 100 µs time accuracy	± 100 ms time accuracy

PRC-028 recognizes challenges of transmitting clock signal within the plant

Source: Manish Patel's NERC IRPS Presentation on 06/26/2025, see also DOE i2X FIRST 03/17/25 Workshop

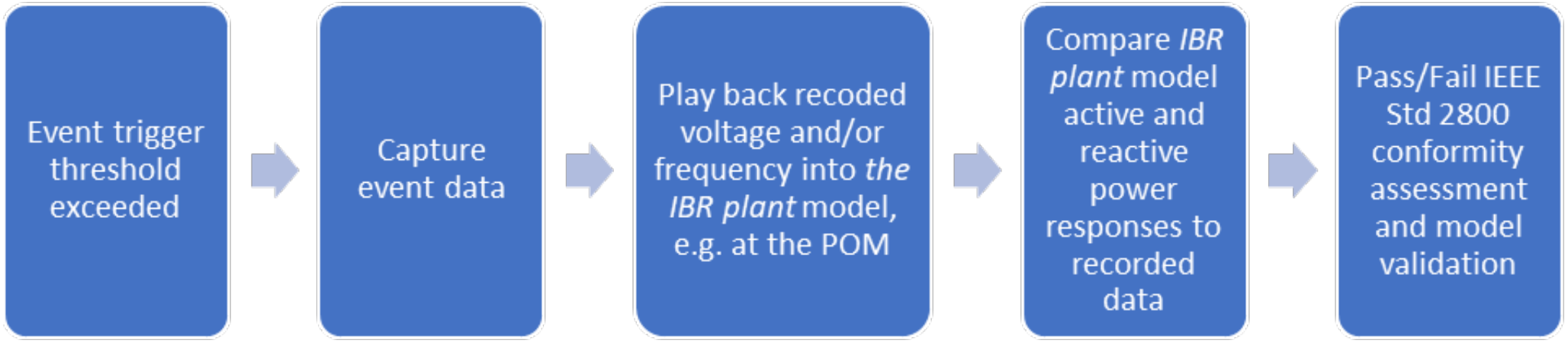
Overview of conformity assessment steps in IEEE P2800.2 Recommended Practice for Test and Verification Procedures for IBRs Interconnecting with Bulk Power Systems



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

Source: Andy Hoke (NREL), Jens Boemer (EPRI)

