
INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

# Forum for the Implementation of Reliability Standards for Transmission (i2X FIRST) | 7/30/24

*An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office*

BERKELEY LAB

ESIG

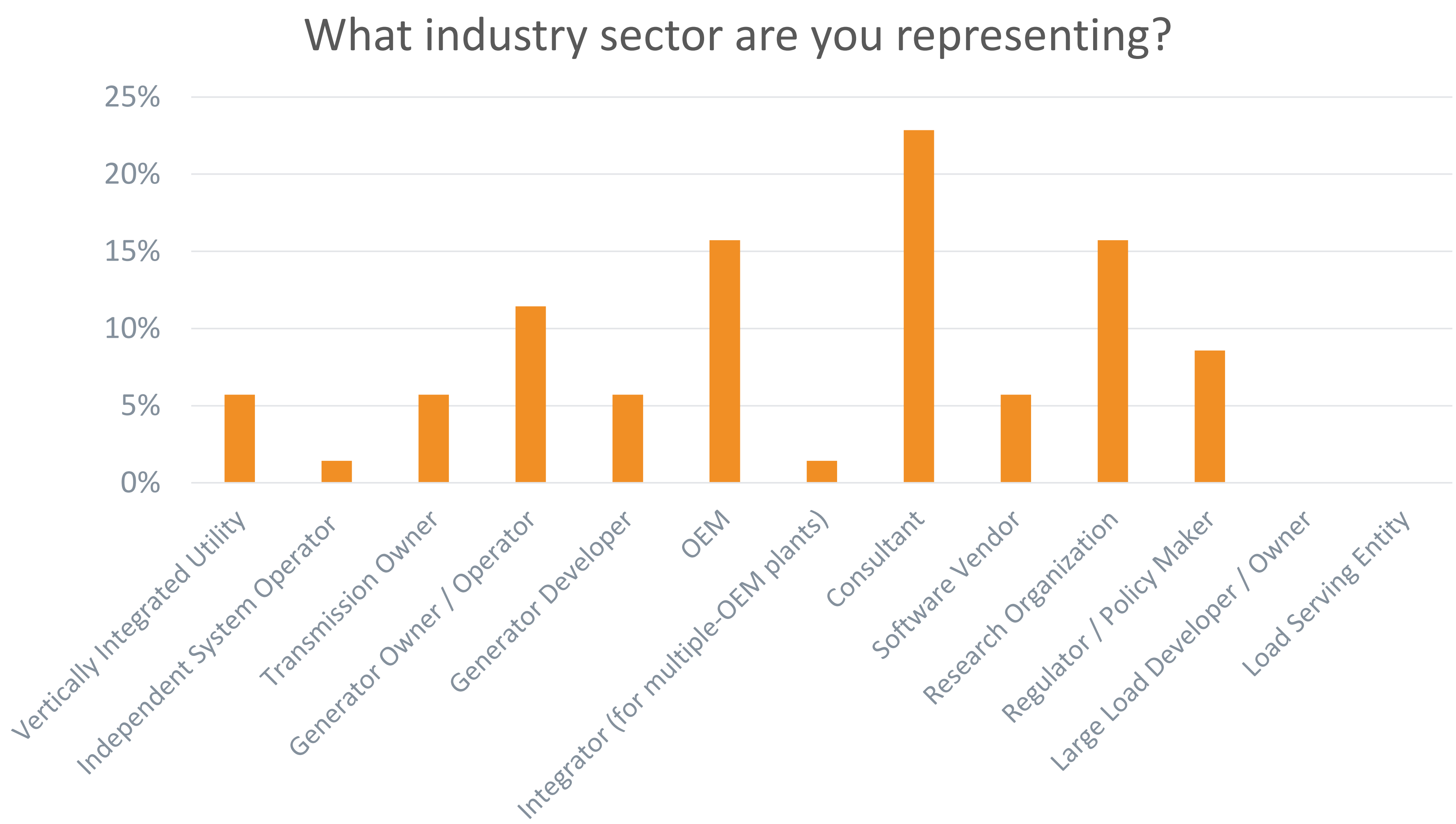
EPRI

The first half of this meeting call is being recorded and may be posted on DOE's website or used internally.  If you do not wish to have your voice recorded, please do not speak during the call.  If you do not wish to have your image recorded, please turn off your camera or participate by phone.  If you speak during the call or use a video connection, you are presumed consent to recording and use of your voice or image.

# Polling Question 1

What industry sector are you representing?

[Go to **slido.com** and enter event code **FIRST4**, then go to **Polls** tab]



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# Key Goals and Outcomes from i2X FIRST

- To facilitate understanding and adoption of new and recently updated standards relevant for existing and newly interconnecting wind, solar and battery storage plants
- The Forum will convene the industry stakeholders to enable practical and more harmonized implementation of these interconnection standards.
- The presentation portion of the meeting will be recorded and posted, and presentation slides will be shared.
- Additionally, the leadership team will produce **a summary of each meeting** capturing:
  - Recommended best practices
  - Challenges
  - Gaps that require future work

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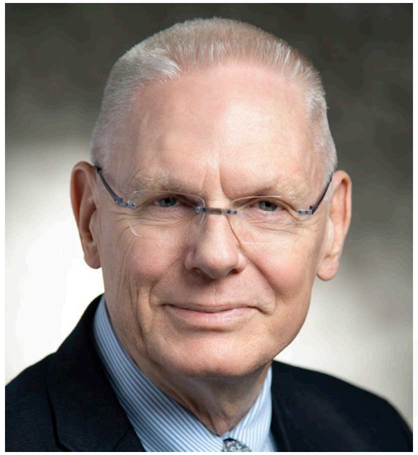
# Leadership Team

Cynthia Bothwell, Boston Government Services, contractor to DOE's Wind Energy Technologies Office



Robert Reedy, Lindahl Reed, contractor to DOE's Solar Energy Technologies Office

Will Gorman, Lawrence Berkley National Laboratory

Jens Boemer, Electric Power Research Institute

Julia Matevosyan, Energy Systems Integration Group

Ryan Quint, Elevate Energy Consulting

# Summary of the last meeting

- IEEE 2800-2022, Clause 7, TMEIC's Perspective – Dinesh Pattabiraman, TMEIC
- IEEE 2800-2022, Clause 7, SMA's Perspective – Ravi Dodballapur, SMA
- IEEE 2800-2022, Clause 7, Vestas's Perspective – Miguel Angel Cova Acosta, Vestas
- IEEE 2800-2022, Clause 7, Summary of OEM Perspectives – Jens Boemer, EPRI
- Q&A

- **Meeting summary, recording & presentations are posted** here (click on Past Events at the bottom of the page)

# Key Themes from the Last Meeting

- OEMs continue to advance ride-through capability of IBR facilities, and OEMs are focused on developing future products that support conformity with IEEE 2800-2022 requirements. OEMs are preparing for widespread adoption of IEEE 2800-2022.
- Some OEMs are waiting for IEEE P2800.2 test and verification procedures to be vetted, approved, and adopted before they can fully certify that their equipment support conformity with IEEE 2800-2022.
- OEMs are also seeking further guidance from transmission providers and ISO/RTOs regarding how to configure and set IBRs. IEEE 2800-2022 leaves some of these options in terms of performance open-ended (intentionally) and this requires additional specificity to be provided by the transmission provider. For example, fault current injections, speed of response, and other factors need to be defined.
- Applying IEEE 2800-2022 retroactively can be problematic because it may require existing assets designed under past interconnection requirements to implement software and hardware upgrades. Hardware upgrades can be costly and may require replacing inverters and other devices within the IBR facility.
- Some of the Clause 7 requirements may be difficult to meet for some OEMs under specific grid conditions (e.g., low SCR conditions). This will need to be handled with technical exemptions or modifications to the IEEE 2800-2022 requirement as industry learns more during implementation and enforcement.

# Upcoming i2X FIRST Meetings

1. May 28th, 2024, 11 a.m.- 1 p.m. ET: Introduction of Evolving Standards Landscape
2. June 25th, 2024, 11 a.m.- 1 p.m. ET: IEEE2800 Ride Through Requirements
3. July 30th, 2024, 11 a.m.- 1 p.m. ET: IEEE2800 Ride Through Requirements, OEM Readiness
4. August 20th, 2024, 11 a.m.- 1 p.m. ET:
5. September 24th, 2024, 11 a.m.- 1 p.m. ET:
6. October 24th, 2024 hybrid, full day, during ESIG Fall Workshop, Providence, RI: Conformity Assessment
7. November 26th, 2024, 11 a.m.- 1 p.m. ET:
8. December 17th, 2024, 11 a.m.- 1 p.m. ET:
9. January 28th 2025, 11 a.m.- 1 p.m. ET:
10. February 25th 2025
11. March 20th, 2025 hybrid full day event during ESIG Spring Workshop, Austin, Texas

**Sign up** for all future i2X FIRST Meetings here: https://www.zoomgov.com/meeting/register/vJItceuorTsiErIC-HInpPbWuTUtrYQAuoM#/registration

**Follow** DOE i2X FIRST website: https://www.energy.gov/eere/i2x/i2x-forum-implementation-reliability-standards-transmission-first for meeting materials & recordings and for future meeting details & agendas

# i2X FIRST One-Day Workshop, Providence, RI | In-person and Online

- Interconnection Standards Workshop with the Focus on Conformity Assessment, **Thursday, October 24, 2024**
- The i2X FIRST workshop will cover **IBR plant design evaluation process, "as-built" evaluation and commissioning testing**, learning from the draft IEEE P2800.2.
- High level agenda is available here and details will be added shortly
- **In-person** and **Free Online** participation options are available
- Held after the ESIG Fall Technical Workshop (10/21-10/23) in Providence, RI

