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

Ryan D. Quint, PhD, PE
President and CEO
Elevate Energy Consulting

Kyle Thomas, PE
Vice President, Engineering and Compliance Services
Elevate Energy Consulting

Farhad Yahyaie, PhD, PE
Head, Power System Studies and Modeling
Elevate Energy Consulting

ESIG Webinar

December 3, 2024

Today's Presenters and Our Team

Ryan Quint, PhD, PE
Founder and CEO

Kyle Thomas, PE
VP, Engineering and Compliance Services

Farhad Yahyaie, PhD, PEng
Head, Power System Studies and Modeling

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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

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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 stud
- Develop process to communicate system interconnection-wide mode 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 interconnecti 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

➢ All projects underway presently; must be submitted to FERC by November 2025

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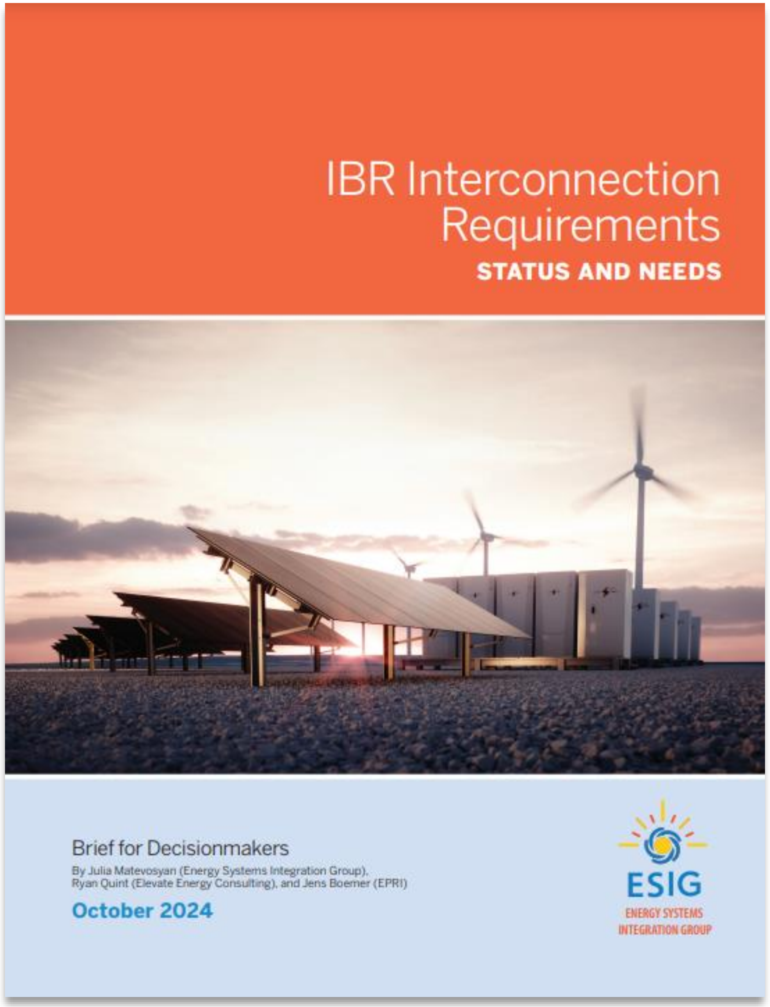
ESIG Brief for Decisionmakers

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.



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ESIG Brief for Decisionmakers

General Reference *Cite IEEE 2800 in Full*	Detailed Reference *Cite IEEE 2800 Clauses*	Hybrid Integration *Organic Integration*	Detailed Spec *Recreate Specs of IEEE 2800*
"Point to standard in existing requirements"	"Point to specific clauses in existing requirements"	"Point to specific clauses and add clarifying language in existing requirements"	"Recreate requirements language entirely"
✓Minimal effort to adopt × **Limited system-specific details*** × Lacks clarity and specificity × **Leaves gaps in implementation and understanding**	✓Targeted enhancements ✓Allows phased approach × **Limited system-specific details***	✓Targeted enhancements ✓Allows phased approach ✓Allows adaptation and additional requirements ✓**System-specific and clear** ✓Enables conformity language additions	✓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.

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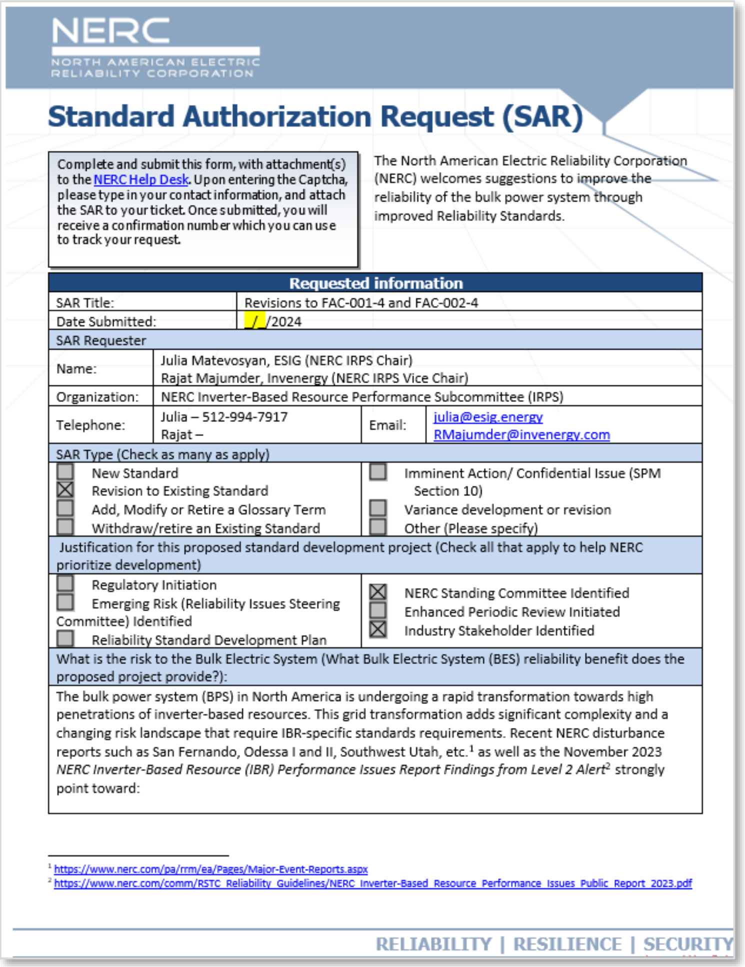
ESIG Brief for Decision Makers: IBR Interconnection Requirements

