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Welcome to the Reliable IBR Integration and Milestone 3 of FERC Order 901 NERC Industry Engagement Workshop – Day 1

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Safety Briefing

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NERC Antitrust Compliance Guidelines and Commission Staff Disclaimer

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Opening Keynote

Jim Robb President and CEO (NERC)
NERC Industry Engagement Workshop
January 15, 2025

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Opening Remarks

Mark Lauby Senior Vice President and Chief Engineer (NERC)
NERC Industry Engagement Workshop
January 15, 2025

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Evolution of Grid Characteristics and Modeling Needs with Changing Resource Mix

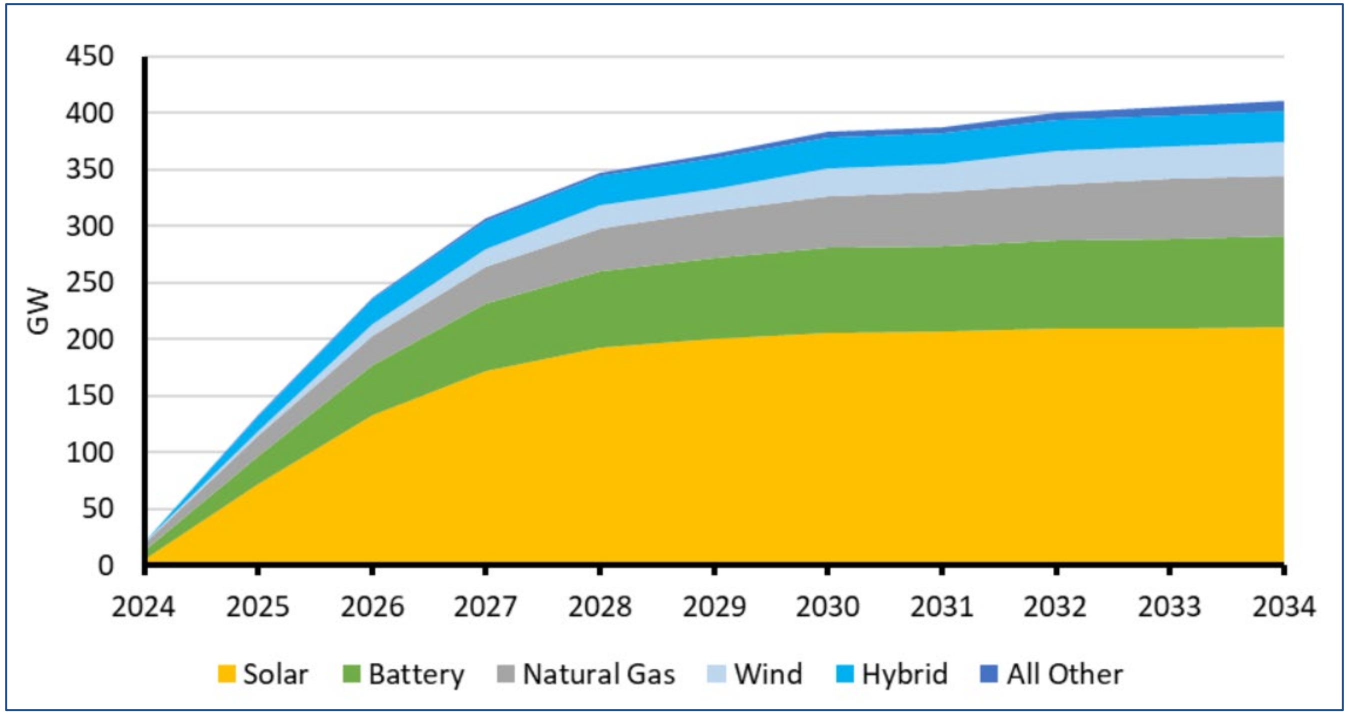
Evan Mickelson, Power Systems Engineer, NERC
Aung Thant, Senior Engineer, NERC
NERC Industry Engagement Workshop
January 15, 2025

Outline

- Changing Resource Mix
- Disturbances & Recommendations

North American Planned Resources Outlook

- NERC Long-Term Reliability Assessment (2024)
- Tier 1 and 2 Planned Resources Projected through 2034
- **Over 300 GW nameplate of IBR**

