



IBR and Data Center Integration: Updates from 2024 and Predictions for 2025

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Today's Presenters and Our Team



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NERC Milestone 2 Work on Order 901

PRC-028

Disturbance Monitoring & Reporting for IBRs

- Sequence of event recording (fault codes, alarms, statuses)
- Fault recording (MPTs, collectors, shunt devices)
- Dynamic disturbance recording (e.g. PMU) at each MPT
- Recording, storage, and reporting thresholds
- **Significantly less stringent than IEEE 2800-2022**

PRC-029

Ride-Through Requirements for IBRs

- Voltage and frequency ride-through req's
- Small disturbance response req's
- Large disturbance dynamic response req's (current injection, active power recovery, etc.)
- **Curves aligned with IEEE 2800-2022; technical details not included**

PRC-030

Unexpected IBR Event Mitigation

- Process to identify unexpected loss or reduction in output
- Event analysis within determined timeframes
- Corrective action plan development and implementation
- **Heavy workload and reporting requirements on IBR owners**

- Applicable to all registered IBRs – BES IBRs and non-BES IBRs that meet the NERC Category 2 GO criteria
- All approved by industry and submitted to FERC for approval in November 2024

NERC Milestone 3 Work on Order 901

Project 2020-06 – Verifications of Models and Data for Generators: Addressing the verification and validation of models for registered inverter-based resources (IBR), unregistered and aggregated IBR, and aggregated distributed energy resources.

Additional Focus:

- Define terms, such as Model Verification and Model Validation
- Develop process for post-interconnection model validation based on performance data
- Set validation expectations using performance data

Standards Include: MOD-026, MOD-027, FAC-002

Project 2021-01 – System Model Validation with IBRs:

Addressing system-level model verification and validation against actual system operational behavior during disturbances as well as aligning steady state and dynamic representation, where appropriate.

Additional Focus:

- Develop criteria for performing validation
- Determine minimum study conditions for conducting validation studies
- Develop process to communicate system interconnection-wide model defects to Transmission Planners and other associated entities

Standards Include: MOD-033

Project 2022-02 – Uniform Framework Model Framework for IBR: Addressing development of a NERC-maintained library consisting of generic IBR model types.

Additional Focus:

- Establish a uniform framework for data sharing and model development
- Ensure other standards use performance data and library using this framework

Standards Include: MOD-032, TOP-003, IRO-010

Project 2022-04 – Electromagnetic Transient (EMT) Modeling (expected to be added December 2024): Addressing establishment of EMT studies, as appropriate, during the interconnection process.

Additional Focus:

- Assure alignment with other modeling requirements developed by Milestone 3 project teams to ensure a streamlined model validation and data sharing process

Standards Include: MOD-032, FAC-001, FAC-002

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Save the Date for Industry Engagement Work- shop

Reliable IBR Integration and Milestone 3 of
FERC Order No. 901

Day 1 | IBR Integration, NERC Engineering
January 15, 2025 | 8:30 a.m. - 4:30 p.m. Mountain

Day 2 | Milestone 3, NERC Standards
January 16, 2025 | 8:30 a.m. - 4:30 p.m. Mountain

In-Person Attendance:
Location: Phoenix, Arizona - Hotel to be Announced

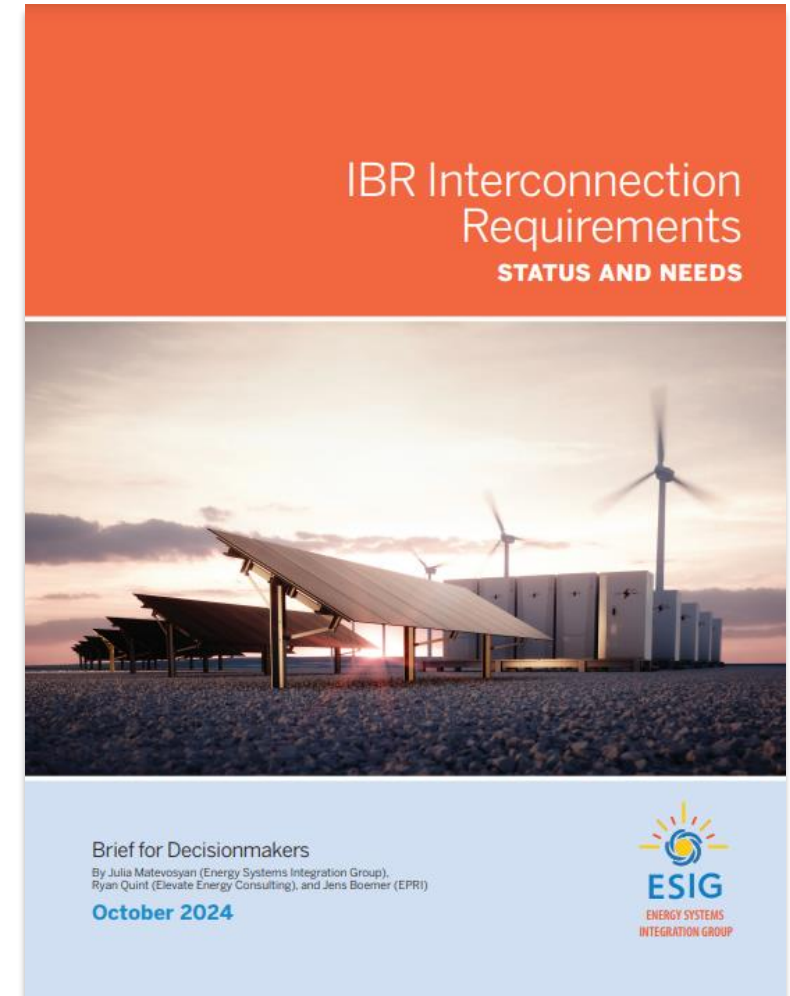
ESIG Brief for Decisionmakers

Oxford v. Merriam-Webster



Call to Action

ISO/RTOs, transmission providers, and their customers will benefit from adopting large parts of voluntary industry standards such as IEEE 2800-2022 as an effective solution to mitigate reliability risks during this energy transition. The rapid pace of the energy transition calls for proactive steps to mitigate risks. The adoption of voluntary technical standards plays a major role in this process and can help inform policies, regulatory rulemaking, and other business decisions, as well as help streamline and expedite the interconnection process for new IBRs.



ESIG Brief for Decisionmakers

General Reference <i>Cite IEEE 2800 in Full</i>	Detailed Reference <i>Cite IEEE 2800 Clauses</i>	Hybrid Integration <i>Organic Integration</i>	Detailed Spec <i>Recreate Specs of IEEE 2800</i>
“Point to standard in existing requirements” ✓ Minimal effort to adopt × Limited system-specific details* × Lacks clarity and specificity × Leaves gaps in implementation and understanding	“Point to specific clauses in existing requirements” ✓ Targeted enhancements ✓ Allows phased approach × Limited system-specific details*	“Point to specific clauses and add clarifying language in existing requirements” ✓ Targeted enhancements ✓ Allows phased approach ✓ Allows adaptation and additional requirements ✓ System-specific and clear ✓ Enables conformity language additions	“Recreate requirements language entirely” ✓ Targeted enhancements ✓ Allows phased approach ✓ Allows adaptation and tailored solution for specific rules framework ✓ Enables conformity language × Significant work and duplication for AGIR × Copyright concerns

* Industry practice has tended not to provide the necessary AGIR-specific details (i.e., functional settings) needed for complete adoption of IEEE 2800-2022.

Notes: Green text indicates advantages of the adoption method, yellow text indicates limitations, and red text indicates gaps. More important advantages, limitations, and gaps are in bold. AGIR = Authority Governing Interconnection Requirements.

Source: Elevate Energy Consulting.