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:	_/_/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 ☒ Revision to Existing Standard ☐ Add, Modify or Retire a Glossary Term ☐ Withdraw/retire an Existing Standard		☐ Imminent Action/ Confidential Issue (SPM Section 10) ☐ Variance development or revision ☐ Other (Please specify)	
Justification for this proposed standard development project (Check all that apply to help NERC prioritize development)			
☐ Regulatory Initiation ☐ Emerging Risk (Reliability Issues Steering Committee) Identified ☐ Reliability Standard Development Plan		☒ NERC Standing Committee Identified ☐ Enhanced Periodic Review Initiated ☒ 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 *NERC Inverter-Based Resource (IBR) Performance Issues Report Findings from Level 2 Alert*[2] strongly point toward:			

[1] https://www.nerc.com/pa/rrm/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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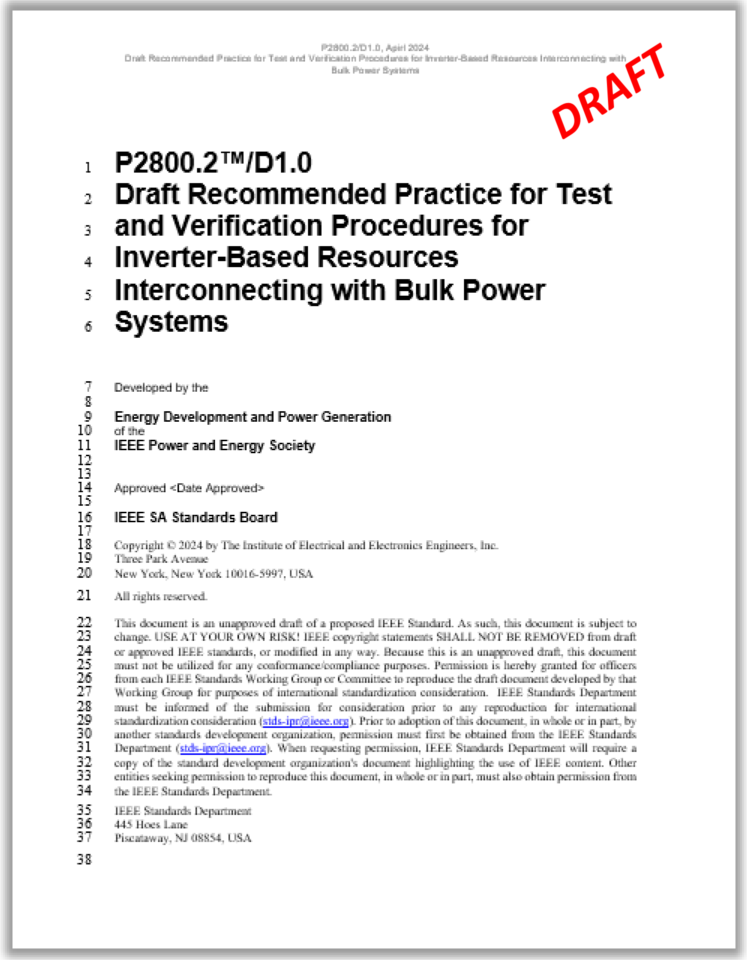
IEEE P2800.2 Recommended Practices



P2800.2/D1.0, April 2024
Draft Recommended Practice for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Bulk Power Systems

DRAFT

P2800.2™/D1.0
Draft Recommended Practice for Test and Verification Procedures for Inverter-Based Resources Interconnecting with Bulk Power Systems

