NERC

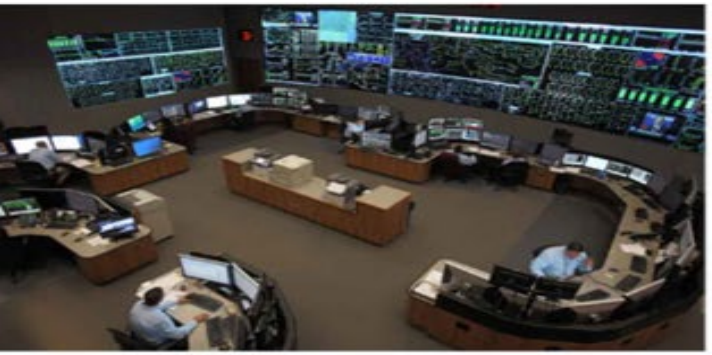
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC Inverter-Based Resource (IBR) Webinar Series:

Session 4: Establishing and Enhancing Interconnection Requirements

June 15, 2023

RELIABILITY | RESILIENCE | SECURITY




Establishing and Enhancing Interconnection Requirements for IBRs

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ESIG

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ENERGY SYSTEMS INTEGRATION GROUP

06/15/2023

Interconnection Requirements Background

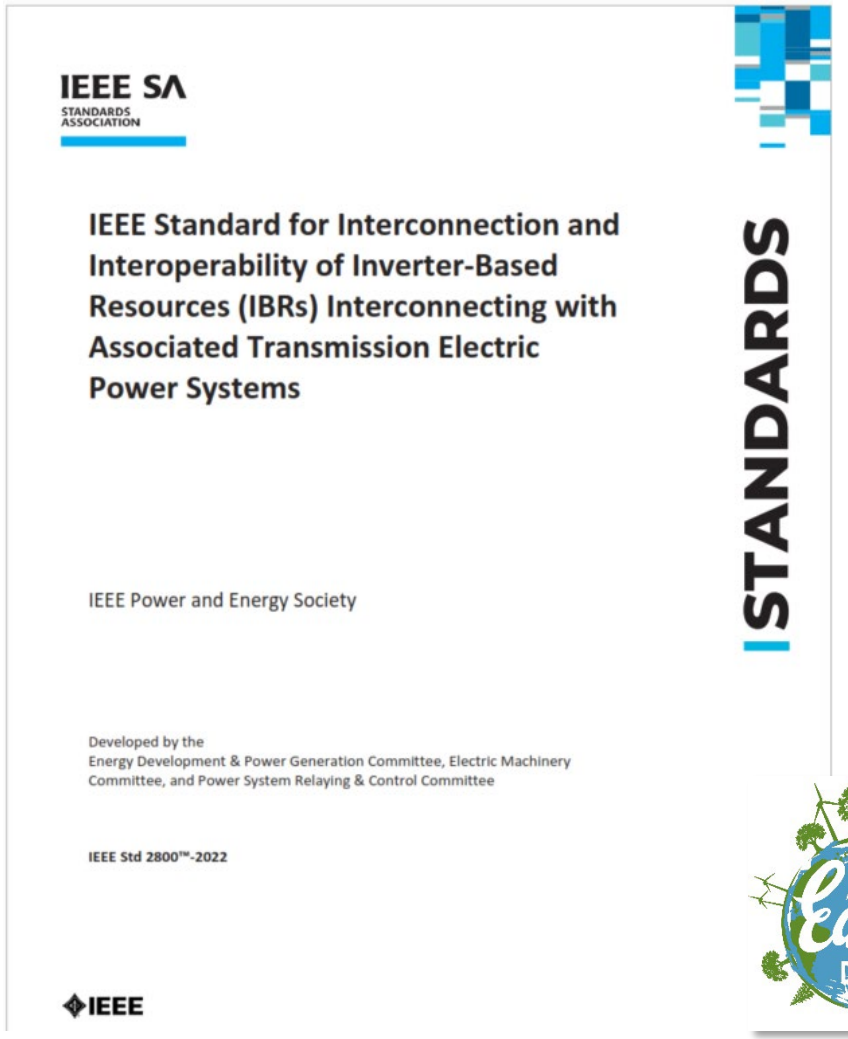
- As inverter-based resources (IBRs) were making up a small share of the generation mix the philosophy was that they should just generate MWs during normal operation and “get out of the way” during disturbances.
- As power systems are changing towards higher shares of IBRs, this strategy is no longer acceptable; losing significant amount of generation following a disturbance puts reliability in jeopardy.
- Gradually, some regions, such as ERCOT, CAL-ISO, ISO-NE, developed more stringent generation interconnection requirements.
- At that time, the capabilities of IBRs were not yet well understood and some requirements were left at the functional level without specifying performance in detail.
- High level requirements lead to misinterpretation and undesired performance, some of which was observed in the recent larger disturbance events analyzed by NERC.

