IEEE P2800

Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems

Virtual Working Group Meeting

Post-Meeting Slide Deck

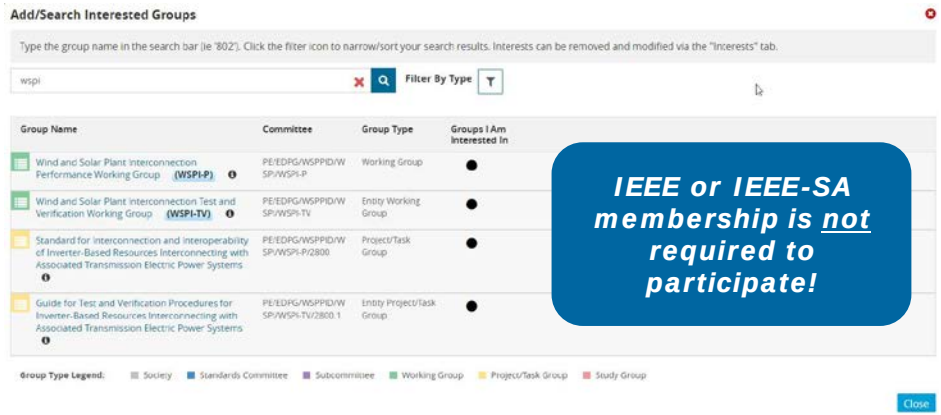
Jens C. Boemer, WG Chair*
Kevin Collins, Bob Cummings, Babak Enayati, Ross Guttromson, Manish Patel, Chenhui Niu, Vice-Chairs
Wes Baker, Secretary – Diwakar Tewari, Treasurer

February 6, 2019

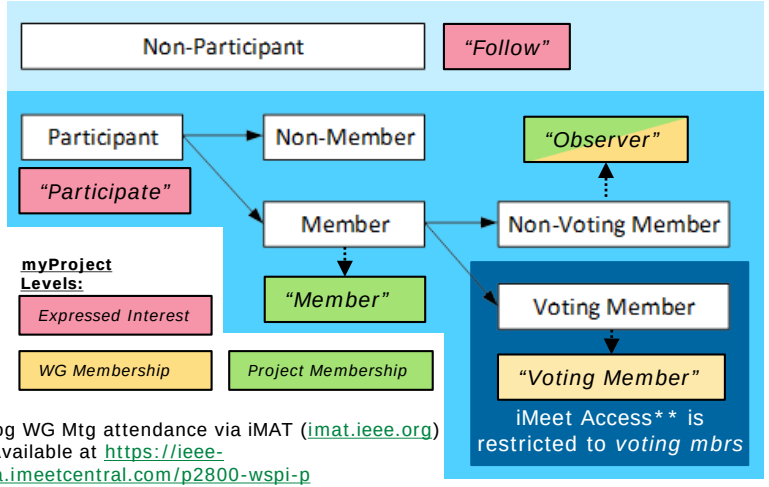
*Also Chair of the sponsoring ED&PG Wind and Solar Plant Interconnection Working Group (Link to Website)

How To Log WG Meeting Attendance via IEEE iMAT?

- *Anyone* with a (free) IEEE account can sign up at https://development.standards.ieee.org/my-site/home to receive P2800 Working Group updates ("Participant").
- *Participants* can attend WG meetings and log their attendance via https://imat.ieee.org/.
- *Once attended 2 of last 4 meetings*, ask the Secretary to become "Voting Member" and get iMeet access.
- *Only IEEE SA members* can ballot P2800.



IEEE or IEEE-SA membership is not required to participate!



* Log WG Mtg attendance via iMAT (imat.ieee.org)
** Available at https://ieee-sa.imeetcentral.com/p2800-wspi-p

1. On the **myProject™ Home Screen**, click on **Menu** and then on **Manage Profile and Interests**.
2. Click on the **Interests** tab and then on **Add Groups**.
3. On the **Add/Search Interested Groups** screen enter "WSPI" into the **Search box** and click the search button.
4. Click in the **Groups I am Interested In** column to indicate interest in the applicable group and project.
5. On the **Add Interested Group I want to follow** screen, indicate if you want to *Participate* or *Follow* the group. Then click **Declare Affiliations**.
6. On the next screen, confirm your current affiliation and add additional affiliations as necessary.
7. Click **Save** or **Return to Level of Interest** to change your selection. Then click **OK** and then click **DONE**.

IEEE iMAT:
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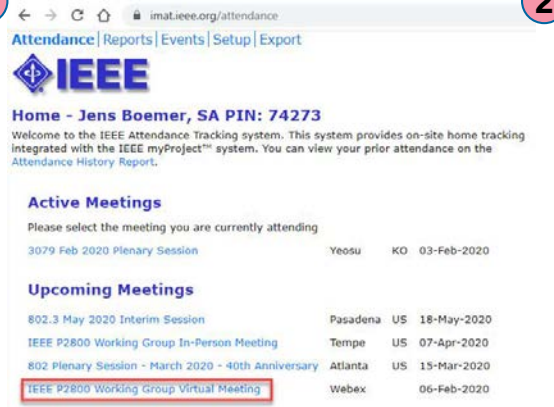

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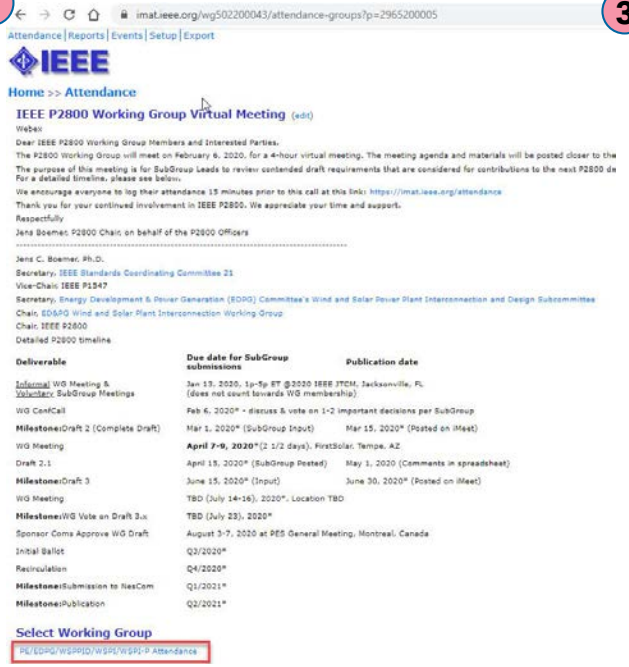

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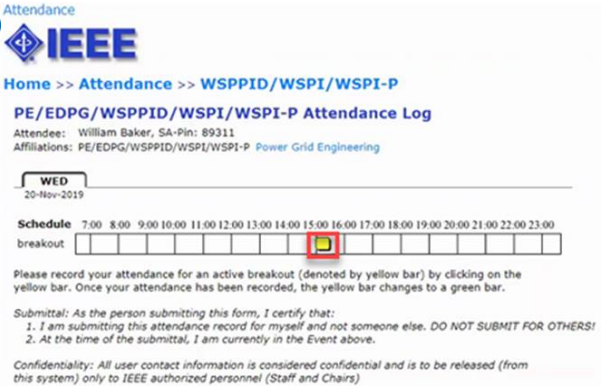
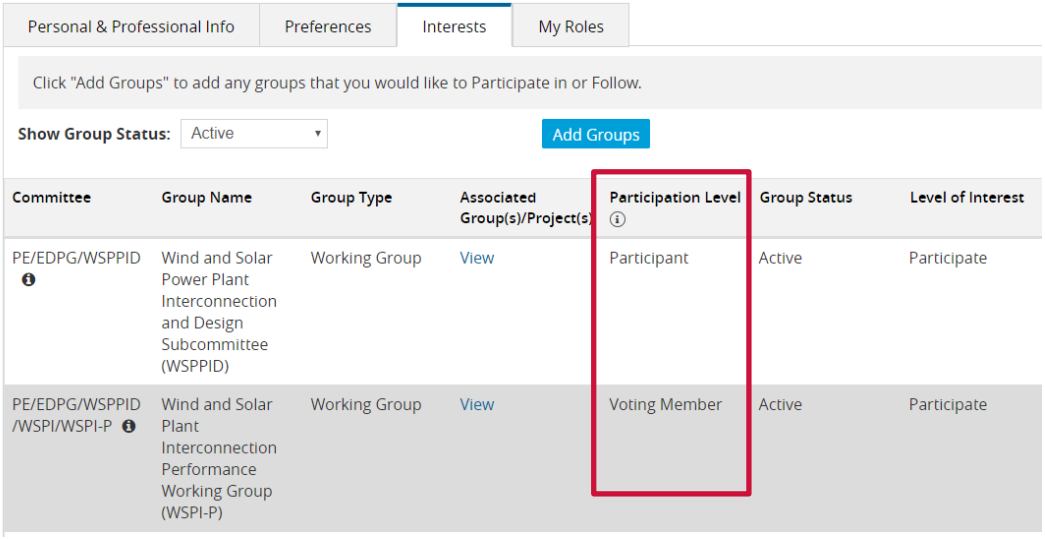


How To Check Membership Status and your Voting Rights on myProject?

1. On the **myProject™** Home Screen, click on **Menu** and then on **Manage Profile and Interests**.
2. Click on the **Interests** tab
3. Column “Participation Level” shows your level of involvement based on participation and voting rights as assigned by a group officer/administrator



If your voting rights are not correctly reflected on myProject, send a request to the secretary with your WG meeting attendance record to update the Participation Level

Meeting Goals

1. Review changes to Policies & Procedures and announce some leadership changes (for information only)

2. Convene Working Group, report on Sub-WGs' progress to date, and vote on Sub-WG's draft requirements & questions.

3. Future WG meetings and timeline for next P2800 draft

IEEE SA Rules,
Standards Classification & Language

Guidelines for IEEE WG meetings

- All IEEE-SA standards meetings shall be conducted **in compliance with all applicable laws**, including **antitrust** and **competition** laws.
  - Don't discuss the interpretation, validity, or essentiality of **patents / patent claims**.
  - Don't discuss specific **license rates, terms, or conditions**.
    - Relative costs of different technical approaches that include relative costs of patent licensing terms may be discussed in standards development meetings.
      - Technical considerations remain the primary focus
  - Don't discuss or engage in the fixing of **product prices, allocation of customers, or division of sales markets**.
  - Don't discuss the status or **substance of ongoing or threatened litigation**.
  - **Don't be silent** if inappropriate topics are discussed … do formally object.

- For more details, see **IEEE-SA Standards Board Operations Manual**, clause 5.3.10 and Antitrust and Competition Policy: What You Need to Know at http://standards.ieee.org/develop/policies/antitrust.pdf

Participants have a duty to inform the IEEE

- Participants shall **inform the IEEE** (or cause the IEEE to be informed) of the **identity of *each* holder** of any **potential Essential Patent Claims**
  - that are **potentially essential to implementation of the proposed standard(s)**
  - of which they are personally aware if the claims are owned or controlled by the participant or the entity the participant is from, employed by, or otherwise represents
- Participants should inform the IEEE (or cause the IEEE to be informed) of the identity of ***any other* holders** of potential Essential Patent Claims
- **Early identification** of holders of potential Essential Patent Claims is **encouraged**
- *At the WG Meeting on Nov 21, 2019, the WG Chair informed the WG that Officers were made aware of 3 potential Essential Patent Claims to date and encouraged WG members to submit others by e-mail.*

Ways to inform IEEE

- Cause an **LOA to be submitted** to the IEEE-SA (patcom@ieee.org); or
- Provide the **chair of this group** with the identity of the holder(s) of any and all such claims as soon as possible; or
- **Speak up now** and respond to this Call for Potentially Essential Patents
- If anyone in this meeting is personally aware of the holder of **any patent** claims that are **potentially essential to implementation of the proposed standard(s)** under consideration by this group and that are not already the subject of an Accepted Letter of Assurance, **please respond at this time** by providing relevant information to the WG Chair

Patent-related information

The patent policy and the procedures used to execute that policy are documented in the:

- *IEEE-SA Standards Board Bylaws*
  (http://standards.ieee.org/develop/policies/bylaws/sect6-7.html#6)
- *IEEE-SA Standards Board Operations Manual*
  (http://standards.ieee.org/develop/policies/opman/sect6.html#6.3)

Material about the patent policy is available at
http://standards.ieee.org/about/sasb/patcom/materials.html

If you have questions, contact the IEEE-SA Standards Board Patent Committee Administrator at patcom@ieee.org

IEEE SA
STANDARDS ASSOCIATION

IEEE SA COPYRIGHT POLICY

NOVEMBER 2019

IEEE

INSTRUCTIONS FOR CHAIRS OF STANDARDS DEVELOPMENT ACTIVITIES

At the beginning of each standards development meeting the chair or a designee is to:

- Show the following slides (or provide them beforehand)

- Advise the standards development group participants that:
  - IEEE SA's copyright policy is described in Clause 7 of the IEEE SA Standards Board Bylaws and Clause 6.1 of the IEEE SA Standards Board Operations Manual;
  - **Any material submitted during standards development, whether verbal, recorded, or in written form, is a Contribution and shall comply with the IEEE SA Copyright Policy;**

- Instruct the Secretary to record in the minutes of the relevant meeting:
  - That the foregoing information was provided and that the copyright slides were shown (or provided beforehand).