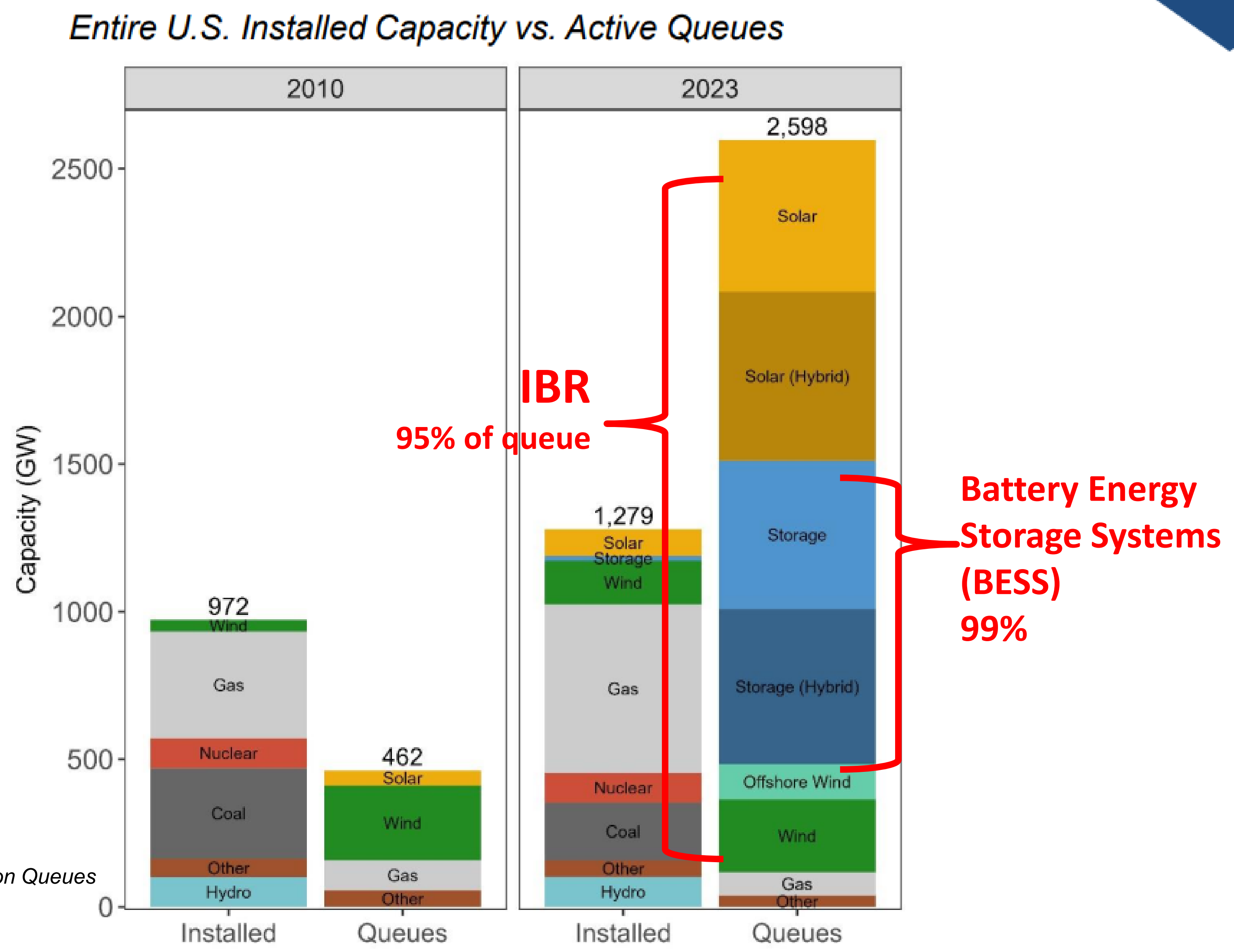


Changing Resource Mix

- ERCOT Fact Sheet & Monthly Generator Interconnection Status Report

Generator Type	Operational Nameplate as of December 2024 (MW)	Maximum Penetration (%)
Energy Storage	10,017	-
Solar	29,148	44.17
Wind	39,470	69.15

