Draft IEEE P2800.2 Working Group Meeting Minutes, August 29-31, 2023

IEEE P2800.2 Recommended Practice for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Bulk Power Systems

Chair: Andy Hoke
Secretary: Manish Patel
Vice-Chairs: Jens Boemer, Bob Cummings, Divya Chandrashekhara,
Julia Matevosyan, Mahesh Morjaria, Steve Wurmlinger

Meeting Date/Time/Location**:** August 29-31, 2023, 11 am – 3 pm ET, Virtual Meeting

August 29, 2023 Notes:

Andy Hoke kicked-off the meeting with a brief introduction. This meeting was the sixth meeting of the IEEE P2800.2 Working Group. The meeting was held virtually. In lieu of a roll call, attendees were requested to put their name and affiliation in the chat window. Attendees were also asked to record attendance at https://imat.ieee.org/attendance. The TEAMS attendance will be used along with data from iMat to record attendance.

Quorum was achieved. The agenda was presented. Pouyan Pourbeik moved to approve the agenda. Mike Ropp seconded. No discussion, objection or abstentions were noted. Agenda was approved.

Bob Cummings moved to approve meeting minutes for the kick-off meeting. Tom McDermott seconded. No discussion, objection or abstentions were noted. Meeting minutes were approved.

The IEEE SA Patents & Copyright policies along with Participants Behavior Expectations were presented. Chair Andy Hoke made a call for potentially essential patents; no one raised concerns for consideration.

The scope and objective of the IEEE P2800.2 was discussed. It was emphasized that the P2800.2 WG is large and encouraged everyone to contribute. The draft 0.5 is posted on iMeet Central and is out for comments from the WG members. Please submit comments by September 7, 2023. Note that any language in brackets or highlighted in yellow does not have consensus but is included in the draft as a place holder to allow for further discussion. As of now, the publication is expected in early- to mid-2025.

SG1 Discussion

The updates to SG1 material presented as follows:

- Cleaned up some language in clause 1.
- Added new subclause 4.2 (Overview of Conformity Assessment Process), which includes updated version of information handoffs flow chart. The information handoffs flow chart was presented. This is figure 2 in draft 0.5.
    - The importance of establishing IBR plant information database (IPID) was noted. Mentioned South Utah disturbance: >900 MW lost (per 4 s SCADA) on normally cleared fault. TO and GO lacked sufficient data/models on all plants. An attendee noted that if plant changes, design evaluation may need to be iterated.
    - A change in the flowchart since the last WG meeting was briefly discussed. SG1 simplified the diagram and merged some boxes.

- It was clarified that type tests may vary depending on equipment under test (EUT) capability and type tests on IBR units, PPC etc. are in general not done to show conformity with IEEE 2800 but rather to validate models. Question was raised regarding how supplemental IBR device may affect the flowchart. SG1 will discuss further and make appropriate edits.

SG2 Discussion

Pramod Ghimire and Steve Wurmlinger led the SG2 discussion. After brief review of scope, changes to clause 5 since the last meeting was presented. The IBR unit and Supplemental IBR device are referred as equipment under test (EUT).

Which supplemental IBR devices are considered for type testing? The supplemental IBR device is defined in the base standard. But more discussion is necessary.

It was stated that at some point WG need to decide type test procedures for which supplemental IBR devices will be provided in the 2800.2. The power plant controller, capacitor bank, STATCOM, SVC, synchronous condenser, etc., could be a supplemental IBR device. It is not feasible to provide type test procedures for all possible supplemental IBR devices. It was stated that some kind of unit-level model-validation type test for any device whose behavior is software-defined, such as IBR units and PPCs is definitely needed. A synchronous condenser is not software defined; it can be reasonably modeled via a physical model with a few data-sheet parameters.

It was stated that definition of type test is not broad enough. A proposed definition is as follows: Type tests are performed on an IBR unit (called equipment under test - EUT). The objectives of type test may include but are not limited to:

- Verifying the performance of the EUT
- Evaluating the capability of the EUT
- Validating the study model presenting the EUT
- Determining the model parameters for the EUT

Type tests are not meant to be applied to entire IBR plants or to ensure plant level compliance just by using type tested EUTs. Procedures recommended in this type test section typically follow existing industry practices and standards. Procedures from other industry practiced or standards may also be acceptable if the results produce information sufficient for the above objectives.