Click Here for In-person i2X FIRST Workshop Registration

Click Here for FREE Online i2X FIRST Workshop Registration

# Ride-Through Requirements, OEM Readiness – Agenda

- Meeting Introduction (10 mins) – Julia Matevosyan, ESIG
- IEEE 2800-2022, Clause 7, GE Vernova Perspective (20 min) – Dustin Howard and Mariana Binda Pereira, GE Vernova
- NERC Milestone 2 Project Update – Jamie Calderon, NERC (10 min)
- IEEE 2800-2022, Clause 7, Sungrow Perspective (20 min) – Henry Aribisala, Sungrow
- Concept of "Maximizing" Ride-Through (20 min) – Ryan Quint, Elevate Energy Consulting
- Q&A and Interactive Group Discussion (40 min)
  - Conformity of IBR plants with new Ride Through Requirements
  - Backward-Compatibility of IBR Plants with New Ride Through Requirements

# Virtual Meetings Code of Conduct

1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*

Mutual Respect . Collaboration . Openness

# Stakeholder Presentations

# Virtual Meetings Code of Conduct

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Mutual Respect . Collaboration . Openness

# Q & A Session

# Interactive Group Discussion Topics

# Topic #1: Conformity of IBR Plants with New Ride Through Requirements

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST3**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - Do you see any barriers for future IBR plants (not yet in the interconnection queue) to comply with new ride through requirements (e.g., per IEEE 2800-2022 Clause 7)?
  - What is the current best practice to get assurance from OEMs and plant developers/owners that they can meet applicable ride through requirements (e.g. IEEE 2800 Clause 7): attestations, simulation results, physical etc.?
  - Are you planning to develop your own conformity assessment process for ride through requirements or wait until IEEE P2800.2 is completed?

# Topic #2: Backward-Compatibility of IBR Plants with New Ride Through Requirements

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST3**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - Do you see the need for compatibility of existing / under construction plants with new ride through requirements (e.g., per IEEE 2800-2022 Clause 7)?
  - Should ride-through capability be configured to meet a set of performance requirements/curves or simply based on maximum equipment capability?
  - How should we be thinking about ride-through capability and performance for legacy (existing) resources? What are good practices being deployed to mitigate risks of ride-through risks for the existing fleet?

# Polling Question 2

Post any remaining questions related to Ride-Through Requirements that were not addressed so far?

[Go to **slido.com** and enter event code **FIRST3**, then go to **Polls** tab]

GE VERNOVA
Our portfolio of energy businesses

# GE Vernova Onshore Wind Perspectives on IEEE 2800-2022 Adoption

i2X FIRST | 20-Aug-2024

Mariana Binda Pereira, GE Vernova Wind, Grid Integration Product Manager
Dustin Howard, GE Vernova Consulting Services, Technical Director

# IEEE 2800-2022 | GE Vernova Onshore Wind Perspectives

GE VERNOVA

## Tailwinds

### Harmonizes interconnection requirements in North America
- Standardized IBRs interconnection requirements

### Enabling better integration of IBRs
- Improving grid reliability with advanced IBRs performance capabilities

### Alignment between Field and Model behavior
- Improving ability to evaluate grid performance with accurate product models

### Fault monitoring improvements
- Ability to review fault event data to support changes for improved performance


IEEE SA

IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

IEEE Power and Energy Society

STANDARDS

IEEE

## Headwinds

### Requirements being adopted in different shapes and forms
- Increasing variability of requirements

### Unknown Compliance Evaluation
- High fidelity simulation vs. lab testing vs. field testing

### Retroactive application of requirements
- Older units requiring significant analysis, testing, and design changes

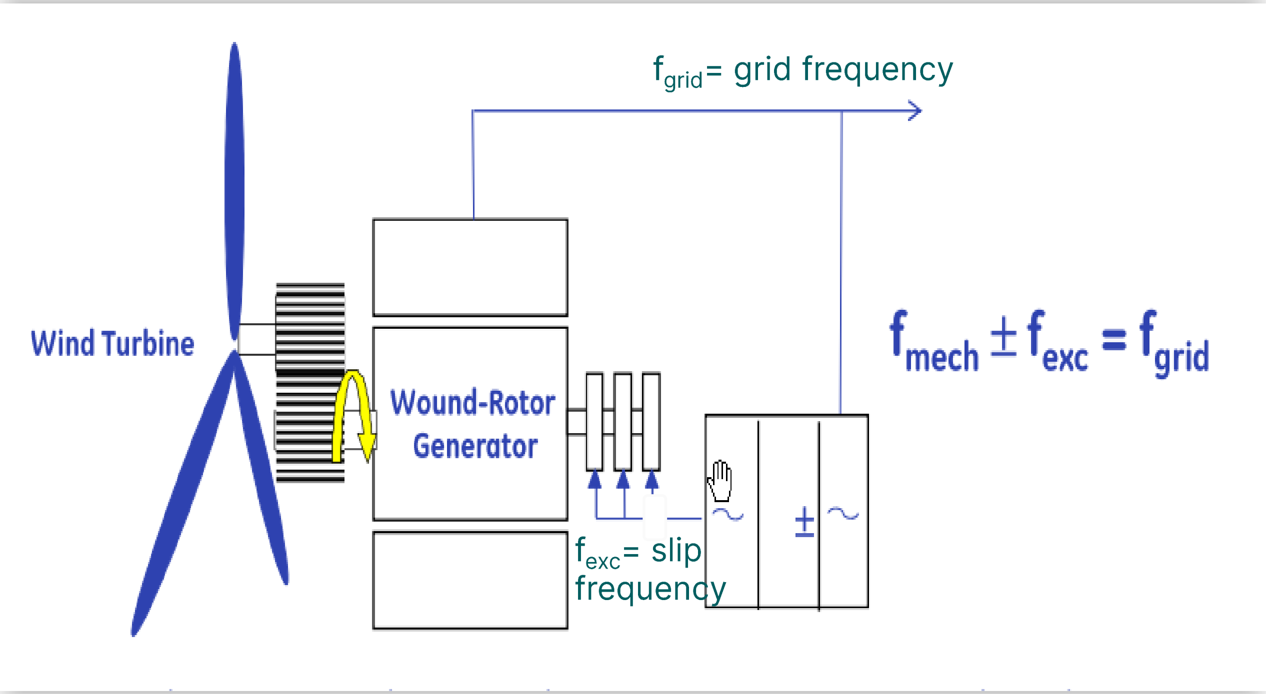
### Disparity of requirements vs. specific grid stability needs
- Specific grid conditions may require performance which differs from requirements, to maintain grid stability (e.g. Weak grids, off grid applications, etc)

**Advanced IBRs performance capabilities are critical for Grid Reliability…**
**Appropriate deployment of requirements is critical to enable IBRs growth.**

# IEEE 2800-2022 | Type 3 Wind Turbines

→ Rotor shaft directly connected to prime mover (same as Type 4)
→ Stator connected directly to grid (different from Type 4)

- Natural response to faults and fault recovery in the transient time-frame. Somewhat like synchronous machines.
- Behaves more like an IBR after an initial transient period.
- Torque transients during faults and fault recovery need to be absorbed by the mechanical drive train – unlike type 4 which uses a chopper to absorb torque transients.
- Type 3 naturally suited for weak grid applications as the drive train can tolerate and benefits from a slower power recovery rate. Type 4 chopper thermal limits drive the need for fast recovery rates.
- Can provide higher fault currents in the first few cycles when compared to converter limited IBRs, however more difficult to control to strict settling bands of current (similar to synchronous machine).




**Type 3 supports weak grid stability and fault current levels, but harder to control to tight settling bands.
Both have technology differences, and requirements should consider positive contributions and limitations of both.**

# IEEE 2800-2022 | Settling time and band

IEEE 2800 requirements on fault current injection much stricter than similar requirements in other grid codes

Challenges with meeting these stricter requirements and demonstrating compliance include:

- Simultaneous requirement to ramp power (and thus change voltage) while keeping effectively constant reactive current (during post-fault period)
- Voltage drop across unit transformer leads to unsettled voltage, thus causing unsettled current output
- Offset saturation of transformers
- Test conditions that keep voltage “stiff” enough to evaluate a step change in voltage at POM
- Electro-mechanical dynamics (e.g. changing speed) cause changes in power (and thus current)
- Temporary DC offsets in current
- Other noise factors associated with practical hardware