North American IBR Outlook



Source: LBL.GOV
Generation, Storage, and Hybrid Capacity in Interconnection Queues

Expectations on IBR

Current:

- Primary Frequency Response (PFR)
- Fast Frequency Response (FFR)
- Transient and Dynamic Voltage Support
  - Point of Interconnection Voltage Control
  - Reactive current injection
  - Reactive priority

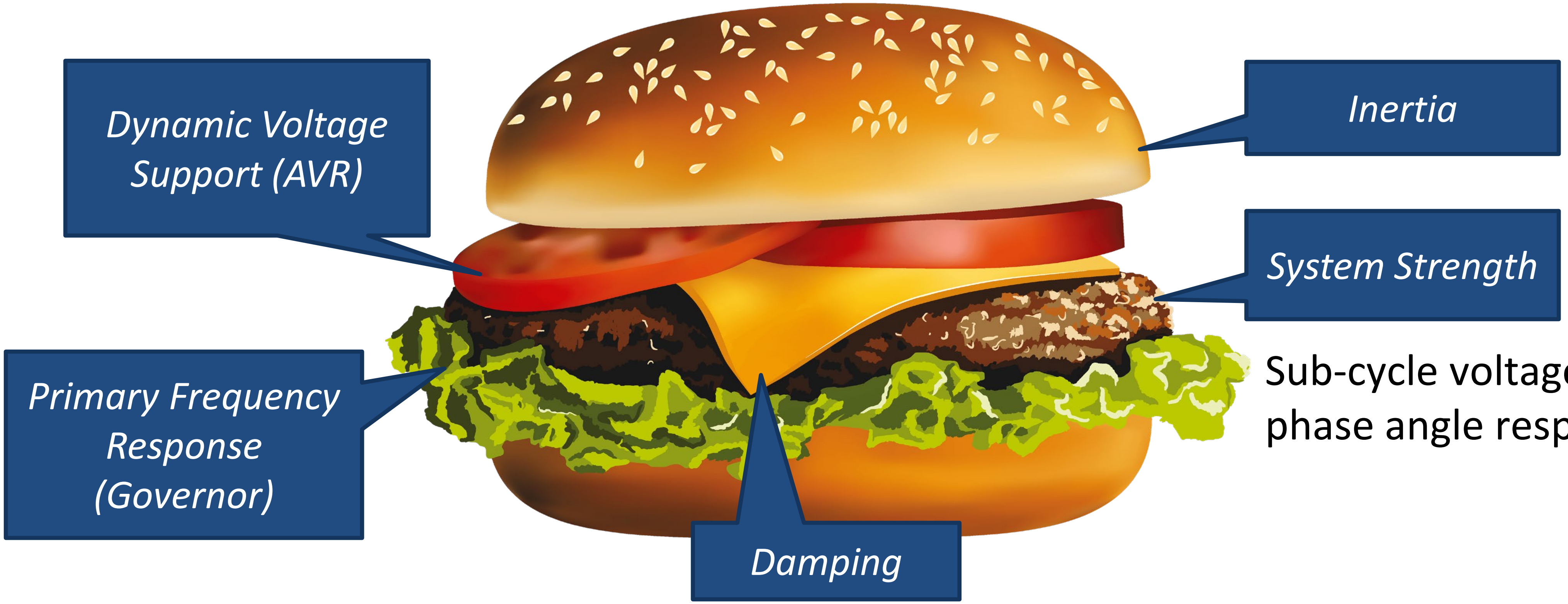
Future:

- More FFR
- Near instantaneous voltage and frequency support (i.e., Grid Forming*)

**https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper_GFM_Functional_Specification.pdf*

What Synchronous Generator Brings

Providing essential services without explicit requirements



Sub-cycle voltage and phase angle response

What Grid Following IBR Brings

Providing *some* essential services when explicitly required

Fast Frequency Response (FFR)

Dynamic Voltage Support (AVR)

Primary Frequency Response (Governor)

Reactive Current Injection

NERC Disturbance Reports

- Different mechanism and effect than conventional generation trips
  - Full/partial outage of real power
  - Some return to full/partial real power after some amount of seconds
  - Inability to recreate in positive sequence phasor domain

Odessa Modeling Deficiencies

Can the models recreate the cause of reduction?