SAR: FAC-001 and FAC-002 for IBRs

- SAR developed by NERC IRPS, endorsed by NERC RSTC and accepted by NERC SC
 - Formal comment period and assigned to Project 2022-04 EMT Modeling
- Proposes to modify NERC FAC-001 and FAC-002
 - Enhancements to interconnection requirements (TOs)
 - Consistent with IEEE 2800-2022 clauses
 - Conformance assessments via studies (TPs and PCs)
 - IBR facility commissioning requirements (GOs)
- Goals to harmonize and standardize technical IBR interconnection details, as much as possible

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Standard Authorization Request (SAR)

Complete and submit this form, with attachment(s) to the [NERC Help Desk](#). Upon entering the Captcha, please type in your contact information, and attach the SAR to your ticket. Once submitted, you will receive a confirmation number which you can use to track your request.

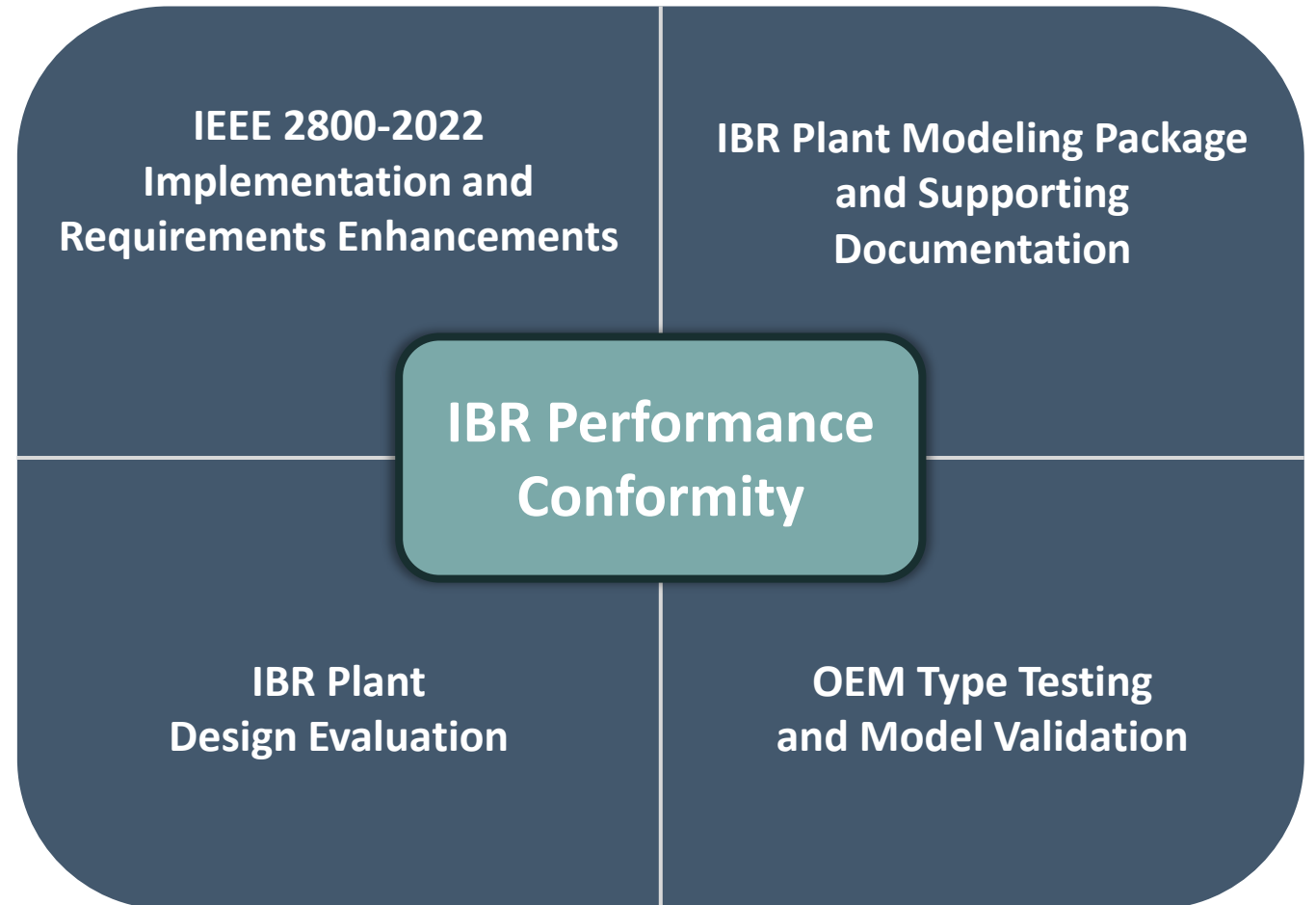
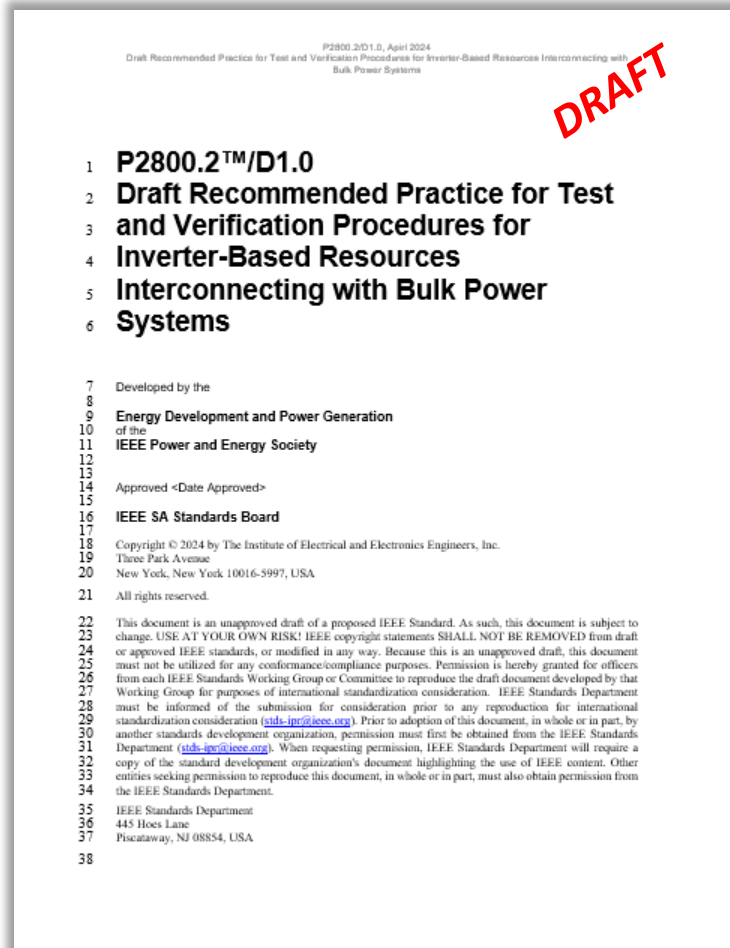
The North American Electric Reliability Corporation (NERC) welcomes suggestions to improve the reliability of the bulk power system through improved Reliability Standards.

Requested information	
SAR Title:	Revisions to FAC-001-4 and FAC-002-4
Date Submitted:	7/2024
SAR Requester	
Name:	Julia Matevosyan, ESIG (NERC IRPS Chair) Rajat Majumder, Invenergy (NERC IRPS Vice Chair)
Organization:	NERC Inverter-Based Resource Performance Subcommittee (IRPS)
Telephone:	Julia – 512-994-7917 Rajat –
Email:	julia@esig.energy RMajumder@invenergy.com
SAR Type (Check as many as apply)	
☐ New Standard	☐ Imminent Action/ Confidential Issue (SPM Section 10)
☒ Revision to Existing Standard	☐ Variance development or revision
☐ Add, Modify or Retire a Glossary Term	☐ Other (Please specify)
☐ Withdraw/retire an Existing Standard	
Justification for this proposed standard development project (Check all that apply to help NERC prioritize development)	
☐ Regulatory Initiation	☒ NERC Standing Committee Identified
☐ Emerging Risk (Reliability Issues Steering Committee) Identified	☐ Enhanced Periodic Review Initiated
☐ Reliability Standard Development Plan	☒ Industry Stakeholder Identified
What is the risk to the Bulk Electric System (What Bulk Electric System (BES) reliability benefit does the proposed project provide?):	
The bulk power system (BPS) in North America is undergoing a rapid transformation towards high penetrations of inverter-based resources. This grid transformation adds significant complexity and a changing risk landscape that require IBR-specific standards requirements. Recent NERC disturbance reports such as San Fernando, Odessa I and II, Southwest Utah, etc. ¹ as well as the November 2023 <i>NERC Inverter-Based Resource (IBR) Performance Issues Report Findings from Level 2 Alert</i> ² strongly point toward:	