Interconnection Requirements, Today

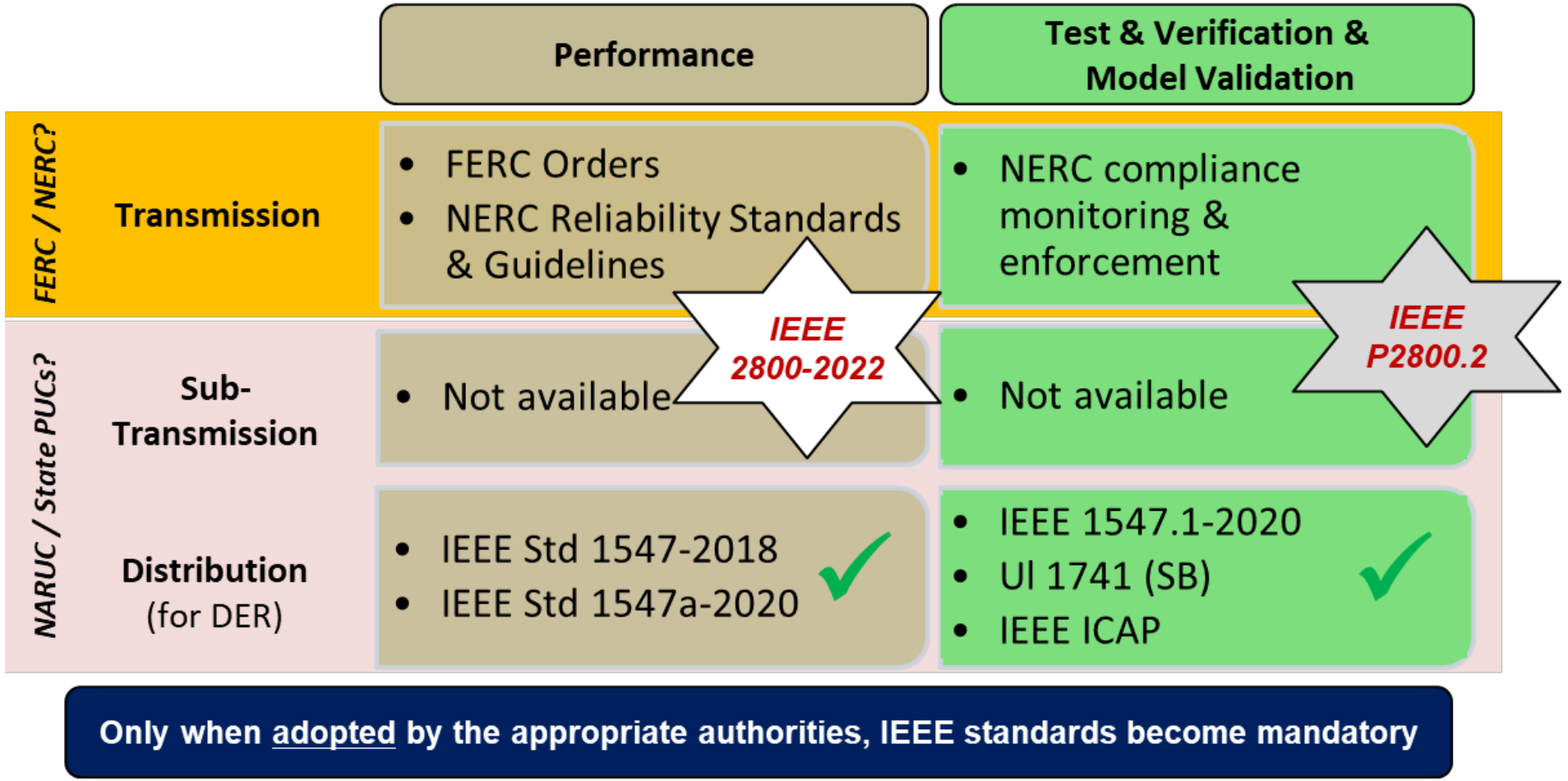
- Many other areas in the U.S. still have very basic interconnection requirements or fully rely on minimal requirements in FERC LGIA.
- NERC introduced reliability guidelines in this area, establishing clear performance expectations and strong recommendations for transmission service providers to adopt them.
- NERC currently has a number of standard revisions underway to address some of these gaps. It is crucial to point out, however, that NERC requirements and standards only apply after commissioning, i.e. there is no requirement today to evaluate conformity with NERC standards during interconnection process.
- With a few exceptions, post-commissioning monitoring and testing process doesn't exist today and the only way to discover non-compliance with NERC standards or interconnection requirements is after a large disturbance happens

Summary of IEEE Std 2800

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



Completing North American Reliability Standards



Source: EPRI, 2021

IEEE Standards Classification

IEEE 1547

IEEE 1547.1

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

IEEE 2800

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

IEEE P2800.2

IEEE P1547.2

IEEE P1547.3

IEEE P1547.9

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

P2800.2 Summary

Title: Recommended Practice for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Bulk Power Systems

Scope:

- Defines **recommended practices** for test and verification procedures that should be used to confirm plant-level conformance of IBRs interconnecting with bulk power systems in compliance with IEEE Std 2800.
- Applies to IBRs interconnected to **transmission and sub-transmission** systems
- May also apply to isolated IBRs that are interconnected to an alternating current (AC) transmission system via dedicated voltage source converter high-voltage direct current (VSC-HVDC) transmission facilities, e.g., offshore wind farms
- Includes specifications for the equipment, conditions, tests, modeling methods, and other verification procedures that should be used to demonstrate conformance with IEEE 2800

P2800.2 Summary

Includes:

- Type tests
  - Unit level, **not full compliance with 2800**
  - Test results are used to validate unit level model
- Design evaluation using verified IBR plant model
  - Includes procedures to validate unit level model
- As-built IBR plant evaluation and commissioning tests
- Post-commissioning IBR plant model validation, monitoring, periodic tests & verifications

- **Recommended Practice**: uses **"should"** language, not "shall" language
  - In recognition that prescribing uniform procedures across all IBR types and interconnecting locations would be very challenging.

Adoption of IEEE 2800:

- Adoption of IEEE 2800 is not contingent upon publication/adoption of IEEE P2800.2
  - ***In absence of IEEE P2800.2*, IBR owners, TS owners/operators, OEMs, etc. could develop their own test and verification procedures or use existing procedures**
- For systems experiencing IBR ride-through events/problems, some requirements may be higher priority than others (ride through of low voltage, TOV, ROCOF, phase jump)
- Needs consideration of enforcement date, grandfathering etc.
- Possible adoption methods:
  - Full adoption by simple reference
  - Full or partial adoption, clause-by-clause reference, additional requirements
- Many utilities/ISOs are already moving towards adoption

ERCOT Adoption of IEEE 2800

- ERCOT already has very comprehensive interconnection and modeling requirements
- Some requirements remain at higher level, which resulted in issues during Odessa disturbance events in 2021 and 2022
- Need to specify ride-through capability in more details
- Considered “wholesale” IEEE 2800 adoption, but it’s hard – partial adoption selected
- EPRI conducted gap analysis between IEEE 2800 and existing ERCOT Requirements, identified 13 gaps
- ERCOT prioritized the gaps and working on adoption of IEEE2800 VRT requirements (highest priority!)

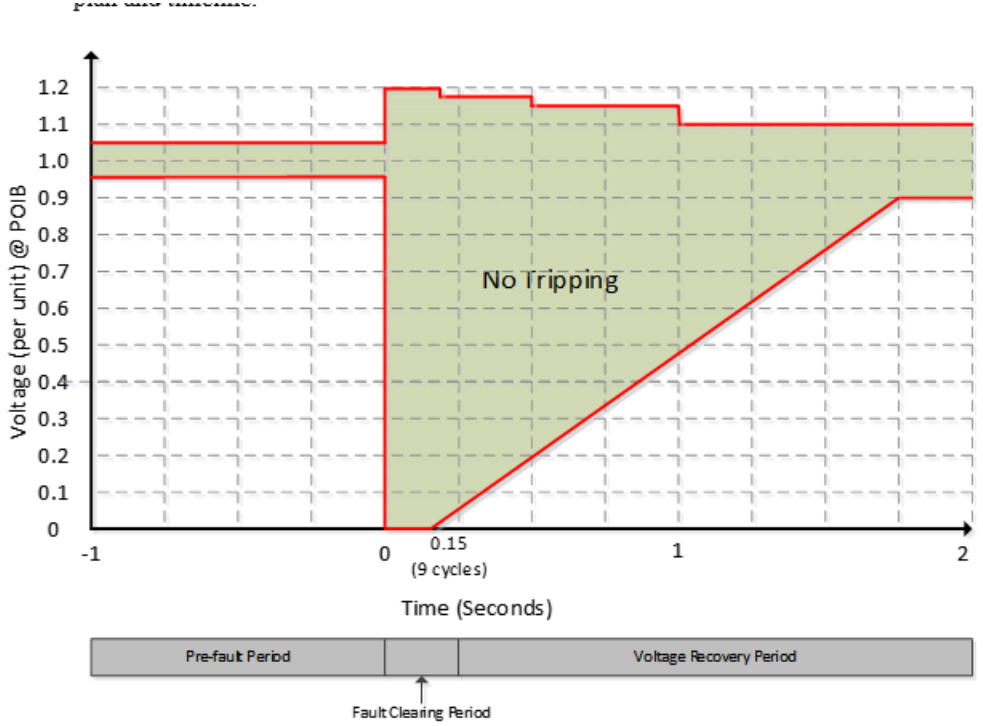


Figure 1: Default Voltage Ride-Through Boundaries for IRRs Connected to the ERCOT Transmission Grid