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- The IEEE SA Copyright Policy is described in the IEEE SA Standards Board Bylaws and IEEE SA Standards Board Operations Manual
  - IEEE SA Copyright Policy, see
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    Clause 6.1 of the IEEE SA Standards Board Operations Manual
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- IEEE SA Copyright FAQs
  - http://standards.ieee.org/faqs/copyrights.html/
- IEEE SA Best Practices for IEEE Standards Development
  - http://standards.ieee.org/develop/policies/best_practices_for_ieee_standards_development_051215.pdf
- Distribution of Draft Standards (see 6.1.3 of the SASB Operations Manual)
  - https://standards.ieee.org/about/policies/opman/sect6.html

Changes in IEEE P2800 Leadership Team

Role	Name	Affiliation	Stakeholder Group	Liaison
Chair	Jens C. Boemer	EPRI	Academic/Research	EDP&G, SCC21
~~Secretary~~	~~Wesley Baker~~	~~Power Grid Eng.~~	~~Service Provider/ Consulting~~	~~EMC, IRPTF~~
Vice-Chair	Bob Cummings	NERC	Regulatory and Governmental Bodies	NERC IRPTF
Vice-Chair	Kevin Collins	FirstSolar	Users, Industrial	NERC IRPTF
Vice-Chair	Babak Enayati	NationalGrid	Stakeholders represented in IEEE Power & Energy Society	T&D, SCC21, PES GovBrd
Vice-Chair	Ross Guttromson	SANDIA National Lab	Academic/Research	DOE
Vice-Chair	Chenhui Niu	State Grid Corporation of China	Stakeholders represented in IEEE P2800.1 Working Group	IEEE P2800.1, IEC SC8A
Vice-Chair	Manish Patel	Southern Company	Utility, Transmission	PSRC, IRPTF
Secretary & Treasurer	Diwakar Tewari	Leidos	Service Provider/ Consulting	EDP&G

Review changes to Policies & Procedures

- The sponsoring PES/ED&PG committee updated their Individual Method Working Group Policies & Procedures (PnPs) to align with the new IEEE Baseline Policies and Procedures for Standards Development – WGs - Individual (December 2017) available at https://standards.ieee.org/about/sasb/audcom/bops.html.
- These are the changes relative to the PnPs that were approved by the P2800 Working Group at the Kick-Off Meeting in January 2019 (available on iMeet at https://ieee-sa.imeetcentral.com/p/aQAAAAAEBR6i):
  - Separated offices of Secretary and Treasurer; can still be filled by same individual.
  - **Quorum revised** from “one-half of WG voting members” to “10% of the current total voting membership or 26, whichever is greater”; this expedites WG approvals.
  - Removed the need to include the “Title of the responsible *subcommittee* and its designation” in the WG roster; this removes burden from the Secretary.
- The new P2800 Working Group PnPs are available on iMeet at https://ieee-sa.imeetcentral.com/p/aQAAAAAEBR8d

Review and Approval of Meeting Agenda

February 6, 2020: 12PM – 4PM ET		
12:00 PM ET	Introduction • IEEE SA Rules, Standards Classification & Language • Leadership changes and review changes to Policies & Procedures (for information only) • Approval of agenda and of minutes from Nov/Dec 2019 virtual calls	J. Boemer
12:15 PM ET	Subgroup 1 & 2 discussion • I. Overall Document • II. General Requirements	J. Boemer / B. Cummings
12:35 PM ET	Subgroup 6 discussion • VI. Power Quality	R. Guttromson
12:55 PM ET	Subgroup 7 discussion • VII. Ride-Through Capability Requirements	B. Cummings
01:25 PM ET	Subgroup 8 discussion • VIII. Ride-Through Performance Requirements	M. Patel
01:35 PM ET	Subgroup 10 & 11 discussion • X. Modeling & Validation, Measurement Data, and Performance Monitoring • XI. Tests and verification requirements	M. Patel/C. Niu
02:15 PM ET	Break	All
02:30 PM ET	Subgroup 9 discussion • IX. IBR Protection	B. Enayati/J. Espinosa
03:05 PM ET	Subgroup 3 discussion • III. Active Power – Frequency Control	K. Collins
03:25 PM ET	Subgroup 4 discussion • IV. Reactive Power – Voltage Control	K. Collins/W. Baker
03:45 PM ET	Subgroup 5 discussion • V. Low Short-Circuit Power	R. Guttromson
02:30 PM ET	Wrap up	J. Boemer
04:00 PM ET	Adjourn	J. Boemer

Approval of Previous Meetings' Minutes

- WG Meeting in September 2019: https://ieee-sa.imeetcentral.com/p/ZgAAAAAAuc8P
- Virtual WG Mtg on Nov 21, 2019: https://ieee-sa.imeetcentral.com/p/aQAAAAAD_rs6
- Virtual WG Mtg on Dec 6, 2019: https://ieee-sa.imeetcentral.com/p/aQAAAAAD_-wr
- Virtual WG Mtg on Dec 17, 2019: https://ieee-sa.imeetcentral.com/p/aQAAAAAEAOaA
- No approval required for the informal WG Meeting on Jan 13, 2020, at the JTCM in Jacksonville.

➢ Motion to approve all the above minutes.
  – *Check for quorum.*

Subgroup 1 & 2 discussion

I. Overall Document

II. General Requirements

Reminder:
IEEE Standards Classification & Language

No use of "can"!

IEEE P2800

IEEE Std 1547

IEEE Std 1547.1

Standards
documents specifying mandatory requirements (***shall***)

Recommended Practices
documents in which procedures and positions preferred by the IEEE are presented (***should***)

Guides
documents that furnish information – e.g., provide alternative approaches for good practice, suggestions stated but no clear-cut recommendations are made (***may***)

IEEE P2800.1

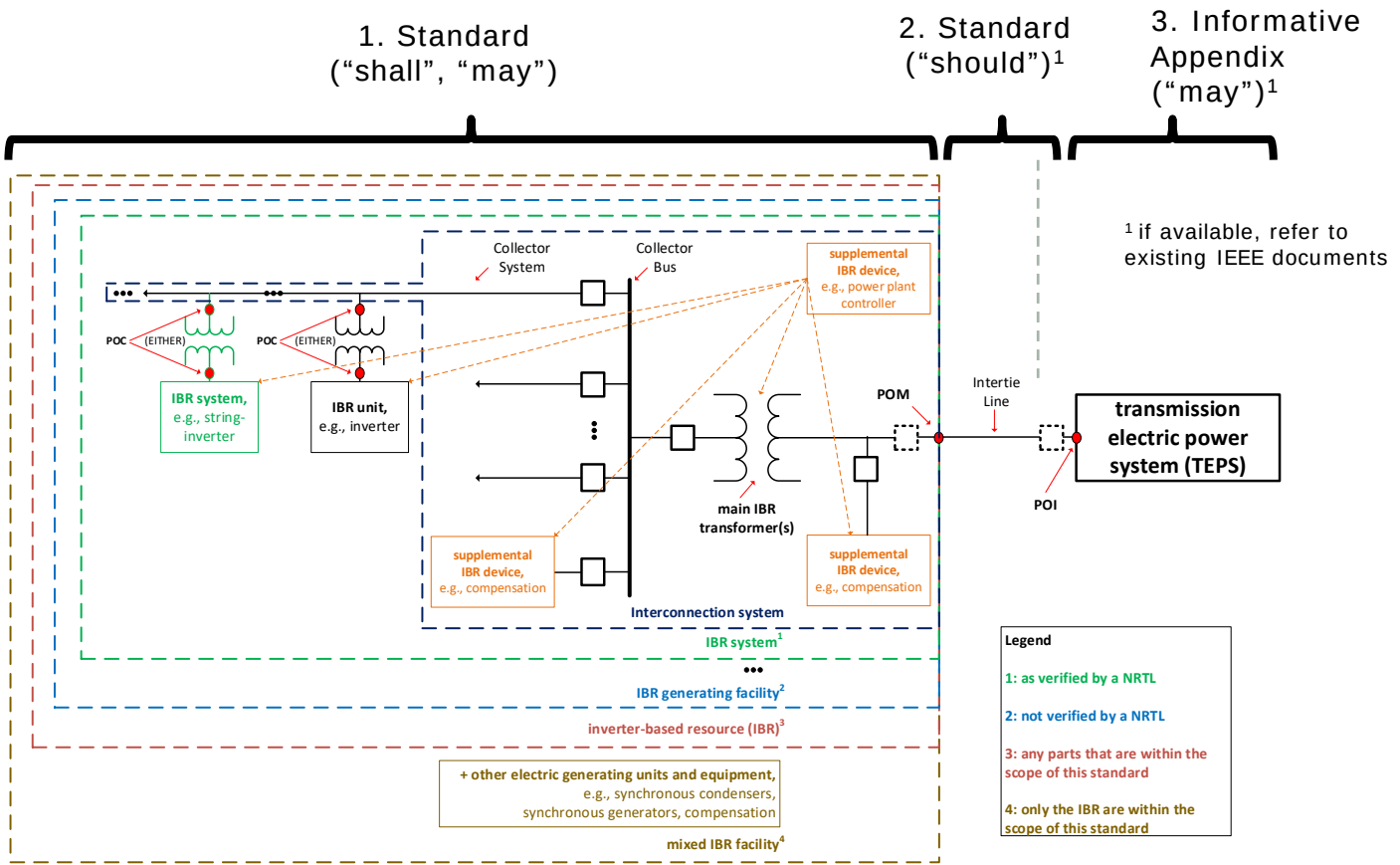
IEEE P1547.2

IEEE P1547.3

IEEE P1547.9

Scope and Language of P2800 Requirements

- POC (terminals)
  - Unit
  - System
- POM (plant)
  - Generating Facility
- POI (interconnection)
  - Generating Facility
  - Intertie line
- TEPS (grid)
  - Bulk power system



Definitions developed in SG1+2

- Latest definitions are available on iMeet: https://ieee-sa.imeetcentral.com/p/aQAAAAAEA4tv
  - 85 definitions proposed in total
  - 60 definitions are completed
  - 11 definitions need more SubGroup discussion
  - 14 definitions need Working Group review
- Symbolic key indicates origin:

(no symbol) IEEE Dictionary	♦ NERC IRPTF
♥, ♣, ■ IEEE Std 1547™-2018	♠ New Definition

- Definitions that need WG review:
  - applicable voltage (identical to below)
  - applicable frequency (identical to above)
  - clearing time (refers to trip)
  - energize (noun or verb?)
  - flicker (for SG6, PQ)
  - IBR load (deleted)
  - main IBR transformer (GSU?)
  - testing agency (NRTL, delete?)
  - high voltage (deleted)
  - momentary cessation (delete?)
  - protective function(s)
  - lock-out (new definition)
  - trip (electric separation)
  - zero-sequence continuity (ask SG9 if can be deleted)

Subgroup 1 + 2 Polling Questions

1. If the same term or concept is defined in both the IEEE Std 1547™-2018 and the NERC IRPTF guideline, which definition should P2800 preferably use?
   - IEEE 1547-2018 definition
   - NERC IRPTF definition

2. Besides wind, solar PV, and battery energy storage, should P2800 also include other inverter-based resources, such as fuel cells, etc.?
   - Yes
   - No

Subgroup 6 discussion

VI. Power Quality

Power Quality Draft Requirements and Questions

- The latest SubGroup 6 draft with power quality requirements is available on iMeet: https://ieee-sa.imeetcentral.com/p/aQAAAAAEBX6D

1. Do you think SubGroup 6's draft Power Quality Requirements go into the right direction for P2800?

7.1 Limitation of dc injection

(Subtopic Lead Dave Mueller)

- The IBR shall not inject dc current greater than 0.5% of the full rated output current at the reference point of applicability (RPA).

(Note that DC current will not pass through the step-up transformer)

7.2.2 Rapid voltage changes (RVC / Flicker)

(Subtopic Lead Harish Sharma)

- $E_{pst.}$ 0.35
- E_{plt} 0.25

- Assessment and measurement methods for flicker are defined in IEEE Std 1453 and IEC/TR 61000-3-7. In addition, the following shall apply:
- Equipment other than a IBR unit shall be allowed to mitigate the flicker induced by a IBR system.
- E_{Pst} is the emission limit for the short-term flicker severity, P_{st} If not specified differently, the P_{st} evaluation time is 600 s.
- E_{Plt} is the emission limit for long-term flicker severity, $P_{lt.}$ If not specified differently, the P_{lt} evaluation time is 2 h.
- P_{lt} can be calculated by using $P_{lt} = \sqrt[3]{\frac{1}{12}\sum_{i=1}^{12} P_{st_i}^3}$

where (i = 1, 2, 3, ...) are consecutive readings of the short-term severity P_{st}

7.3 Limitation of Voltage and Current distortion

(Subtopic Lead Ramesh Hariharan)

Voltage Limits

The maximum allowable voltage distortion at the PCC is shown below in Table 14.

Table 14 —Maximum Voltage distortion in percent of rated voltage (V1)

Bus Voltage V at PCC	Individual Voltage distortion (Vi) (%)	Total Harmonic Distortion including inter-harmonic (THD) (%)
V <= 69kV	3.0	5.0
69kV < V <= 161 kV	1.5	2.5
161 kV < V	1	1.5

7.3 Limitation of Voltage and Current distortion

Voltage Limits (continued)

Notes to the limits:

1. IBR plants are subject to non-incremental harmonic voltage limits which is a responsibility that the utility IBR owner and IBR plant owner must share.
2. The utility is required to ensure the system's voltage harmonic content is below the limits stated in Table 14 prior to the interconnection of any IBR plant. Harmonic Voltage background measurements are needed before the plant commissioning. Its recommended to take seasonal harmonic measurements with different grid loading and generation conditions.
3. The limits specified in the Table 14 is a joint responsibility between TEPS and IBR plant. It is recommended that TEPS and IBR plant discuss/collaborate on harmonic levels that could be injected to meet the limits specified in Table 14 or voltage harmonic level that would be acceptable to TEPS. Additionally, upon mutual agreement between the facility and the utility, the limits shown in Table 14 may be exceeded.
4. The grid voltage at the at the point of common coupling (PCC) should be balanced within 2% of the rated voltage for the limits specified in Table 14 to be enforced in accordance with IEC 61400-21.
5. Care should be utilized when Capacitively Coupled Voltage Transformers (CCVTs) are used for measuring voltage harmonics. An applicable Ratio Correction Factor may need to be applied.

$$THD\% = \frac{\sqrt{Vrms^2 - V_1^2}}{V_1} \qquad (2)$$

7.3 Limitation of Voltage and Current distortion

Current Limits

Table 15 -- Current Distortion Limits

Individual odd and even harmonic or h	RPA LL Voltage (kV)	h < 11	11≤ h < 17	17 ≤ h	Total rated current distortion (TRD)
Percent (%)	<=69	4.0	2.0	1.5	5.0
	69.001 - 161	2.00	1.00	1.00	2.50
(see note 1 below)	>161	1.5	1.0	1.0	2.0

Notes to the limits:

1. The limits for systems >161 are modified from the IEEE 519-2014 requirements. The values in the table are closer to the original limits that were in the IEEE 519-1992 version. This change was made so that resistive loads can meet the requirements if the system voltage distortion is below the recommend harmonic guidelines.
2. An IBR plant should not be subjected to harmonic current limits if the harmonic currents at the PCC cause the voltage harmonics to decrease.
3. IBR plants are subject to absolute harmonic current injection limits as long as the harmonic currents are large enough to be measured within reasonable accuracy. Otherwise, limits that are below the resolution of measuring equipment do not apply.
4. System studies may show that limits omitted from IEEE 519-2014 limits are harmful, then they should be implemented per the study results. Likewise, if a study shows that these limits are too restrictive, then they should be relaxed.

7.3 Limitation of Voltage and Current distortion

Current Limits (continued)

The total rated current distortion (TRD) in Table 15, which includes the harmonic distortion and inter-harmonic distortion, can be calculated using Equation (2):

$$\%TRD = \frac{\sqrt{I_{rms}^2 - I_1^2}}{I_{rated}} \times 100\%$$

Where:

I1 is the fundamental current as measured at the RPA

Irated is the IBR rated current capacity based on IBR MVA rating at the RPA (calculated based on the interconnection request) without any shunt devices installed as part of the installed project.