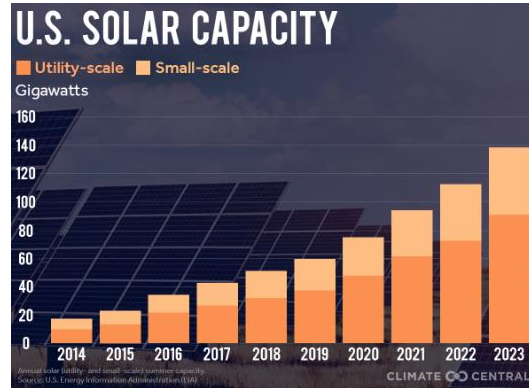
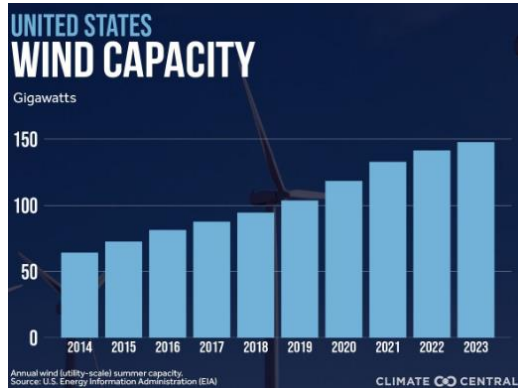
¹ <https://www.nerc.com/pa/rmm/ea/Pages/Major-Event-Reports.aspx>
² https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Inverter-Based_Resource_Performance_Issues_Public_Report_2023.pdf

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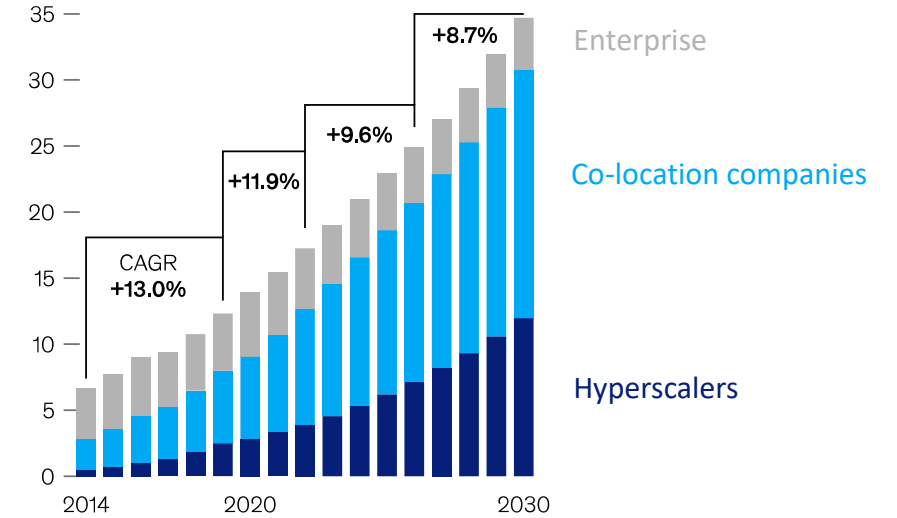
IEEE P2800.2 Recommended Practices



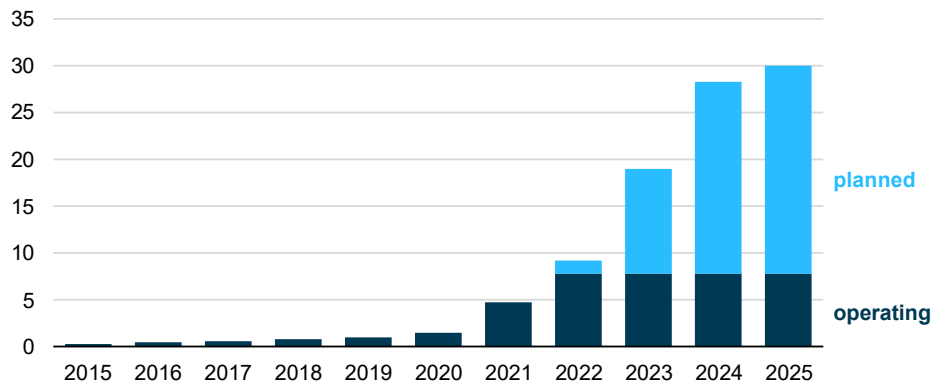
Emerging Technologies & New Challenges/Opportunities



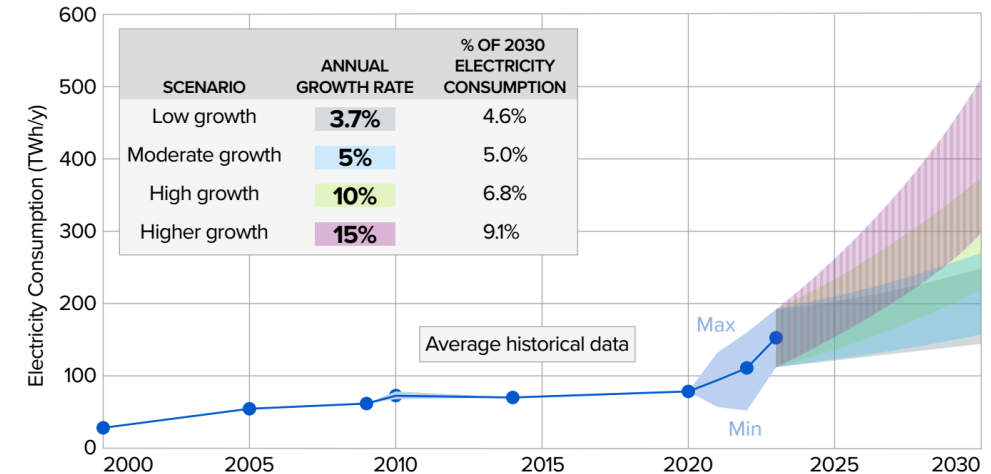
U.S. wind and solar capacity [Source: Climate Central]



Data center power consumption in GW [Source: McKinsey & Company]

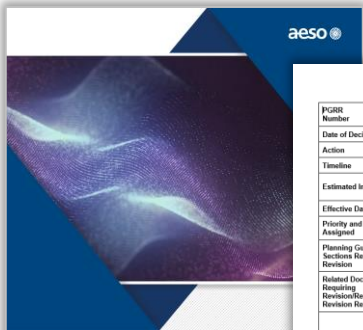


U.S. battery storage capacity in GW [Source: US EIA]



Projections of potential power consumption in U.S. data centers scenarios [Source: EPRI]

Requirements



AESO Connection Requirements for Inverter-Based Resources

PUCT Report		
PGRR Number	309	PGRR Title
Dynamic Model Review Process Improvements for Inverter-Based Resource (IBR) Modification		
Date of Decision	April 11, 2024	
Action	Approved	
Timeline	Normal	
Estimated Impacts	Cost/Budgetary: None Project Duration: No project required	
Effective Date	May 1, 2024	
Priority and Rank Assigned	Not applicable	
Planning Guide Sections Requiring Revision	5.2.1, Applicability 5.6, Generator Contribution and Continuing Operation 5.2, Dynamics Model Development	
Related Documents Requiring Revision	None	
Revision Description	This Planning Guide Revision Request (PGRR) introduces a new review process for interconnecting inverter-based resources (IBRs) to undergo a dynamic model review process prior to the Resource Contribution Study. Additionally, this PGRR mandates that Resource IBRs controlling operational IBRs must undergo a review process implementing modification to any control settings or equipment dynamic response (e.g., voltage, frequency, injections) at the Point of Interconnection (POI). As part of the review process, ERCOT shall review the needs identified by an IE or Resource Entity. In the case of operational IBRs, the review process may require the Transmission Service Provider (TSP) conducting a first stability study to compare and evaluate the electrical behavior before and after the proposed modifications.	
Reason for Revision	Strategic Plan Objective 1 – Be an industry leader in reliability and resilience	

MISO Grid-Forming Battery Energy Storage Capabilities, Performance, and Simulation Test Requirements Proposal



DRAFT Whitepaper July 2024 (Version 1.0)

Highlights

- The evolving energy landscape requires MISO and the industry to adapt available grid-forming control technology to support reliable, resilient, and secure energy for today and future generations.
- MISO proposes an initial draft framework of capability and performance requirements with supporting simulation tests to determine conformity.
- MISO's current effort aligns with the general direction of industry to anticipate advancements in grid-forming control technology capabilities and standard industry.