Conclusions

- IBR performance issues are **not due to the shortcomings of the IBR technology**!
- Shortcomings of the interconnection process and lack of harmonized, comprehensive standards applicable as early as the interconnection process and throughout the lifetime of an IBR project are leading to IBR performance issues
- Until these gaps are closed, the developers will be naturally choosing cheaper equipment that may have inferior performance and large disturbance events will continue happening.
- This is where NERC has a very important role to play thorough standards, reliability guidelines and event analysis.
- Adoption of IEEE 2800 and implementation at federal level and implementation of appropriate testing, verification and conformance assessment procedures are a key for achieving reliable implementation of high shares of IBRs.

THANK YOU

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Questions and Answers After All Presentations

Establishing and Enhancing Interconnection Requirements

ISO New England Approaches and Lessons Learned

Al McBride

DIRECTOR, TRANSMISSION SERVICES AND RESOURCE QUALIFICATION

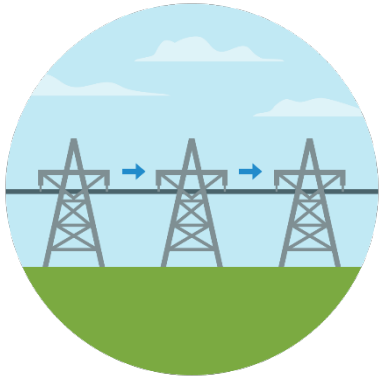
Highlights

- Since 2016, ISO New England (ISO-NE) has required PSCAD models, and has conducted PSCAD studies, for new Inverter-Based Resource (IBR) interconnections
  - High-level requirements are included in the pro forma Interconnection Agreement/Interconnection Procedures – which are filed with FERC
  - Detailed requirements are contained in ISO-NE Planning Procedures – which are reviewed with the regional stakeholders
- ISO-NE is planning a significant revision of these requirements as part of our adoption of IEEE 2800 (Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems)

ISO New England Performs Three Critical Roles to Ensure Reliable Electricity at Competitive Prices

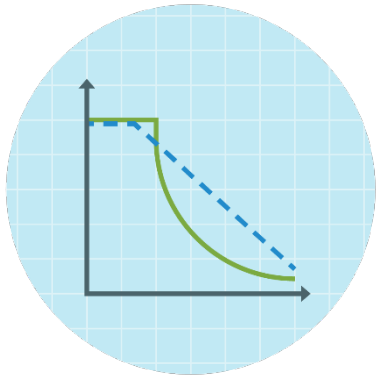
Grid Operation

Coordinate and direct the flow of electricity over the region's high-voltage transmission system



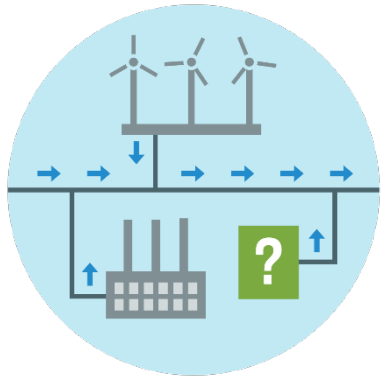
Market Administration

Design, run, and oversee the markets where wholesale electricity is bought and sold



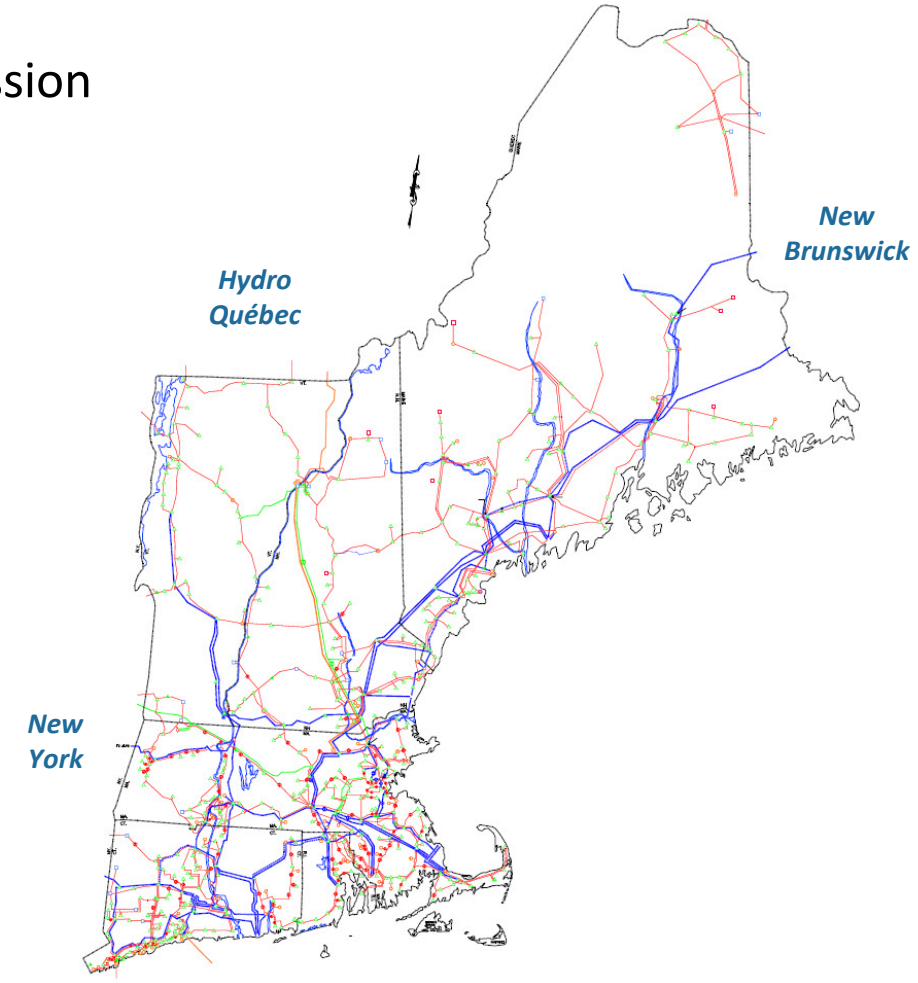
Power System Planning

Study, analyze, and plan to make sure New England's electricity needs will be met over the next 10 years