A brief discussion followed regarding where a PPC fits into the conversation. Officially, a PPC is a “supplemental IBR device”, and there were some objections to that designation because the PPC is essential, and central to the performance of the plant.

A question via chat: Are there more details on testing for the power plant controller model? It would not be part of IBR unit here so would come in at the plant level, but there should be checks on the PPC model itself.

Yes, SGs leads have started discussing how to handle PPCs in the SG coordination call. The likely direction is that they would be tested similarly to IBR units to produce a validated PPC model that can be included in the plant model.

A hesitation was raised to call the testing procedures for PPCs "type tests." Given how flexible PPCs need to be, (both the services they run, as well as the control philosophy that defines the performance) the functions demonstrated are indicative more than a fixed expectation what one would see in a finished project.

An attendee noted via chat - What we need is a "reasonable" model of the PPC at the design evaluation stage. By "reasonable", I mean that the model accurately represents how the PPC is actually going to work in the real plant, as understood at that time. Things do change as we go through the process; and that needs to be accommodated (probably, unfortunately, by a model revision). But, we need sufficient risk reduction at the design evaluation stage that the plant can be allowed to proceed, and achieving that requires a PPC model.

A further discussion to take place in SG coordination calls. The ultimate goal is to get to a validated model of the PPC somehow.

Measurement Accuracies: The clause 5.1.3 from draft 0.5 regarding the measurement accuracies was presented. It was mentioned that SG2 intends to rely as heavily as possible on existing industrial practice and standards. There is no need to re-invent.

Measurement Accuracy (P2800.2 – 5.1.3)

Minimum measurement accuracy for instrument used for Type test

- Calibration by accredited institute traceable to ISO/IEC 17025.
- Measurement equipment according to IEC 61869-103
- Measurement methodology and power quality assessment according to IEC61400-4-7 class 1.0 and IEC 61400-4-30 Class A

Measuring instrument	Accuracy
Voltage	IEC class 1.0
Current	IEC class 1.0
Data acquisition system	1% of full scale

EUT accuracy required by 2800 – clause 4.4 still need information.

It was emphasized that the measurement device requirements needs to be synchronized with PQTF to make sure that measurement device is covering all requirements.

An inconsistency between IEC class 1.0 and measurement accuracy required in clause 4.4 of the base standard was noted by one of the attendees. It was clarified that measurement accuracies in P2800.2 is for measurements recorded during a type test, whereas measurement accuracies included in clause 4.4 of the base standard are for measurements for IBR plant monitoring during the lifetime.

The concern with measurements during a transient window was also recognized. Do we need transient and steady-state guidelines? OEMs need guidelines on how to select appropriate probes. “Class 1” doesn’t provide enough info.

An ambiguity in how one chooses the right instruments for demonstrating device performance was noted. Frequency is a good example; some markets have very strict frequency requirements, but it can be measured and calculated in a lot of different ways. More guidance was requested.

Are these accuracy requirements applicable at LV or MV? Proposed accuracy requirements are applicable up to MV.

Further discussion on this topic to take place within SG2 after the WG meeting.

Inadvertent Energization of TS (clause 4.9 in the base standard): The base standard states that the IBR plant shall not energize the TS when the TS is de-energized. Exceptions may be given for black-start IBR at the discretion of the TS operator.

SG2 asked the WG following: Is there any test for this that would produce data for unit models or plant models, or is this just a manufacturer's statement of operation?

An attendee stated that a simple statement from IBR unit manufacturer is enough. The logic to take care of this requirement could be implemented in a device controlling a breaker at the POM.

Isn't there a similar requirement in IEEE 1547? Can't we use the test procedure from IEEE 1547.1 for IBR units?

After some discussion, it was concluded that type testing IBR unit for inadvertent energization requirement is not necessary.