PUCT Report		
DGR Number	245	NOGRR Title
Inverter-Based Resource (IBR) Ride-Through Requirements		
Date of Decision	September 28, 2024	
Action	Approved	
Timeline	Urgent	
Estimated Impacts	Cost/Budgetary: Between \$150k and \$250k; Between \$1.3M and \$2.3M (annual recurring O&M); Between \$0.5M and \$0.9M (short term contract labor O&M) Project Duration: 6 to 9 months	
Effective Date	October 1, 2024	
Priority and Rank Assigned	Priority – 2025, Rank – 3515 (for automation)	
Related Documents Requiring Revision	2.6.2, Generators and Energy Storage Resources 2.6.2.1, Frequency Ride-Through Requirements for Distribution Generation Resources (DGRs) and Distribution Energy Storage Resources (DESRs) 2.6.2.1, Frequency Ride-Through Requirements for Transmission-Connected Inverter-Based Resources (IBRs), Type 1 Wind-Powered Generation Resources (WGRs) and Type 2 WGRs (new) 2.6.2.1.1, Temporary Frequency Ride-Through Requirements for Transmission-Connected Inverter-Based Resources (IBRs), Type 1 Wind-Powered Generation Resources (WGRs) and Type 2 WGRs (new) 2.6. Voltage Ride-Through Requirements for Generation Resources and Energy Storage Resources 2.6.1, Voltage Ride-Through Requirements for Intermittent Renewable Resources Connected to the ERCOT Transmission Grid 2.6.1.1, Preferred Voltage Ride-Through Requirements for Transmission-Connected Inverter-Based Resources (IBRs) (new) 2.6.1.2, Legacy Voltage Ride-Through Requirements for Transmission-Connected Inverter-Based Resources (IBRs), Type 1	

PJM Dynamic Model Development Guidelines for Interconnection Analysis

Prepared by:
Interconnection Analysis & Interconnection Planning Analysis Department
PJM Interconnection

Revision 1.1
October 1, 2024

For Public Use

FERC Order 961 Milestone 3 Projects	
Project 1: 2024-2025, Installation of 100MW to 150MW of new capacity. The project will be completed by 2025.	Project 2: 2024-2025, Installation of 100MW to 150MW of new capacity. The project will be completed by 2025.
Project 3: 2024-2025, Installation of 100MW to 150MW of new capacity. The project will be completed by 2025.	Project 4: 2024-2025, Installation of 100MW to 150MW of new capacity. The project will be completed by 2025.

P2800.2™/D2.0 Draft Recommended Practice for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Bulk Power Systems	
Developed by the Energy Development and Power Generation of the IEEE Power and Energy Society	IEEE SA Standards Board
Approved -Date Approved- IEEE SA Standards Board	Copyright © 2024 by The Institute of Electrical and Electronics Engineers, Inc. Three Park Avenue New York, New York 10016-1997, USA

APPENDIX B ATTACHMENT 3
EXHIBIT 6
APPENDIX B ATTACHMENT 3
PAGE 1 OF 36

HAWAIIAN ELECTRIC GENERATION FACILITY TECHNICAL MODEL REQUIREMENTS AND REVIEW PROCESS: TRANSMISSION OR SUB-TRANSMISSION INTERCONNECTED PROJECTS

April 17, 2024

ERCOT PUBLIC REPORT

Dynamics Working Group Procedure Manual

Advanced Grid Support Energy Storage Resource (AGS-ESR)
Functional Specification and Test Framework for the ERCOT Grid

Version 1.0
September 2024

ercot

Dynamics Working Group Procedure Manual

Revision 22

ROS Approved: November 7, 2024

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LIABILITY ACTIVITY

Reliability Guideline Recommended Practices for Performing EMT System Studies for Inverter-Based Resources

December 2024

DRAFT

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3353 Peachtree Road NE
Suite 400, North Tower
Atlanta, GA 30326
404-446-2500 | www.nerc.com

ercot

Home > Market Rules > Issues

PGRR115

Summary Action

Title: Related to NP Load 25 MW

Next Group: ROS

Next Step: ROS for consideration

Status: Pending

Home > Market Rules > Issues

NPRR1234

Summary Action

Title: Interconnection Requirements for Large Loads and Modeling Standards for Loads 25 MW or Greater

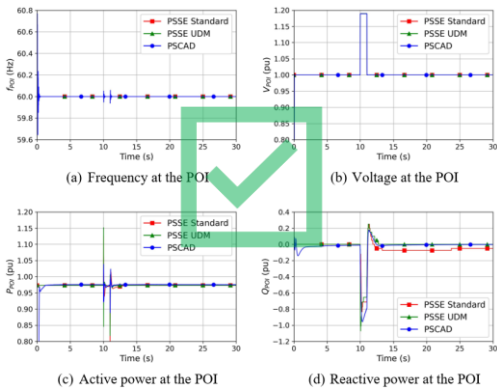
Next Group: PRC

Next Step: PRC for consideration

Status: Pending

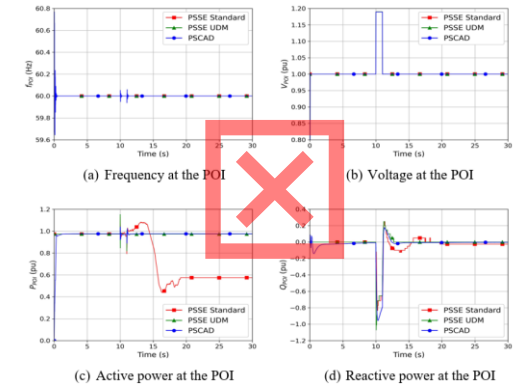


Modeling



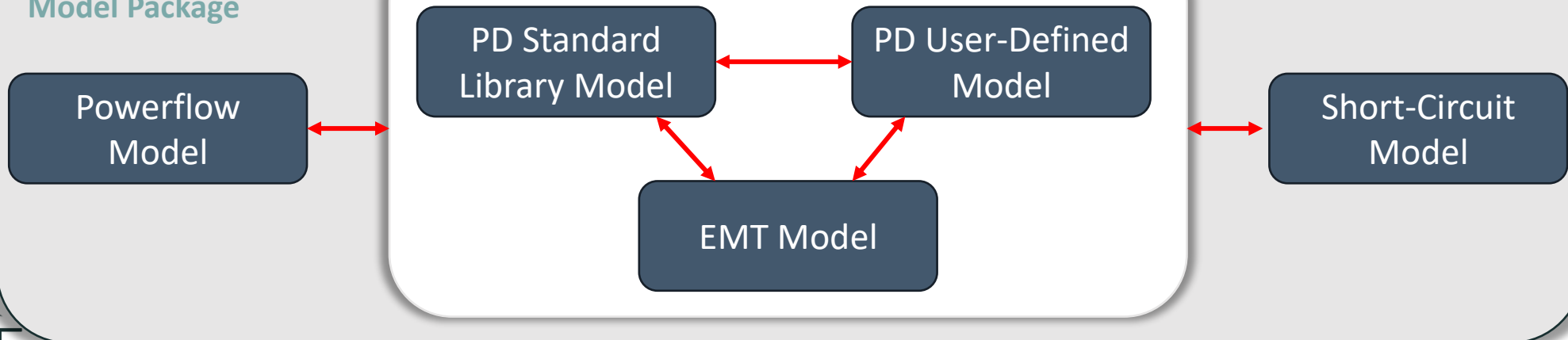
IBR Plant / Data Center (Designed or Actual)

- Inverters / turbines
 - Power Plant Controller
 - Collector System
 - Substation Equipment
 - Tie Line
 - Balance of Plant
 - Etc.
- IT Equipment
 - Power Distribution Units (PDU)
 - Cooling System
 - Lighting
 - Transformer
 - Switchgear
 - Etc.