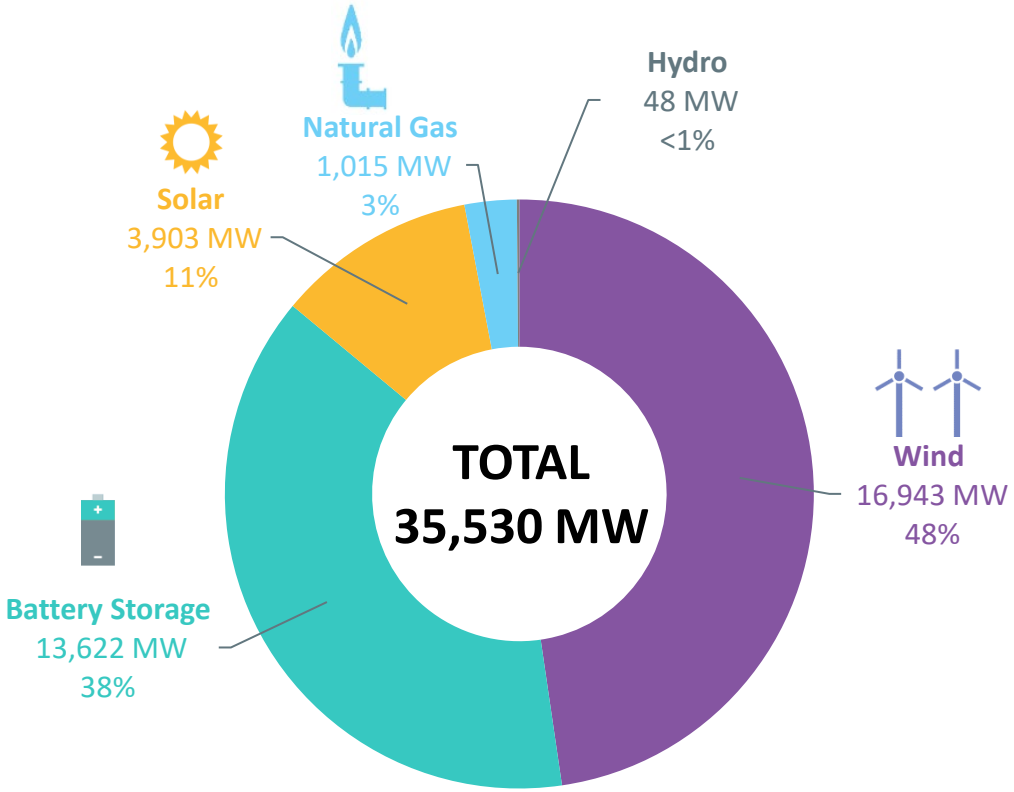
New England's Transmission Grid Is the Interstate Highway System for Electricity

- **9,000 miles** of high-voltage transmission lines (primarily 115 kV and 345 kV)
- **13 transmission interconnections** to power systems in New York and Eastern Canada
- **14%** of region's energy needs met by imports in 2022
- **$11.9 billion** invested to strengthen transmission system reliability since 2002; **$1.3 billion** planned
- Developers have proposed multiple transmission projects to access **non-carbon-emitting resources** inside and outside the region



IBRs Comprise Nearly All of New Resource Proposals in the ISO Interconnection Queue

All Proposed Resources



Source: ISO Generator Interconnection Queue (June 2023)
FERC Jurisdictional Proposals; Nameplate Capacity Ratings
Note: Some natural gas proposals include dual-fuel units (with oil backup).
Some natural gas, wind, and solar proposals include battery storage. Other includes hydro, biomass, fuel cells and nuclear uprate.

Proposals by State

(all proposed resources)

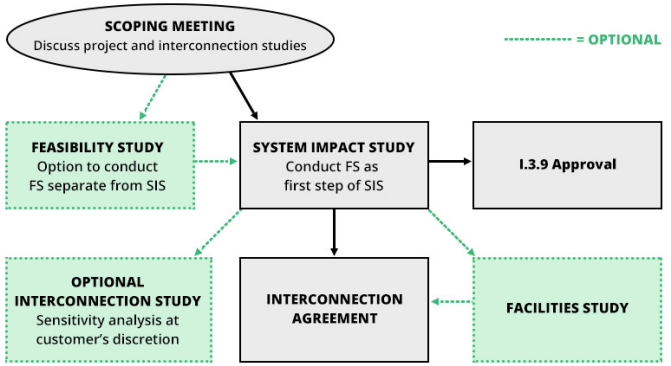
State	Megawatts (MW)
Massachusetts	19,700
Connecticut	7,125
Maine	5,461
Rhode Island	1,574
New Hampshire	1,295
Vermont	375
Total	**35,530**

Source: ISO Generator Interconnection Queue (June 2023)
FERC Jurisdictional Proposals

New Generator Interconnection Process

ISO-NE Study & Data Overview

- Interconnection Request
- Technical Data Submittal
- Scoping Meeting
  - Interconnection Studies and Options



*Type of study determines type of data submitted

Data submittal and timing requirements

	Large Generator (>20MW)	Small Generator (≤20MW)
Technical data submittal timing:	No later than the due date of execution of the System Impact Study Agreement: •All generators must submit Schedule 22, Appendix 1, Attachment A. •Wind and inverter-based generating facilities (e.g., solar, battery) must **also** submit the technical data required in Appendix 1, Attachment A-1.	**All** technical data are due at the time the interconnection request is submitted. Schedule 23, Attachment 2, and Attachment A to the IR form, provide details for the data required.
Technical data submittal: electrical one-line diagram	Required with technical data submission	Must be signed and stamped by a licensed professional engineer and included with the submission
Technical data submittal: models	All wind and inverter-based projects (e.g., solar, battery) must provide acceptable PSSE and PSCAD models along with technical data submission. Other types of generators must provide a PSSE model and may also be required to supply a PSCAD, as discussed at the scoping meeting.	All wind and inverter-based projects (e.g., solar, battery) must provide acceptable PSSE and PSCAD models. Other types of generators may also be required to supply an acceptable simulation model, as discussed at the scoping meeting.