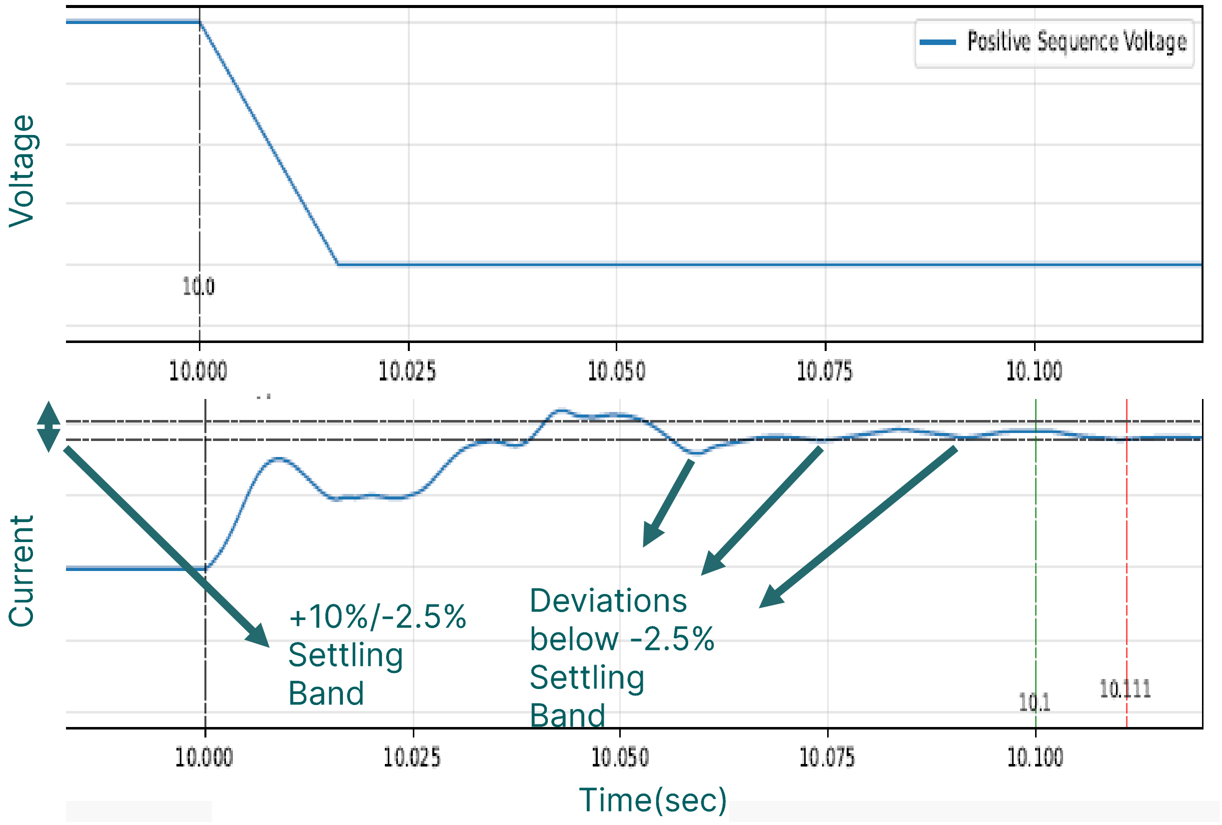
| Performance Aspect | Other Grid Codes | IEEE 2800 |
|---|---|---|
| In-Fault Settling Time of Reactive Current Required? | Yes | Yes |
| In-Fault Settling Time of Active Current Required?* | No | Yes |
| Post-Fault settling time of current required? | No | Yes |
| Settling Band of Current | +/-10%** | +10%/-2.5% |
| Settling Time of Current | 3-5 cycles | 4-6 cycles |

*IEEE 2800 requirement is on total current settling time not explicitly on active current. However, it is implied that active current must also settle within the time/band to satisfy the requirement (in addition to reactive current).

**Australian requirement. Allows negotiation

**Stricter Settling Time Requirement Makes Compliance Challenging Considering Practical Hardware Aspects**

# IEEE 2800-2022 | Settling Time Assessment Example




Example High-Fidelity EMT Simulation showing non-compliance with 2800 Settling Time for Short (<150msec) Fault

- In-fault current rises and settles stably and provides reactive current for grid voltage support
- Tiny deviations below narrow -2.5% ~double the settling time compared to a -10% lower band
- Impacts to grid for small deviations outside settling band are negligible
- Total Current Settles in 111msec, 11msec longer than IEEE 2800 requirement

**Stricter Settling Time Requirement Makes Compliance Challenging Considering Practical Hardware Aspects**

# IEEE 2800-2022 | Additional Considerations

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## Type testing for FRT

- Performance requirements like settling time/band should be allowed to be validated using CHIL.
  - Too many noise factors during lab and/or field testing that will by themselves exceed the 2.5% settling band. E.g. IEEE 2800 allows measurement inaccuracy of IBR unit voltage and current (which drives the controls response) to be +/-10% transient and +/-2.5% steady state. Additional inaccuracy of lab measuring equipment, lab motor drive speed variations etc. etc. In addition, field testing introduces wind speed variation, turbulence, shear etc which impact settling time/band.

## Model accuracy

- Structural similarity and parameter matching should be the main measure for model accuracy.
- Tight trace matching should not be used as a measure for model accuracy.
- Tight trace matching may cause the model to structurally deviate from the actual product just to cancel out noise factors from the validation test.

## Project Applications Requiring Waivers from IEEE 2800

- Strict application of IEEE 2800 requirements to projects with special grid conditions may be detrimental to stability driving need for site specific exceptions.

| Existing / Emerging Project Applications | Necessary Capability Conflicting with IEEE 2800 |
|---|---|
| Weak Grids | Adapt current to stabilize voltage |
| Series Compensated Grids | Oscillate current to damp resonance |
| Off Grid / Grid Forming | Exhibit voltage source characteristic,<br>Meet load demands |

- Future version of Std should specify requirements for special grid conditions. E.g. settling time requirement applicable only for SCR >XX. Present “mutual agreement” deviation provisions still require proof of capability which may be impractical or even infeasible for some grid conditions.

## Retroactive application of requirements

- Re-designing very old units to meet new requirements may lead to significant hardware upgrades or may not be practical due to decommissioned lab and prototype equipment.
- Products are normally designed at the time of their development to the maximum of its capability (with reasonable design margins).
- Exemptions should be allowed for retroactive requirements.

**IEEE P2800.2 development is critical to demonstrate evidence of compatibility. Recommended to allow deviation provisions or exemptions based on grid stability needs, technical feasibility, and practicality.**

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

# Standards Development FERC Order 901

Jamie Calderon - Manager, Standards Development
i2X Forum – August 20, 2024

RELIABILITY | RESILIENCE | SECURITY




# Order 901 Summary

- FERC Order 901
  - October 2023
  - 4 Milestones through November 2026
  - IBR related performance issues
  - Leverage existing guidance where possible

# FERC Order 901 Milestones

**1**
**COMPLETED JANUARY 2024**

Order No. 901 Work Plan submission

**2**
**DUE NOVEMBER 4, 2024**

Standards development and filing to address performance requirements and post-performance validations for Registered IBRs

**3**
**DUE NOVEMBER 4, 2025**

Development and filing of Reliability Standards to address data sharing and model validation for all IBRs

**4**
**DUE NOVEMBER 4, 2026**

Development and filing of Reliability Standards to address use of performance data in Operational and Planning studies

# Milestone 2

| IBR Definition | New PRC-028 | New PRC-029 | New PRC-030 |
|---|---|---|---|
| 91.30% | Draft: 80.70% | Draft: 52.89% | Draft: 76.11% |
| IP: 92.45% | IP: 84.55% | IP: 60.04% | IP: 85.20% |

# Rule 321 – Two Paths

- Technical Conference Path
  - Standards Committee hosts technical conference
  - Draft Memo to Board based on results
  - Revise Draft
  - Re-ballot (need 60%)
- NOPR Path
  - Board directs NERC to revise and submit revision
  - No Ballot

# Technical Conference

- Scheduled September 4$^{th}$ and 5$^{th}$
- DC Area – Finalizing Event Space
- Accepting Comments from Industry as part of filing
- Will have presentations and speakers
- SC will leverage all information for revisions

# Questions and Answers

# IEEE 2800-2022 Clause 7
# Sungrow's Perspective

Commercial Secret Level III Speaker: Henry Aribisala

# IEEE 2800-2022 Sungrow's Perspective

SUNGROW

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# Sungrow's Global Presence

**170+**
Countries in Operation

**20+**
International Subsidiaries

**490+**
Service Outlets

Headquarters
Branches

# 515GW+

Power electronic converters installation

Global PV Inverter Shipment in 2023 **130GW**

Global PV Inverter Shipment **NO.1**

S&P Global
Commodity Insights

Have been **NO.1** US supplier since 2022.

# Sungrow : Product Reference

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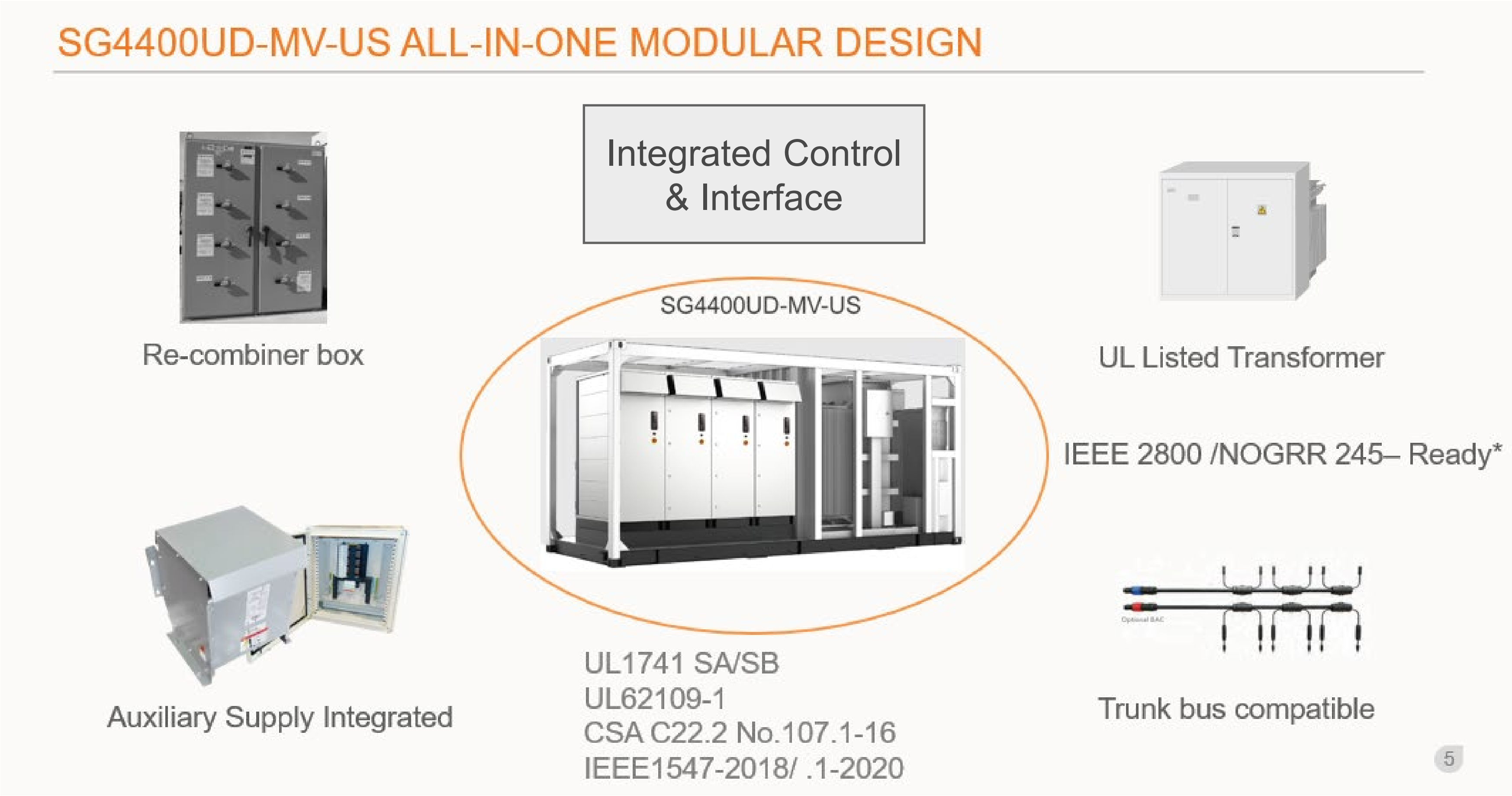
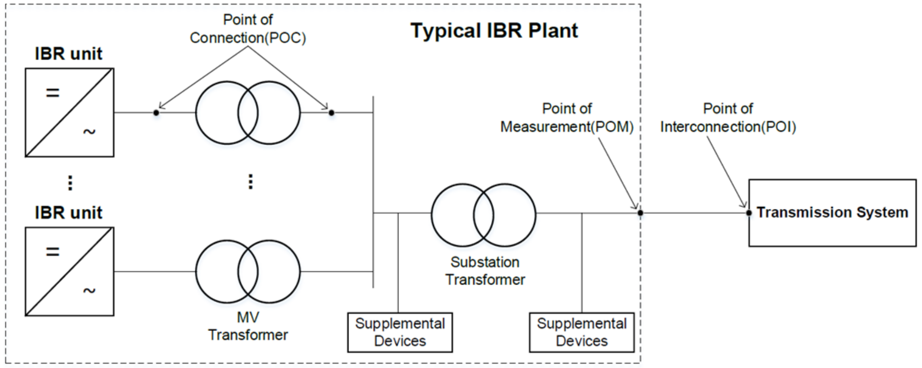