7.3 Unbalanced Voltages

(Subtopic Lead McPharlen Mgunda)

- These standards are currently being discussed. They will likely be established in the form of negative sequence current withstand. Consistency with current design standards used in wind turbines will be highly encouraged

Subgroup 7 discussion

VII. Ride-Through *Capability* Requirements

Some General Thoughts

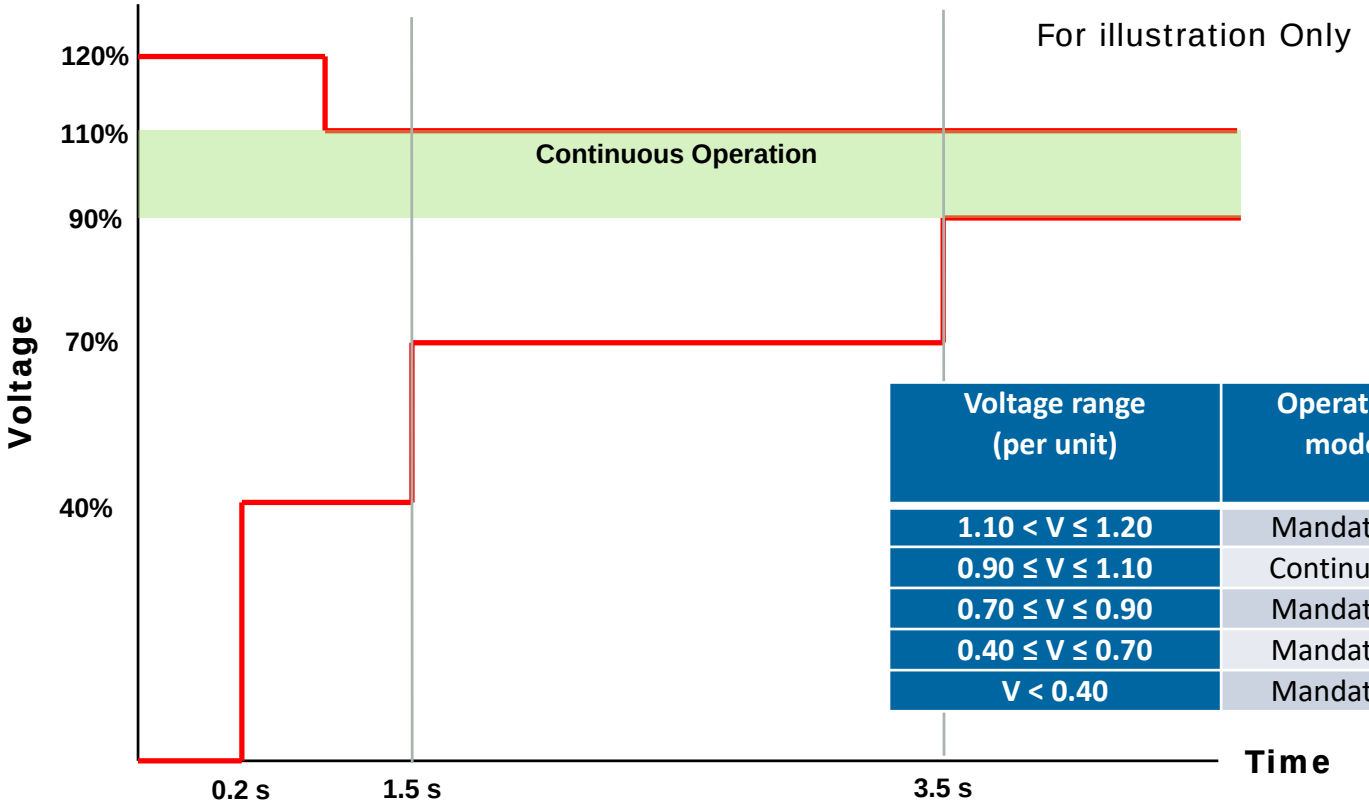
- Voltage dips and recovery have many forms and duration.
  - Transmission planning events are often defined as the worst-case
  - Actual events look different: shallower voltage dip, longer recovery.
- During low voltage ride-through (LVRT), energy exchange with the grid is limited. IBR shall be capable of…
  - maintaining reliable operation of auxiliary equipment like controls, and
  - handling mechanical stress.
- IBR self-protection shall not be allowed to operate “near” the specified LVRT curves.
  - LVRT curves are not intended to be used for programming of IBR protection.

Q1: Voltage Ride-Through Capability Curve

- What is your interpretation of (or expectation from) the voltage ride-through capability curve?

1. Voltage versus Time Curve: For a given voltage, IBR shall not trip until the duration at this voltage exceeds ride-through curve boundary (similar to NERC PRC-024 curve).
2. Voltage Deviation *times* Time Area: Area between a nominal voltage (100%) and either a low or high voltage ride-through boundary.
3. Volt versus Time Envelope: Ride-through curves define an envelope to lay as a template over a voltage versus time trajectory.

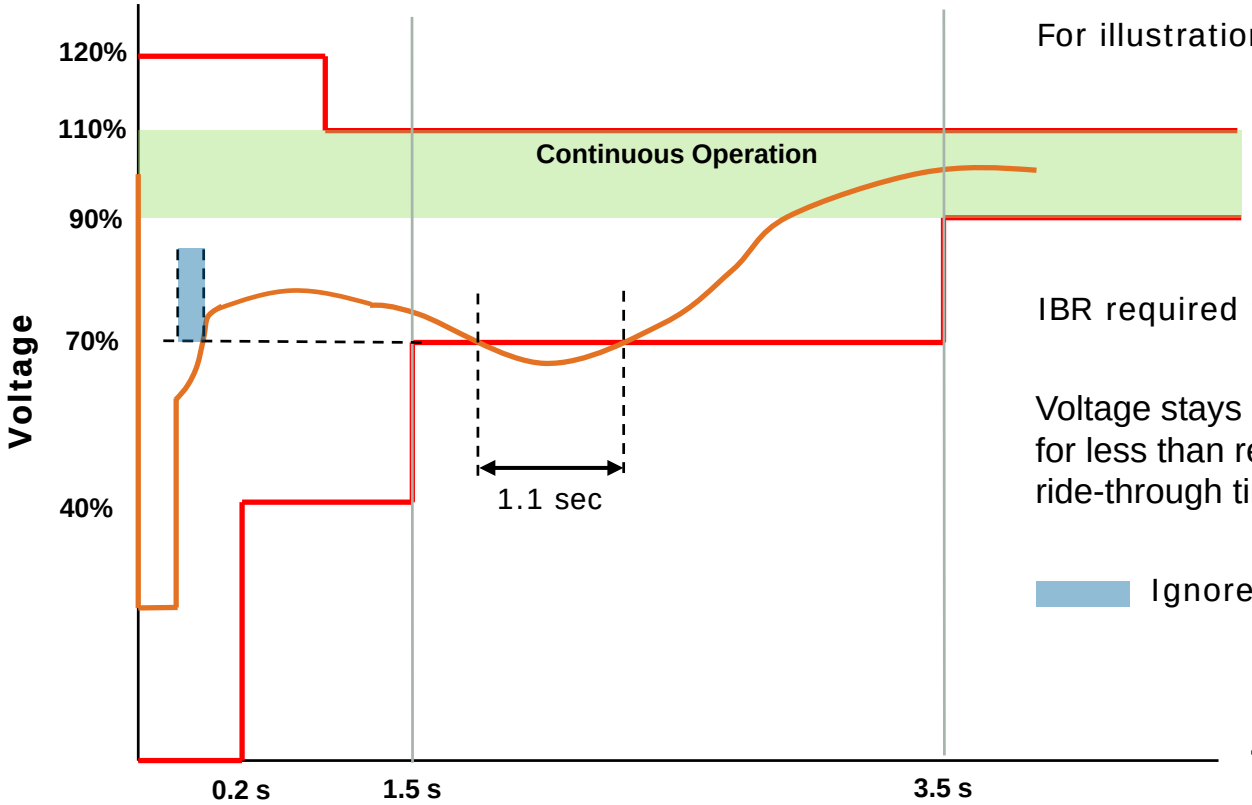
Voltage Ride-Through: Example



Voltage range (per unit)	Operating mode	Minimum ride-through time (seconds)
1.10 < V ≤ 1.20	Mandatory	1.0
0.90 ≤ V ≤ 1.10	Continuous	Infinite
0.70 ≤ V ≤ 0.90	Mandatory	3.0
0.40 ≤ V ≤ 0.70	Mandatory	1.3
V < 0.40	Mandatory	0.2

Interpretation #1: Volt versus Time Curve

similar to NERC PRC-024 curve



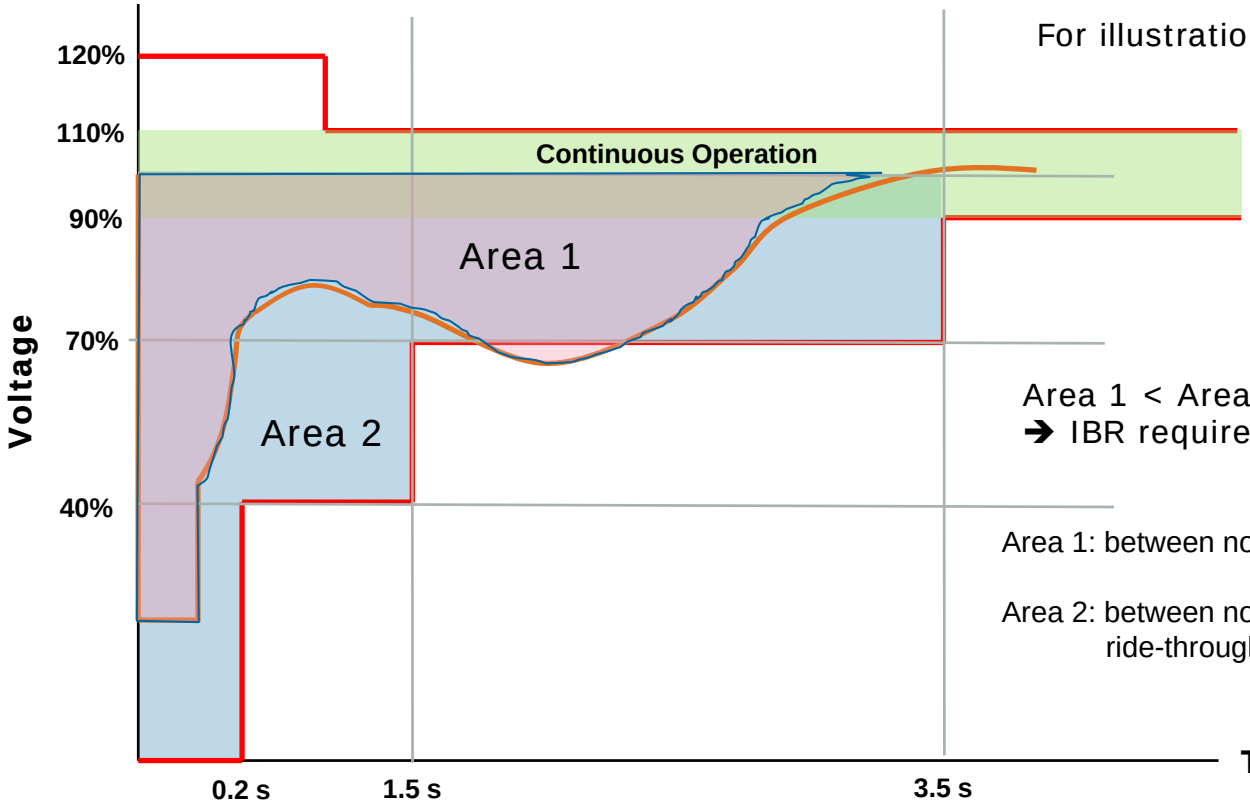
For illustration Only

IBR required to ride-through

Voltage stays between 40% and 70% for less than required 1.3 second ride-through time

Ignore for now

Interpretation #2: Voltage Deviation *times* Time Area



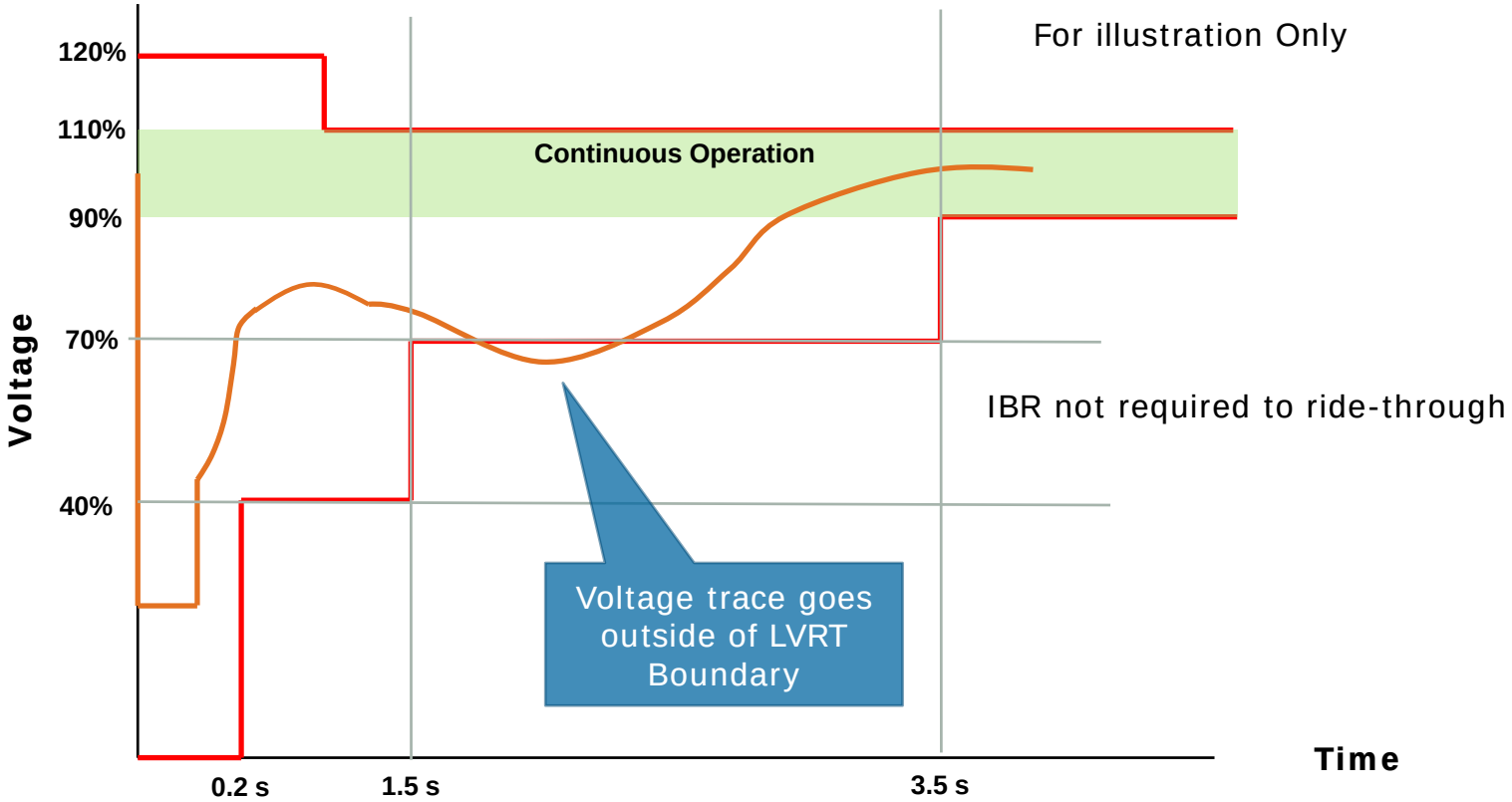
For illustration Only

Area 1 < Area 2
➔ IBR required to ride-through

Area 1: between nominal and voltage trace

Area 2: between nominal and low voltage ride-through boundary

Interpretation #3: Volt versus Time Envelope



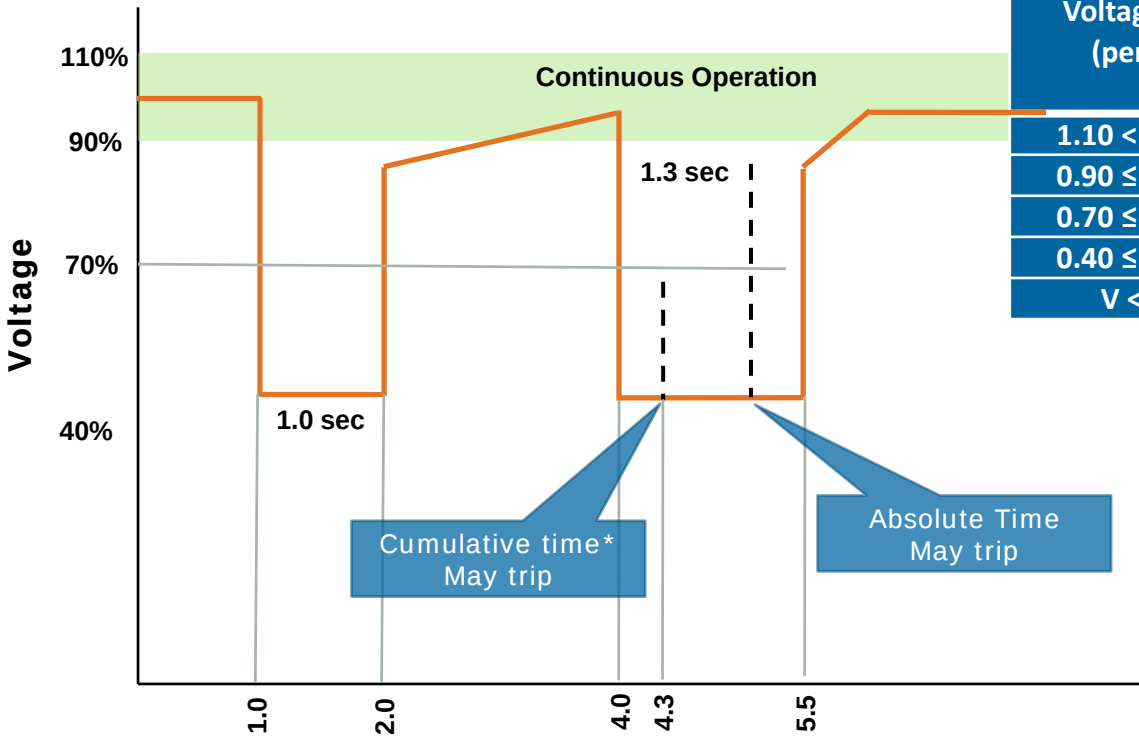
Q2: Cumulative or Absolute Time?