Interconnection Integrity (clause 4.9 in the base standard):

SG2 asked the WG following: The base standard already defined the test standards and requirements for the compliance of this clause. Is this just verification of compliance?

It was stated that verification of compliance seems sufficient.

Following question was asked: Why this requirement exists in the base standard?

Voltage and Reactive Power Control Tests: The proposed test included in clause 5.7 of draft 0.5 was presented. Discussion of power levels, and how this might be done in HIL versus in actual HW. In HIL, there are fewer constraints on the power levels. Suggestion was made that there should be a footnote explaining how these power levels might change in HIL vs HW. It was recognized that the base standard requires capability for constant power factor and constant reactive power mode as well. Suggest language/test procedure is generic enough where it would apply to all three control modes.

Active Power Control Tests: The proposed procedure is included in clause 5.8 of draft 0.5. It was noted that active power steps only show reductions in power, would it make sense to also include steps back up? SG2 to discuss further after the WG meeting.

Frequency Response Tests: The proposed procedure is included in clause 5.9 of draft 0.5. The basis for 300mHz step in frequency was questioned. It was recognized that this step is likely higher than largest deadbands used at plants in real world. The recommended frequency ramp is based on requirements in the base standard. But further discussion might be needed for larger IBR units.

Voltage ride-through tests: The test procedure from FGW TR3 was used as a starting point. VRT tests should be done for high (>3) and low (as specified by manufacturer) SCRs. The goal is to validate the IBR unit model for both conditions. The load level (full or partial) might need further discussion.

Current injection performance requirements: The proposed procedure is included in clause 5.11.5 of draft 0.5. The requirements should be verified for SCR >3 and does not apply when SCR <3. The base standard allows flexibility when SCR is low but it was suggested that SG2 should include justification in 2800.2.

Then test procedures for phase angle jump, unit protection, and rate-of-change-of-frequency protection were presented. SG2 does not recommend a type test for transient overvoltage ride-through requirements. Following question was asked: How IBR unit's transient overvoltage ride-through capability can be included in the model? It was stated that it is not possible to include this capability in a model. The manufacturer should provide a capability which should be considered in design evaluation.

An attendee asked about a sampling rate of measurement data gathered during type testing. The sampling rate will be recommended in the 2800.2 Suggestion was made to specify minimum sampling rate.

Next steps for SG2 include test procedures for PPC and any other supplemental IBR device, coordination with PQTF and SG3, and firming up test procedures. WG members were thanked for providing the feedback.

IEEE P2004: The secretary, Blake Lundstrom, of the IEEE P2004 WG gave an overview of the Recommended Practice for Hardware-in-the-Loop Simulation Based Testing of Electric Power Apparatus and Controls. The standard just finished an initial ballot and publication is expected in early 2024. The draft is available to P2800.2 WG members.

Andy thanked Blake for his time to present to the 2800.2 WG.

Meeting in recess at approximately 3 pm ET. WG to reconvene at 11 am ET on August 30, 2023.

August 30, 2023 Notes:

Manish Patel kicked-off session with a reminder to be mindful of IEEE policies and requested attendees to log attendance on iMat.

SG3 Discussion

Jens Boemer kicked off the SG3 discussion with brief overview of SG3 scope. IBR developers were encouraged to get involved in SG3 and WG as well. All redlines were reviewed quickly.

The objectives of design evaluation were presented. The focus of design evaluation may lay on one or the other objective depending on when it is done.

Difference between model quality testing/model quality assessment and model validation was also noted.

Procedures to validate IBR unit/Supplemental IBR device model: A strawman for model validation procedures was presented. All categories of models (OEM specific EMT, OEM specific positive-sequence phasor domain and generic positive-sequence phasor domain) should be looked at. Variables to simulate and to be compared with measured or derived quantities were also presented. The strawman proposes a

quantitative approach to model validation based on FGW-TG4, however, error definitions and acceptable errors needs further discussion.

Then a two-tiered model validation approach was presented. If error between type test and model simulation results for various tests is less than a certain threshold (i.e., results are close) then quantitative assessment passes. Failing the quantitative assessment requires a detailed engineering review and qualitative assessment. Passing quantitative assessment requires a basic engineering review and qualitative assessment. The quantitative assessment offers efficiency in model validation process.