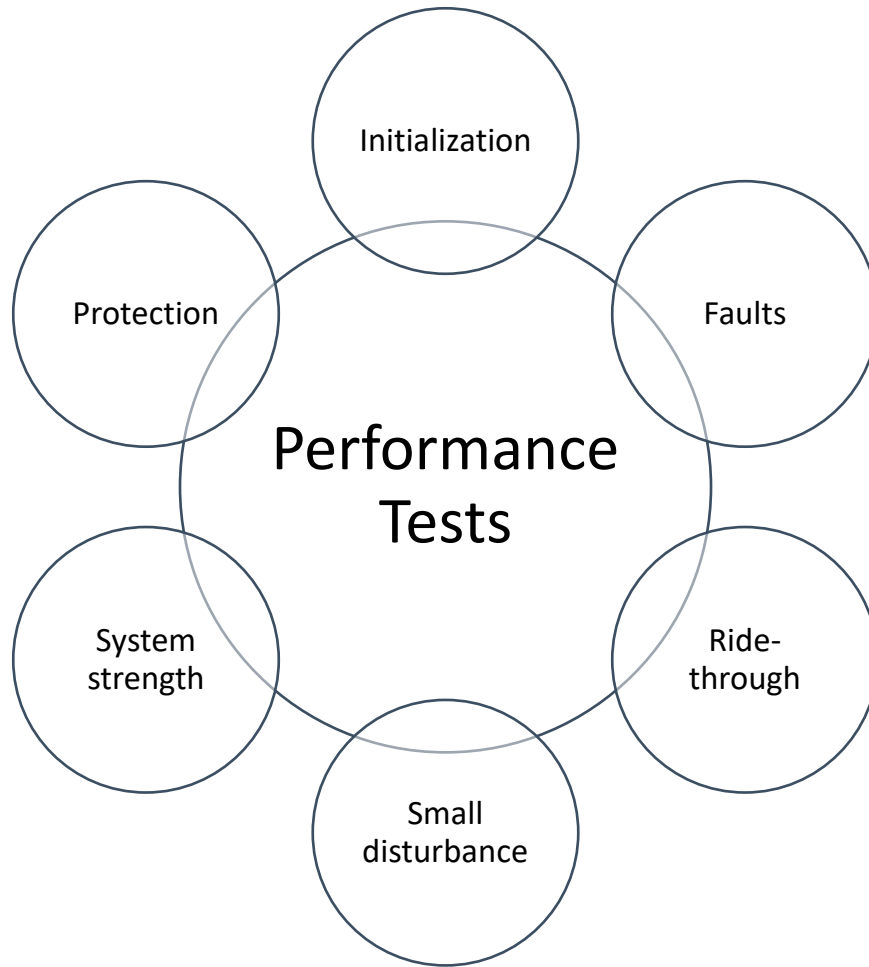


Models should accurately reflect designed/actual equipment

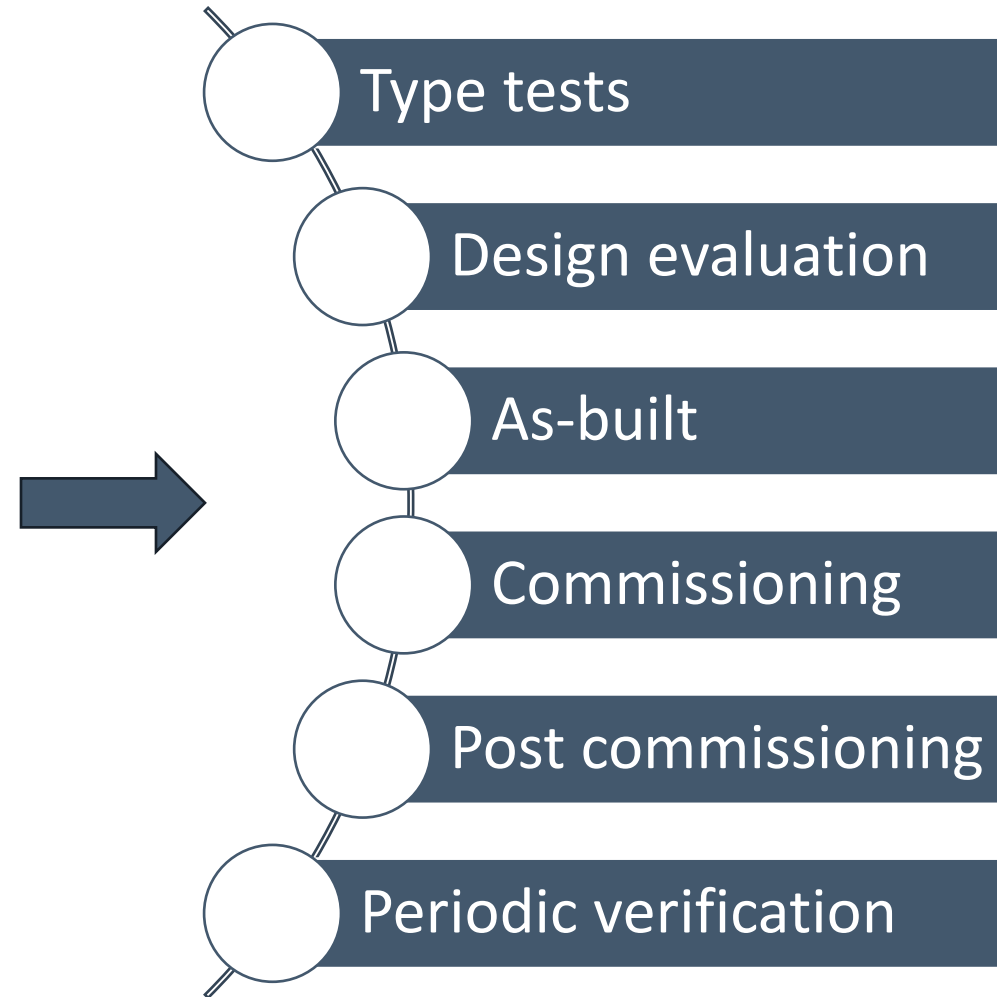
IBR Plant / Data Center Model Package



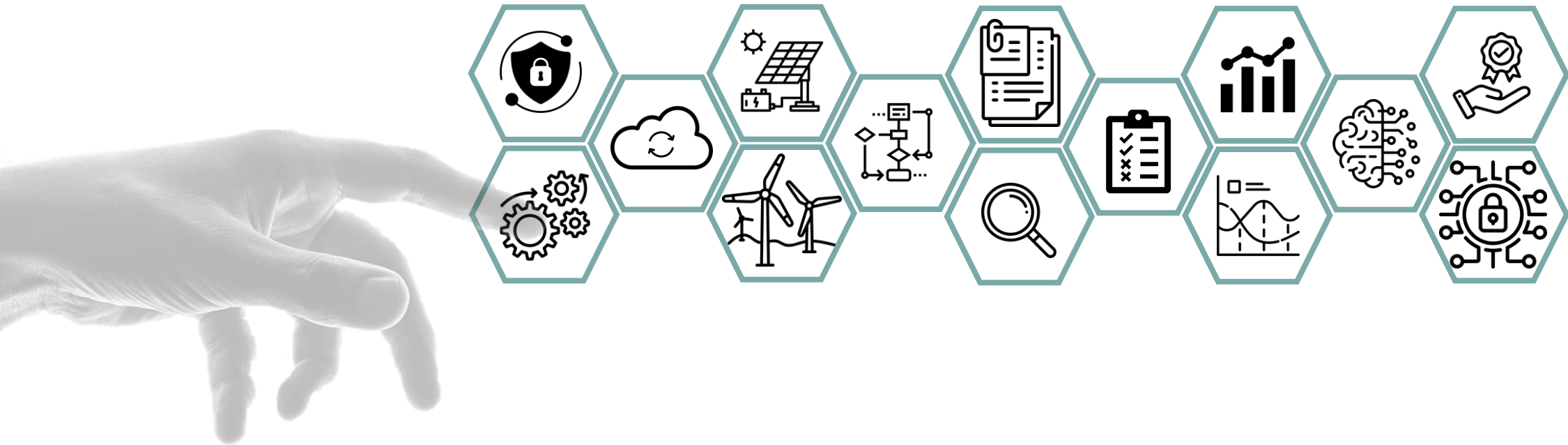
Performance Tests



Core IEEE P2800.2 Practices



Automation



“Perfection is not attainable, but if we chase perfection we can catch excellence.” – Vince Lombardi