- What is your interpretation of (or expectation from) the time axis of the voltage ride-through capability curve?

1. Cumulative Time
   - duration of voltage condition in a specified moving time window
2. Absolute Time
   - time passed since voltage goes beyond specified threshold
   - similar to digital relay functioning

Interpretation #1: Volt versus Time Curve

Cumulative or Absolute Time



Voltage range (per unit)	Operating mode	Minimum ride-through time (seconds)
1.10 < V ≤ 1.20	Mandatory	1.0
0.90 ≤ V ≤ 1.10	Continuous	Infinite
0.70 ≤ V ≤ 0.90	Mandatory	3.0
0.40 ≤ V ≤ 0.70	Mandatory	1.3
V < 0.40	Mandatory	0.2

*Needs defining of a moving time window.

Subgroup 8 discussion

VIII. Ride-Through *Performance* Requirements

Ride-Through *Performance* Requirements

General Requirements

During a ride-through mode,

- *IBR shall continue to exchange current with the Area TEPS based on note 1.*
- *IBR unit shall be capable to inject current to its maximum limit.*
- *The Area TEPS may specify required magnitude of current injection within IBR unit's limits based on system studies.*

Note 1: The type and magnitude of current injection during ride-through mode shall be dependent on voltage deviation at the terminals of the inverter. The inverter shall maintain automatic voltage control during ride-through operation.

Ride-Through Per Requirements
Fault Response

No specification for current magnitude

Time required (1 cycle DFT) to extract phasor quantities (active, reactive, positive, negative sequence currents etc.) is included in times specified in this table.

Between initiation of a fault and a rise of current to 90% of the final value.

	Type III WTG	Type IV WTG, PV, BESS
Step Response Time	NA[1]	<=~2.5 cycles (<=40 ms)
Settling Time	<=6.0 cycles (<=100 ms)	<=~4.0 cycles (<=65 ms)

Note 1: Induction Gen, response based on machine parameters, during crowbar action frequency may be different from system frequency

Slower response may be allowed with mutual agreement between area TEPS and resource owner.

Ride-Through *Performance* Requirements

Negative Sequence Current

- *During unbalanced faults, inject unbalanced current, i.e., inject reactive current in a faulted phase(s) only based on the respective terminal voltage[1].*
  - *This results in injection of negative sequence reactive current and it leads the terminal negative sequence voltage by 90 degrees.*
- *Similar to concept of active and reactive current priority:*
  - *If negative sequence current output is limited by IBR unit's rating, positive sequence current can be reduced.*
  - *However, positive sequence current output shall not be reduced below negative sequence current output.*
  - *The Area TEPS may require a specific ratio of negative sequence to positive sequence current.*

1: Type III WTGs naturally contributes negative sequence current

Ride-Through *Performance* Requirements

Question: Do you think SubGroup 8's draft Ride-Through Performance Requirements go into the right direction for P2800?

Subgroup 10 & 11 discussion

X. Modeling & Validation, Measurement Data, and Performance Monitoring

XI. Tests and verification requirements

Why Requirement for Models in a Performance Standard?

- Some performance requirements, such as performance during voltage ride-through mode, cannot be verified based on test results. *IBR Evaluation* using models is necessary during study process & commissioning.

  – Verified Models are necessary.

- IBR Evaluation: IBR Evaluation comprises a design evaluation study during the interconnection review process and an as-built evaluation at the time of commissioning and regular operation review to verify that the IBR system (facility) meets performance requirements of this standard. .

Why Requirement for Models in a Performance Standard?

- Verified Models are necessary for IBR Evaluation.

- Upon request from Area TEPS, IBR owner shall provide verified plant level models such as:
  - Steady-state, RMS (generic and/or user written), EMT, Short Circuit etc.

Potential Performance Requirements Verification methods

I. Type Tests (NRTL, manufacturer)

II. Production Tests (manufacturer)

III. IBR Evaluations (IBR developer, TEPS operator and/or 3rd party)
- *Guidance on how to use modeling for verification purposes could be given in P2800.1.*

IV. Commissioning Tests (TEPS operator and/or 3rd party)

V. Post-Commissioning Test/Verification (TEPS operator and/or 3rd party)
- *Periodic/scheduled tests (Lifecycle, Major Changes)*
- *Verification required if any changes occur*
- *Post-event analysis, as they occur (use of digital fault recordings, need to define what to measure)*
- *Any post-commissioning measurements if a “Conditional Permission to Operate" had been issued during the commissioning step*

Test & verification requirements in P2800 vs. P2800.1 – *What belongs where?*

	P2800	P2800.1
1) Any **performance requirement** that can be verified with any of the verification methods below*	X	
2) For each performance requirements from 1), specify **which verification method*** shall be used ▪ Current practice for BPS-resources is verification of performance by post-event analysis ▪ SubGroup XI. (Tests and verification requirements) to start with a structure similar to Tables 43 and 44 in IEEE 1547-2018 but need to add additional column(as) as needed. See next slides for details.	X	
3) For each performance requirement from 1), specify guidelines for detailed **verification procedures** (step-by-step instructions) regarding **how** to conduct the required verification method* ▪ SubGroup XI. (Tests and verification requirements) to start with P1547.1 Draft 9.6 (Recirc 2)		X

*** Potential Verification methods**

I. Type Tests (NRTL, manufacturer)
II. Production Tests (manufacturer)
III. IBR Evaluations (IBR developer, TEPS operator and/or 3rd party)
   - Guidance on how to use modeling for verification purposes could be given in P2800.1.
IV. Commissioning Tests (TEPS operator and/or 3rd party)
V. Post-Commissioning Test/Verification (TEPS operator and/or 3rd party)
   - Periodic/scheduled tests (Lifecycle, Major Changes)
   - Verification required if any changes occur
   - Post-event analysis, as they occur (use of digital fault recordings, need to define what to measure)
   - Any post-commissioning measurements if a “Conditional Permission to Operate" had been issued during the commissioning step

Verified Models

Verification philosophy could vary among OEMs. A common practice to develop verified models is:

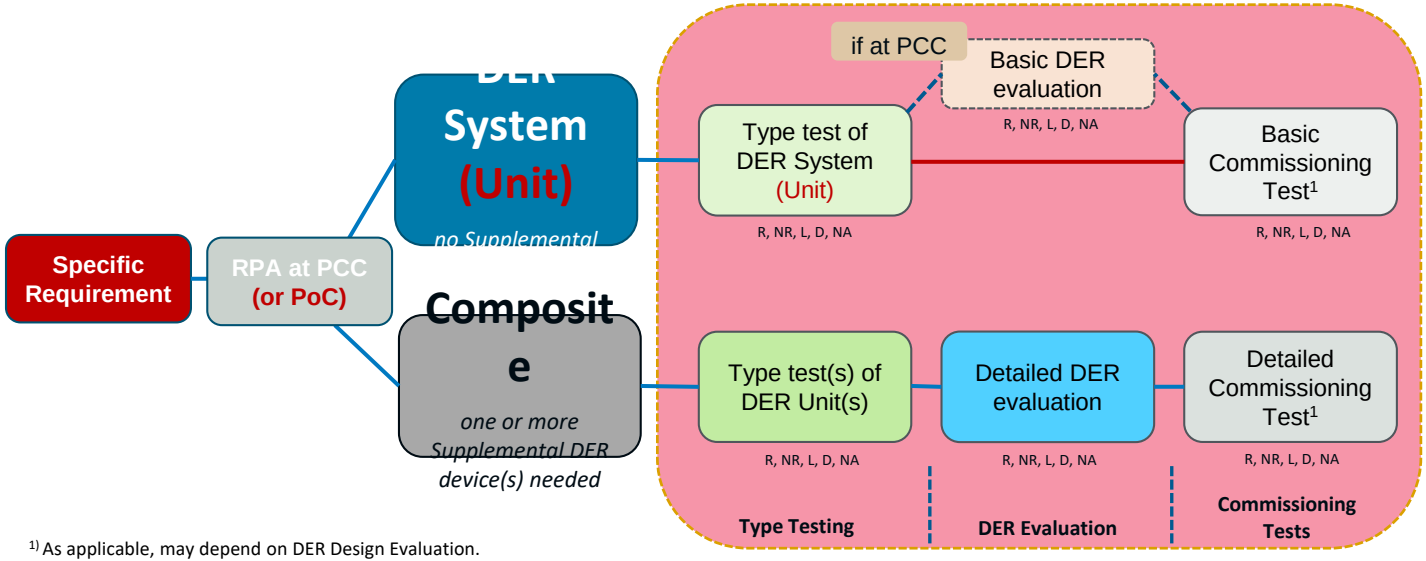
- Non-aggregated IBR unit EMT model – shall be verified with test results.
- Aggregated plant level EMT model – developed using verified IBR unit and supplementary equipment models.
- Positive sequence IBR unit RMS dynamic (user written and generic) & short circuit models, etc. – shall be verified against non-aggregated IBR unit EMT model.
  - The plant controller aspect of the RMS model is typically verified or calibrated with plant commissioning test results.

Plan to reference existing literature that discusses development of models. Advise if aware of any.

Example New IEEE 1547-2018 Test & Verification Requirements for DER

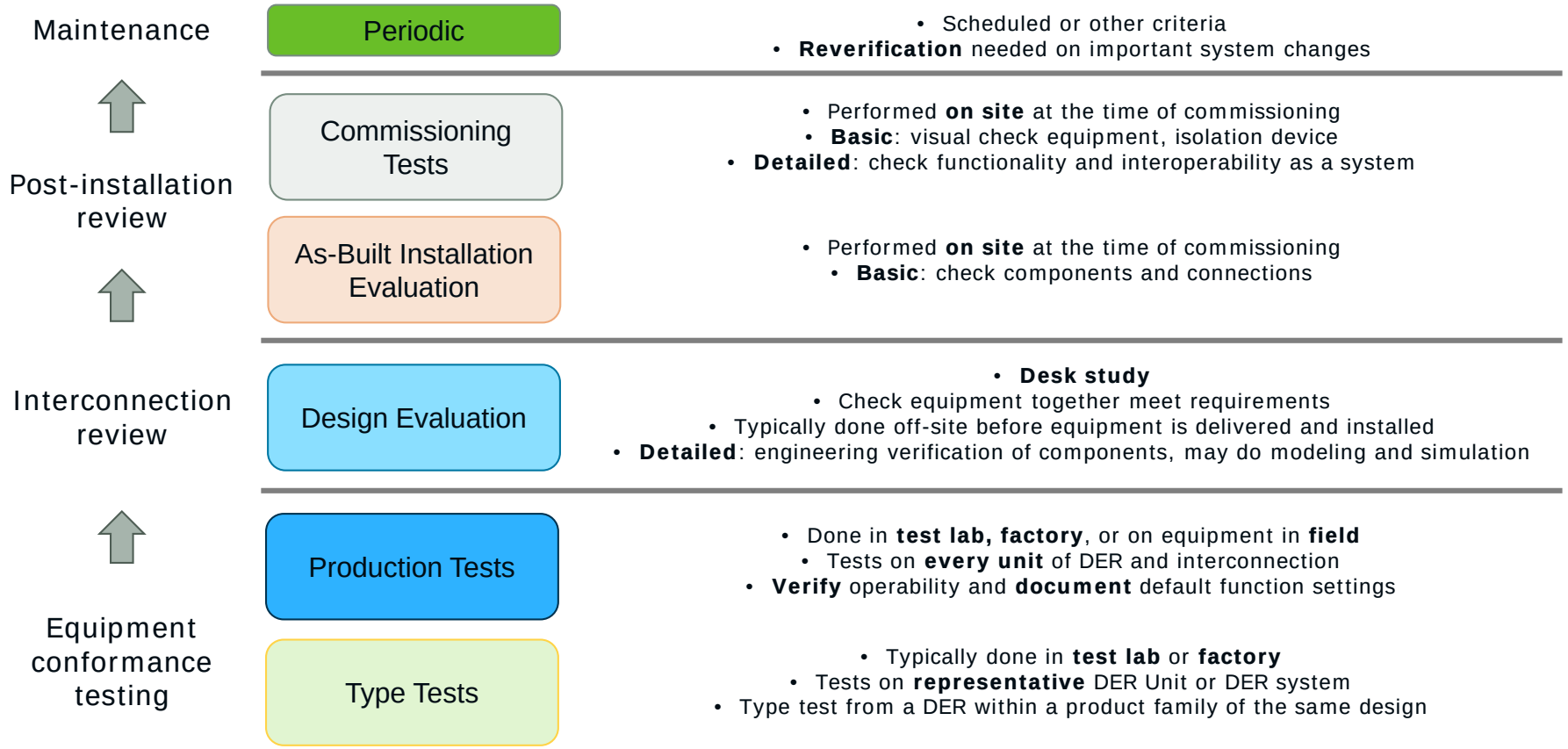
What's the requirement? → Where's the reference point of applicability? → DER Capability & Conformance achieved by → Category of test and verification needed

R: Required
NR: Not required
L: Limited
D: Depends on DER design eval.
NA: Not applicable

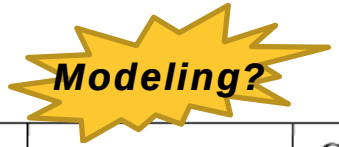


[1] As applicable, may depend on DER Design Evaluation.