Error statistics from IEC 61400-27-2 that might be used in IEEE 2800.2 were also presented. The various options for time windows defining transient, quasi steady-state, and transient period after the faults are of importance in model validation process. Finally, table structures were also presented.

Discussion concluded with presentation of qualitative criteria which is based on engineering review. Some noteworthy comments are as follows:

> Will 2800.2 require models for all three categories? The approach in 2800.2 is that whichever model is used should be validated.
>
> It was clarified that IBR unit model validation is associated with particular IBR unit and typically occurs following development of IBR units and subsequent type testing; in other words it is done once for each IBR unit model, not once for each plant.
>
> It was recognized that a close match between type test and model simulation results is possible for some type test methods. But same may not be true for all type test methods. It may be worthwhile to specify error bands based on type test methods. The size and type of IBR unit may also need attention.
>
> An attendee noted that talking about error band does not make sense without considering type test methods and simulation tools. Also, consider total vector error for transient measurements as is the case in table 2 of the base standard. It was acknowledged more alignment with SG2 is necessary as accuracies for type test measurements is defined by SG2.
>
> Why have different expectations for EMT and positive-sequence phasor domain models? Different expectations for EMT and positive-sequence phasor domain models in FGW-TG4 was recognized. Suggestion was made that it was due to some limitations of the simulation platform at the time. Going forward and considering other simulation platforms, both models could be equally accurate. Miguel also noted that Germany does not require submitting EMT models so the error bands specified in this latest FGW standard have not really been used and tested yet. The RMS model error bands however have been in use for several years now and evolved based on the feedback from various stakeholders.

Key takeaways from brief OEM presentations regarding IBR unit model validation are noted below:

> Important to define tolerances for model validation. Good match between EMT and user defined positive sequence phasor domain models is possible.
>
> One OEM uses a very tight margin for validating EMT model. Notes that not all models are same. Source code/real code-based models, any errors are due to hardware limitations, signal

processing and feedbacks. Reduced order models are benchmarked against source code-based models and measurements.

Type test method and manufacturing tolerances of electrical components involved are important. Uncertainty from measurement setup needs to be considered.

It was recognized that unit level model validation is not new to most OEMs.

SG3 is seeking feedback from the WG members via a poll available at IEEE P2800.2 WG Meeting August 2023 - SG3 (Design Evaluation) (sli.do). The poll will remain open till the next SG3 meeting.

SG4 Discussion

Divya K kicked off the SG4 discussion with brief overview of SG4 scope.

As-built evaluations: detailed procedures are not specified, as the procedures in design evaluation clause should be used for as-built evaluation as well.

Commissioning Tests: A brief overview was provided. The addition of limiting factor documentation in draft 0.5 was discussed. Commissioning tests for measurement accuracy (clause 4.4 in the base standard), isolation device (clause 4.8 in the base standard), and enter service (clause 4.10 in the base standard) requirements are not specified. These requirements need a simple verification based on engineering design.

Also presented were commissioning test procedures for minimum reactive power capability, voltage and reactive power control, and frequency response requirements.

An attendee mentioned that the amount of energy available in a turbine, and the recovery of a wind turbine post frequency response is very dependent on the conditions at each individual turbine. It is very likely that the POI response of the recovery doesn't look the same twice within the life of a facility. Is this recording of the recovery anything more than an informative result? The concern was acknowledged and mentioned that this is already recognized, for example, figure 36 in draft 0.5.

An attendee also asked which bucket hybrid facilities fall into? Is there consensus? The clause 4.4 (alignment of requirements) recognizes this and leaves it up to entities to agree on.

An attendee asked: Is it feasible to test FFR on a plant basis? Is it not the normal practice to implement FFR at the unit level, autonomously responding? Yes, see language in clause 9.7. The capability could be at plant level or unit level. The procedure recognizes that controls could be at plant level or unit level. It was mentioned that GE's current FFR offering for onshore wind is on a plant basis, coordinated through a plant controller.