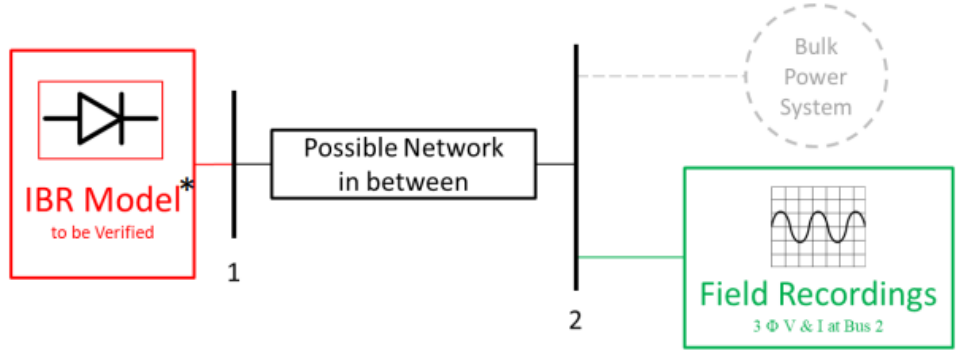
Post-Commissioning Monitoring Process

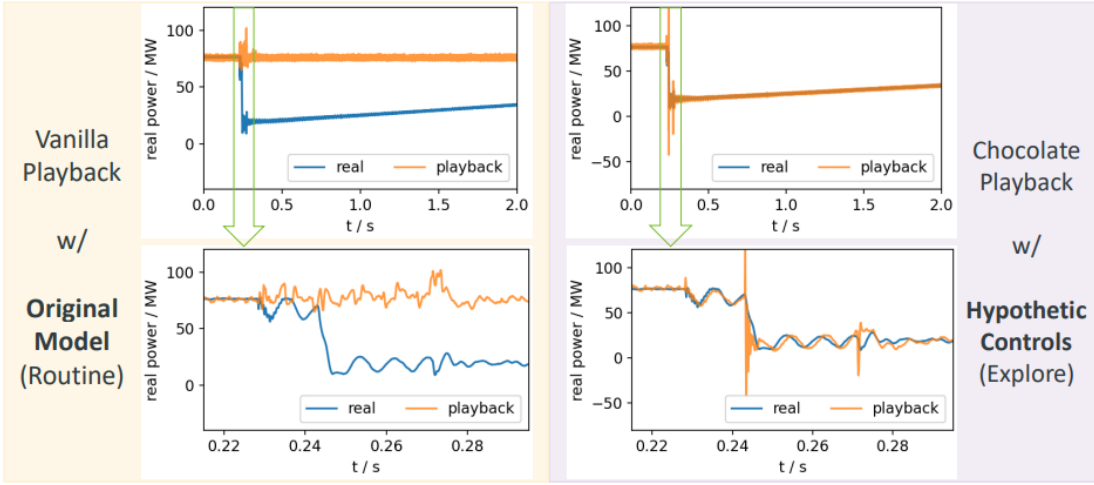


Source: Draft of IEEE P2800.2 SG5

Post-Commissioning Model Validation - Example

- Data recording and retention requirements are set in IEEE 2800 and
- IEEE P2800.2 recommends:
- Procedure for capturing data and performing Phasor-Domain Transient and Electromagnetic Transient model validation as well as
- IBR Plant performance assessment
- At NERC IRPS and IEEE PES GM, ISO-NE has presented an example of an EMT model validation of a PV plant.





Source: [Qiang "Frankie" Zhang, "IBR Model Verification at ISO-NE Using Playback Method", NERC IRPS Meeting, June 2023]

Path/Fail Considerations

- If there is a reasonable match between the measured and simulated response, then the existing “as-built” IBR plant model is accurately representing the IBR plant.
- If the simulated response for the event does not match recording, then one or more of the following:
  - The IBR plant model does not represent the IBR plant adequately,
  - An event cannot be accurately replicated in the simulation domain the model is created for,
  - The measurements from the event are not accurate,
  - Post-processing of raw phase voltages and currents into RMS quantities within the data recording equipment may differ from the corresponding processing of the same quantities in the simulation tool
  - If a full (or partial) TS model used for IBR plant model validation rather than playback, the accuracy of the TS model may also be a reason for a mismatch
- A mutual investigation is necessary among all parties (TS owner and IBR owner) to determine, which of the above is the cause and what further actions are necessary.
- Assess whether IEEE 2800 requirements are satisfied by IBR plant performance in the recorded event.