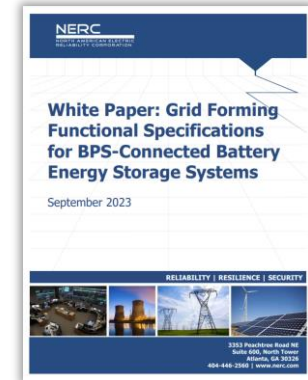
Leveraging Grid Forming BESS Technology

Exploratory Study Questions:

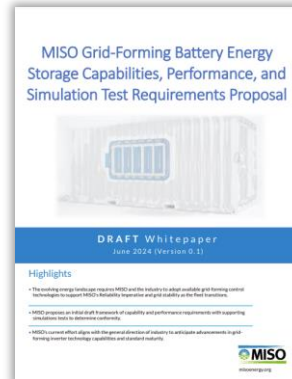
- Is GFM BESS a “do no harm” solution options? ✓
- Can it support stabilizing weak grid areas? ✓
- Does it work properly in strong grids areas? ✓
- Are GFM BESS controls interoperable across OEMs? ✓
- Do GFM BESS Controls require any unique or special tuning? ✓
- Could GFM BESS unlock IBR capacity or defer expensive / long lead time solutions? ✓
- Do commercial GFM BESS controls “hold up” to industry specifications? ✓

Overarching Finding and Takeaway:

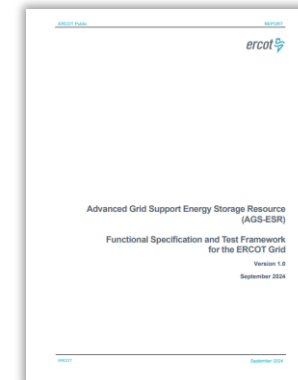
Widespread deployment of GFM BESS can enhance bulk power system **stability** at a **low incremental cost**, **simplify planning** in challenging regions, and **increase IBR capacity**.



[NERC GFM Functional Spec and Test Procedure](#)



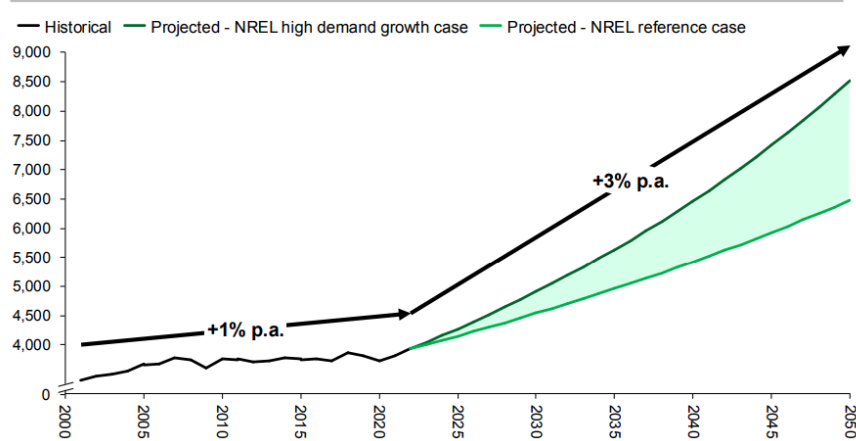
[MISO Draft GFM Requirements Proposal](#)



[ERCOT AGS-ESR Spec and Test Framework](#)

The Exponential Growth of Large Loads

US electric power demand, 2000-2050, TWh¹



U.S. Electricity demand could more than double by 2050 [Source: DOE]

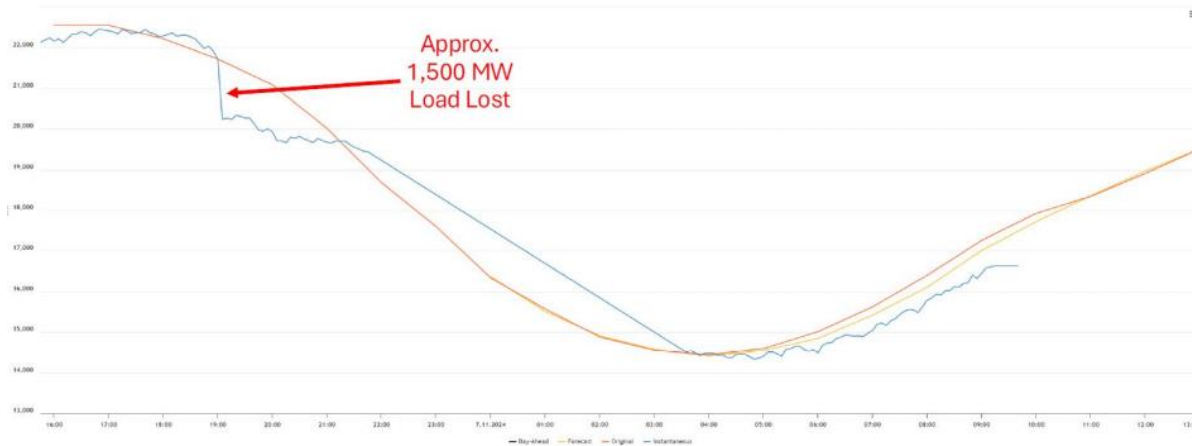
Data center boom fuels demand for nuclear projects

A shift in how tech companies like Google and Amazon meet their energy needs is creating opportunities for construction firms equipped to handle atomic power work.

Nuclear + Large Load Announcements: Co-location, SMRs, restart of retired reactors, and more. [Source: Utility Dive]

Grid Risks & Challenges being addressed by the industry: Interconnection Processes, Requirements, Models & Studies, Modeling, and more

WECC Large Load Risk Assessment



New and growing grid disturbances involving large loads [Source: NERC]



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Call for Volunteers
Large Loads Task Force (LLTF)

The Reliability and Security Technical Committee (RSTC) has given the green light for the establishment of the **Large Loads Task Force (LLTF)** to better understand the reliability impact(s) of emerging large loads such as Data Centers (including crypto and AI), hydrogen fuel plants, etc., and their impact on the bulk power system (BPS). The LLTF will first focus on identifying the unique characteristics and risks associated with emerging large loads, and then validate and prioritize these risks. Following this, the LLTF will identify gaps and mitigation of potential risks to support BPS reliability including enhancements to existing planning and operations processes to help transmission planners and operators mitigate these risks.

Background
The LLTF is seeking volunteers to join the team with specific skills, knowledge, and technical expertise in the following areas:

- Assessing the reliability impacts of emerging large loads on the BPS.
- Implementing emerging large loads in BPS planning studies and real-time operations.
- Forecasting and modeling of emerging large loads.
- Design and operation of large loads.

If you are interested in becoming a member, please fill out this brief [survey](#).

Contact
Questions should be directed to the LLTF NERC Liaison [Marlyn Jagaschandes](#), (via email). Please share this information with others who may be able to contribute to this effort.

Meetings
The group is expected to have hybrid or virtual monthly meetings, supplemented with conference calls, to facilitate the completion of work products.