- Other Sungrow Products that supports IEEE2800:
- SC210HX-US,
- SC5000UD-MV-US-P3

# IEEE 2800-2022 Clauses 4-6

| Section | Requirements | Sungrow Remark |
|---|---|---|
| 4.4 | Measurement accuracy | Similar requirements with IEEE1547-2018, Sungrow PCSs can meet them and already passed the IEEE1547-2018 certification test. |
| 4.7 | Prioritization of IBR responses | Similar requirements with IEEE1547-2018, Sungrow PCSs can meet them and already passed the IEEE1547-2018 certification test. |
| 4.11 | Interconnection integrity | Similar requirements with IEEE1547-2018, Sungrow PCSs can meet them and already passed the IEEE1547-2018 certification test. |
| 5.1 | Reactive power capability | See note 2. |
| 6.2 | Fast frequency response (FFR) | Sungrow PCSs supports this requirement. |

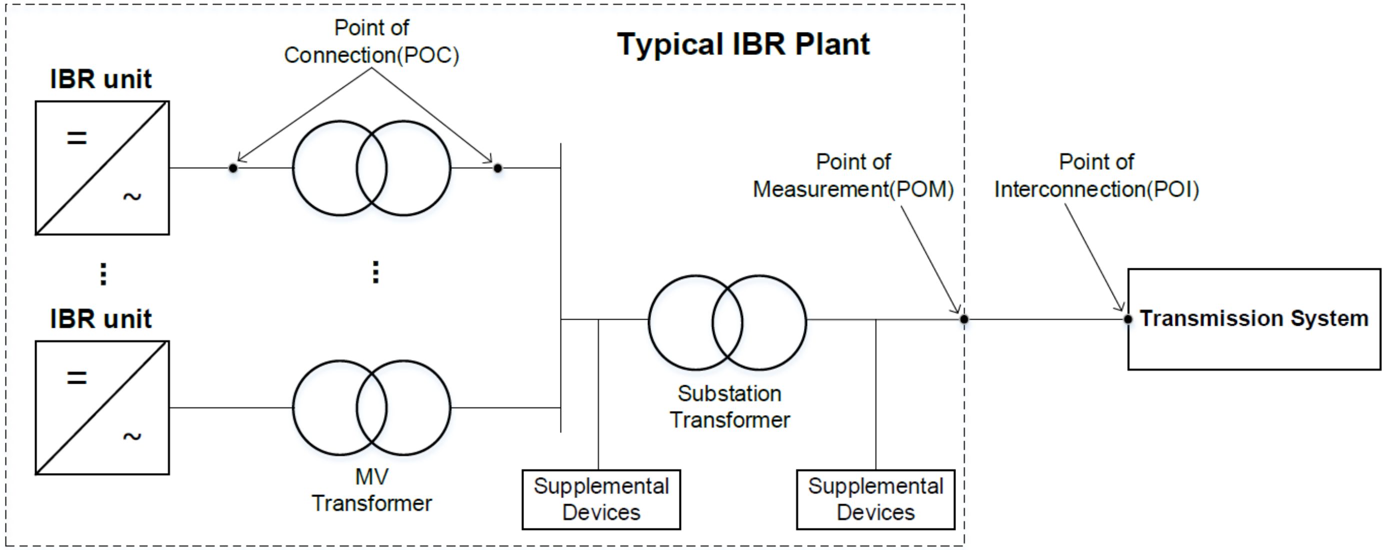


Typical IBR Plant Block Diagram

- **Challenges –**
- Note 2: Sungrow PCSs have reactive power capability as specified in the products' respective datasheet/ specifications.
- The challenge- Reference Point of Application (RPA) of the reactive power capability requirements at the IBR plant level, - Point of Measurement (POM), based on section 5.1 of IEEE2800-2022, it could be premature to categorically specify meeting the reactive power capability requirements without additional specific plant modeling and studies by the respective asset owner/plant designer.
- The IBR plant design should be coordinated with the extra reactive power compensation devices within the IBR plant MV collector system (including supplemental IBR units, static var compensator [SVC], static synchronous compensator [STATCOM], etc.) as may be necessary.

# IEEE 2800-2022 Clause 7

| 7.2.2 | Voltage disturbance ride-through requirements |
| --- | --- |




Typical IBR Plant Block Diagram

- Challenges & Status –
- Based on Sungrow's self-evaluation: Modeling and analytical studies ,
  - Most Sungrow's PV inverters, including SG3150/4400UD-MV-US, and SG3425/ 3600UD-MV, meets the Voltage disturbance ride-through requirements:
  - Supports negative sequence reactive current injection requirements at inverter terminals/Point of Connection (POC),
  - **SW/FW update**: Sungrow has released new software for these, please contact Sungrow for more details.
  - The older fielded legacy products could be a challenge

# 7.2.3 Transient overvoltage ride-through requirements

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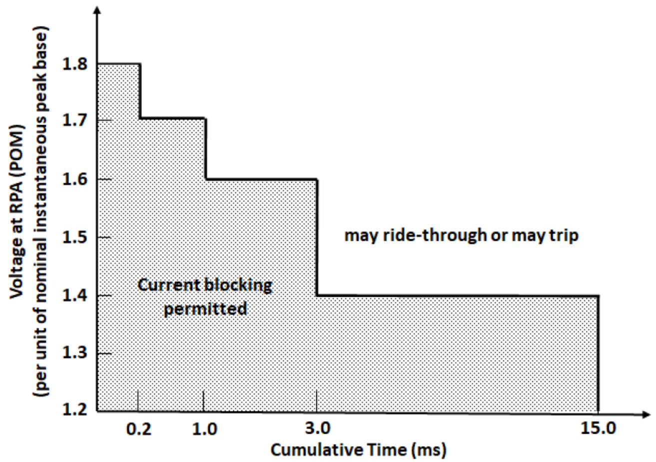


Figure 11 —Transient overvoltage ride-through requirements for *IBR plant* (informative)

**Table 14 —Transient overvoltage ride-through requirements at the RPA**

| Voltage[c] (p.u.) at the RPA | Minimum ride-through time (ms)[d] (design criteria)[b] |
|---|---|
| V > 1.80 | See footnote[a] |
| V > 1.70 | 0.2 |
| V > 1.60 | 1.0 |
| V > 1.40 | 3.0 |
| V > 1.20 | 15.0 |

[a] Appropriate surge protection shall be applied at the RPA as well as within the *IBR plant*, including *IBR unit* terminals (POC), as necessary.
[b] The minimum ride-through times specified in Table 14 apply to both 50 Hz and 60 Hz systems.
[c] Specified voltage magnitudes are the residual voltages with surge arresters applied.
[d] Cumulative time over a 1-min time window.