PLANNING PROCEDURE REQUIREMENTS

Planning Procedure 5-6

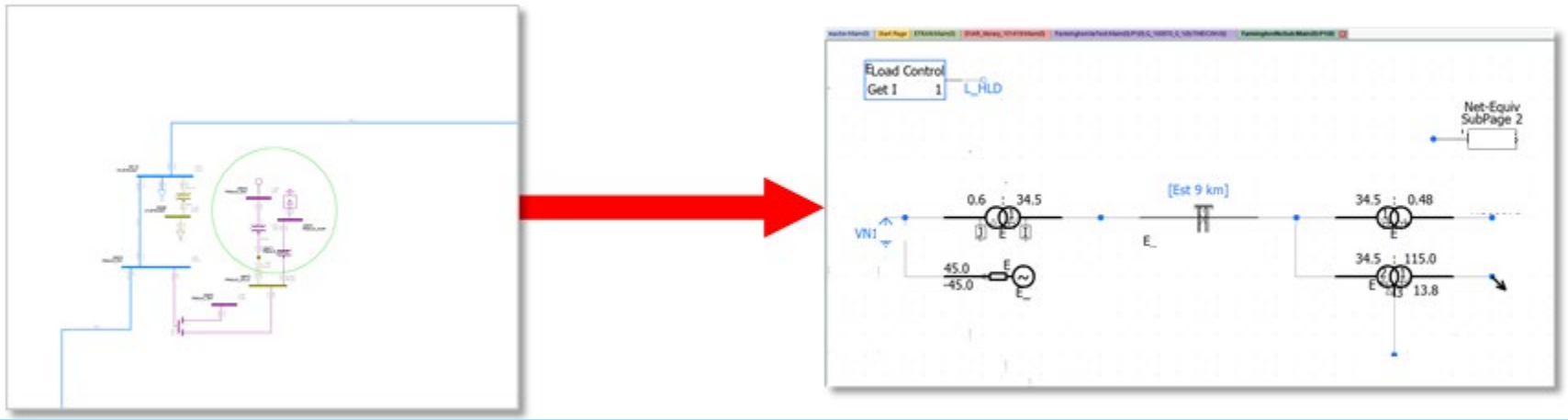
Interconnection Planning Procedure for Generation and Elective Transmission Upgrades

When does ISO-NE require EMT studies?

- Studies are required when there are concerns about certain grid conditions, interactions, or phenomena
  - Weak system conditions (low short circuit strength)
  - Ride-through or large signal disturbance performance
  - Control interactions
  - Voltage Transients
  - Sub-synchronous oscillations such as sub-synchronous torsional interactions (SSTI) or sub-synchronous control interactions (SSCI)
  - Performance verification
- ISO-NE requires an Electromagnetic Transient (EMT) study for each inverter-based generating facility, or Elective Transmission Upgrade (ETU) that utilizes power electronics as part of the facility or network upgrade

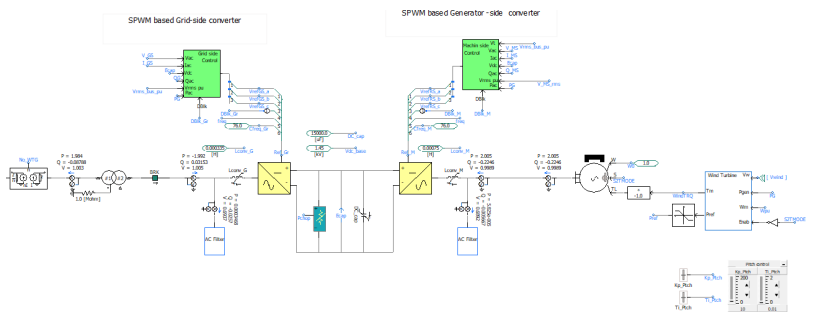
EMT Study Requirements

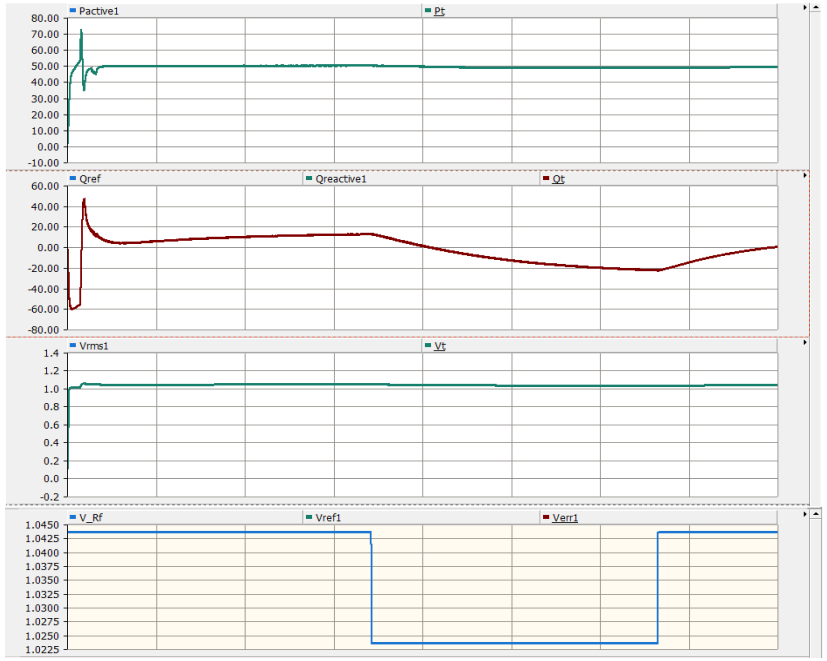
- ISO-NE uses PSCAD software to accomplish EMT analysis
- System Impact Studies require full N-1 and N-1-1 fault testing along with any other EMT analyses identified during scoping
- Study area includes all electrically relevant transmission and generating facilities
  - Mostly local, PSCAD cases represent portions of the overall system and use voltage sources that represent system strength as boundaries
  - Initial conditions are informed by the steady state and stability studies