Other Information
For more information about the LLTF, see the [LLTF Scope](#) document.

We appreciate your support in this effort.

ESIG

Large Loads Task Force

Large electrical loads, such as AI and other data centers, hydrogen production facilities, and EV fleet charging centers, may present new challenges for the electric power industry. Utility planners face difficulties in forecasting demand, transmission planners struggle to build infrastructure at the required pace, and system operators must address grid stability risks caused by large loads disconnecting during faults. Meanwhile, large load developers grapple with slow and complex interconnection processes, stringent reliability requirements, and limited access to wholesale markets and real-time pricing.

To address these challenges, the Energy Systems Integration Group (ESIG) is launching a **Large Loads Task Force (LLTF)** to unite stakeholders, identify practical solutions, and develop harmonized practices that ensure reliable and efficient grid integration while supporting industry growth. The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy and Meta are helping to fund this effort.

The LLTF will kick off with a webinar on **December 17th**, which will outline the scope, format, and deliverables of the task force, as well as introduce the leadership team.

[REGISTER FOR THE WEBINAR](#)

The ESIG LLTF will be organized into eight specialized project teams, each focusing on the following key areas ([see more detail on each project team here](#)):

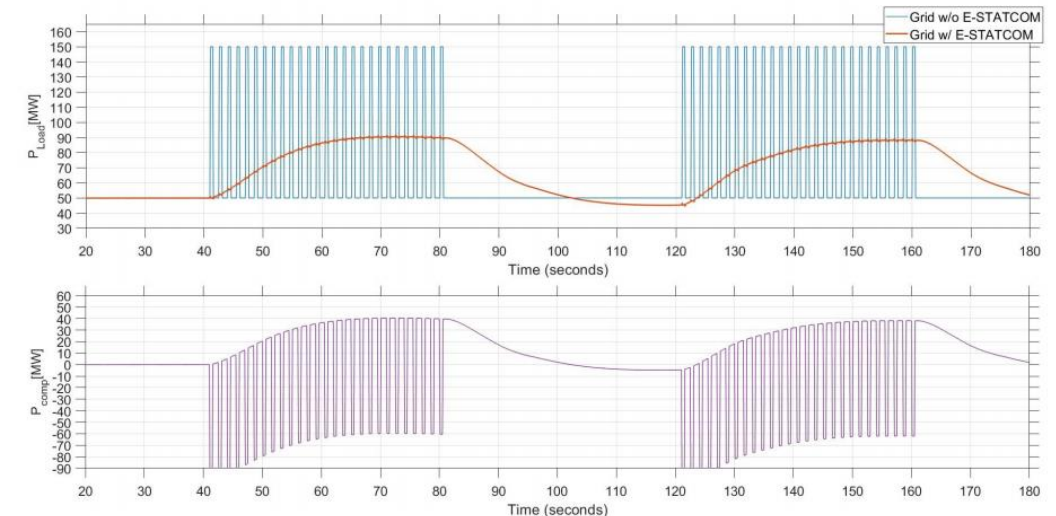
1. Data collection on the characteristics of data centers and other large loads
2. Load forecasting
3. Interconnection process
4. Interconnection performance requirements
5. Modeling requirements for interconnection
6. Transmission planning
7. Wholesale market options
8. Resource adequacy

Large Load Technical Challenges & Risks

- Interconnection processes & queues
- Interconnection requirements and standards
- Large load vs. transmission / distribution construction times
- Transmission planning models & studies
- New operating characteristics and risks (load ramping, power quality, oscillations)
- Generation resource adequacy
- Demand response impacts
- Large load forecasting



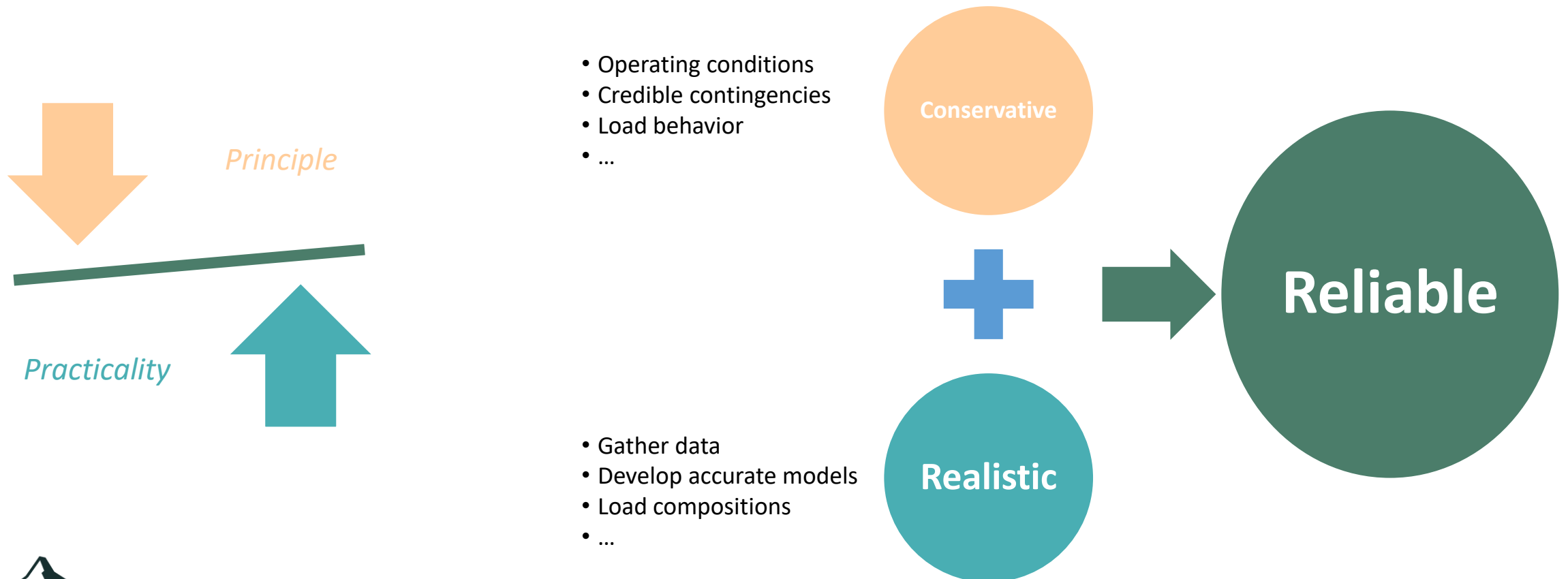
Interconnection requirements for entire lifecycle of LL
(from Interconnection Process to Operations)



Study of Sub-second LL Ramping and mitigation by an E-STATCOM [Source: Siemens Energy]

Fundamentals of Modeling and Studies

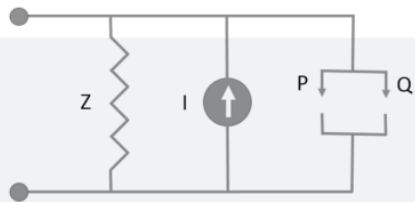
Conservative, Yet Realistic!