Table 3.1: Solar PV Tripping and Modeling Capabilities and Practices

Cause of Reduction	Can Be Accurately Modeled in Positive Sequence Simulations?	Can Be Accurately Modeled in EMT Simulations?
Inverter Instantaneous AC Overcurrent	No	Yes
Passive Anti-Islanding (Phase Jump)	Yes[a]	Yes
Inverter Instantaneous AC Overvoltage	No	Yes
Inverter DC Bus Voltage Unbalance	No	Yes
Feeder Underfrequency	No[b]	No[c]
Incorrect Ride-Through Configuration	Yes	Yes
Plant Controller Interactions	Yes[d]	Yes[e]
Momentary Cessation	Yes	Yes
Inverter Overfrequency	No[b]	Yes
PLL Loss of Synchronism	No	Yes
Feeder AC Overvoltage	Yes[f]	Yes
Inverter Underfrequency	No[b]	Yes

Table 3.4: Review of Solar PV Facilities

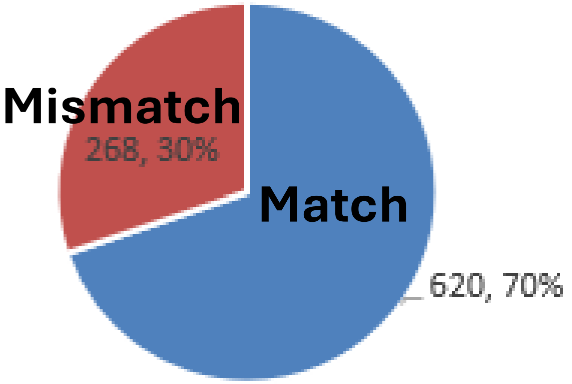
Facility ID	Reduction [MW]	Cause of Reduction	Positive Sequence Model Capable?	EMT Model Capable?
Plant B	133	Inverter phase jump (passive anti-islanding) tripping.	Unknown*	Unknown
Plant C	56	Inverter phase jump (passive anti-islanding) tripping.	Unknown	Unknown
Plant E	159	Inverter ac overvoltage tripping.	Unknown*	Unknown
Plant U	136	Inverter ac overvoltage tripping; feeder underfrequency tripping.	Unknown	Unknown
Plant F	46	Unknown.	Unknown	Unknown
Plant I	196	Inverter phase jump (passive anti-islanding) tripping.	Unknown	Unknown
Plant J	106	Inverter dc voltage imbalance tripping.	Unknown	Unknown
Plants K + L	130	Momentary cessation/inverter power supply failure.	Unknown	Unknown
Plant M	146	Inverter dc voltage imbalance tripping; incorrect inverter ride through configuration.	Unknown	Unknown
Plant N	35	Unknown.	Unknown	Unknown
Plant O	15	Unknown.	Unknown	Unknown
Plant P	10	Inverter ac overcurrent tripping.	Unknown*	Unknown
Plant Q	12	Inverter ac overcurrent tripping.	Unknown	Unknown
Plant R	261	Inverter ac overcurrent tripping.	Unknown*	Unknown
Plant S	94	Inverter dc voltage imbalance tripping.	Unknown*	Unknown
Plant T	176	Inverter ac overcurrent tripping; feeder underfrequency tripping.	Unknown*	Unknown

Do the models recreate the cause of reduction?