PSCAD Models – Planning Procedure Requirements

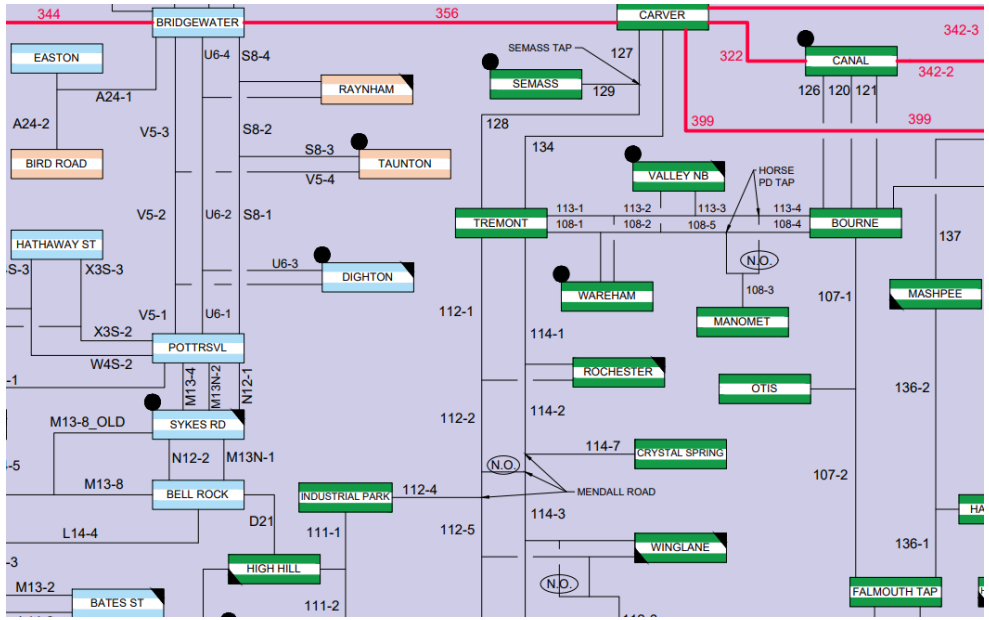
- Models are required to be provided as part of the interconnection request for all IBRs and ETUs utilizing power electronics
- Models are vetted for accuracy, useability, and efficiency as part of the interconnection request review process
  - Benchmarking
  - Single Machine infinite bus
  - Playback Testing





Distributed Energy Resources (DERs)

- Accumulations of DER (i.e. distribution system-connected) proposals are aggregated and studies may be needed
  - All individual projects 5MW or greater
  - Aggregates of 20MW or more at a single station, or between electrically proximal stations
- Different types of studies may be needed
  - Steady State
  - Short Circuit
  - Stability
  - EMT



Motivation for EMT Studies of DER Aggregations

- Concerns with high penetrations
  - Other market participants
  - Ride through for bulk grid events
  - Interactions with other nearby IBRs
  - Weak Grid Instabilities
- Manufacturer models are considered more accurate than generic models and contain actual inverter protections
  - Over/under voltage Phase Locked Loop loss of sync
  - Rate of change of frequency
  - Vector Shift
- Can be used to benchmark PSS/e results
  - Benchmark at the high side of the T&D interface

FUTURE CHANGES

Updates to incorporate IEEE 2800 requirements

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

Possible IEEE 2800-2022 Adoption Methods

General Reference

- Full adoption of standard by general reference
- Specification of
  - technical minimum capability per IEEE 2800-2022
  - functional settings/ performance (in ranges of available settings)
- Decision whether to specify additional requirements or not
  - e.g., for non-exhaustive reqs.

Detailed Reference

- Full or partial adoption of std
- Clause-by-clause references
- Any additional requirements

Benefit: *Consistency to standard*

Risk: *Fragmentation of requirements, certification challenges, additional costs*

Full Specification

- All on the left
- Clause-by-clause own language
- Any additional requirements

Benefit: *No need to buy standard*

Risk: *Inconsistencies to standard and fragmentation of requirements, certification challenges, additional costs*

Source: EPRI

Adoption Approach by ISO-NE: Detailed Reference

- Plan is to develop **minimum performance** specifications for newly interconnecting resources, using the IEEE Std 2800
- Seek to implement performance requirements clause by clause, rather than wholesale adoption for now
- Performance specifications will be added to multiple planning and operating documents
- In future, adoption of IEEE Std 2800 by general reference, i.e., wholesale adoption, will be reviewed to determine if possible
- Development of verification requirements to follow in conjunction or after publication of IEEE P2800.2
  - Interim approach may be to accept developer provided verification/validation in conjunction with conformity assessment performed by ISO-NE

Planning Procedure
Items to be Incorporated from IEEE 2800

- Applicability
- Definition
- Reference Point of Applicability
- Enter Service
- Active Power Frequency Response
- Reactive Power Capability & Voltage Control
- Voltage Ride-Through
- Transient Ride-Through

Lessons Learned

- Include high-level requirements in the Tariff documents and details in the local operating documents
- Incorporate industry expertise in drafting technical requirements
- Prepare to invest in model management resources and databases
- Continue to evolve with industry standards

Questions

Questions and Answers After All Presentations

Generation Interconnection Requirements at BPA

Presentation at NERC IBR Series

Webinar 4: Establishing and Enhancing Interconnection Requirements

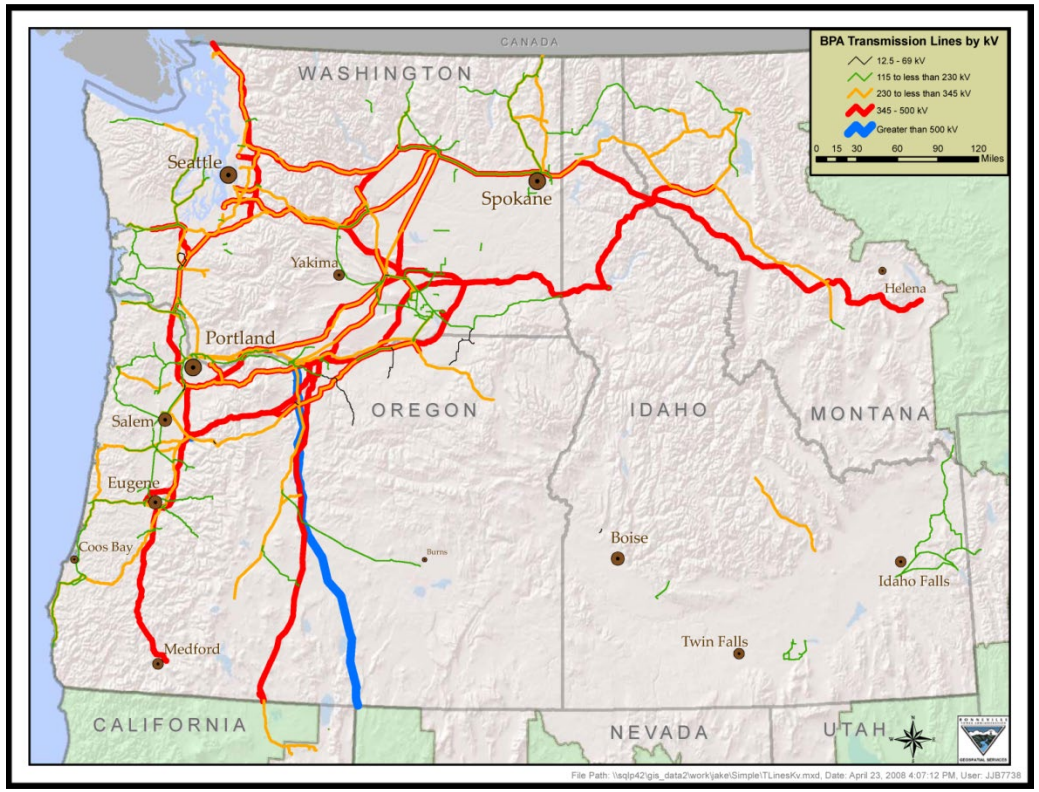
Dmitry Kosterev

Transmission Planning

Bonneville Power Administration

June 2023

BPA Overview



- Bonneville Power Administration (BPA) is a federal Power Marketing Agency in Pacific Northwest
- BPA markets power from 31 Federal dams (about 22 GW of generating capacity) and 1.2 GW Columbia Generating Station Nuclear Plant
- BPA operates more than 15,000 miles of transmission, including 4,735 miles of 500-kV lines
- **BPA has about 7 GW of mostly wind and some solar generation interconnected**