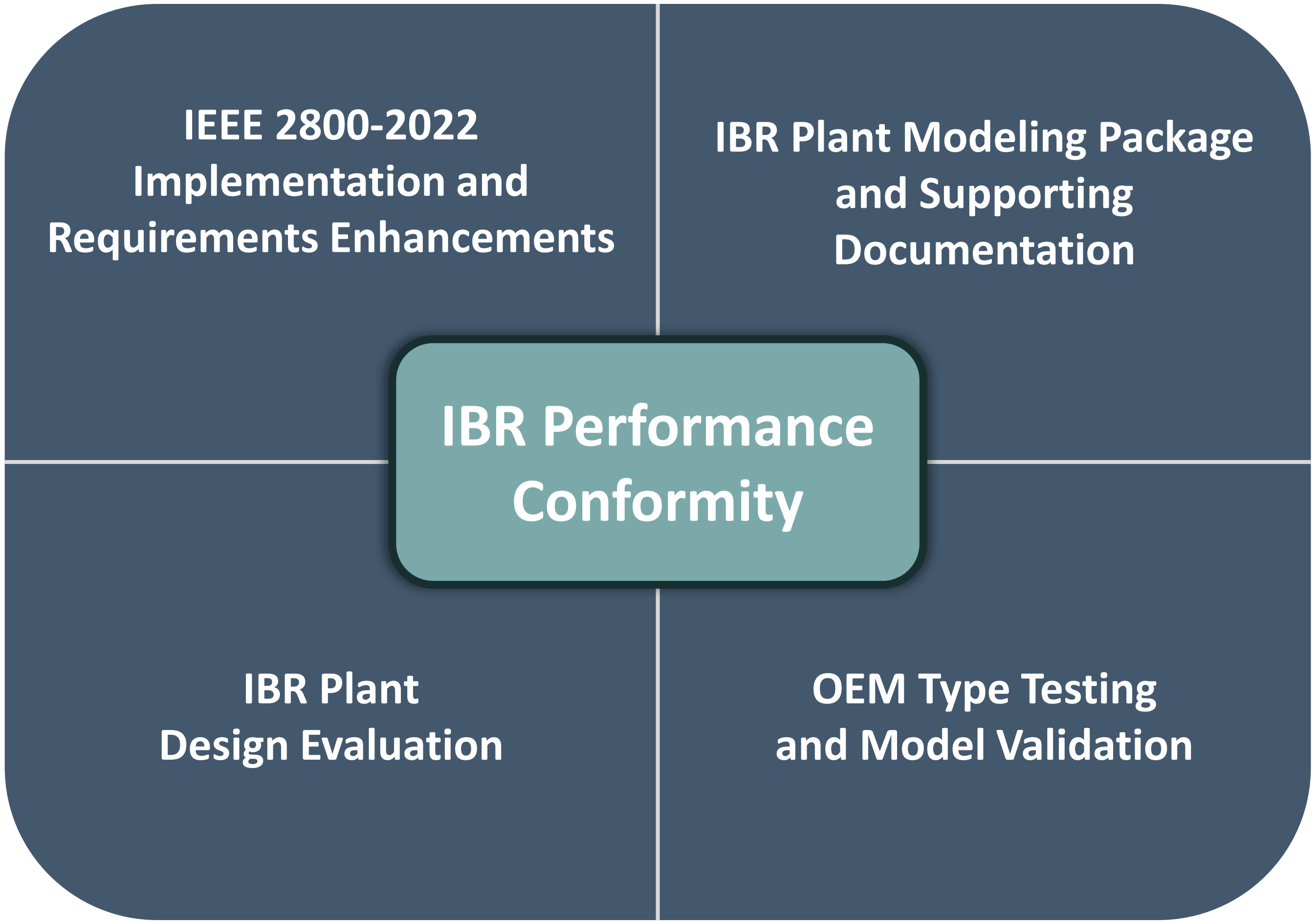
Developed by the

Energy Development and Power Generation
of the
IEEE Power and Energy Society

Approved <Date Approved>

IEEE SA Standards Board

IEEE Standards Department
445 Hoes Lane
Piscataway, NJ 08854, USA



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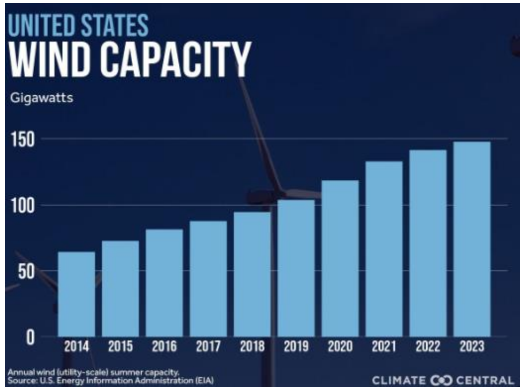
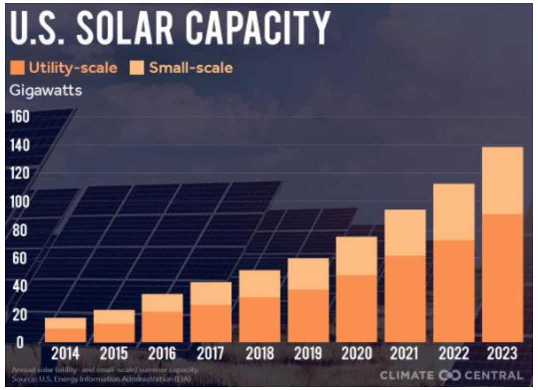
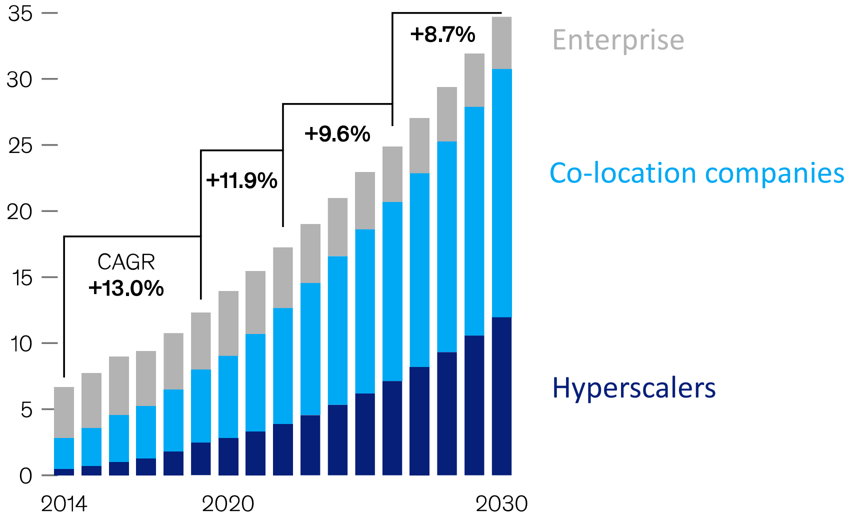
Emerging Technologies & New Challenges/Opportunities