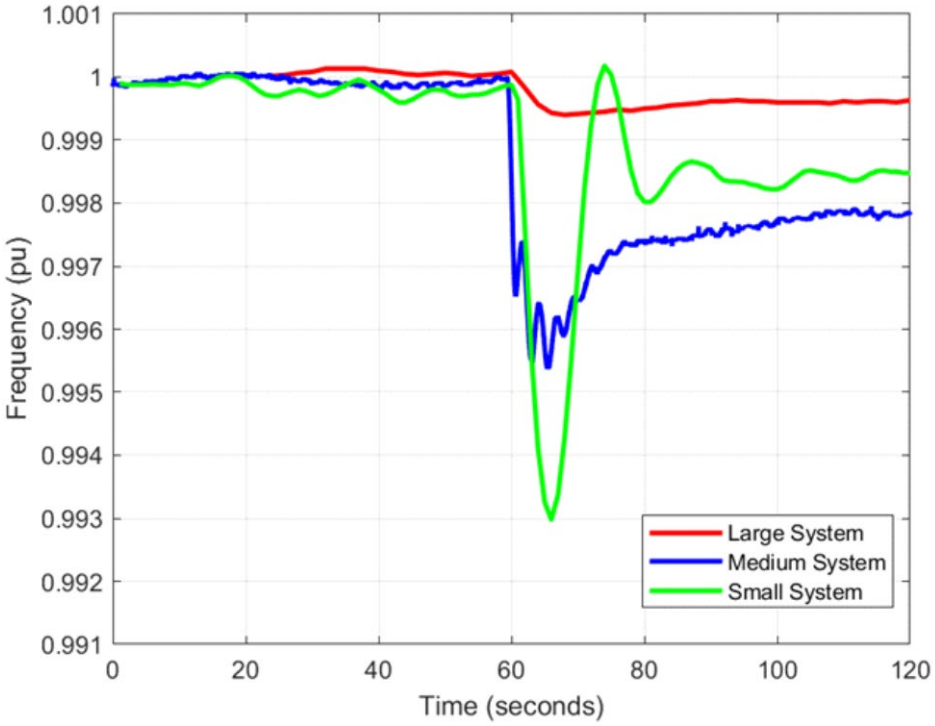
Event Triggers - General Considerations

- Multi-phase transmission faults are rare
- Even with post-commissioning monitoring conformity with all aspects of the performance requirements cannot necessarily be verified during the life of the plant
- The vast majority of disturbances will be smaller, e.g. a sudden (few %) change in POM voltage due to
  - remote faults or
  - transmission equipment switching events.
- Small disturbance data are still helpful in routine conformity assessment of the volt/var response and dynamic performance of the IBR plant.
- Frequency events due to the loss of large generation or large load are useful for routine conformity assessment of the primary frequency response (PFR) or fast frequency response (FFR) dynamic performance of the IBR plant.

Selection of Event Triggers

- The appropriate evet trigger settings depend on the characteristics of the BPS
- If the triggers are set too narrow:
  - too many events may be recorded
  - data storage of the recording device fills up and
  - data overwriting happens.
- If the triggers are set too wide:
  - the events useful for conformity assessment may not be captured
- A balance should be achieved between the trigger settings and data retention time, as per Table 19 of IEEE 2800
- The trigger settings may need to be adjusted periodically due to changing generation mix, other nearby resource installations, or changes to other system characteristics.

Frequency response after a generator trip event for different system sizes



Source: IEEE Task Force Report, Stability Definitions and Characterization of Dynamic Behavior in Systems with High Penetration of Power Electronic Interfaced Technologies, PES-TR77, April 2020

Example Frequency Event Trigger

- If the system is large (>400 GW), start with a setting of ±40 mHz.
- If the system is medium sized (100 GW to 200 GW) then start with a setting of ±100 mHz.
- If the system is small (<20 GW) then start with a setting of ±200 mHz.
- Depending on a number of captured events these triggers can be revised, as needed and when practical, in consultation with the TS owner/TS operator.
- The trigger should be set to capture PFR or FFR response, and thus needs to be coordinated with applicable PFR or FFR deadband (e.g. ±36 mHz as per IEEE 2800)

Example Voltage Event Trigger

- Voltage trigger setpoints may also be system-dependent based on factors such as, e.g.:
  - fault current availability and fault characteristics,
  - weather patterns (e.g., areas prone to lightning will have greater occurrence of voltage disturbances), etc.
- A similar approach should be taken to that above, with due consideration given to usefulness of the recorded event and efforts involved in evaluating those.
- Start by setting a trigger to record events if there is voltage deviation of greater than ± 2%.
- In some cases, the voltage deviation trigger could be set to as high as ±10%.
- Depending on a number of captured events, the triggers can be revised, as needed and when practical, in consultation with the TS owner/TS operator.

Capturing Event Data

- IEEE 2800 Table 19 outlines measurement data points, minimum recording sampling rate, data retention time, recording duration for various types of monitored and recorded data, including:
  - plant SCADA,
  - plant equipment status,
  - unit functional settings,
  - sequence of events recording (SER) data,
  - digital fault recorder (DFR) data,
  - dynamic disturbance recorder (DDR) data,
  - IBR fault codes and dynamic recordings, and
  - a host of power quality data.
- Applicable measurements are also specified in Table 19 and throughout the standard

Digital Fault Recorders (DFRs)