BPA operates several large paths in the Western Interconnection – Northwest AC Intertie with California (4,800 MW), Pacific HVDC Intertie (3,220 MW), Northern Intertie with Canada (3,150 MW), and Montana Intertie (2,200 MW)

Need to Stay Engaged

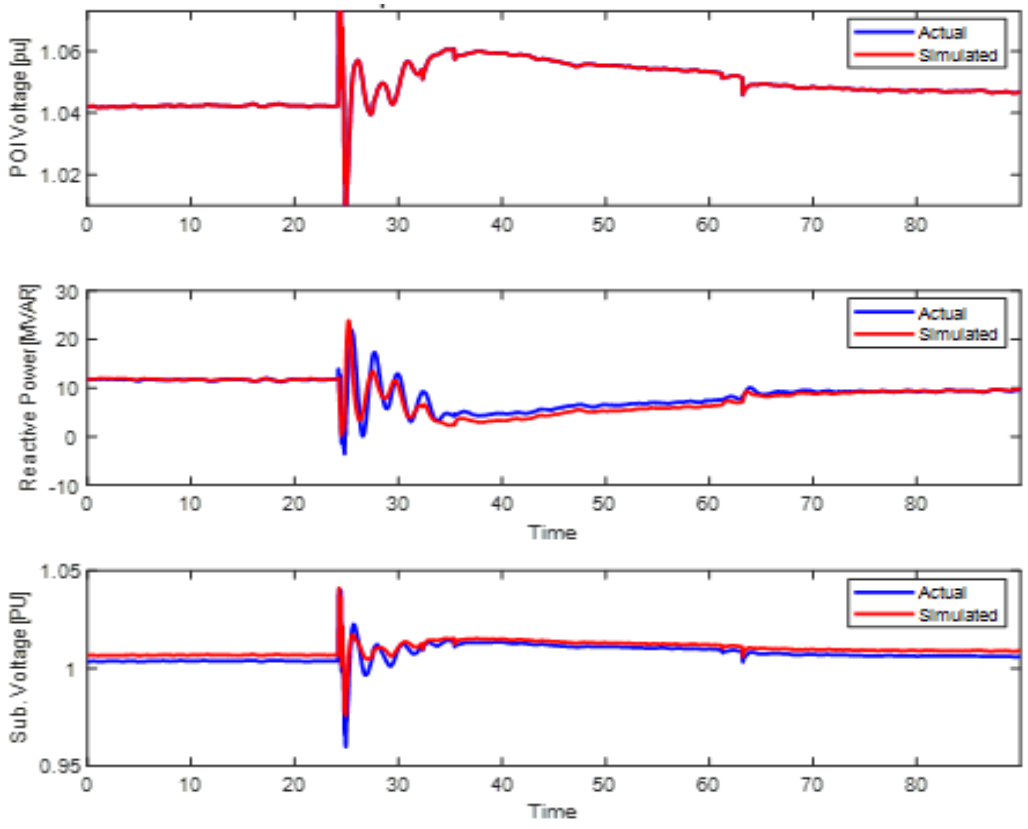
- Advancements in wind, solar and storage technologies
- Learning experiences from other TOs
- Stay engaged with
  - ESIG
  - NERC IRPWG
  - WECC MVS
  - NATF
  - EPRI

Generation Interconnection Requirements

- BPA was one of the early adopters of NERC Reliability Guideline for BPS-Connected Inverter Based Resources in its “Technical Requirements for Interconnection”:
  - Reactive Capabilities
  - Voltage Controls
  - Frequency controls
  - Disturbance ride-through
- BPA requires point-on-wave PMUs at generator POIs
- BPA recently added performance verification tests for voltage and frequency controls

Disturbance Ride-Through and EMT Studies

- Emerging EMT requirements
- EMT models and studies are needed to assess (a) disturbance ride-through, (b) control interactions, (c) SSCO issues
- Looking for **NERC EMT Task Force** to provide guidelines and automated tools for EMT model data intake and disturbance ride-through analysis
- Need EMT training – classes and expert support

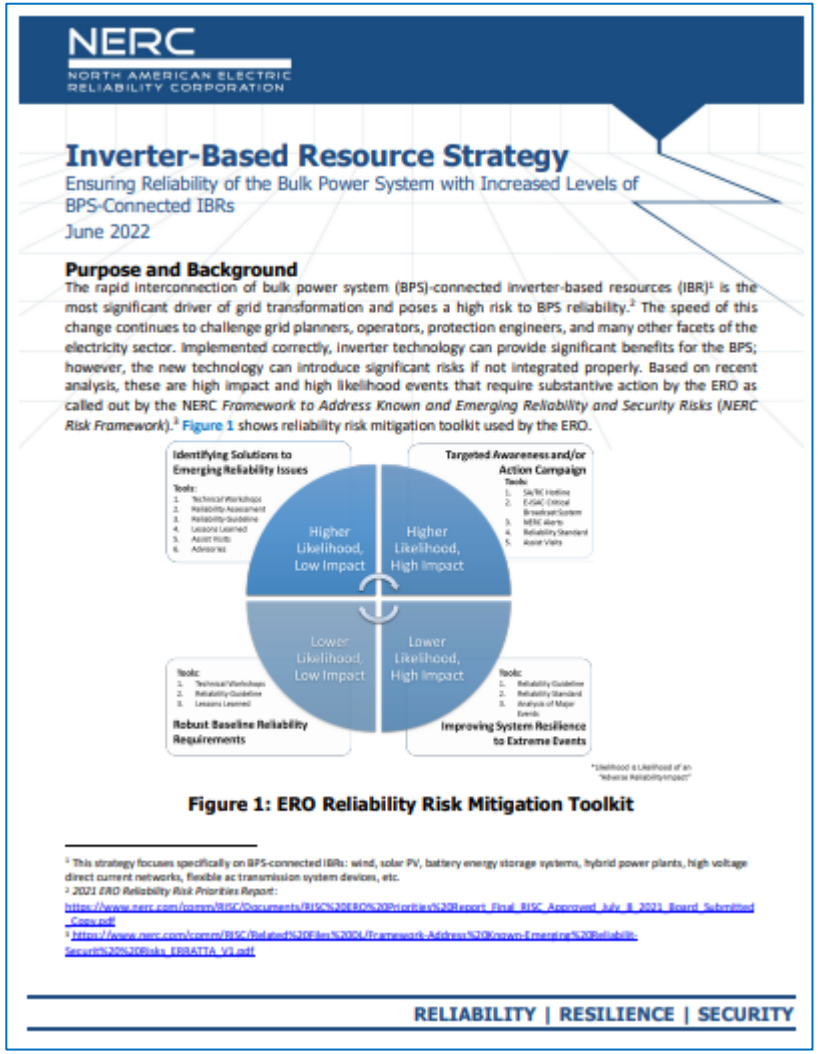


BPA uses PMU disturbance recordings for IBR plant performance monitoring and model validation