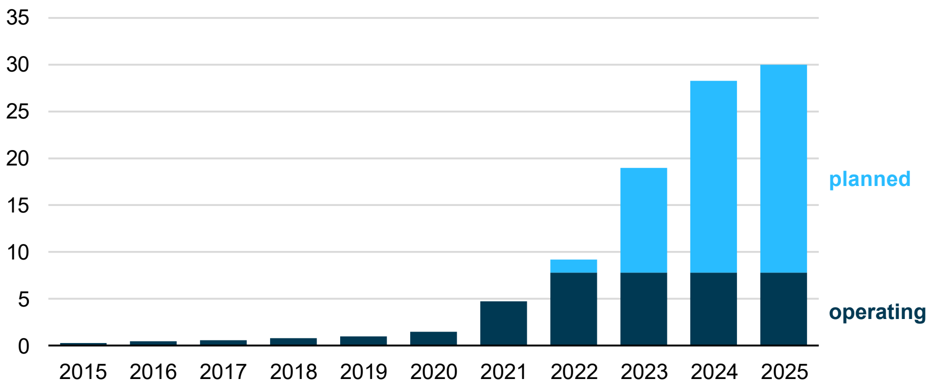




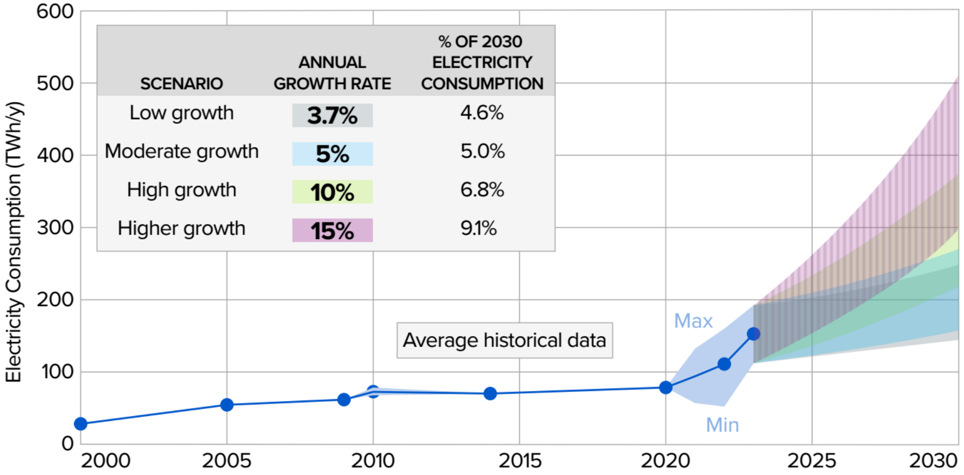
U.S. wind and solar capacity [Source: Climate Central]



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



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



SCENARIO	ANNUAL GROWTH RATE	% OF 2030 ELECTRICITY CONSUMPTION
Low growth	3.7%	4.6%
Moderate growth	5%	5.0%
High growth	10%	6.8%
Higher growth	15%	9.1%

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

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Requirements

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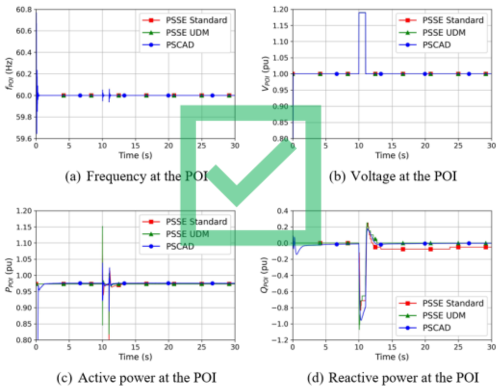
Modeling



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

Models should match across domains

- Powerflow Model
- PD Standard Library Model
- PD User-Defined Model
- EMT Model
- Short-Circuit Model

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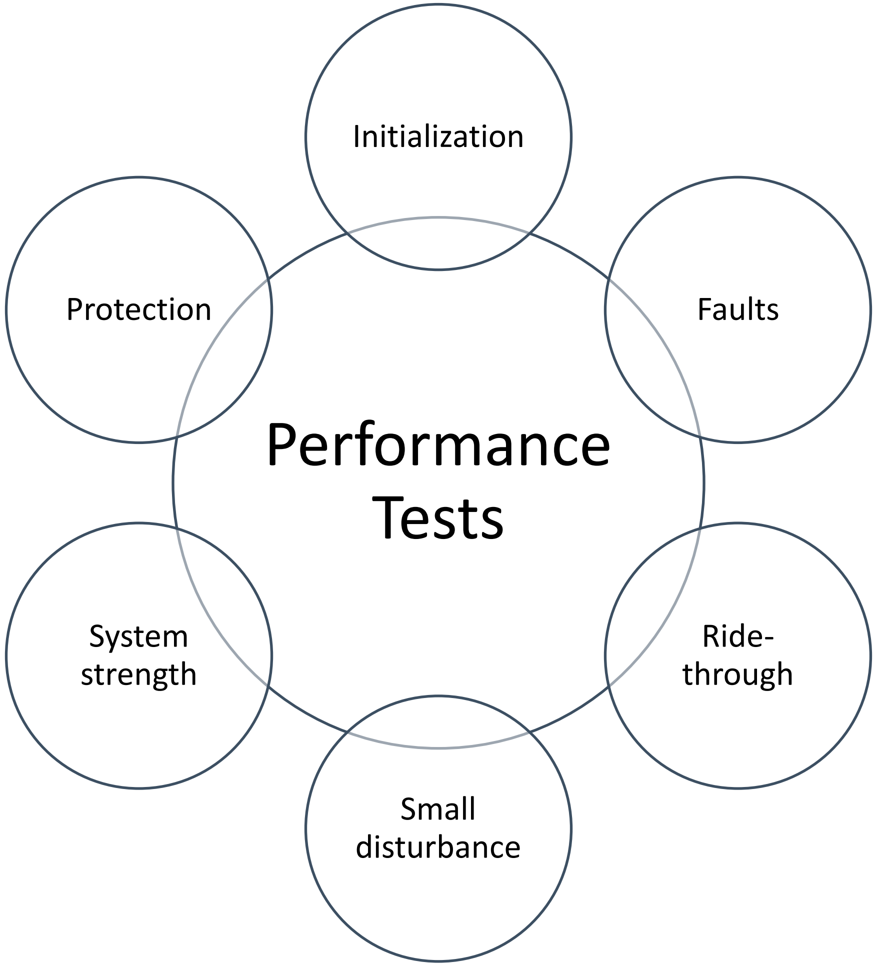
Performance Tests