- Challenges & Status –
- Note 4: PV inverter SG3150/4400UD-MV-US, SG3425/3600UD-MV supports TOV ride-through requirements at inverter terminals/Point of Connection (POC),
- The IBR unit's TOV ride-through capability may differ from the IBR plant's TOV ride-through requirement. The IBR plant design should be coordinated with the IBR unit's TOV ride-through capability and with surge arrester protection design implemented within the IBR plant MV collector system to allow the IBR plant to meet specified TOV ride-through requirements.
- Fault data recording requirements- Table 19 of IEEE2800-2022, Inverter delivered next year will meet the requirement – also PRC-028
- Challenging to some HW PCS components
- Customers can contact Sungrow for additional details

# **Other Key Standard Requirements:** Frequency disturbance, ROCOF, Phase Angle - ride-through requirements

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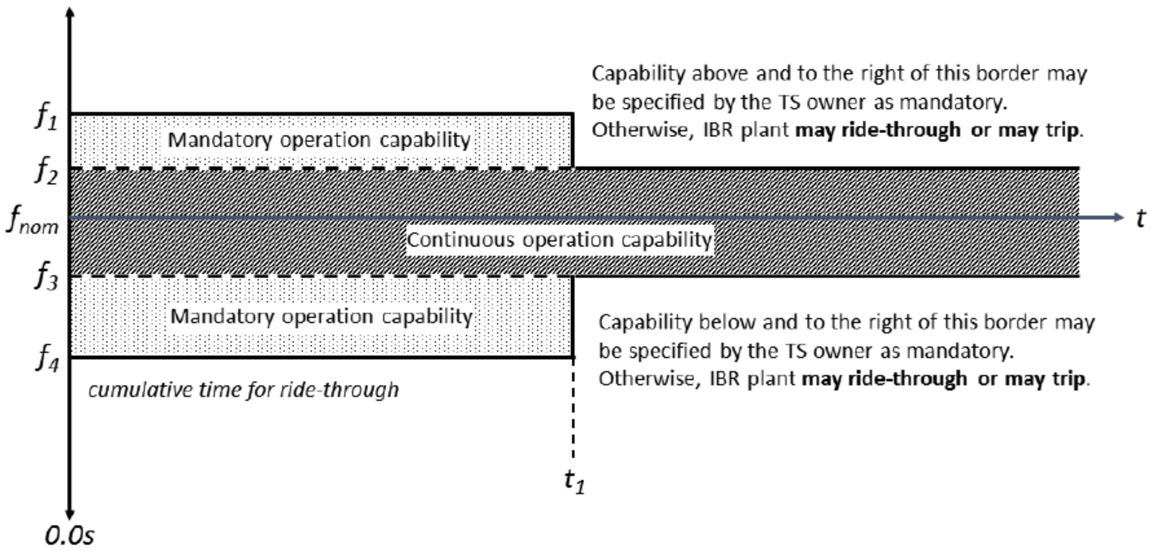


**Figure 12—Frequency ride-through capability requirements for *IBR plant***

**Table 15—Frequency ride-through capability for an *IBR plant* (see Figure 12)**

| Frequency range (Hz) | Percent from $f_{nom}$ | Minimum time (s) (design criteria) | Operation |
|---|---|---|---|
| $f_1$, $f_4$ | +3, −5 | 299.0 ($t_1$) | Mandatory operation |
| $f_2$, $f_3$ | +2, −2 | ∞ | Continuous operation |

- Challenges & Status –
- Sungrow Inverters supports the Frequency disturbance ride-through requirements of the IEEE-2800
- Other Key standard Requirements that Sungrow Inverters support:
  - 7.3.2.3.5 Rate of change of frequency (ROCOF) ride-through
  - 7.3.2.4 Voltage phase angle changes ride-through
  - We supports these requirements with no issue .

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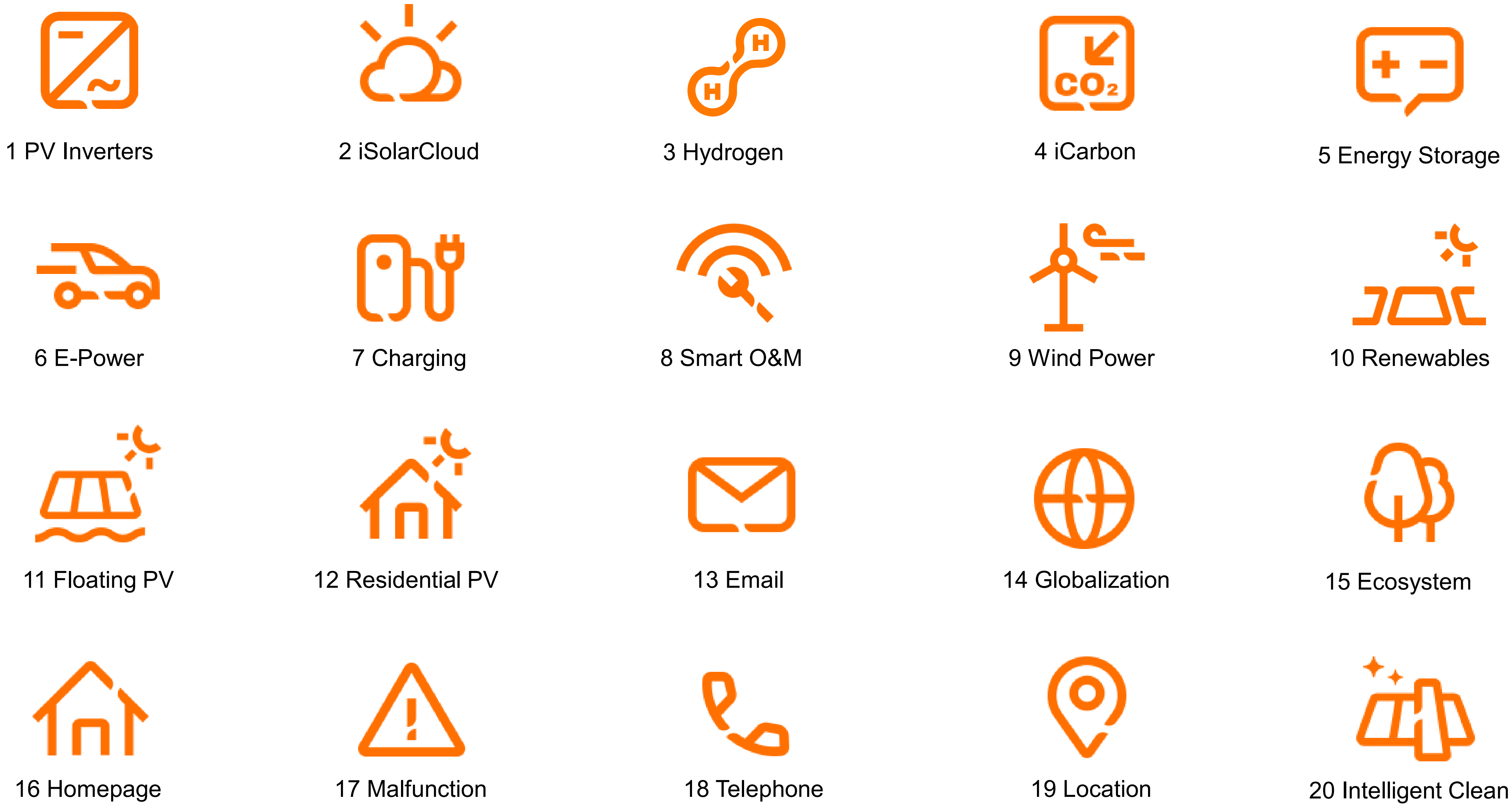
# IEEE 2800-2022 Conclusion

- Settings are important – IBR Unit Parameter settings should match actual plant model requirements accurately. Especially Protection parameter settings
- We have default settings - based on PRC-024.3, IEEE 1547, IEEE-2800-
- Reference point of applicability: Sungrow's evaluation may be different from specific project characteristics and scenarios
- Employ appropriate Verifications - IBR unit type tests, IBR plant design evaluations, commissioning tests, and post-commissioning operational evaluation
- Sungrow supports Plant developer- via product training, modeling support, etc.

# Brand Icons


1 PV Inverters
2 iSolarCloud
3 Hydrogen
4 iCarbon
5 Energy Storage
6 E-Power
7 Charging
8 Smart O&M
9 Wind Power
10 Renewables
11 Floating PV
12 Residential PV
13 Email
14 Globalization
15 Ecosystem
16 Homepage
17 Malfunction
18 Telephone
19 Location
20 Intelligent Clean