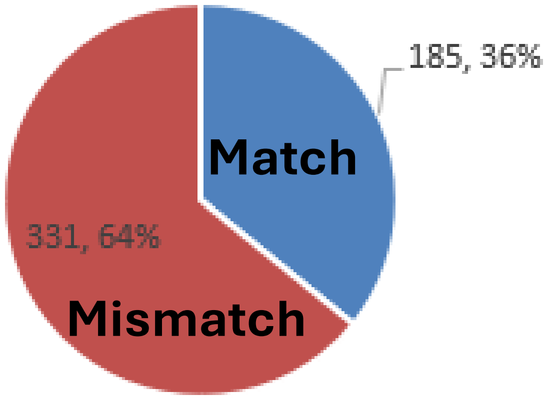
Level 2 NERC Alert on Modeling Deficiencies

Models Reflecting Reported Controls and Parameters* – Primary Frequency Response (PFR)

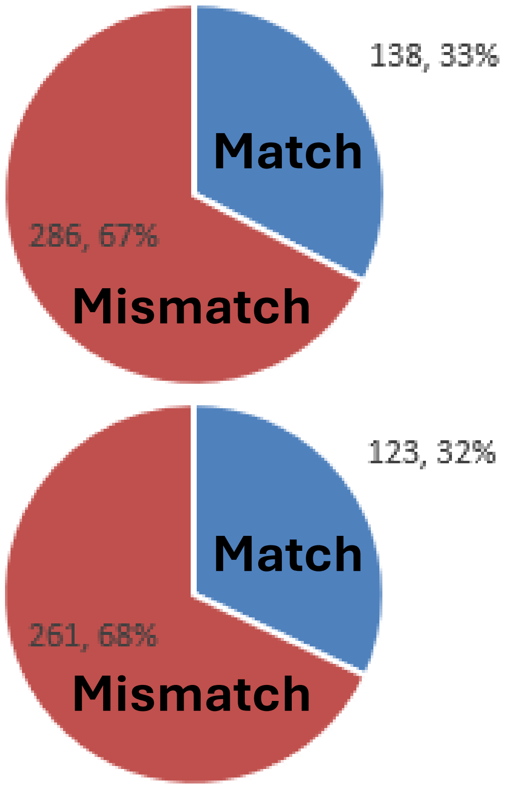
PFR Control Mode Enable



PFR Droop

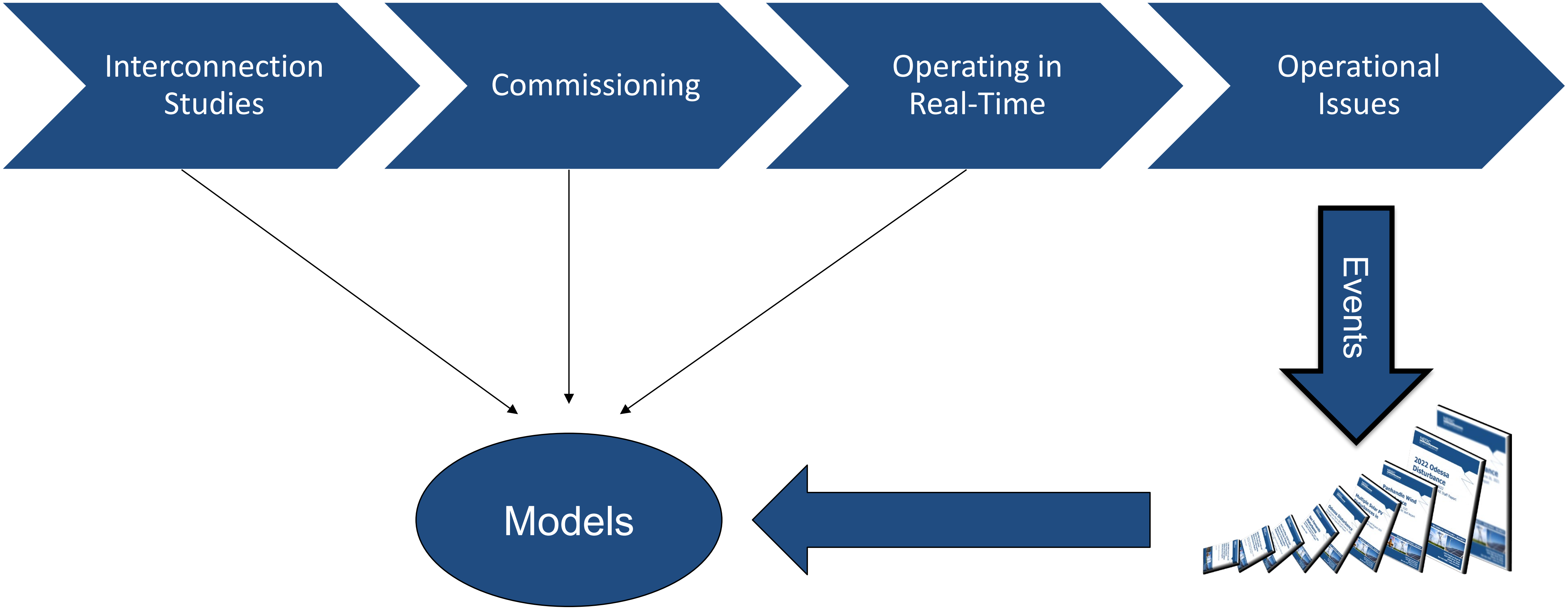


PFR Deadbands



*Preliminary Results

Role of Models in Operational Issues



Key Modeling Takeaways

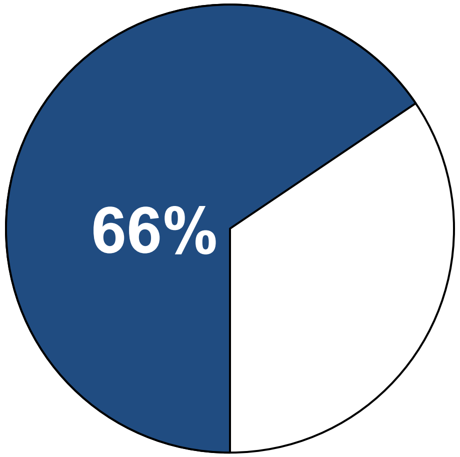
- EMT modeling requirements are critical moving forward
  - Modeling requirements will drive model improvements
- EMT model quality checks are necessary for model accuracy
  - Positive sequence benchmarking against EMT is necessary
- Model parameterization needs to match reality
  - Explicit verification of commissioned parameters against those studied during the interconnection process
- Forms of protections and controls that can trip the facility should be represented in models (ride-through studies)