Core IEEE P2800.2 Practices

- Type tests
- Design evaluation
- As-built
- Commissioning
- Post commissioning
- Periodic verification

Automation

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

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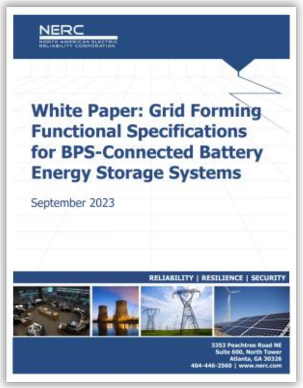
Leveraging Grid Forming BESS Technology

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? ✓

<u>Overarching Finding and Takeaway:</u>
***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

White Paper: Grid Forming Functional Specifications for BPS-Connected Battery Energy Storage Systems

September 2023

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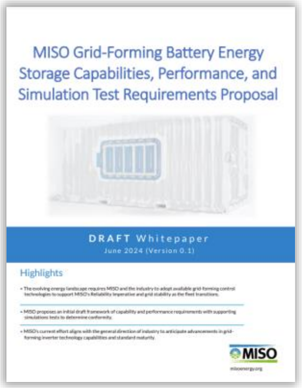
NERC GFM Functional Spec and Test Procedure

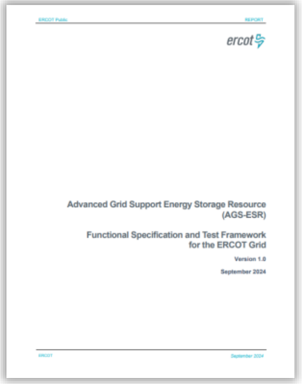

MISO Grid-Forming Battery Energy Storage Capabilities, Performance, and Simulation Test Requirements Proposal

DRAFT Whitepaper

Highlights

MISO

MISO Draft GFM Requirements Proposal


ercot

Advanced Grid Support Energy Storage Resource (AGS-ESR)

Functional Specification and Test Framework for the ERCOT Grid

Version 1.0

September 2024

ERCOT AGS-ESR Spec and Test Framework

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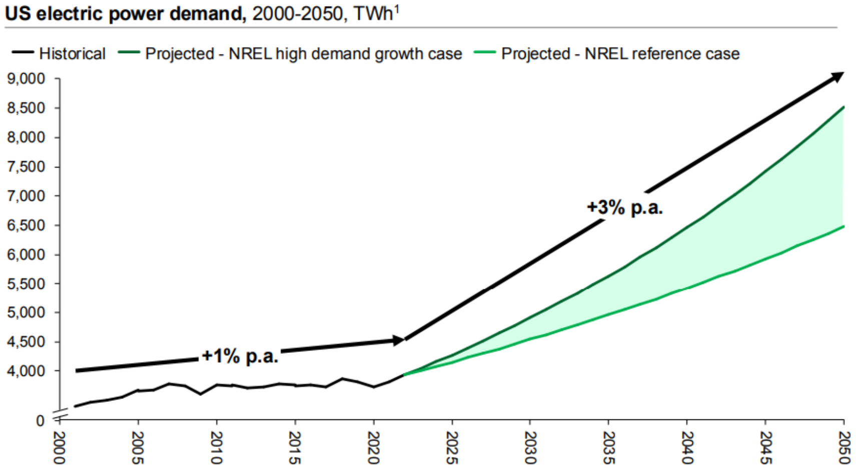
The Exponential Growth of Large Loads

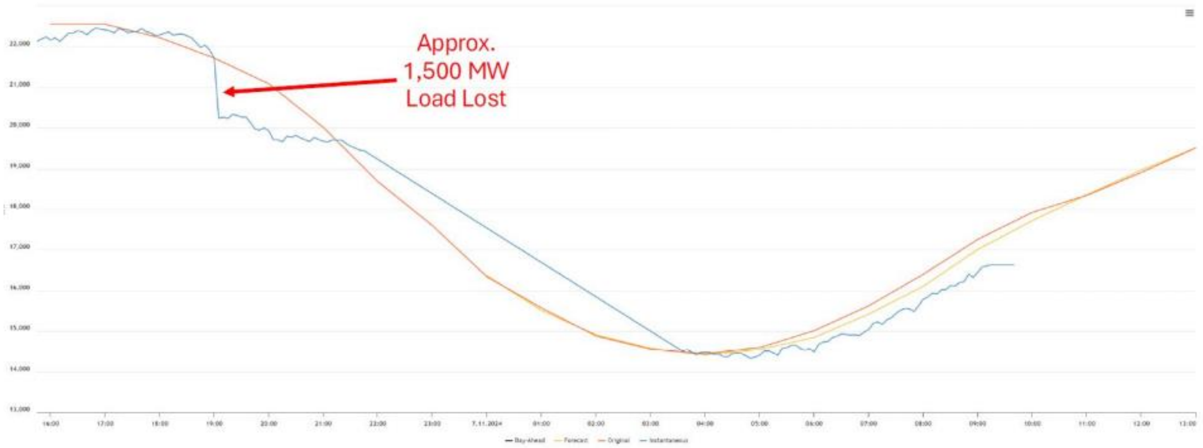


U.S. Electricity demand could more than double by 2050 [Source: DOE]