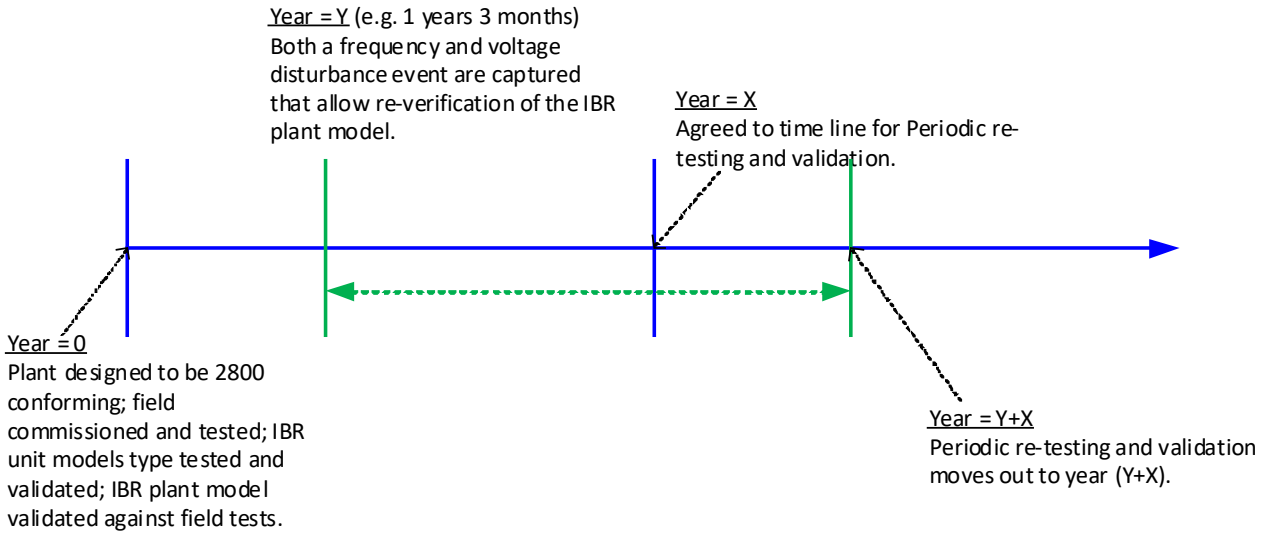
- DFRs should be used to capture the desirable point-on-wave data to evaluate IBR plant performance during and shortly after the disturbance events.
- DFRs triggers to record disturbance events for the purposes of model validation and conformity assessment should be selected in consultation with the TS owner/TS operator.
- It is important to:
  - Coordinate DFR triggering settings at an IBR plant with the triggering settings of the DFRs in the bulk power system (BPS)
  - Use a common time reference so that data from different DFRs can be visually "lined up", for analysis.

Frequency and number of model validation instances

- The IBR plant performance evaluation, model revalidation, and conformity assessment should be performed with the relevant clauses of IEEE 2800 at least once every 24 months, assuming a significant voltage or frequency event occurred
- An entity may perform such work on every event captured if they so wish.
- Some events may still be too small to assess conformity with IEEE 2800 but may provide an opportunity to assess performance of the IBR plant controls and to validate the relevant aspects of the plant model.

Periodic Tests

- Periodic tests should be conducted to reassess conformity of the IBR plant with requirements specified in IEEE 2800
- The periodicity of testing should be mutually agreed between TS owner/TS operator and IBR owner or as required by applicable regulatory standards.
- If during the period since the last testing, and before the next periodic testing is due, IBR plant model validation and IEEE 2800 conformity assessment were performed based on system disturbance(s) the timeline for the next periodic testing should be reset.



Q&A Correction (provided after the webinar)

- During the Q&A a question by Slava Maslennikov (ISO-NE): DFR measurements are not suitable for oscillation source localization as they are limited to disturbance location and short in time. Are there any requirements for continuous point-on-wave (POW) high resolution measurements, to be able to capture IBR-related oscillations?
- I responded that IEEE 2800 has requirements for DDR, which is continuous POW recording, while PRC-028 does not require.
- **Correction from me** (after the webinar): My initial response wasn't correct. Both NERC PRC-028 and IEEE 2800 require DDRs to capture specified plant-level data continuously, with input of ≥ 960 samples/s and output of ≥ 60 records/s, retention differs with 1 year required in IEEE 2800 and 20-days required in PRC-028.
- **Follow up response from Slava (offline), which I also want to capture here**: The question was inspired by the experience of using PMU for oscillations source detection. Constantly streamed PMU data is sufficient for traditional 0.2…2Hz oscillations, but not for IBR-related oscillations >3-4Hz. DFR measurements are not suitable for oscillation source localization as they are limited to disturbance location and short in time. New type of POW continuous measurements provided by SEL-735 (3000 sample/sec, stored locally at the substation) would be perfect for all types of analysis. Would it make sense to put into the governing documents a recommendation to install POW continuous measurements? 60 samples per sec as output of DDRs is too low. Probably, that is too early requirements as SEL-735 is not widely used yet. Retention period TBD.

THANK YOU

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