High-Level Test and Verification Process



Examples from Clause 11 of IEEE 1547-2018

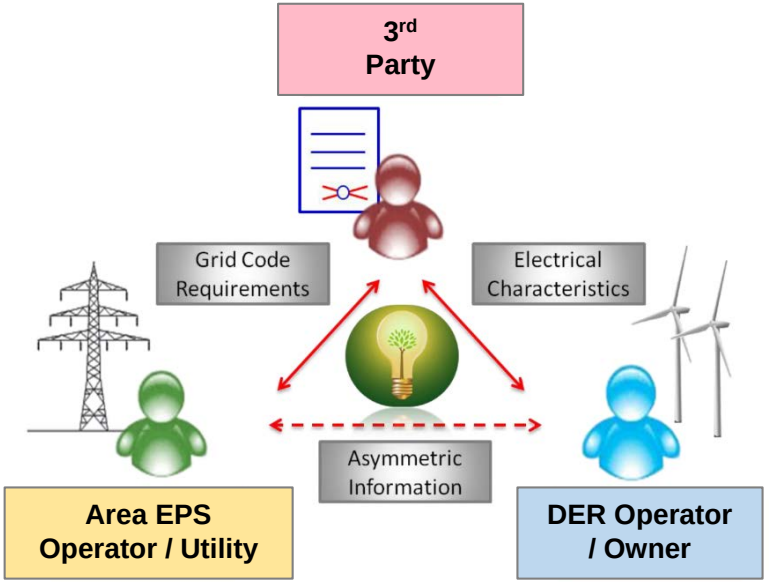


Requirement	Compliance at PCC achieved by:	Type tests	IBR evaluation	Commissioning tests
6.4 Voltage				
6.4.1 Mandatory voltage tripping requirements	DER System	R	Design: R[a] Installation: R[b]	D
	Composite	L	Design: R[a] Installation: R[b]	D
6.4.2.1 General requirements and exceptions	DER System	R	R	D
	Composite	L	R	D[a]
6.4.2.2 Voltage disturbances within continuous operation region	DER System	R	Design: R[a] Installation: R[b]	D
	Composite	L	R	D[a]

- Review Tables 43 and 44 of IEEE Std 1547™-2018 as needed: **R**equired; **L**imited; **D**epends

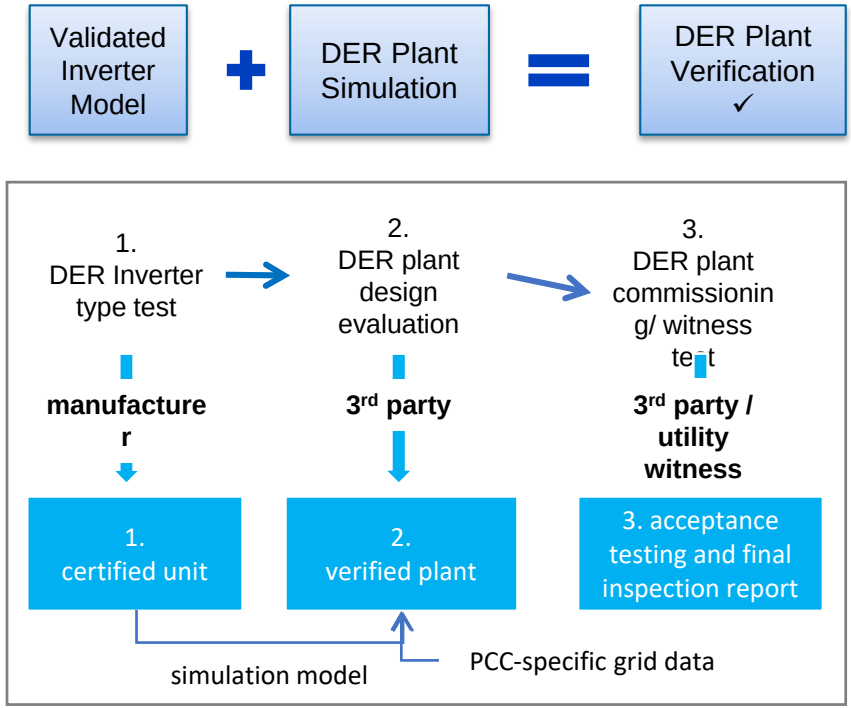
Example Verification Requirements for Utility-Scale DER Facilities in Germany

The Certification Triangle



Source: J. Langstädtler, B. Schowe-Von der Brelie, and F. Kalverkamp, "Certified wind power plants as a dependable solution for effective system integration," in World Wind Energy Conference, 2012.

The Certification Triplet



Break

Subgroup 9 discussion

IX. IBR Protection

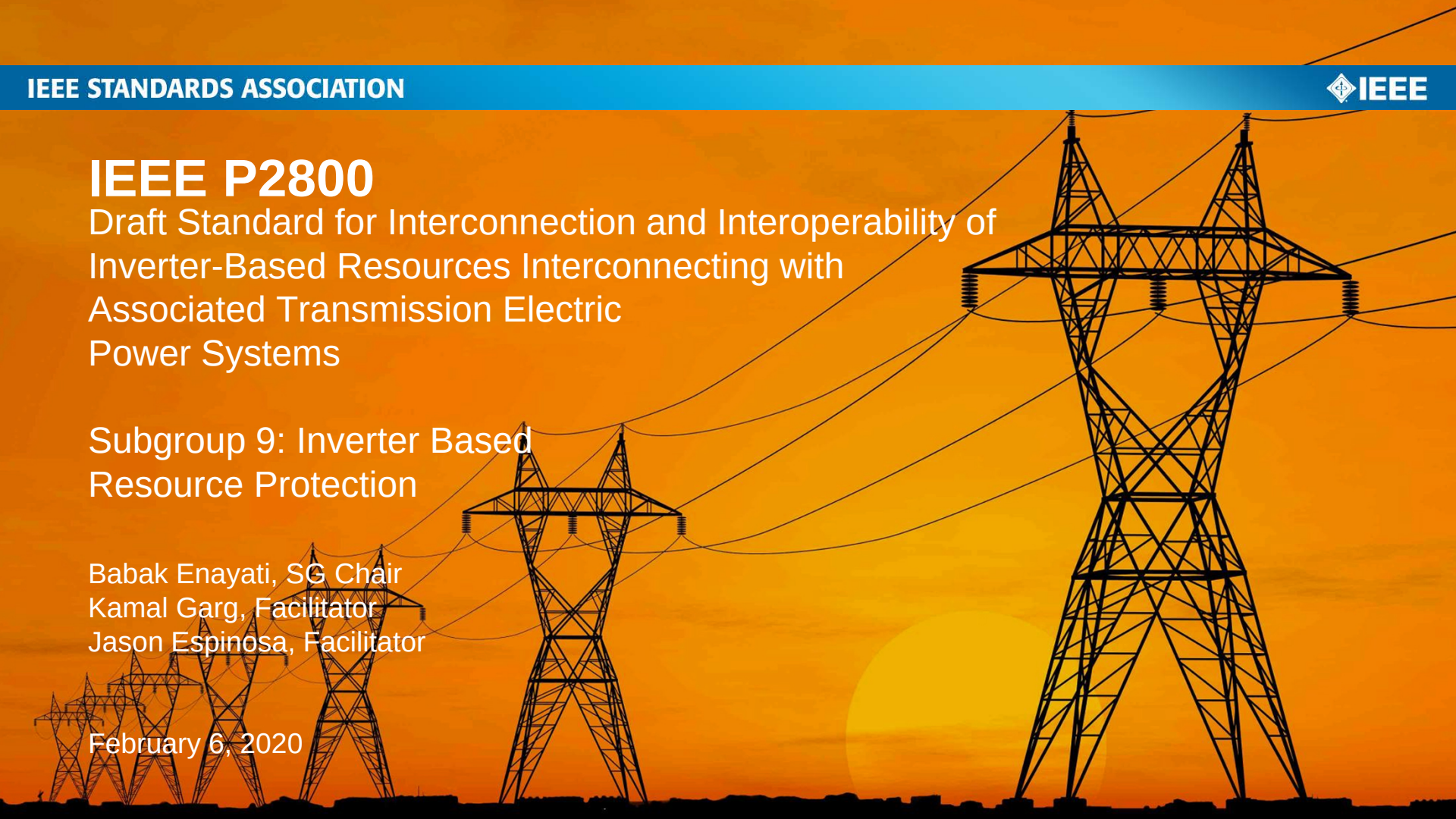
IEEE P2800

Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems

Subgroup 9: Inverter Based Resource Protection

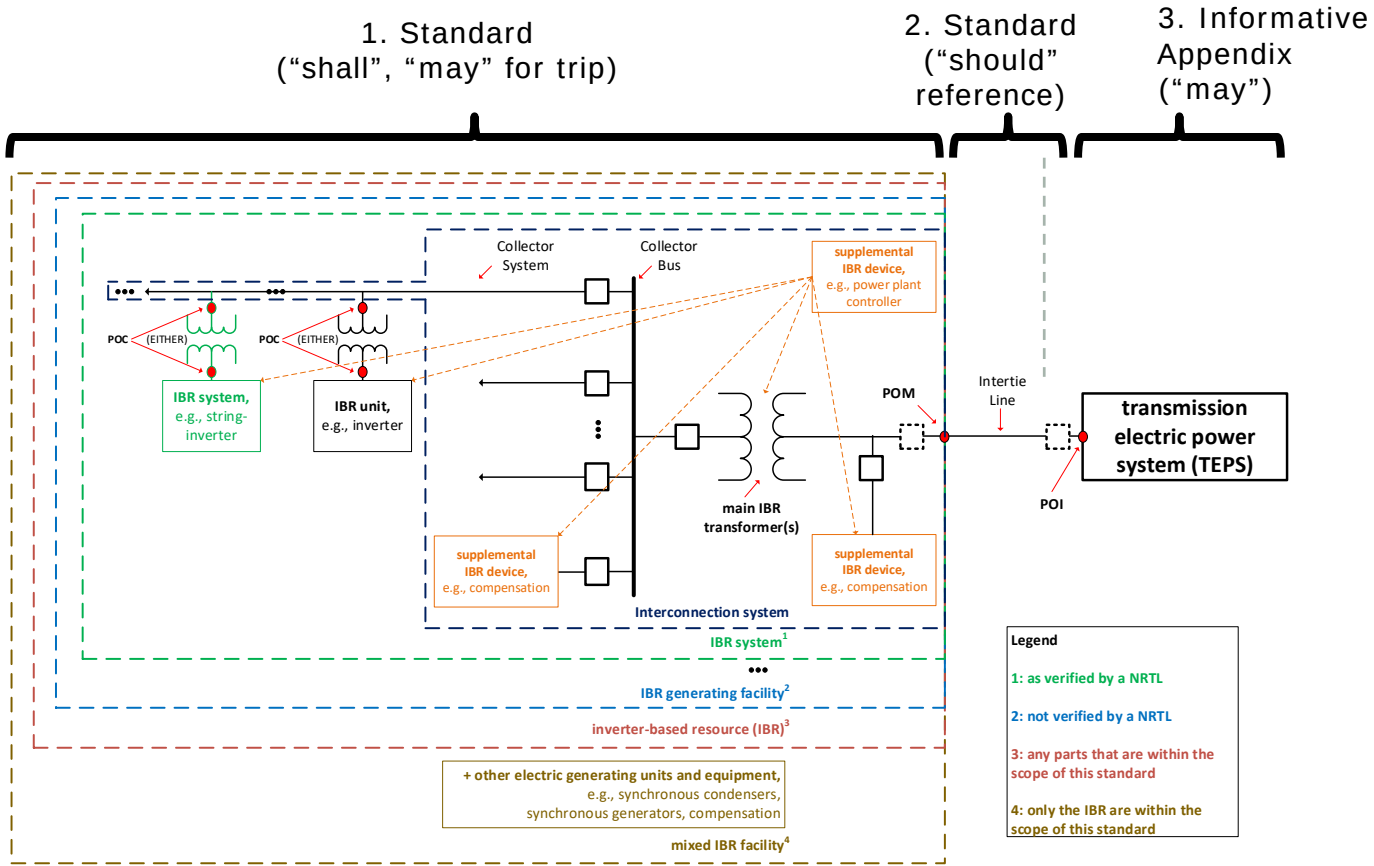
Babak Enayati, SG Chair
Kamal Garg, Facilitator
Jason Espinosa, Facilitator

February 6, 2020



Scoping of protection requirements

- POC
  - Unit
  - System
- POM
  - Generating Facility
- POI
  - Generating Facility
  - Intertie line
- TEPS
  - System protection



DC Phase Overcurrent Protection

- Should we make minimum requirements for DC Reverse Current/Overcurrent Protection??
  - This protection scheme is located on the DC side of the IBR unit
  - This is a self protection function that will react to voltage transients on the AC system.
- There was a misoperation in the Blue Cut Wild Fire event
  - The element was set too sensitive and responded to a transmission level fault
  - DC overcurrent protection should not operate for an AC grid system transient that does not risk damage to the associated equipment.
- **Should P2800 specify low- and high-voltage ride-through requirements that include the appropriate design of DC Reverse Current/Overcurrent Protection?**

Loss of Synchronism (Phase Lock Loop)

- This function was identified in the IBR Protection chapter of the NERC IRPTF BPS Connected IBR Performance
- Phase Lock Loop (PLL) is a function within a control loop that tracks the voltage phase angle of the grid and enables the inverter to follow the grid.
- We believe that this is a control function/stability issue instead of a protection function.
  - Inaccurate PLL angles and severe voltage angle excursions can cause stability and control problems

- **Should P2800 specify voltage ride-through requirements that include the appropriate design of Phase Lock Loop Loss?**

Loss of Synchronism (Phase Lock Loop)

- **Should P2800 specify voltage ride-through performance requirements in case of PLL Loss of Synchronism?**

Phase Voltage Protection

- SG9's current position on requirements
  - Any control system within the IBR generating facility shall **NOT** use an instantaneous operating quantity for the voltage protection algorithm.
  - IBR unit voltage protection shall be used in conjunction with surge arrestors to allow adequate ride-through capability
    - These arrestors will help clamp transient voltages to acceptable BIL levels
- **Should P2800 prohibit instantaneous voltage measurement as a criteria for voltage protection?**
- **Should P2800 specify the usage of surge arrestors, in conjunction with a voltage protection scheme, to clamp transient voltage spikes?**

Interconnection System Protection

- We will focus on creating requirements for the performance of the protection system between the high-side of the GSU and the interconnecting system
  - This is identical to the scope of NERC PRC-025
- The protection system **MUST** have sufficient infrastructure to reliably protect the interconnecting system from all possible abnormalities
- The infrastructure **MUST** include a communication medium
- A communication-based protection scheme must be implemented as the primary protection system

Questions?