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]



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

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

WECC Large Load Risk Assessment

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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. [1] 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 Marilyn Jayachandran, (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

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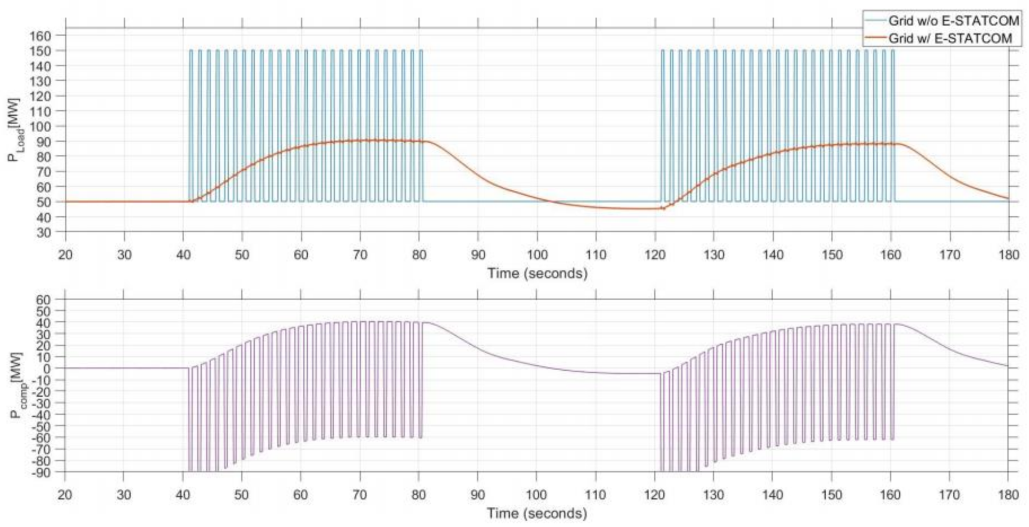
Large Load Technical Challenges & Risks

- 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]

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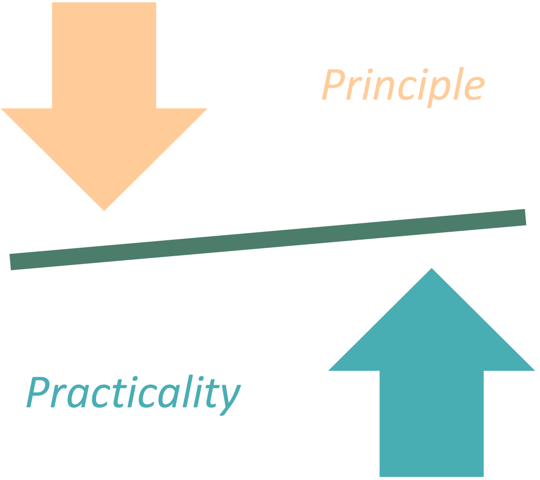
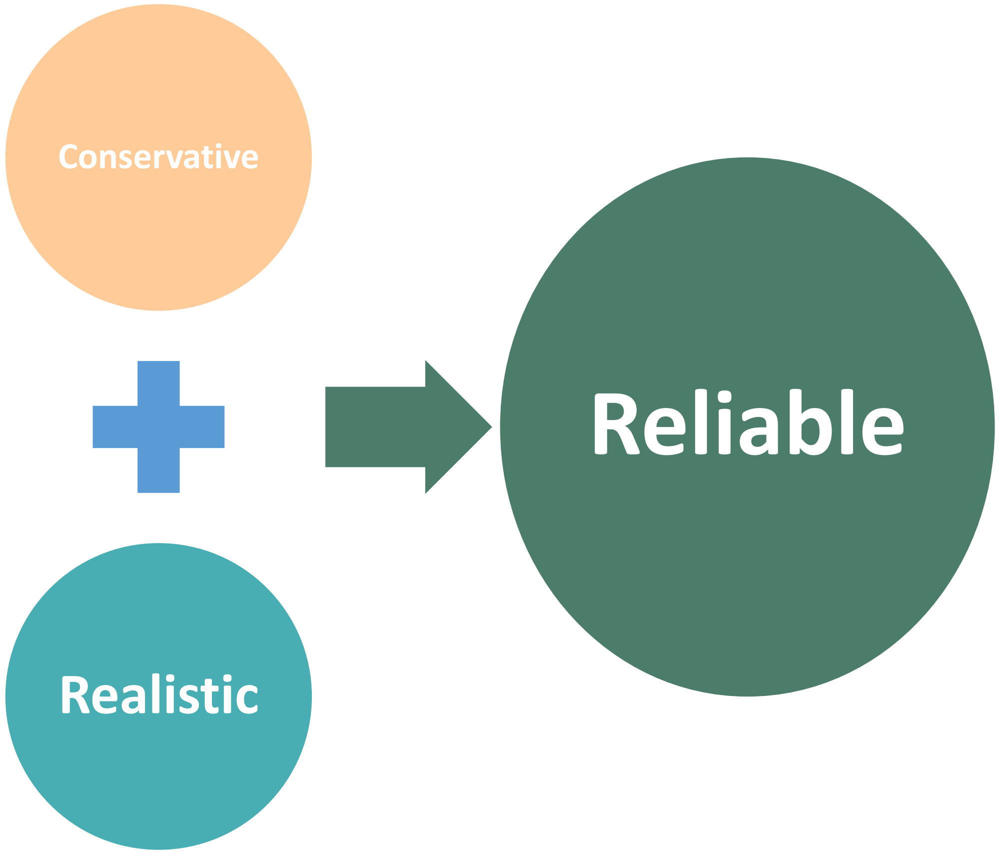
Fundamentals of Modeling and Studies



Conversative, Yet Realistic!