# Thanks

SUNGROW

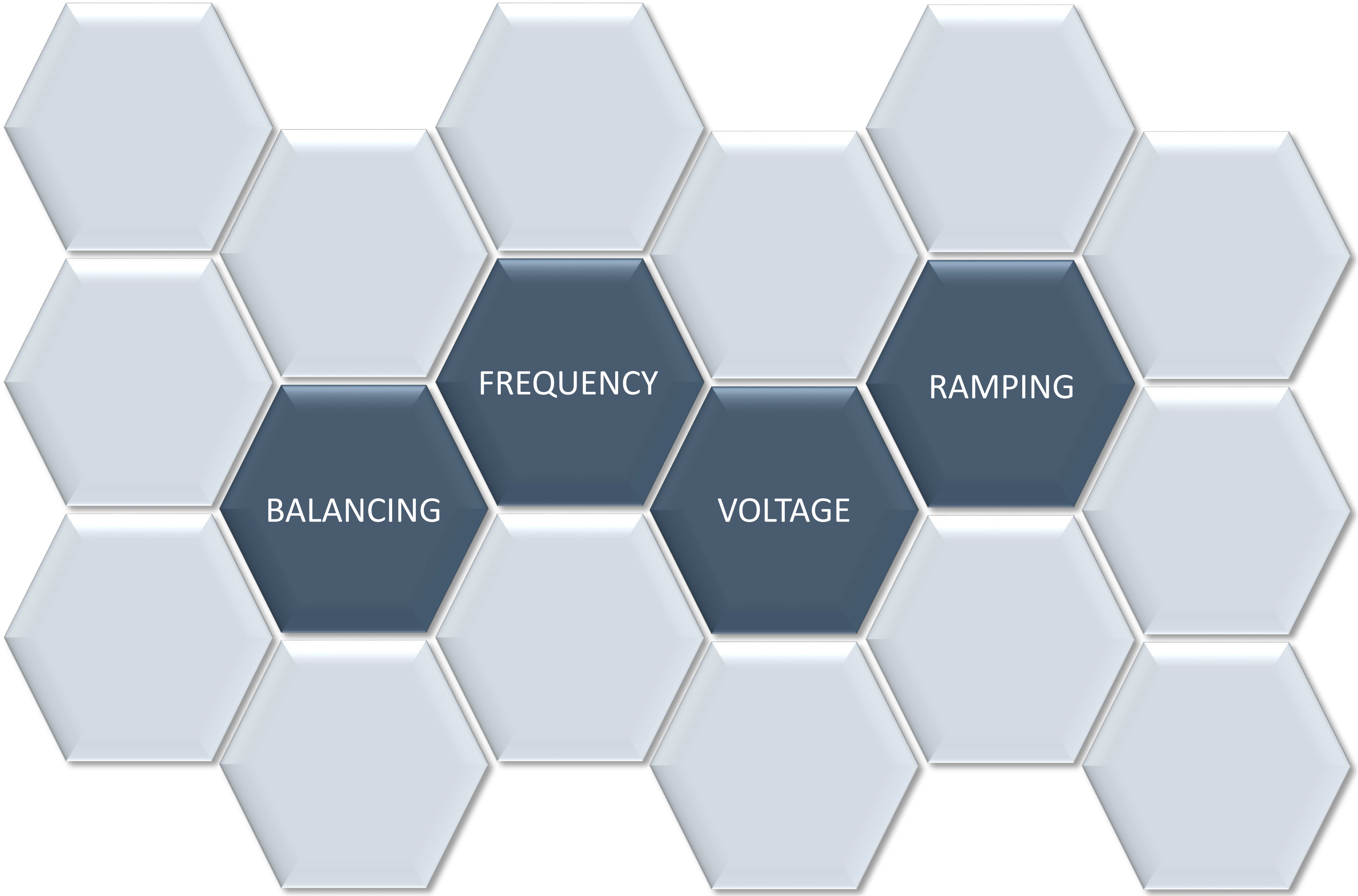
# Concept of “Maximizing” Ride-Through

*Handling Uncertainty of Ride-Through Performance with the Existing IBR Fleet*

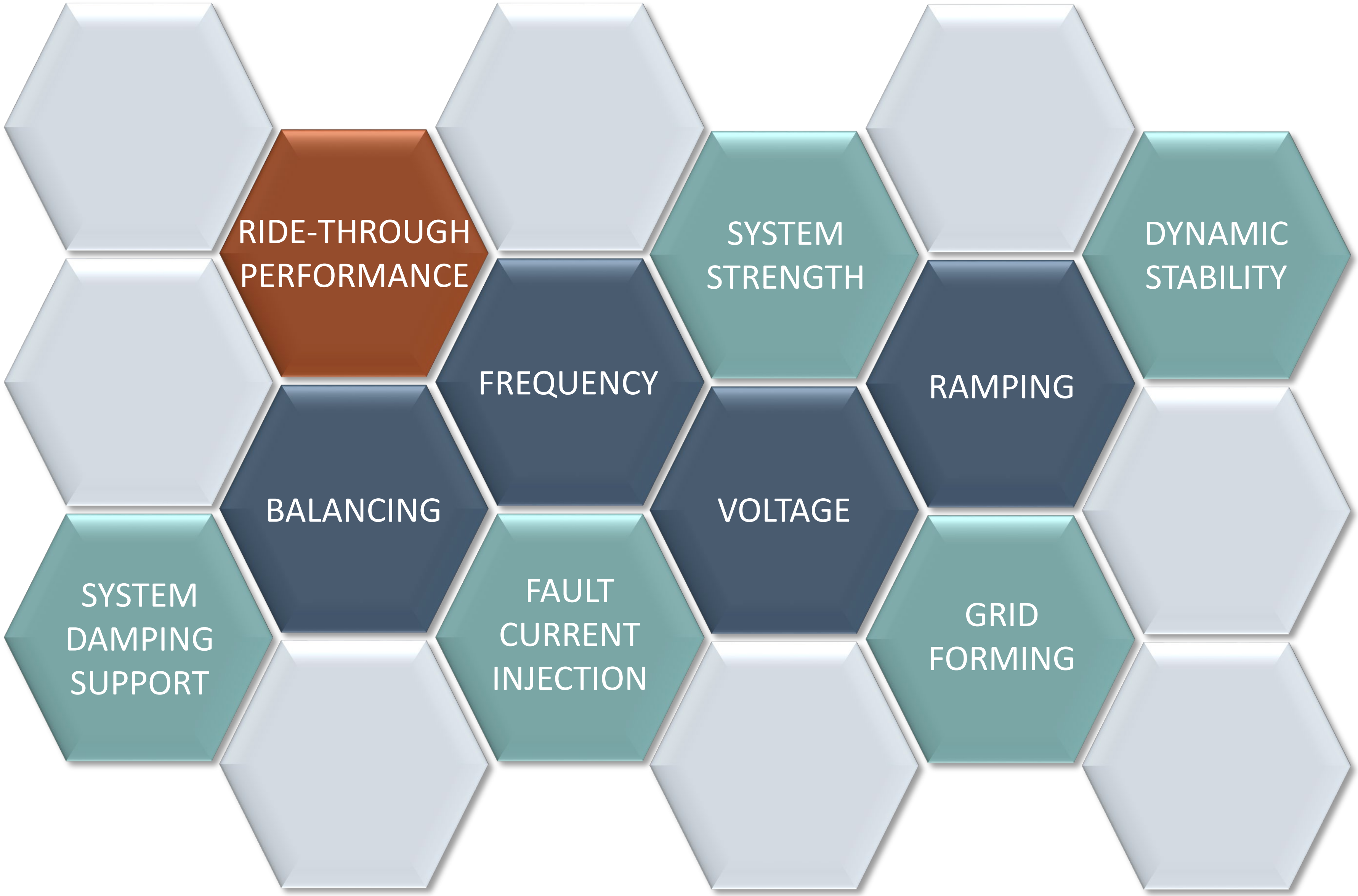
Ryan D. Quint, PhD, PE
Founder and CEO

**August 20, 2024**

# NERC Essential Reliability Services



# Additional Essential Reliability Services



# Background

- Generator ride-through capability is a fundamental essential reliability service
  - Continuity of load is dependent on continuity of generation
- IEEE 2800-2022 is generally applicable for newly connecting IBRs
- Retroactivity of new requirements is a significant challenge
- May be needed in some areas – should be a risk-based decision
- Concept of "maximization" introduced
- ***Does*** the resource ride through versus ***how*** the resources ride through

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# "Maximization" and Exemptions

**NERC PRC-024-3:**

**R3.** Each Generator Owner shall document each known regulatory or equipment limitation[6] that prevents an applicable generating resource(s) with frequency or voltage protection from meeting the protection setting criteria in Requirements R1 or R2, including (but not limited to) study results, experience from an actual event, or manufacturer's advice. *[Violation Risk Factor: Lower] [Time Horizon: Long-term Planning]*

**3.1.** The Generator Owner shall communicate the documented regulatory or equipment limitation, or the removal of a previously documented regulatory or equipment limitation, to its Planning Coordinator and Transmission Planner within 30 calendar days of any of the following:

- Identification of a regulatory or equipment limitation.
- Repair of the equipment causing the limitation that removes the limitation.
- Replacement of the equipment causing the limitation with equipment that removes the limitation.
- Creation or adjustment of an equipment limitation caused by consumption of the cumulative turbine life-time frequency excursion allowance.

**Draft NERC PRC-029-1:**

**R4.** Each Generator Owner identifying an IBR that is in-service by the effective date of PRC-029-1, has known hardware limitations that prevent the IBR from meeting voltage Ride-through criteria as detailed in Requirements R1 and R2, and requires an exemption from specific voltage Ride-through criteria shall:[10] *Lower] [Time Horizon: Long-term Planning]*

**4.1.** Document information supporting the identified hardware limitation no later than 12 months following the effective date of PRC-029-1. This documentation shall include:

**4.1.1** Identifying information of the IBR (name and facility #);

**4.1.2** Which aspects of voltage Ride-through requirements that the IBR would be unable to meet and the capability of the hardware due to the limitation;

**4.1.3** Identify the specific piece(s) of hardware causing the limitation;

**4.1.4** Supporting technical documentation verifying the limitation is due to hardware that needs to be physically replaced or that the limitation cannot be removed by software updates or setting changes, and;

**4.1.5** Information regarding any plans to remedy the hardware limitation (such as an estimated date).

- Current NERC PRC-024 "ride-through" requirements allow for exemptions through documented equipment limitations
- ***Draft*** PRC-029 includes exemptions for voltage ride-through limitations
- Logical that application of new requirements would require exemptions for existing assets – not designed with new requirements in mind
- Need thoughtful adaptations within existing equipment (hardware) capabilities

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# "Maximization" as a Compromise

**<u>No Retroactivity:</u>**
- Typical status quo
- Technical complexities
- Equipment design considerations
- Applicable to areas with relatively low IBR penetration
- Suitable if IBR-related performance risks are minimal

**<u>Software-Based Maximization:</u>**
- Some entities exploring this approach
- Suitable in areas with higher IBR penetration where IBR performance risks may be more prevalent
- Requires careful definition of "maximization" and stakeholder engagement/input

**<u>Complete Retroactivity:</u>**
- Relatively rare implementation
- Technical complexities and nuances
- Controversial subject that may result in stakeholder backlash
- May cause delays in requirements
- Can be very costly and put generator resource lifecycles in jeopardy
- Maybe necessary if reliability studies justify need