Subgroup 3 discussion

III. Active Power – Frequency Control

Sub-Group 3 Priorities

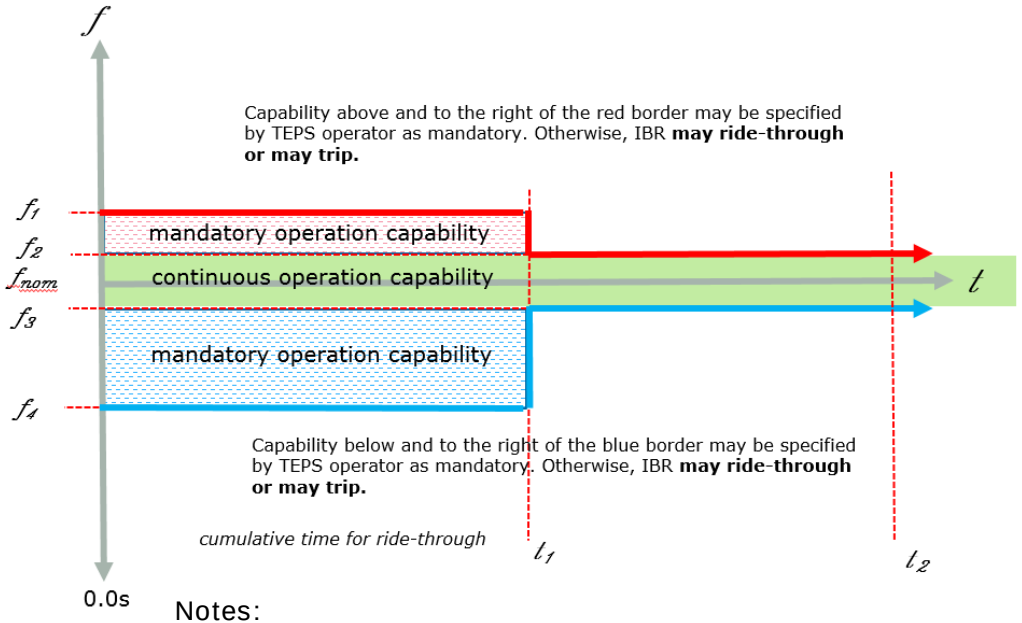
Today

- Frequency Ride-through capability

Next Up

- Primary Frequency Response
- Fast Frequency Response
- Frequency measurement (work with Sub-Group 2)

Sub-Group 3 – Frequency Ride-through Capability

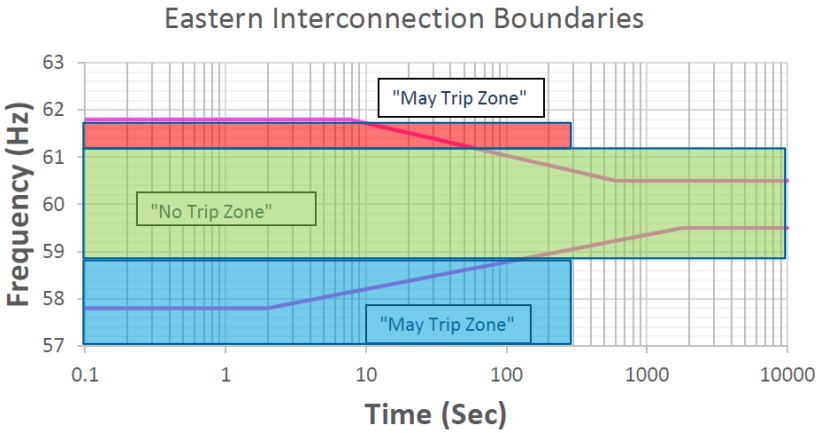


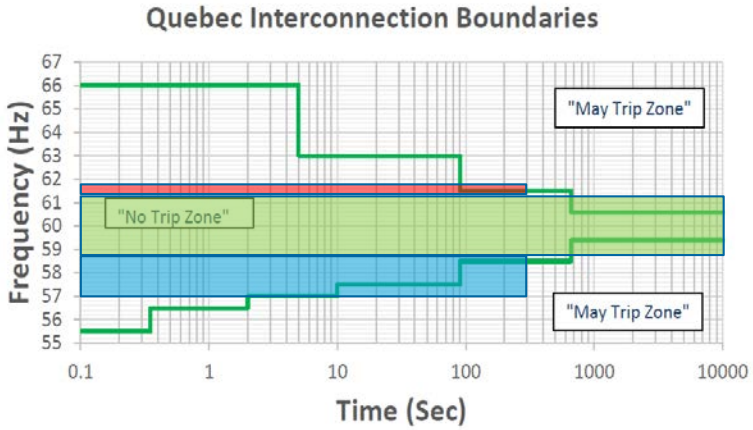
f_{nom}	60 Hz	
f_2	61.2 Hz	Continuous
f_3	58.8 Hz	
f_1	61.8 Hz	Mandatory
f_4	57.0 Hz	
t_1	299 sec	Cumulative Time & Window
t_2	600 sec	

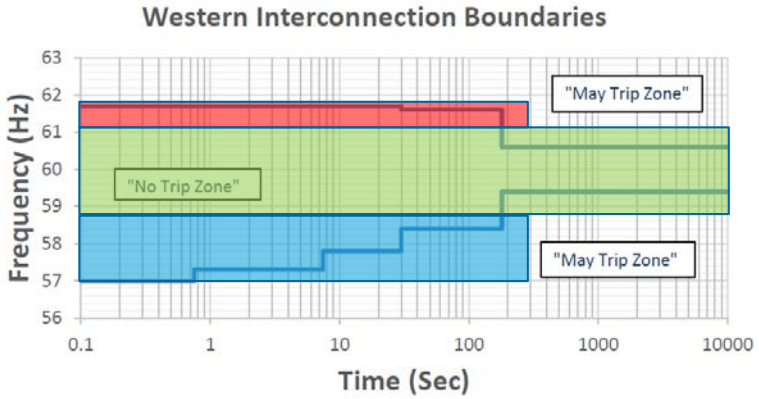
Notes:

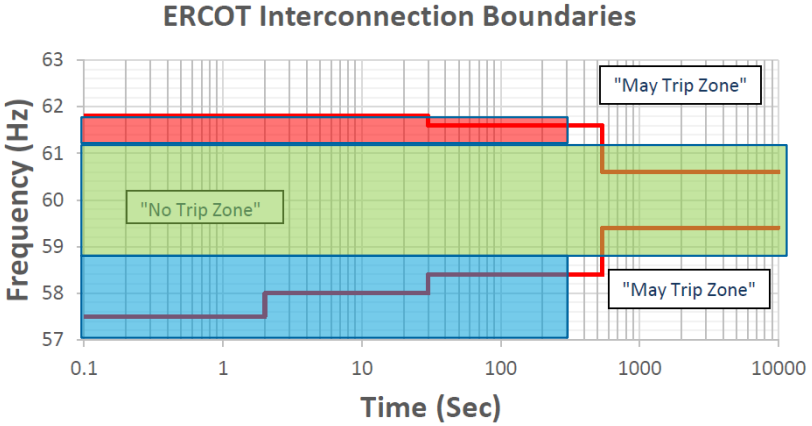
- applies only when voltage is in continuous region
- Assumes frequency measurement accurately represents system frequency (requirements definition needed – reference standard?)

Frequency Reqt. Comparison – NERC v P2800









Cumulative Time v Consecutive Time

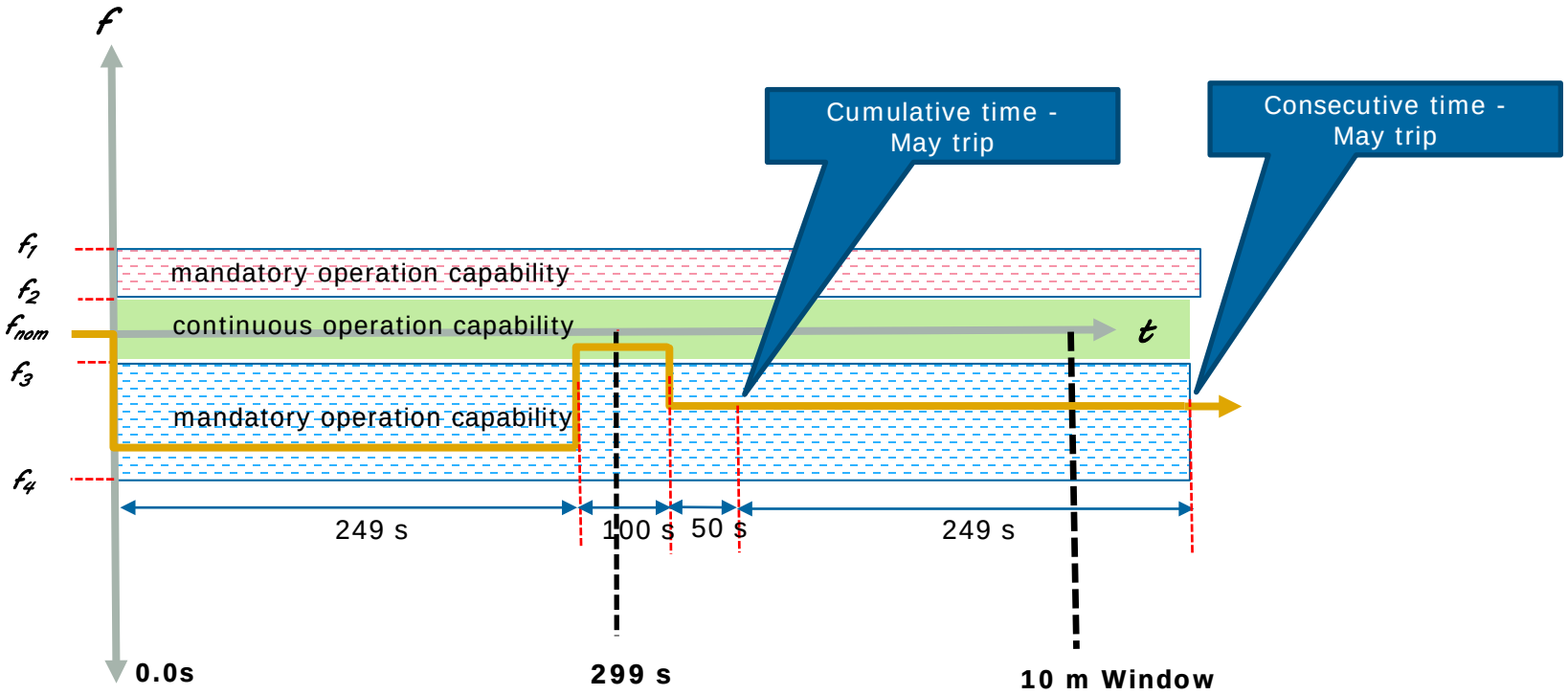
- The current requirement for frequency ride-through = cumulative time of 299 seconds within a 10 minute window

- If the requirement is simply consecutive time (ie without the minute window):
  - could potentially require IBR units to be capable to operate in the Mandatory region for extended periods of repetitive disturbances
  - this may impose impractical V/f design requirements on IBR units (such as WTGs) and IBR transformers - some appropriate limit should be included in a consecutive time requirement.

- Operation in the Mandatory region for up to 299 seconds should be sufficient for system frequency recovery when coupled with primary frequency response (and possible fast frequency response)

- System frequency in the Mandatory region for more than 299 seconds would be indicative of a very severe and un-recoverable grid unbalance condition.

Frequency Ride-Thru Capability -Cumulative Time versus Consecutive Time



Questions for the Working Group

1. Do you think the proposed Frequency Ride-through requirement is generally sufficient as the “technical minimum”?

2. Do you think the proposed Frequency Ride-through Requirements are clearly stated?

Subgroup 4 discussion

IV. Reactive Power – Voltage Control

Sub-Group 4 – priorities

- Today
  - Voltage Control mode performance

- Next Up
  - Voltages Ranges and Reactive Power Capabilities
  - Power Factor control mode performance
  - Reactive Power control mode performance

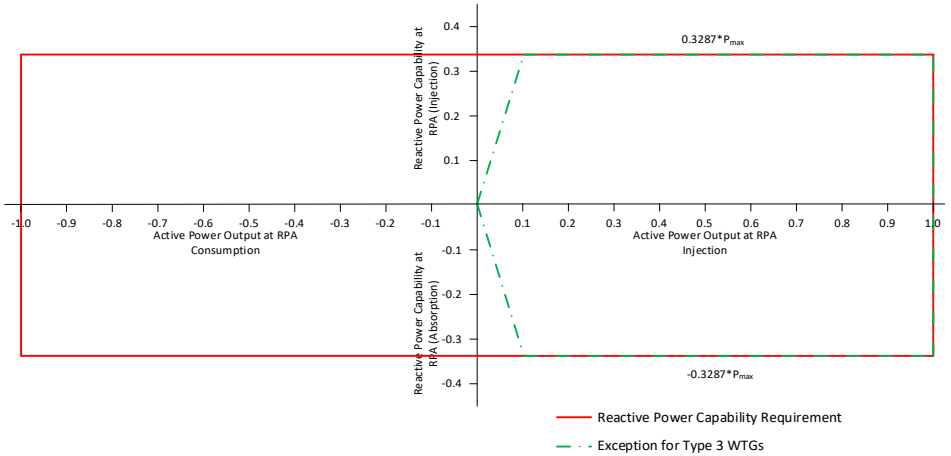
Voltage Control Mode Performance

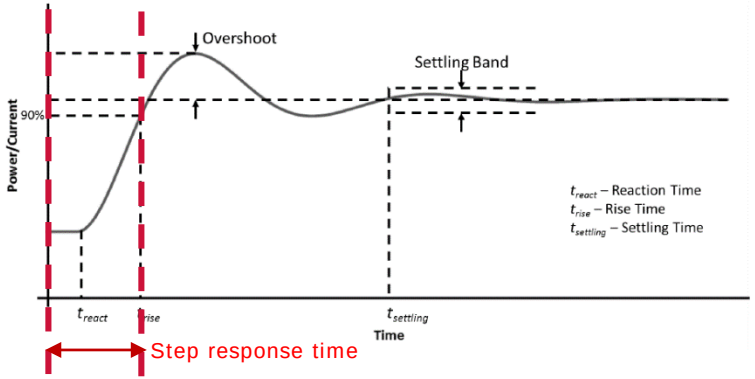
Table 1

Parameter	Description	Performance Target
Step Response Time	Time between a step change in RPA voltage and when the reactive power output changes by 90 percent of its final value	<1sec[ab]
Overshoot	Percentage of rated reactive power output that the resource can exceed while reaching the settling band	< 5 percent[c]

The maximum amount that the reactive power output can exceed the final value expressed as a percent.

Figure 1
(Shown for reference)





- **Step Response Time capability** based on **infinite bus connection** to separate the voltage control loop's dependency on grid strength. (It is equivalent to "open loop response time" in IEEE-1547.)
- The **actual step response time** performance **will be tuned** to account for the TEPS needs and the actual grid strength
- switched shunts or transformer tap change operation needed to maintain the dynamics capability in Figure 1 should respond within 60 seconds.
- Overshoot in reactive power response should not cause TEPS voltage to exceed limits specified by the TEPS Operator.

Question for the Working Group:

1. Do you agree, in general, with the proposed Voltage Control Performance Requirements?

2. Do you think the proposed Voltage Control Performance Requirements are clearly stated?

Subgroup 5 discussion

V. Low Short-Circuit Power

Low Short-Circuit Power Guidance and Questions

- The latest SubGroup 5 draft with power quality requirements is available on iMeet: https://ieee-sa.imeetcentral.com/p/aQAAAAAEBXqg

1. Pending future coordination with SubGroup X (Manish), do you think SubGroup 5's draft informative annex on "Inverter Stability and System Strength" goes into the right direction for P2800?