- Operating conditions
- Credible contingencies
- Load behavior
- …

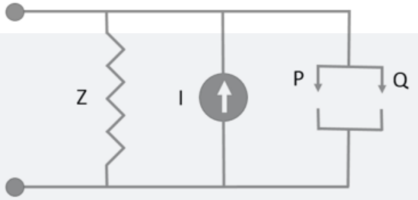
- Gather data
- Develop accurate models
- Load compositions
- …



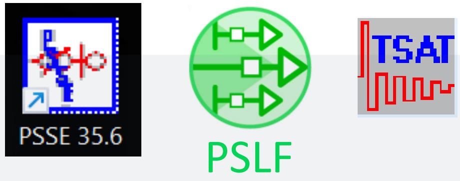
Modeling of Large Loads

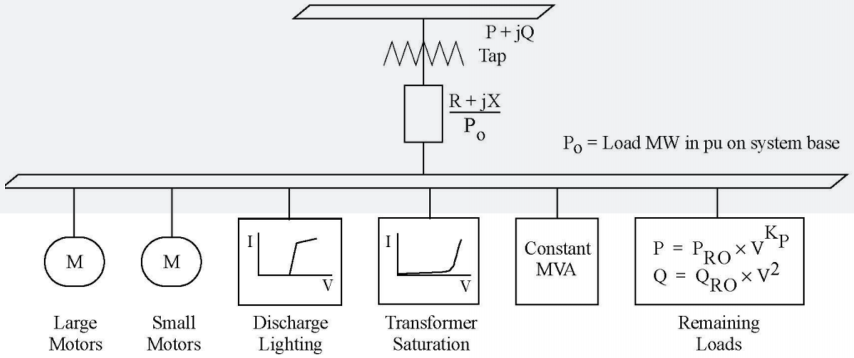
“All models are wrong, but some are useful”

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

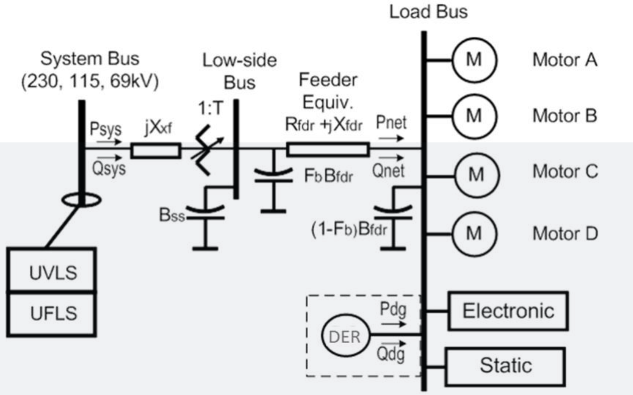


Static Load Models

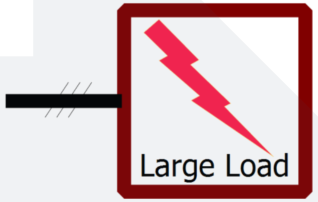


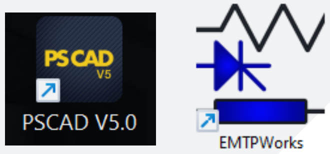


Dynamic Complex Load Model [Source: Siemens PSS®E]



Dynamic Composite Load Model [Source: NERC]





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

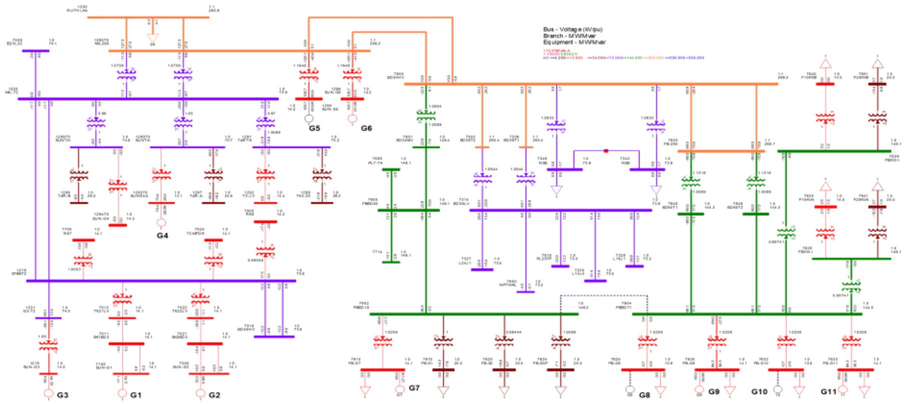
- Voltage and frequency ride through
- Breaker short circuit duty
- Protection coordination

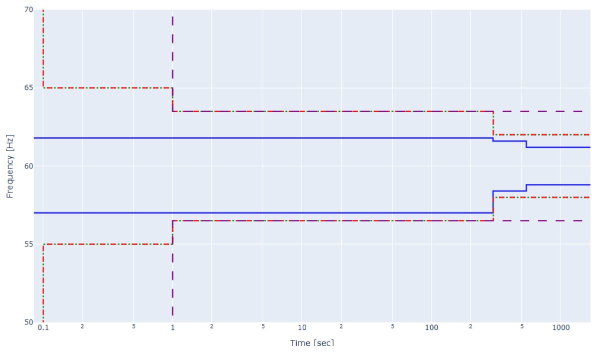
Stability Studies

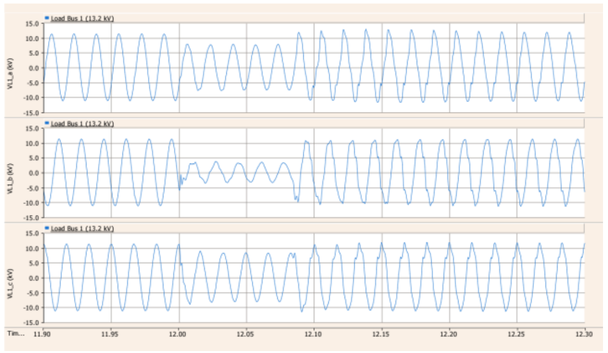
- Transient stability
- Small signal stability
- Voltage stability
- Oscillations