Modeling and Performance

- BPA is revising Generation Interconnection requirements to keep with NERC IBR Strategy:
  - Existing version includes 2018 NERC Guidelines
  - Strengthen ride-through requirements
  - Add EMT Modeling requirements
  - Add Grid-Forming requirements for battery storage

- Proposing Model and Performance Attestation Form
  - Performance will meet BPA interconnection requirements
  - Models accurately represent equipment performance



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Inverter-Based Resource Strategy

Ensuring Reliability of the Bulk Power System with Increased Levels of BPS-Connected IBRs

June 2022

Purpose and Background

The rapid interconnection of bulk power system (BPS)-connected inverter-based resources (IBR)[1] is the most significant driver of grid transformation and poses a high risk to BPS reliability.[2] The speed of this change continues to challenge grid planners, operators, protection engineers, and many other facets of the electricity sector. Implemented correctly, inverter technology can provide significant benefits for the BPS; however, the new technology can introduce significant risks if not integrated properly. Based on recent analysis, these are high impact and high likelihood events that require substantive action by the ERO as called out by the NERC *Framework to Address Known and Emerging Reliability and Security Risks* (*NERC Risk Framework*).[3] Figure 1 shows reliability risk mitigation toolkit used by the ERO.

Figure 1: ERO Reliability Risk Mitigation Toolkit

[1] This strategy focuses specifically on BPS-connected IBRs: wind, solar PV, battery energy storage systems, hybrid power plants, high voltage direct current networks, flexible ac transmission system devices, etc.
[2] *2021 ERO Reliability Risk Priorities Report*: https://www.nerc.com/comm/RISC/Documents/RISC%20ERO%20Priorities%20Report_Final_RISC_Approved_July_8_2021_Board_Submitted_Copy.pdf
[3] https://www.nerc.com/comm/RISC/Related%20Files%202014/Framework-Address%20Known-Emerging%20Reliability-Security%20%20Risks_ERRATTA_V1.pdf

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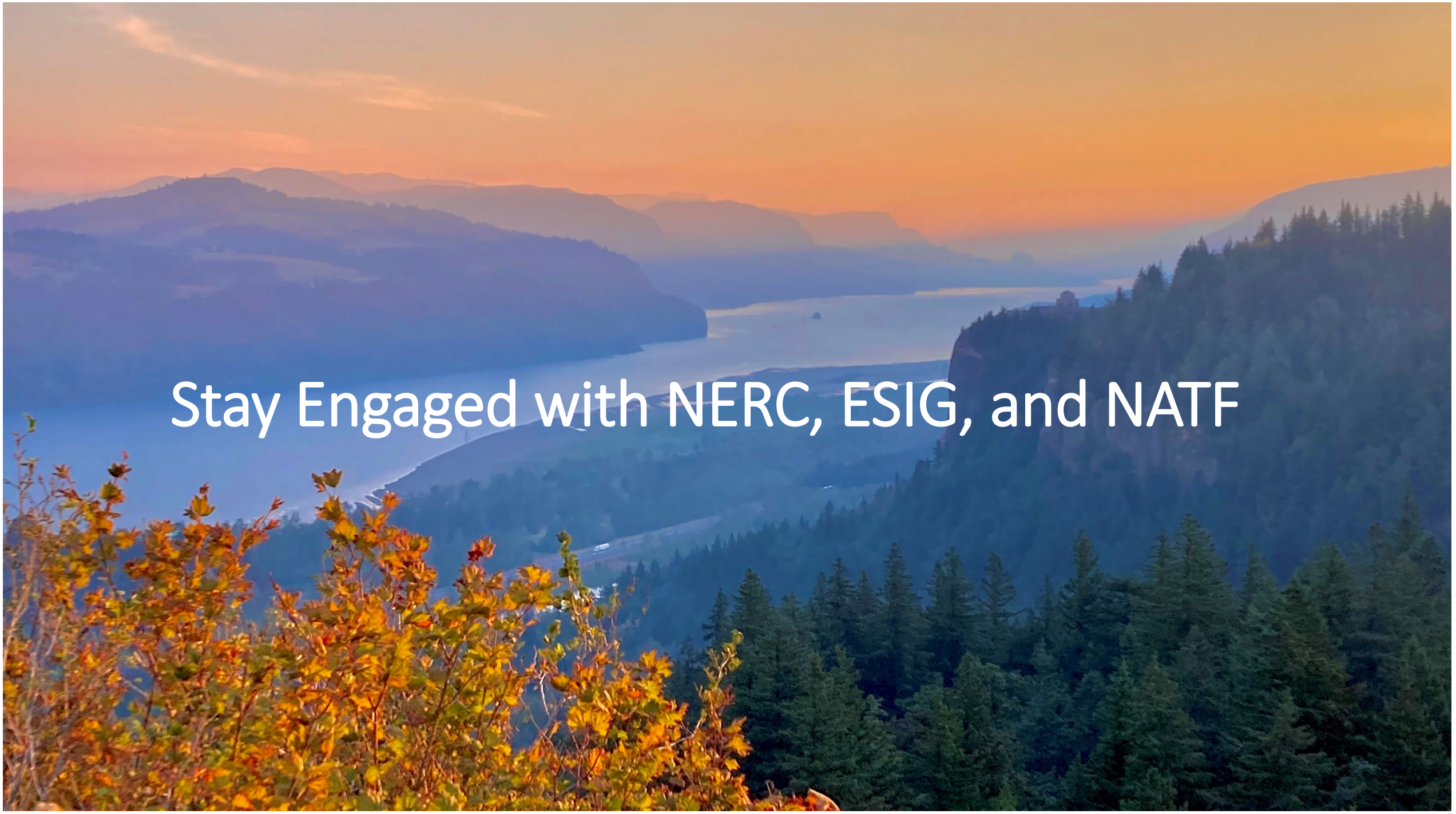
Stay Engaged with NERC, ESIG, and NATF

Questions and Answers

Feel free to reach out to us if interested in participating in the NERC IRPS or EMTTF!