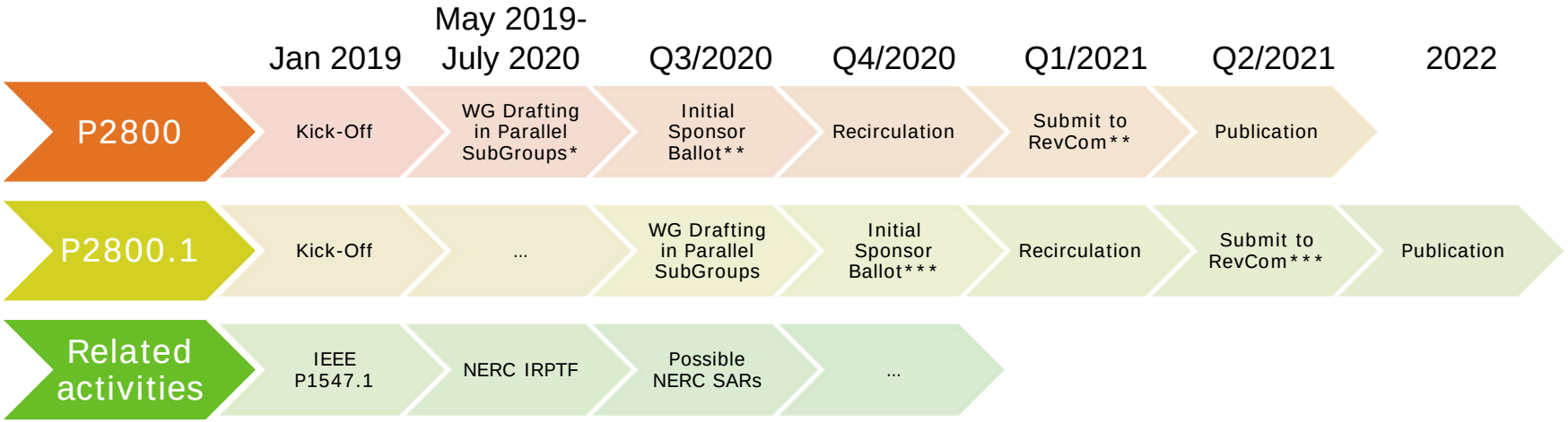
Wrap up

Next Deliverables, Milestones & Meetings

Deliverable	Due date for SubGroup submissions	Publication date
Draft 1.1 (Annotated)	Oct 31, 2019 (Officer Comments)	Nov 6, 2019 (Posted on iMeet)
WG ConfCall	Nov 21, 2019 – discuss & vote on important decisions, e.g., Definitions	
WG ConfCall	Dec 6, 2019 – discuss & vote on 1-2 important decisions per SubGroup	
WG ConfCall	Dec 17, 2019 – discuss & vote on 1-2 important decisions per SubGroup	
Informal WG Meeting & Voluntary SubGroup Meetings	Jan 13, 2020, 1p-5p ET @2020 IEEE JTCM, Jacksonville, FL (does not count towards WG membership)	
WG ConfCall	Feb 6, 2020 – discuss & vote on 1-2 important decisions per SubGroup	
Milestone: Draft 2 (Complete Draft)	**Mar 1, 2020 (SubGroup Input)**	Mar 15, 2020* (Posted on iMeet)
WG Meeting	**April 7-9, 2020** (2 ½ days), FirstSolar, Tempe, AZ *registration link pending*	
Draft 2.1	April 15, 2020* (SubGroup Posted)	May 1, 2020 (Comments in spreadsheet)
Milestone: Draft 3	June 15, 2020* (Input)	June 30, 2020* (Posted on iMeet)
WG Meeting	TBD (July 14-16), 2020*, Location TBD	
Milestone: WG Vote on Draft 3.x	TBD (July 23), 2020*	
Sponsor Coms Approve WG Draft	August 3-7, 2020* at PES General Meeting, Montreal, Canada	
Initial Ballot	Q3/2020*	
Recirculation	Q4/2020*	
Milestone: Submission to NesCom	Q1/2021*	
Milestone: Publication	Q2/2021*	

* Tentative dates

Updated Timeline With Strech Goals



* Please contact the SubGroup leads and sign up for their Mailing Lists to engage.
** The P2800 PAR states June 2021 for Initial Sponsor Ballot and October 2022 for submission to RevCom.
*** The P2800.1 PAR states Dec 2021 for Initial Sponsor Ballot and October 2022 for submission to RevCom.

The ability to meet this tentative timeline may be subject to strong commitments of Working Group leadership team, i.e., support/funding.

Thank you for your participation!

Contacts

IEEE P2800

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IEEE P2800.1

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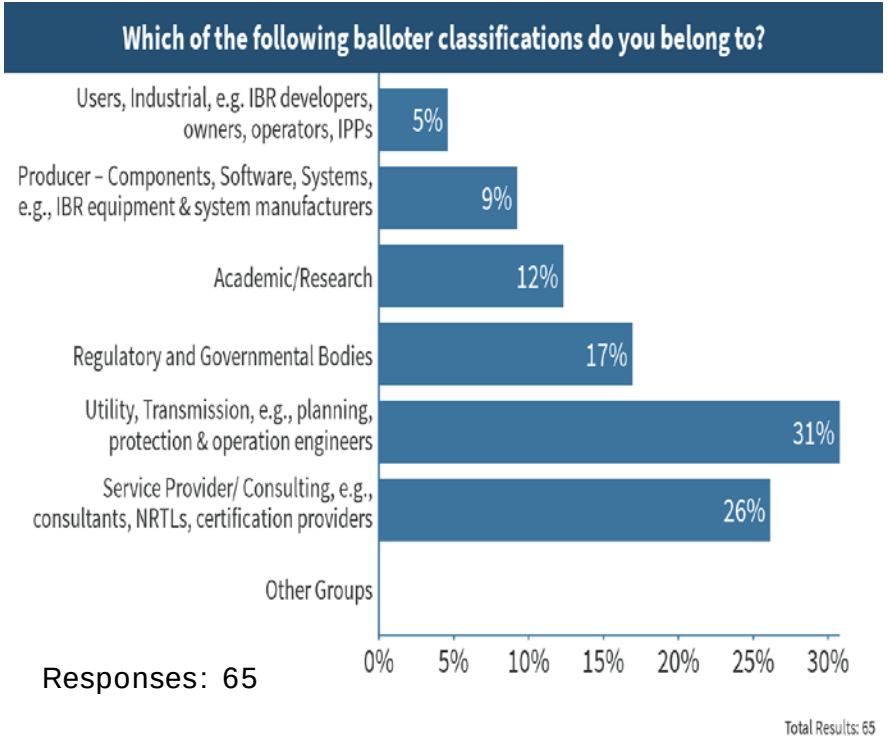
- Jens C Boemer, j.c.boemer@ieee.org

BACKUP SLIDES

Approximately 300 Interested Parties

- Most of the inverter-based resource vendors
- Many Transmission Planners
- Many Service Providers & Consultants
- Several Regulatory Bodies
- Supported by Academics & Researchers

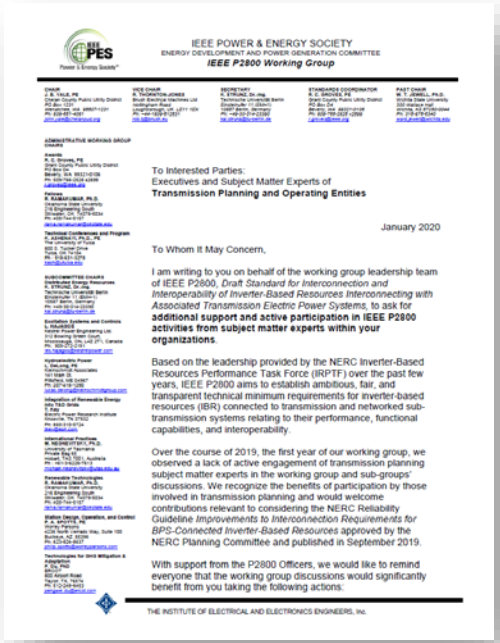


Responses: 65

The Type of Involvement Matters…

- Identify subject matter experts (SMEs) in your organization to **join the IEEE P2800 Working Group** and one or several of its eleven sub-groups.[1]
- Provide SMEs with enough time to attend meetings and conference calls and to **contribute draft language** to the standard.
- Encourage SMEs to **actively engage in meetings and conference calls**, to not remain silent, and to speak up whenever they support the direction in addition to providing verbal or written feedback where they may have concerns.

P2800 Leadership Call for Active Involvement of Transmission Planning & Ops Entities



IEEE POWER & ENERGY SOCIETY
ENERGY DEVELOPMENT AND POWER GENERATION COMMITTEE
IEEE P2800 Working Group

To Interested Parties:
Executives and Subject Matter Experts of
Transmission Planning and Operating Entities

January 2020

To Whom It May Concern,

I am writing to you on behalf of the working group leadership team of IEEE P2800, *Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems*, to ask for **additional support and active participation in IEEE P2800 activities from subject matter experts within your organizations.**

Based on the leadership provided by the NERC Inverter-Based Resources Performance Task Force (IRPTF) over the past few years, IEEE P2800 aims to establish ambitious, fair, and transparent technical minimum requirements for inverter-based resources (IBR) connected to transmission and networked sub-transmission systems relating to their performance, functional capabilities, and interoperability.

Over the course of 2019, the first year of our working group, we observed a lack of active engagement of transmission planning subject matter experts in the working group and sub-groups' discussions. We recognize the benefits of participation by those involved in transmission planning and would welcome contributions relevant to considering the NERC Reliability Guideline *Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources* approved by the NERC Planning Committee and published in September 2019.

With support from the P2800 Officers, we would like to remind everyone that the working group discussions would significantly benefit from you taking the following actions:

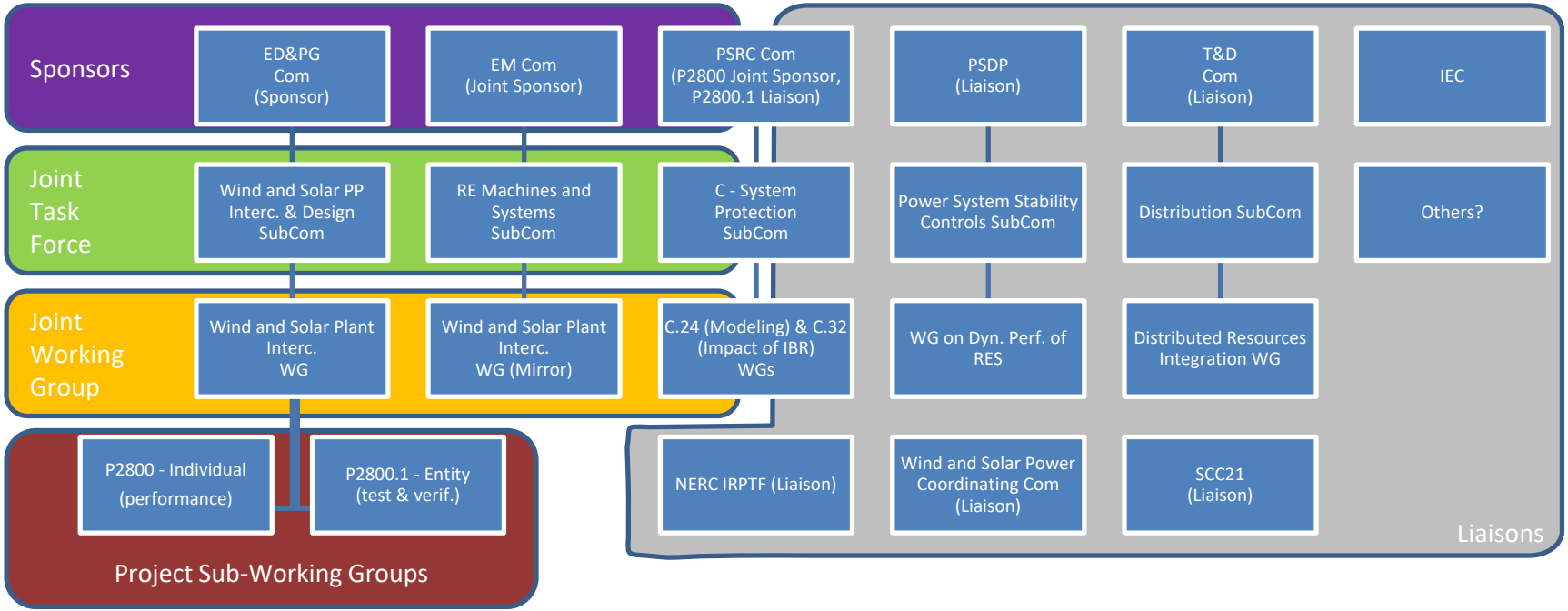
THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Inc.

January 2020

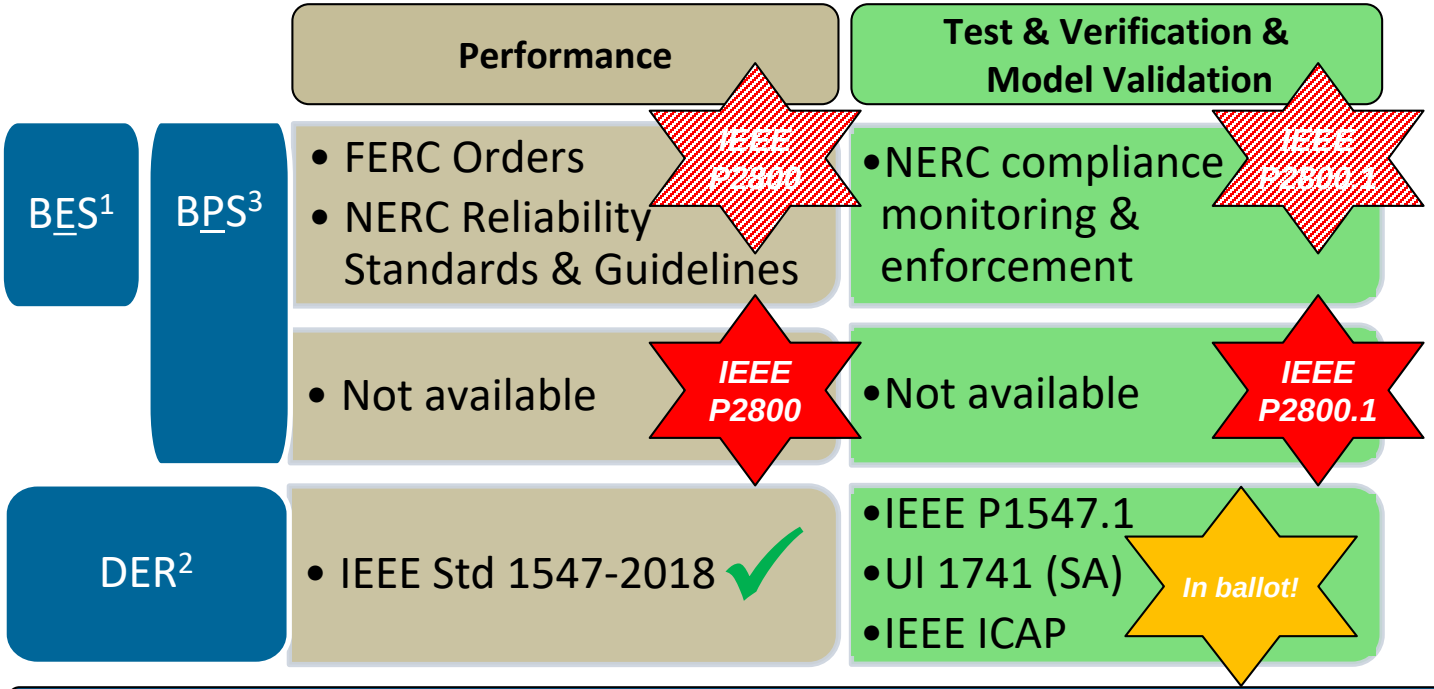
Clarifications of the Scope

- Voluntary standard, requires reference by responsible parties', e.g., interconnection requirements / agreements
  - Candidate parties are transmission owners, state regulators, NERC, and FERC
- Technical minimum requirements, intention is that responsible parties can specify additional requirements
  - Some participants see a risk that it may be regarded as exhaustive requirements
  - Strive for balance between the common denominator and exhaustive requirements
  - May want to consider tiered requirements by use of "performance categories"
- Only "inverter-based" resources, e.g., wind power, solar photovoltaic, energy storage
  - Some participants suggested renaming to "inverter-coupled"
  - "Type 3" wind turbines (doubly-fed induction generators) are in scope
- Applicable to transmission and meshed sub-transmission grids (broad BPS definition)
  - May need different set of requirements for transmission and sub-transmission

Coordination Approach



Filling the Gaps in North American Standards for Inverter-Based Generating Resources



[1] NERC definition of Bulk Electric System: ≥100 kV with gross individual / aggregate nameplate rating greater than 20 MVA / 75 MVA

[2] DER connected at typical (radial) primary and secondary voltage levels

[3] transmission and meshed sub-transmission

IEEE standards are voluntary industry standards and must be adopted by the appropriate authority to become mandatory.

What to expect from IEEE P2800?