EMT Studies

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







Learn from the Past; Look to the Future

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

ELEVATE ENERGY CONSULTING

Ryan D. Quint, PhD, PE
President and CEO
ryan.quint@elevate.energy

Kyle Thomas, PE
Vice President, Engineering and Compliance Services
kyle.thomas@elevate.energy

Farhad Yahyaie, PhD, PEng
Head, Power System Studies and Modeling
Elevate Energy Consulting
farhad.yahyaie@elevate.energy

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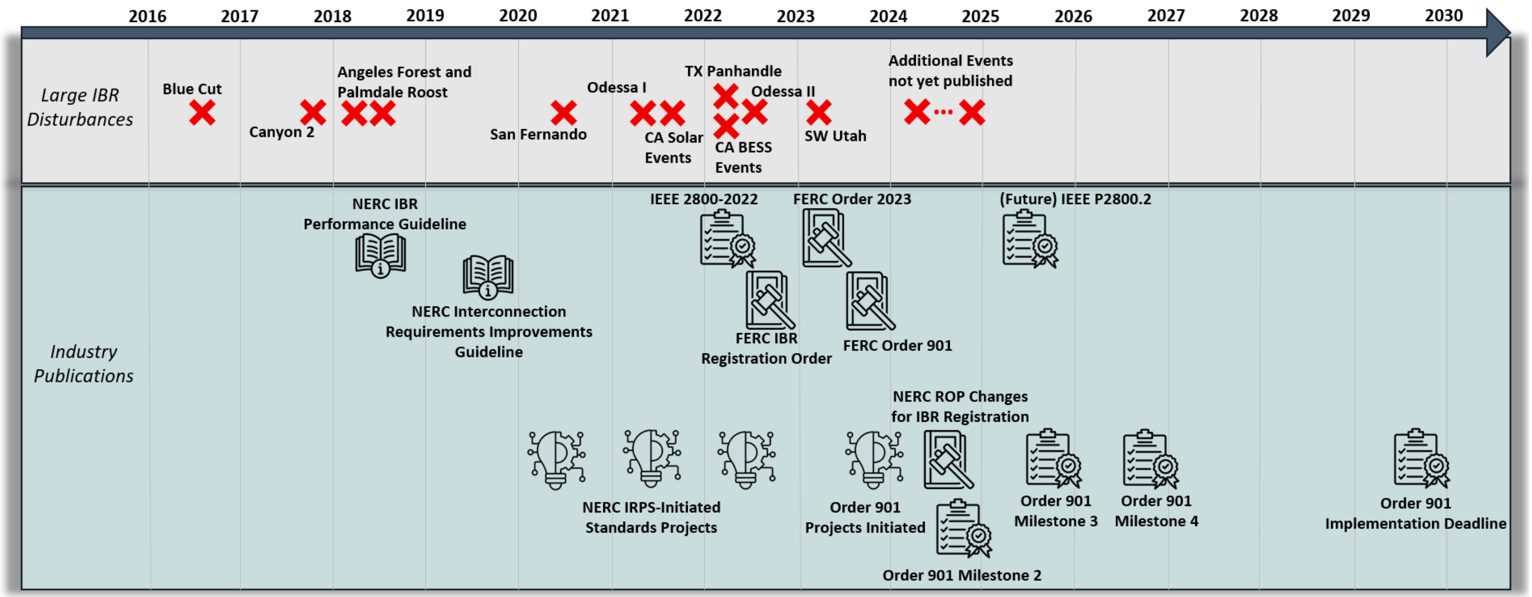
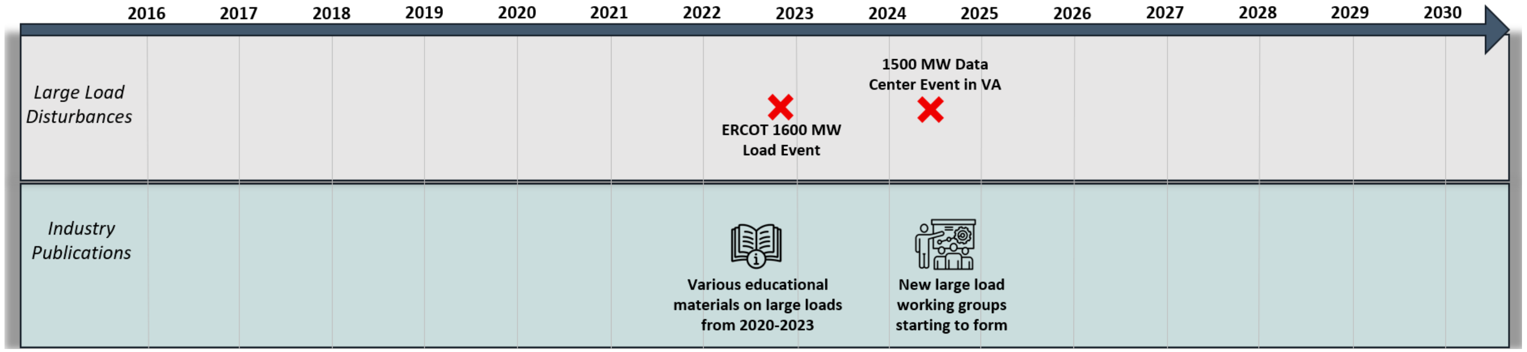
Interconnection of IBRs vs. Large Loads

IBRs since 2016



Large Loads since 2020



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