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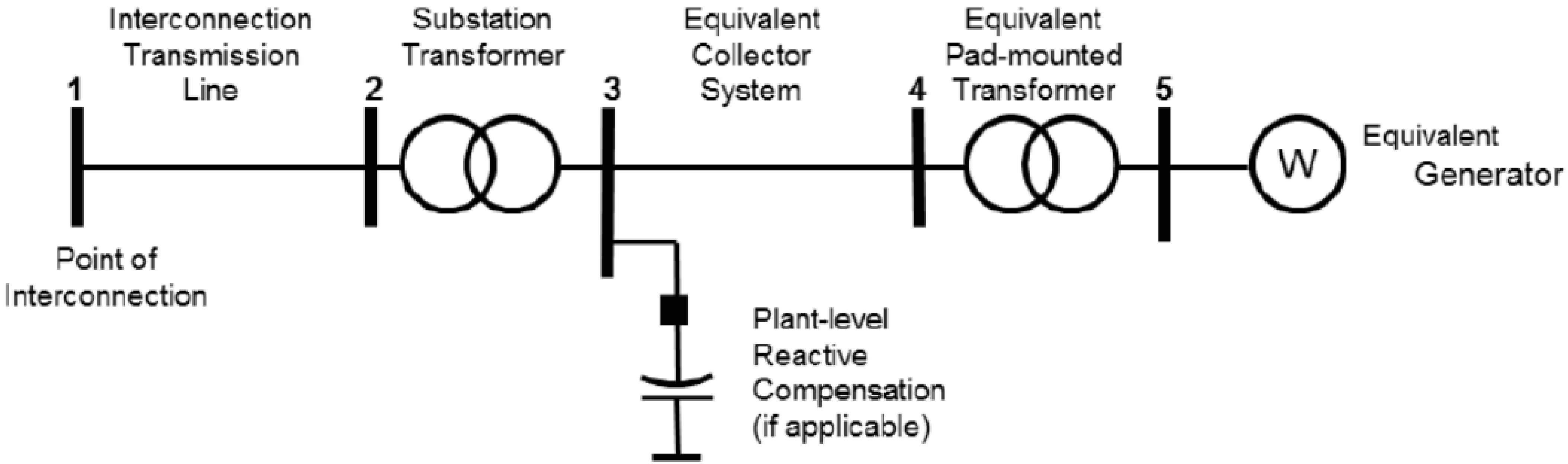
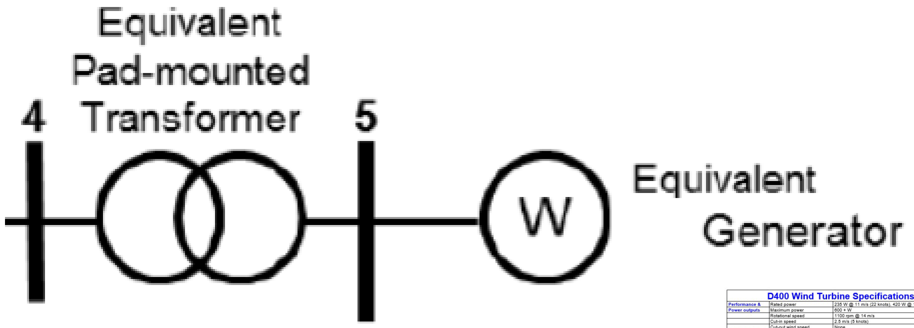
# Reviewing "Maximization"




Source: WECC

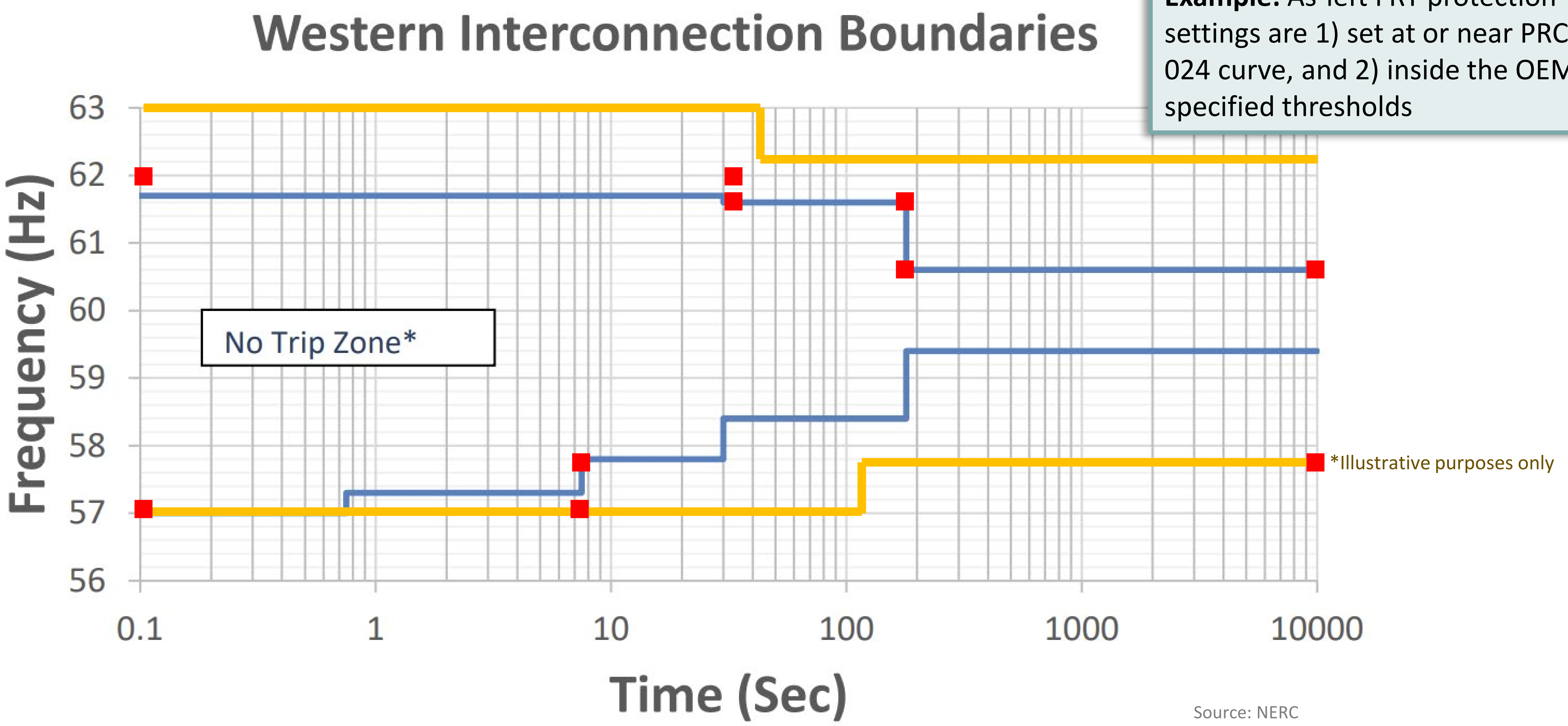
# Inverter Protection

- AC and DC current protection
- AC and DC voltage protection
- Instantaneous peak measurement quantities
- Loss of synchronism and/or anti-islanding protection
- Rate-of-change-of-frequency and phase jump
- Ground fault protection and/or current unbalance
- Negative sequence current protection
- Reverse current protection
- Ride-through mode configuration




# Example: Frequency Ride-Through

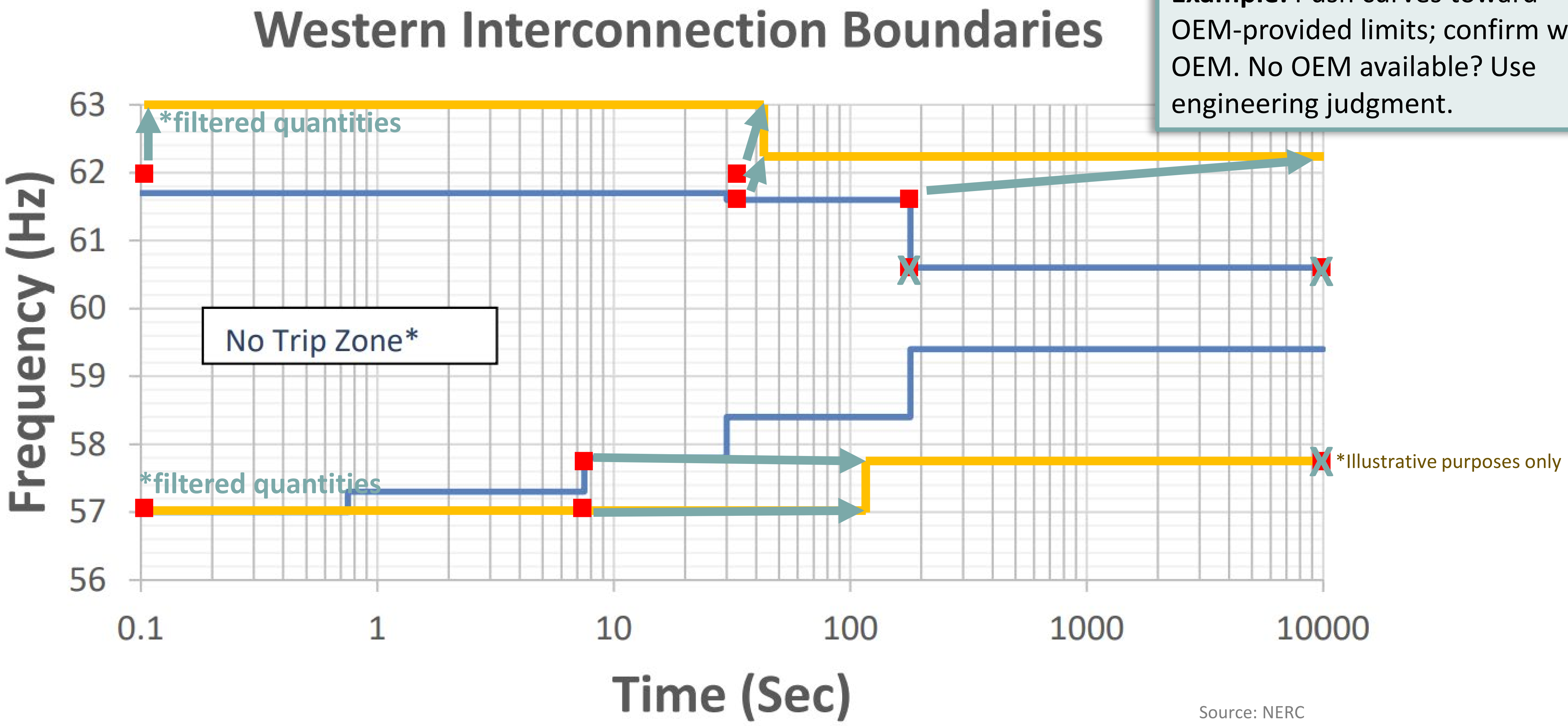
**Example:** As-left FRT protection settings are 1) set at or near PRC-024 curve, and 2) inside the OEM-specified thresholds