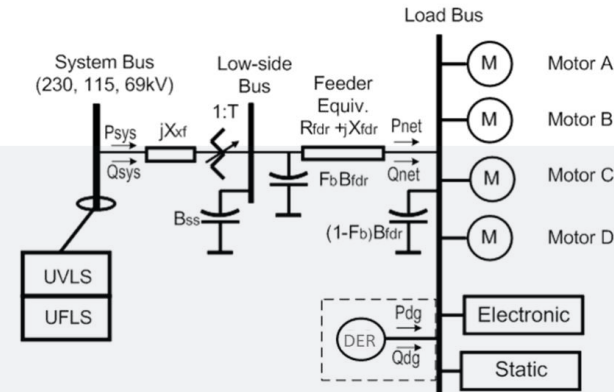
Modeling of Large Loads

“All models are wrong, but some are useful”

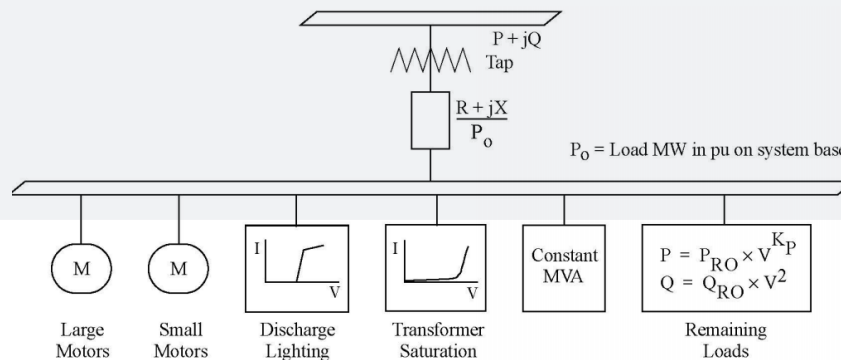
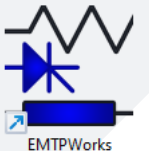
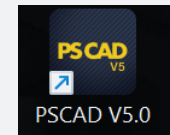
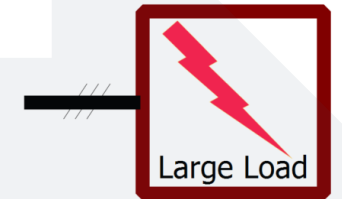
George E. P. Box, “Science and Statistics”, 1976



Static Load Models



Dynamic Composite Load Model [Source: NERC]



Dynamic Complex Load Model [Source: Siemens PSS®E]

Studies of Large Loads

Steady State Studies

- Capacity studies
- Network upgrade studies and cost allocation
- System impact studies

Power Quality

- Harmonics
- Flickers
- Ramping

Protection Studies

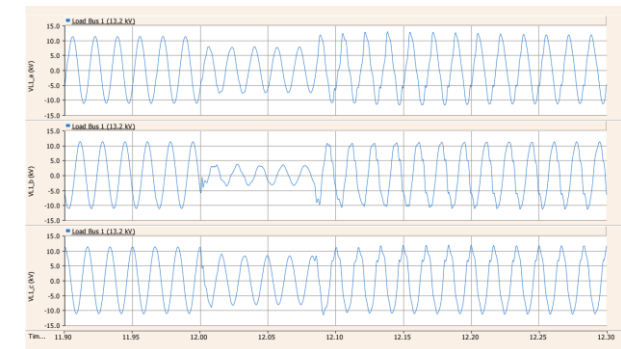
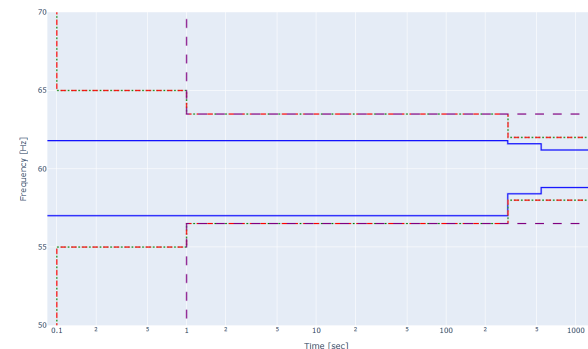
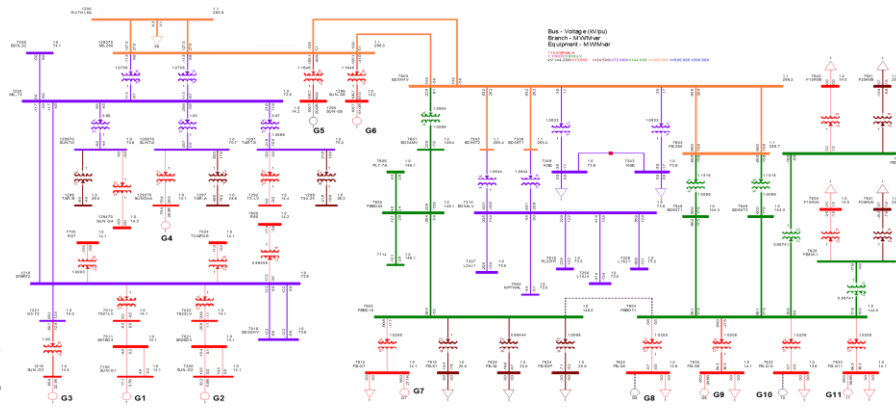
- Voltage and frequency ride through
- Breaker short circuit duty
- Protection coordination

Stability Studies

- Transient stability
- Small signal stability
- Voltage stability
- Oscillations

EMT Studies

- Insulation coordination (TRV, SOV, LOV)
- Transformer energization
- Control interactions
- Ferroresonance



Learn from the Past; Look to the Future

Learnings	Application
• Exponential growth • Fundamentals matter • Voluntary not working • Requirements aren't a bad thing • Engineering detail matters • Don't walk and then try to sprint	• Be proactive • IBRs and large loads alike • Requirements matter • Harmonization can speed up process • Engineering, hurray! • Be the tortoise, not the hare

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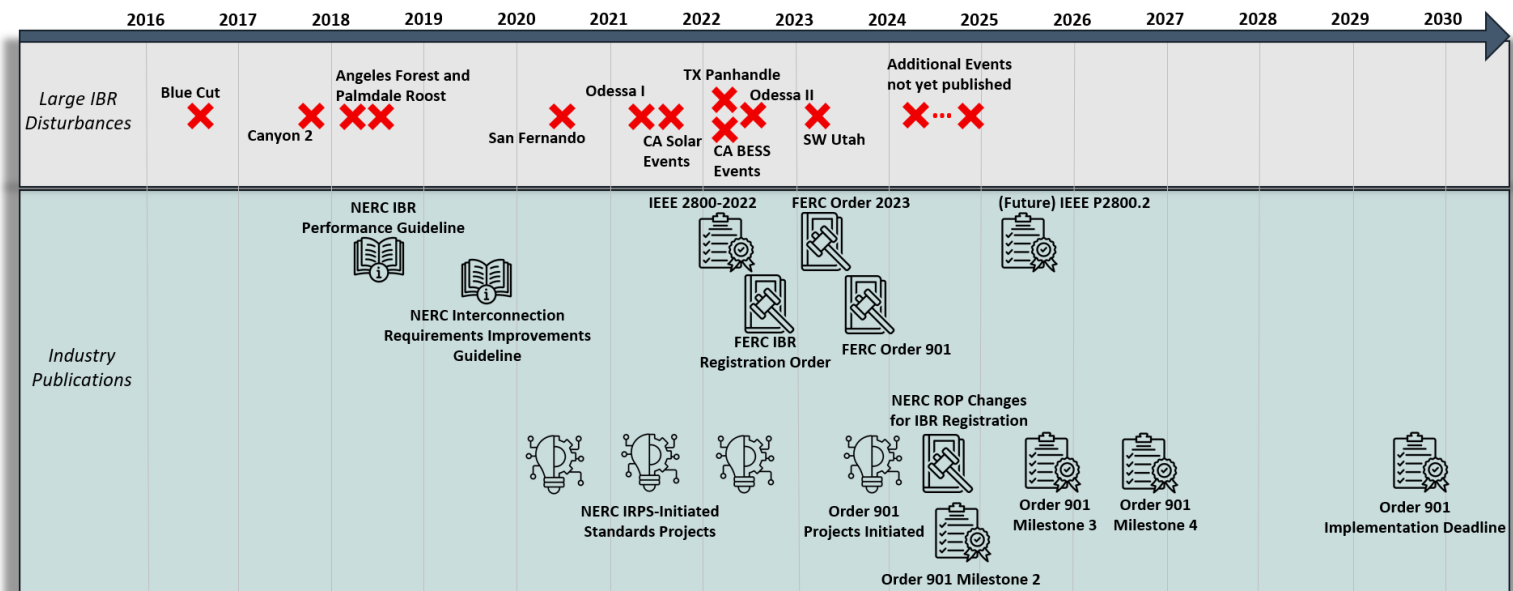
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Interconnection of IBRs vs. Large Loads

IBRs since 2016



Large Loads since 2020