Then clause 9.9 which focuses on voltage disturbances within continuous operating region was presented. The test is performed to assess the resonance conditions within an IBR plant and can be performed at any active and reactive power level.

Regarding various protection implemented within the IBR plant, commissioning tests are not required. A simple verification that settings implemented do not limit ride-through capability is sufficient.

In summary, the content in draft 0.5 is fairly matured and encouraged WG members with interest in commissioning test procedures to review and provide feedback.

Power Plant Controller Model Validation

The remaining time was used to discuss validation of power plant controller (PPC) model. The PPC plays a significant role in plant's performance. How do we make sure that the PPC is accurately replicated in a model? Approach of validating PPC model could be like approach of validating IBR unit model, i.e., validate the PPC model against type test results. And then it could be further validated based on commissioning test results.

It was recognized that this is no different from validating an IBR unit model.

An attendee asked – How would one type test PPC? One option is to test using HIL. In that case, the 'H' in HIL is the PPC. The test is just to verify that output of PPC is as expected for given input signals. The software-in-loop (SIL) approach could also be used.

It was recognized that validated PPC model should be available for design evaluation. Also, the plant controller should not get in a way, especially during a frequency response.

One member mentioned that it is hard to test PPC in isolation.

However, noted was that it is important to test PPC for realistic condition. In response, it was recognized that realistic conditions may not be included in the type test. The design evaluation may address PPC's interaction with IBR units.

–Challenges due to the differing PPCs currently in use were realized. Some are third party, relatively simple PLC based devices that are essentially tacked on to a project, and others are highly sophisticated, fast, and customized controllers which directly influence fast dynamics in inverters via fast comms.

It was also recognized that proper modeling of comms is essential for reasonable plant modeling accuracy. Some comms is not just a pure transport delay but rather dominated by a sampling rate.

It was recognized that comms are improving and should not be a big issue in future.

The importance of plant comm delay depends on if it is part of an open-loop function or a closed loop function. Unless a grid is incredibly low inertia, frequency response is practically open loop. Voltage regulation, particularly in a weaker system, is closed loop and a pure time delay in the loop can add lots of phase lag, which can adversely affect the closed loop performance and stability of a function that has an intended response time an order of magnitude longer.

SG2 to further discuss and draft type test procedure for the PPC.

Meeting in recess at approximately 3 pm ET. WG to reconvene at 11 am ET on August 31, 2023.

August 31, 2023 Notes:

Andy Hoke kicked off the meeting. Attendees were reminded to log their attendance on iMat.

PQTF Discussion

Eugen Starschich kicked off the discussion with brief update. PQTF's contribution is included in an Annex G for now. This content will be moved to appropriate clauses in the main body in the next draft.

PQTF's perspective on type tests was presented. These are:

- Determine the parameters of the unit's harmonic model.
- Determine the unit's harmonic and interharmonic emission level.

Depending on IBR unit and application frequency dependent Thevenin or Norton equivalent on an IBR unit could be used. A flowchart for IBR unit test procedure was presented, which recognizes both lab-based tests on an actual unit and simulation-based test on a simulated unit. Also, recognized were some special cases, e.g., HVDC link.

Then further details on type testing of IBR units were presented.

- Lab testing of full-scale IBR unit – preferred for deriving impedance and harmonic current/voltage sources. However, not feasible for large IBR units such as HVDC.
- Control HIL testing of IBR converter controls – high fidelity EMT model of electrical components shall be included. Power electronic non-idealities needs to be considered. This is an accurate method for harmonic impedance derivation. However, accurate derivation of harmonic voltage/current source will be a challenge.
- EMT simulation of the benchmarked IBR unit model – accurate representation of converter controls is required in addition to HIL considerations.

Procedures for Norton/Thevenin impedance and current/voltage source derivation were presented.

It was noted that change of parameters in IBR unit should not change the model. Only inner-loop controls should significantly impact harmonic source and impedance characteristics.

An attendee asked: For 3-phase IBRs, is it proposed to consider the phase sequence of different harmonics, both in terms of injection by the IBR and the estimation of its internal impedance? Yes, both positive and negative sequences at different frequencies are included.