  - These functions should also be tested for functionality and accuracy
  - Includes inverter **and** balance of plant protections

Key Modeling Takeaways

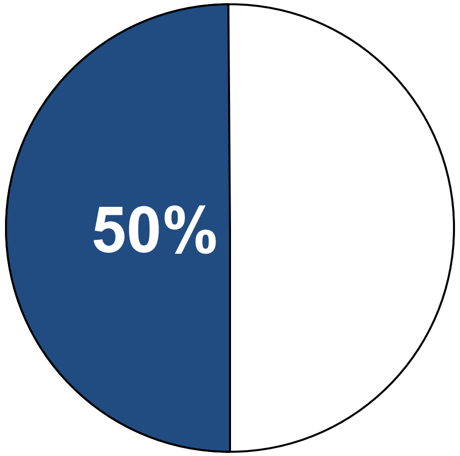
- Positive sequence models unable to ensure plant ride-through performance before real-time operations
- Strong and growing need for EMT modeling/studies moving forward
  - EMT models should be used for detailed and accurate ride through studies and for benchmarking of positive sequence models
- Changes to facilities require studies and approval by TP/PC ***before*** being made
  - Consider any change to electrical behavior (steady-state or dynamic) a “qualified change” per NERC FAC-002-4

Model Quality Requirements

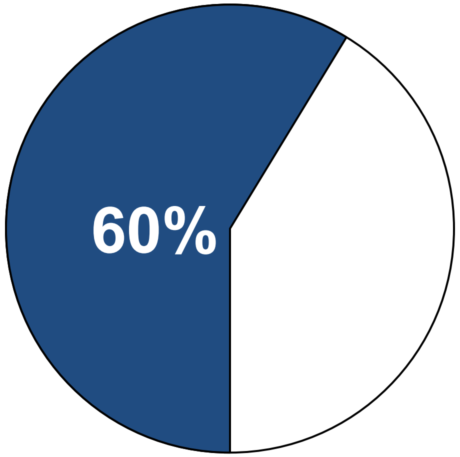
Out of 190 Transmission Planners (TP) and Planning Coordinators (PC)…