Source: NERC

# Example: Frequency Ride-Through

**Example:** Push curves toward OEM-provided limits; confirm with OEM. No OEM available? Use engineering judgment.




Source: NERC

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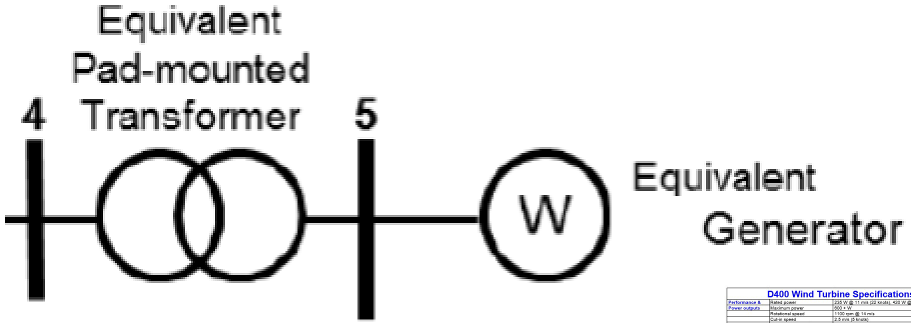
# What About Protections Not Modeled?

- Yaw protection
- Pitch controller protection
- Braking system protection
- Uninterruptible power supply protection
- Overtemperature protection
- Chopper circuit protection
- Vibration sensors and protection
- Tower sway protection
- Hydraulic system / pressure protections
- Icing detection and protection





**Note:** These types of protections are not typically the most limiting aspect of ride-through performance; generally, should not be included in a “maximization” assessment.

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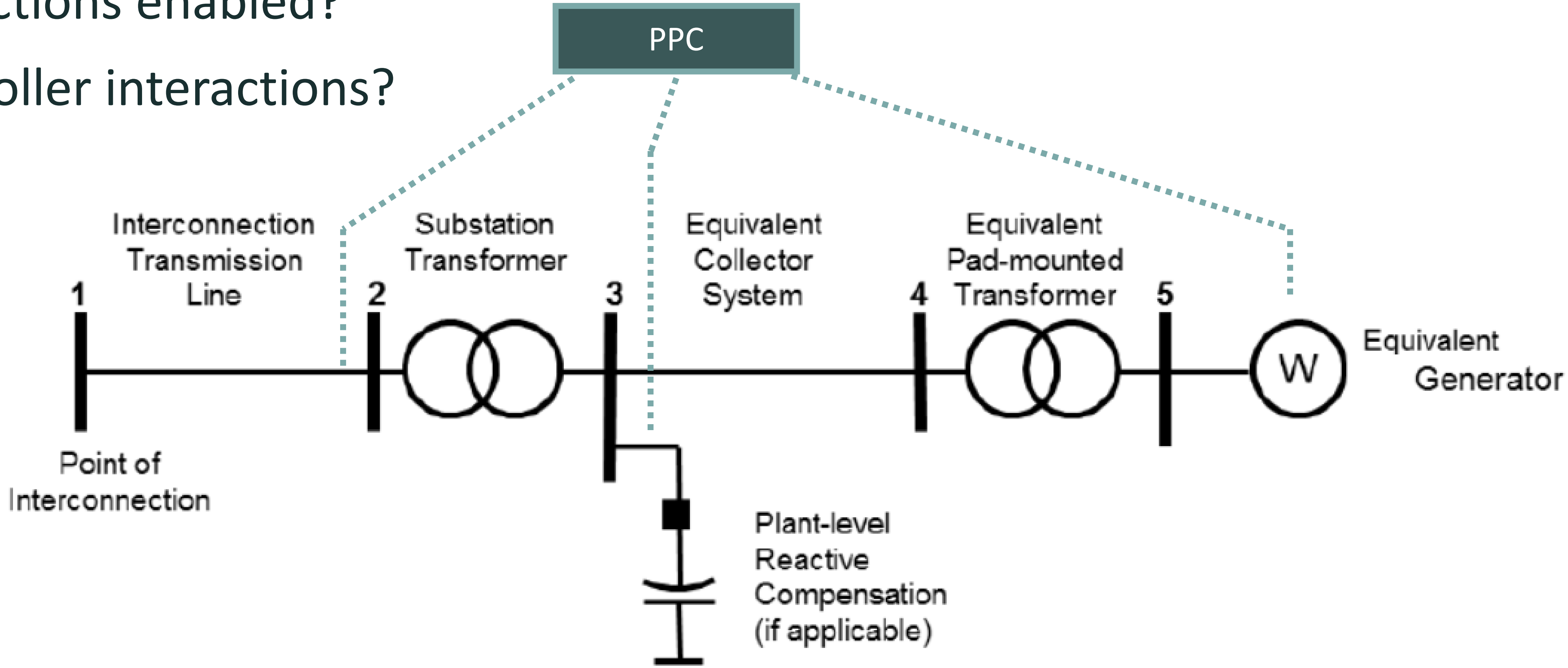
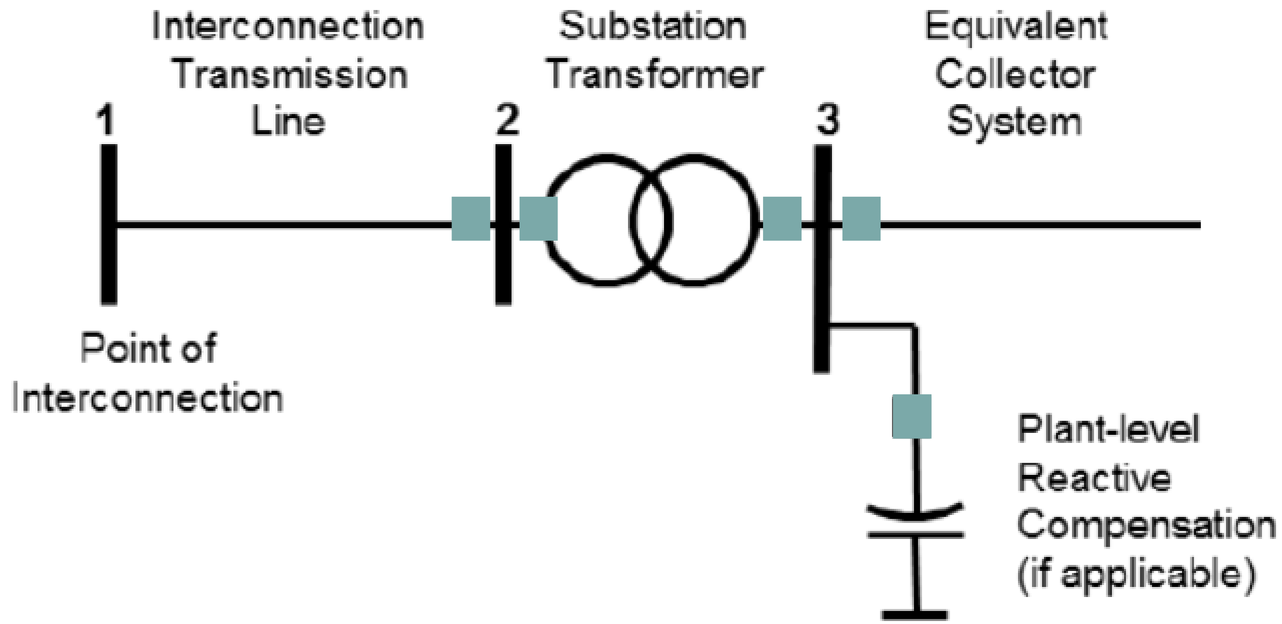
# Power Plant Controller Protection

- Protections enabled?
- Controller interactions?




Source: WECC

# Other Balance of Plant Protection




- Collector protection
- Substation protection
  - Transformers
  - Switchgear and breakers
  - Lightning arrestors
  - Gen tie line
- Supplemental device protection
  - D-STATCOM
  - Shunt capacitors
- Gen tie line protection

- ***What are they protecting?***
- ***What are the equipment ratings?***
- ***Are their protections coordinated with inverter/PPC?***

Source: WECC

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# Modeling Considerations

- Dynamic model(s) should* match changes to the actual facilities
- Requirements and procedures exist regarding how changes are handled
  - Local transmission provider interconnection requirements
  - Transmission planner/planning coordinator modeling requirements
  - NERC FAC-002 requirements
  - FERC LGIP
- Changes to facilities may require extensive re-verification of model accuracy and model quality tests – necessary, but should be a thoughtful exercise

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*Using "should" as a recommendation, but this is a critically important topic

# Maximization Process Concept

**Baseline:**
- Collect protection and control data from throughout facility
- Inverter, PPC, balance of plant, protective relays, etc.
- Get as-left configuration and settings

***Understand current configuration, capabilities, and settings***

**Review:**
- OEM specification sheets
- OEM capability curves and/or limits
- Equipment ratings
- Protection settings
- User-settable parameters
- Control settings and limits

***Determine protection changes that can be made to "maximize"; ensure coordination among changes***

**Model Updates and Studies:**
- Possible changes that may be reflected in dynamic model across simulation platforms
- Conduct ride-through studies, only if needed

***Update dynamic models, as needed***

**Approval and Changes:**
- Understand req's
- Transmission provider process
- Submit changes for review and approval
- Make changes in field

***Submit updated information, get sign-off, make changes (and consider modeling requirements)***

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