An attendee asked: Have we decided to assume a Norton model or Thevenin model? Both are equivalent, but I believe that using a Thevenin model more clearly conveys the message that VSC is not a constant-current source as is so widely assumed based on legacy LCC technology. Proposal was made to keep options open for OEMs. It was stated that PQTF started with a Thevenin circuit but for convenience it is OK to allow Norton equivalent as well.

The PQTF also has drafted procedures for commissioning tests and are included in Draft 0.5.

Frequency Scanning for IBR unit model validation

Wes Baker and Shahil Shah provided a brief overview. The purpose of frequency scanning is to validate the EMT model of the IBR unit over a frequency range. In draft 0.5, this is included in informative Annex E. The goal is to discuss various types of frequency scans, procedures for frequency scanning, model validation criteria, examples etc.

The draft content along with examples of few case studies were presented. Ideally would like to see a good match between EMT model and hardware frequency scan results but would like to hear from OEMs regarding reasonable expectations.

An attendee asked: Will these scans be performed in the phase domain (e.g, phase voltage perturbation) or in the synchronous domain (e.g., voltage magnitude or phase angle perturbation? Both sequence domain and dq reference frame are going to be included and will also show how they are mathematically equivalent.

It was recognized that in examples presented, impedance magnitude seems to match up pretty well but same is not true for phase angles.

An attendee asked: Will criteria (error) for model validation be included? Criteria will be included but group needs to discuss further. Criteria may not be very restrictive.

Will the annex be informative or normative? Will "should" or "may" language be used? It was stated that annex is currently being drafted as an informative annex and will likely use "may" language for test procedures. But also need some input from SGs 2 and 3.

Questions for OEMs:

- Do you currently perform frequency scans of the equipment? Lab test or CHIL?
    - OEM #1 – performs frequency scan. Details vary.
    - OEM #2 – does some of these, but unsure of details.
    - OEM #3 – does scans using CHIL to satisfy requirement by ERCOT
- How well do you expect the model to match the hardware scans?
    - OEM #3 – do see some error between model and CHIL results. Emphasized that perturbation magnitude is very import. Shahil agrees.

Folks with interest and experience in this topic are encouraged to join this group.

SG5 Discussion

Jason McDowell presented progress made by SG5 since the last WG meeting. The framework and content of SG5 contribution is in a good place. There may be some cleaning up needed but SG5 has progressed very well.

Since the last WG meeting, the post-commissioning monitoring process is updated and reflected in the draft 0.5. The process outlines to select and set event trigger data and capturing event data, followed by using captured data to validate the plant level model. Reasons for which simulated response may not match with measured response are also provided. The guidance to select event recording triggers is provided. The accuracy requirements for measurement data are already defined in Table 19 of the base standard.

It is recommended to performance evaluation and conformity assessment at least once every twenty-four months. Also recommended is to revalidate the plant model based on disturbance monitoring events. The base standard also requires periodic testing of the plant. The SG5 recommends that periodic tests should be performed according to a timeline mutually agreed upon by TS owner/TS operator and IBR owner. However, if the system disturbance affords an opportunity to evaluate plant conformity, then the timeline

for periodic testing could be reset. Periodic testing procedures are no different than commissioning test procedures.

It is well understood that it is not possible to verify full reactive power capability of an IBR plant during commissioning tests. Over a long period of IBR plant operation, by analyzing plant measurement data, it may be possible to validate the reactive power capability of the plant.

Next steps are to ensure alignment with SG4. add plant level model matching criteria, and add more event-based examples to Annex E.

Closing Remarks

Everyone was reminded that draft 0.5 is posted for comments, which are due by September 7, 2023. Please submit comments on the clean version. Draft is available to members only. If you are eligible to become a member, then send a request to Manish Patel or Andy Hoke. The timeline has slipped a bit, hoping to start IEEE-SA ballot in late 2nd quarter of 2024 and publication by mid-2025. The next meeting is tentatively scheduled for December 12-14, 2023.

The meeting adjourned at 3:00 pm ET.