have publicly available model **submission** requirements



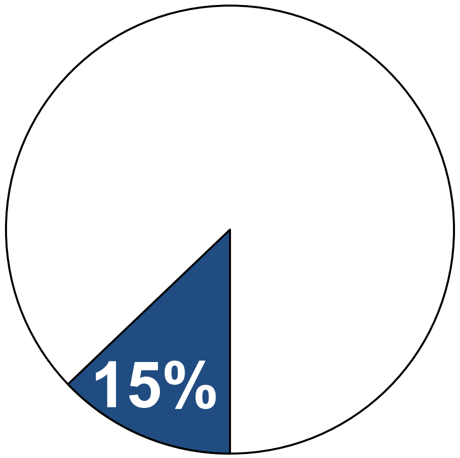
have publicly available model **quality** requirements



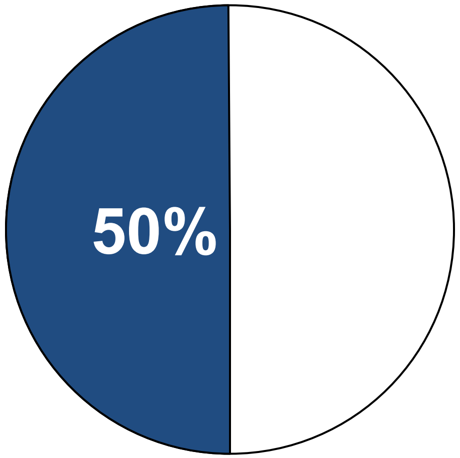
believe their modeling requirements align with NERC's Dynamic Modeling Recommendations

User-Defined Models (UDM) in Positive-Sequence Phasor Domain (PSPD)

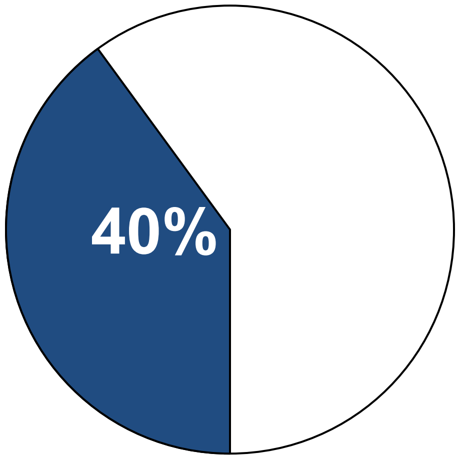
Out of 190 Transmission Planners (TP) and Planning Coordinators (PC)…



require the submission of **equipment-specific**, UDM PSPD generator models **for interconnection studies**

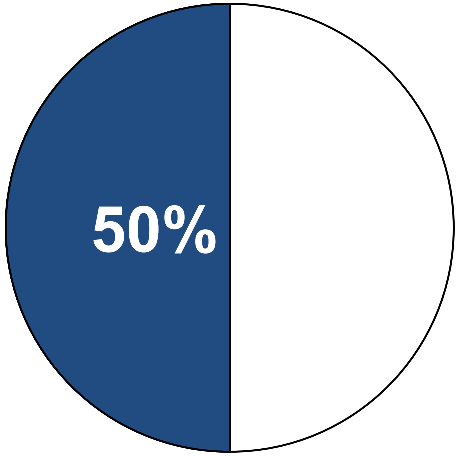


allow the submission of **equipment-specific**, UDM PSPD generator models **for interconnection studies**

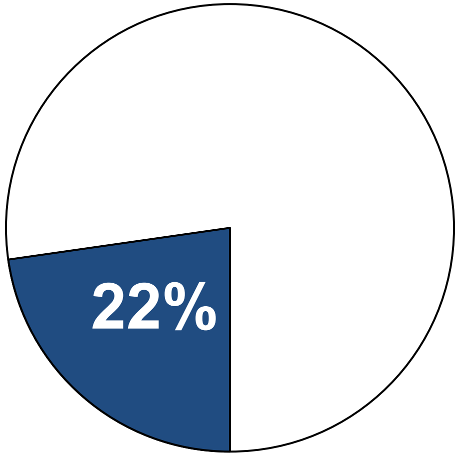


have the **tools** and **personnel** to **effectively perform analysis** with **equipment-specific, user-written** models