- Specify performance and functional *capabilities.*

- Specify functional *default settings.*
- Specify functional *ranges of allowable settings.*

- Specify modeling data, and measurement data for performance monitoring and validation.
- Specify required tests and verifications, but not their detailed procedures (➔ P2800.1)

IEEE P2800 Officers' Guidance / Nov 21

- The use of IEEE 1547 as a reference
  - Use as a framework for ToC, definitions, clause names, requirements concepts
  - Divert from it where it makes sense
    - Example 1: "may" instead of "shall" requirements
    - Example 2: frequency ride-through capability
      - Concept is agreeable
      - Values in 1547 seem to be too stringent for wind turbines
  - May not bring up 1547 in the first place but only use as an informational resource

IEEE P2800 Working Group		
	Mailing List	**stds-p2800@listserv.ieee.org**
	Collaborative Workspace for WG Members (only)	**https://ieee-sa.imeetcentral.com/p2800-wspi-p/**

IEEE P2800 SubGroup	Lead (=Officer)	Mailing List
I. Overall Document	Jens C Boemer	stds-p2800-sg1@listserv.ieee.org
II. General Requirements	Bob Cummings	stds-p2800-sg2@listserv.ieee.org
III. Active Power – Frequency Control	Kevin Collins	stds-p2800-sg3@listserv.ieee.org
IV. Reactive Power – Voltage Control	Kevin Collins	stds-p2800-sg4@listserv.ieee.org
V. Low Short-Circuit Power	Ross Guttromson	stds-p2800-sg5@listserv.ieee.org
VI. Power Quality	Ross Guttromson	stds-p2800-sg6@listserv.ieee.org
VII. Ride-Through *Capability* Requirements	Bob Cummings	stds-p2800-sg7@listserv.ieee.org
VIII. Ride-Through *Performance* Requirements	Manish Patel	stds-p2800-sg8@listserv.ieee.org
IX. IBR Protection	Babak Enayati	stds-p2800-sg9@listserv.ieee.org
X. Modeling & Validation, Measurement Data, and Performance Monitoring	Manish Patel	stds-p2800-sg10@listserv.ieee.org
XI. Tests and verification requirements	Chenhui Niu	stds-p2800-sg11@listserv.ieee.org

- Mailing lists are open to all Interested Parties (“Participants”), not only to WG Members.

Logistics of Bi-weekly SubGroup

P2800 Mailing List at stds-p2800@listserv.ieee.org

P2800 SubGroup	Lead	Mailing List	iMeetCentral Folder	Mon	Tues	Wed	Thurs	Fri
I. Overall Document	Jens Boemer	stds-p2800-sg1@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIla				12 PM ET (even weeks)	
II. General Requirements	Bob Cummings	stds-p2800-sg2@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlb					3 PM ET (odd weeks)
III. Active Power – Frequency Control	Kevin Collins	stds-p2800-sg3@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlc				12 PM ET (odd weeks)	
IV. Reactive Power – Voltage Control	Kevin Collins	stds-p2800-sg4@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIld		1 PM ET (odd weeks)			
V. Low Short-Circuit Power	Ross Guttromson	stds-p2800-sg5@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIle		11 AM ET (odd weeks)			
VI. Power Quality	Ross Guttromson	stds-p2800-sg6@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlf		11 AM ET (even weeks)			

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P2800 SubGroup	Lead	Mailing List	iMeetCentral Folder	Mon	Tues	Wed	Thurs	Fri
VII. Ride-Through Capability Requirements	Bob Cummings	stds-p2800-sg7@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlg					3 PM ET (even weeks)
VIII. Ride-Through Performance Requirements	Manish Patel	stds-p2800-sg8@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlh			1 PM ET (even weeks)		
IX. IBR Protection	Babak Enayati	stds-p2800-sg9@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIli				4 PM ET (odd weeks)	
X. Modeling & Validation, Measurement Data, and Performance Monitoring	Manish Patel	stds-p2800-sg10@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlj			1 PM ET (odd weeks)		
XI. Tests and verification requirements	Chenhui Niu	stds-p2800-sg11@listserv.ieee.org	https://ieee-sa.imeetcentral.com/p/ZgAAAAAAtIlk	Intentionally Delayed				

Overview of the Project Authorization Request

IEEE Project Authorization Requests

Project	Scope	Status	Lead	Joint Sponsors / Liaisons	Next Steps
P2800 - Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems Link on myProject  Adobe Acrobat Document	**Standard** on Performance (**Individual** Project)	Approved by NESCOM/SASB on 9/27/18.	Chair: Dr. Jens Boemer +1.206.471.1180 j.c.boemer@ieee.org	EDP&G – Sponsor EMC – Joint Sponsor PSRC – Joint Sponsor PSDP – Liaison T&D – Liaison Others, see the figure below	Convene WG at 2019 IEEE PES JTCM in January 2019 **Initial Sponsor Ballot: June 2021** Submission to RevCom: October 2022
P2800.1 - Guide for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems Link on myProject  Adobe Acrobat Document	**Guide** on Testing (**Entity** Project)	Approved by NESCOM/SASB on 9/27/18.	c/o China State Grid Dr. Chenhui Niu International Department NARI Group Cooperation +86 13451870987 niuchenhui@sgepri.sgcc.com.cn	Same as for P2800, except that PSRC is a Liaison and not a Joint Sponsor	Convene WG at 2019 IEEE PES JTCM in January 2019 Initial Sponsor Ballot: **December 2021** Submission to RevCom: October 2022

IEEE P2800: Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems

Need for the Project:

The global increase in penetration levels of inverter-based resources is expected to significantly change the dynamic performance of the power grid. As the penetration levels of inverter-based resources increase and the technology of inverter-based resources evolves, specifications and standards are needed to address the performance requirements of inverter-based resources. Currently, there is no one single document of consensus performance requirements covering inverter-based resources interconnected with transmission and sub-transmission systems. Recent events in North America such as the Blue Cut Fire Disturbance as well as institutional challenges in North America that suggest the inappropriate use of IEEE Std 1547 for large-scale solar plants underscore this need. The proposed new standard fulfills this need and can help equipment manufacturers, project developers, transmission planners, and power grid operators improve the quality of the inverter and facility performance to enhance the stability of the power grid. This effort should be aimed to minimize the affected customers and to shorten the time of resynchronizing to the grid if the plant is separated from the grid. Given that IEEE standards are voluntary industry standards, enforcement of any of the requirements specified in this standard will require its adoption by the regional Authority Governing Interconnection Requirements (AGIR); an AGIR is a cognizant and responsible entity that defines, codifies, communicates, administers, and enforces the policies and procedures for allowing electrical interconnection of inverter-based resources interconnecting with associated transmission electric power systems.

IEEE P2800: Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems

Scope:

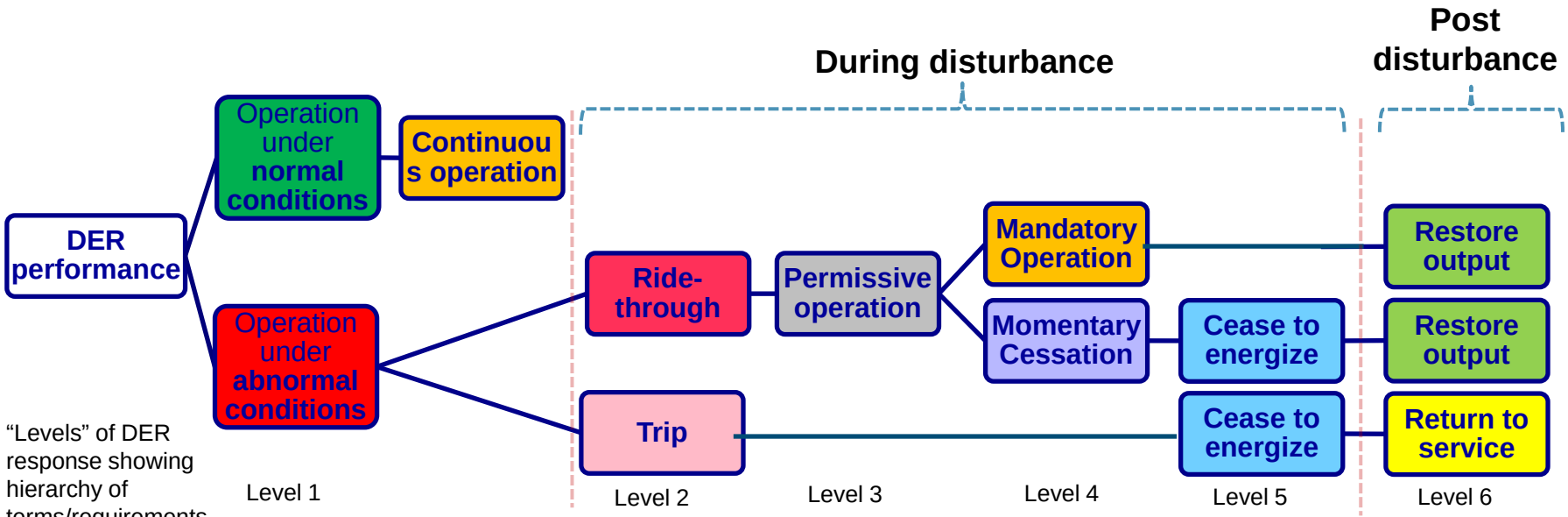
This standard establishes the recommended **interconnection capability and performance criteria** for inverter-based resources interconnected with transmission and networked sub-transmission systems. Included in this standard are recommendations on performance for reliable integration of inverter-based resources into the bulk power system, including, but not limited to, **voltage and frequency ride-through**, active power control, reactive power control, dynamic active power support under abnormal frequency conditions, **dynamic voltage support under abnormal voltage conditions**, power quality, **negative sequence current injection**, and system protection.

Related activities:

IEC initiative to develop a single framework for connecting and controlling renewables. Contact: Charlie Smith, Charlie@esig.energy , U.S. TA for SC 8A.

Disturbance Ride-Through Terminology

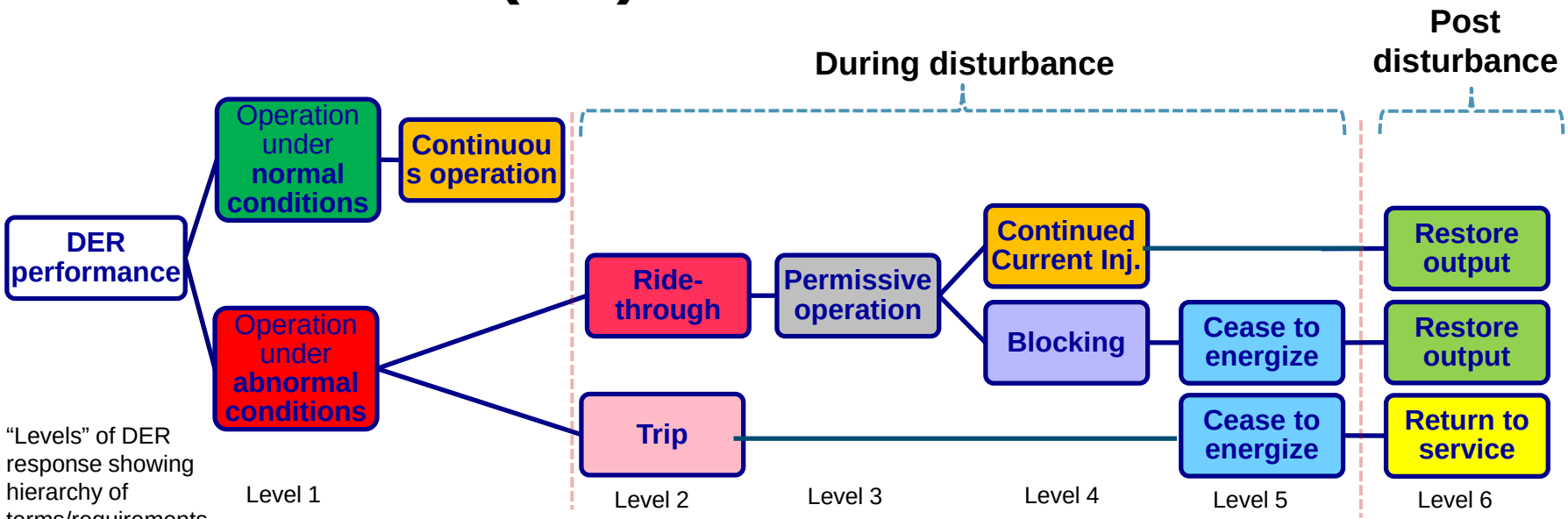
Disturbance performance terminology – IEEE 1547-2018



"Levels" of DER response showing hierarchy of terms/requirements :

- **Ride-through** – ability to withstand voltage or frequency disturbances
  - **Permissive operation** – DER may either continue operation or may cease to energize, at its discretion
    - **Mandatory operation** – required active and reactive current delivery
    - **Momentary cessation** – cessation of energization for the duration of a disturbance with rapid recovery when voltage or frequency return to defined range
  - **Restore output** – DER recovery to normal output following a disturbance that does not cause a ***trip***.
- **Trip** – cessation of output without immediate return to service; not necessarily disconnection
  - **Return to service** – re-entry of DER to service following a trip; equivalent to start-up of DER

Disturbance performance terminology – NERC IRPTF (RL)



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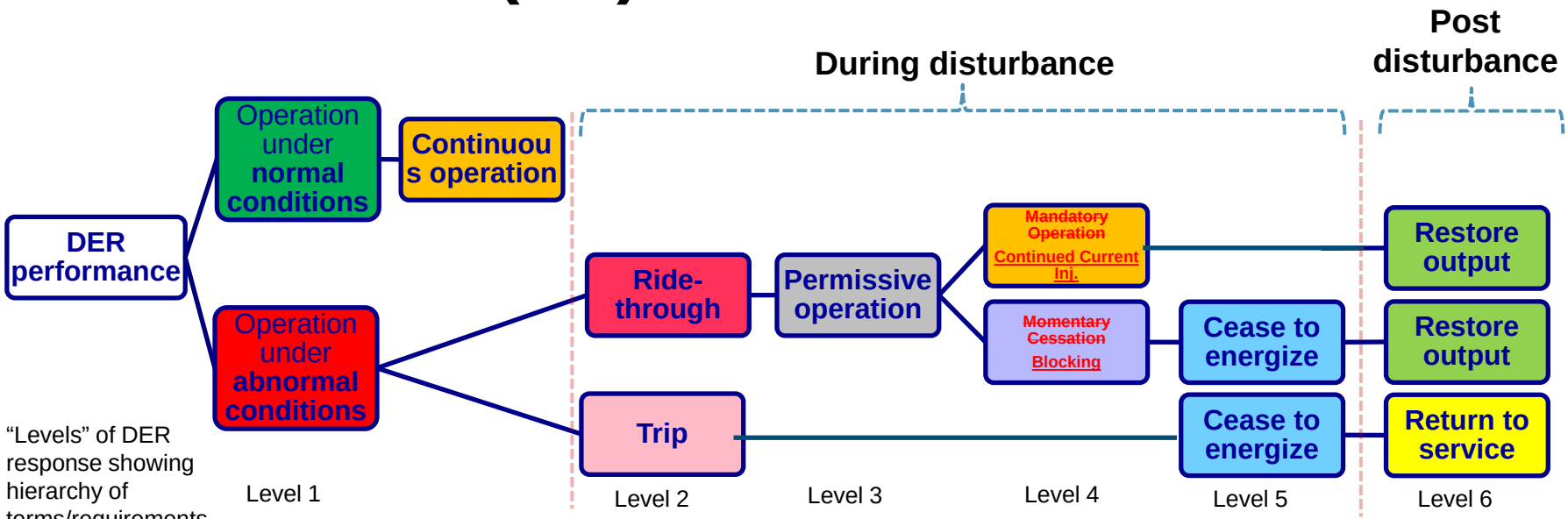

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