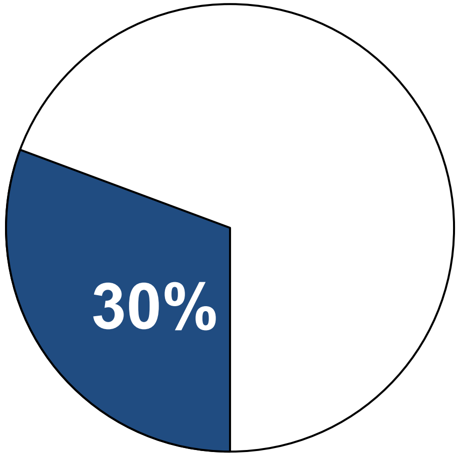
Out of 190 Transmission Planners (TP) and Planning Coordinators (PC)…



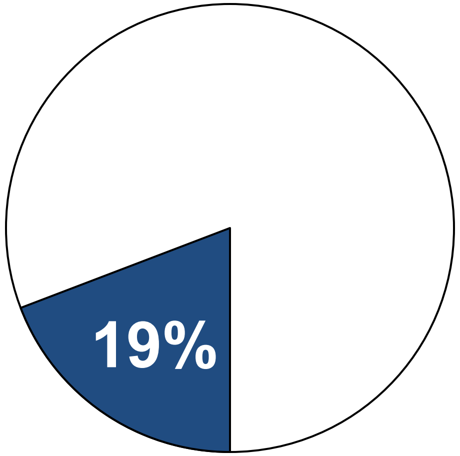
require the submission of **equipment- and site-specific EMT generator models** during the interconnection process



perform EMT model verifications to determine **if the model meets published requirements**



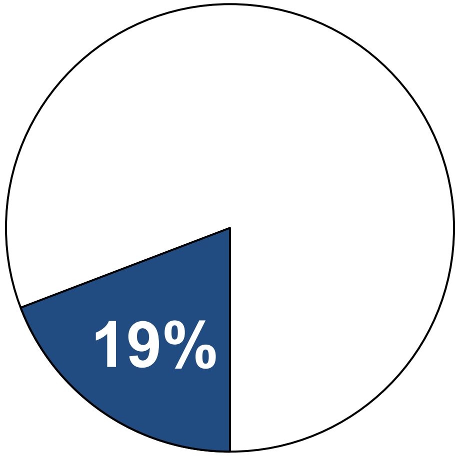
integrate EMT models into studies performed for **generator interconnection** procedures



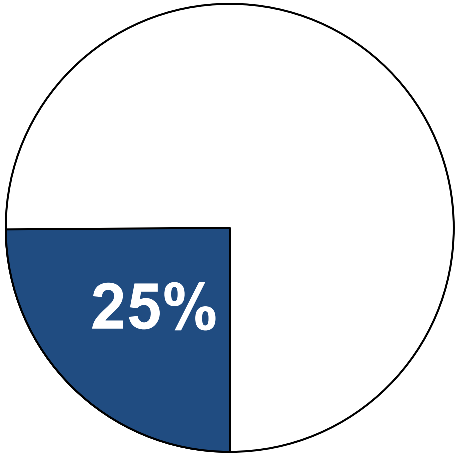
have the tools and personnel to effectively perform EMT analysis

Benchmarking and Model Accuracy

Out of 190 Transmission Planners (TP) and Planning Coordinators (PC)…



require generator model benchmarking reports that contain comparisons between **all model types and actual equipment**



have quantitative metrics to determine model accuracy

Conclusions

- There are demonstrated IBR performance and model quality issues
  - Shown through event analysis
  - There are also demonstrated solutions for these issues
  - **“All models are wrong, but some are useful”**
- Modeling needs change with the resource mix

Questions and Answers

Questions and Answers

- Option 1
  - Navigate in browser to www.slido.com
  - Enter Event Code: NERC901
  - Email address requested on entry
    – so we can respond to all questions!

- Option 2:
  - You may also scan this QR code
    to be auto-directed to the event

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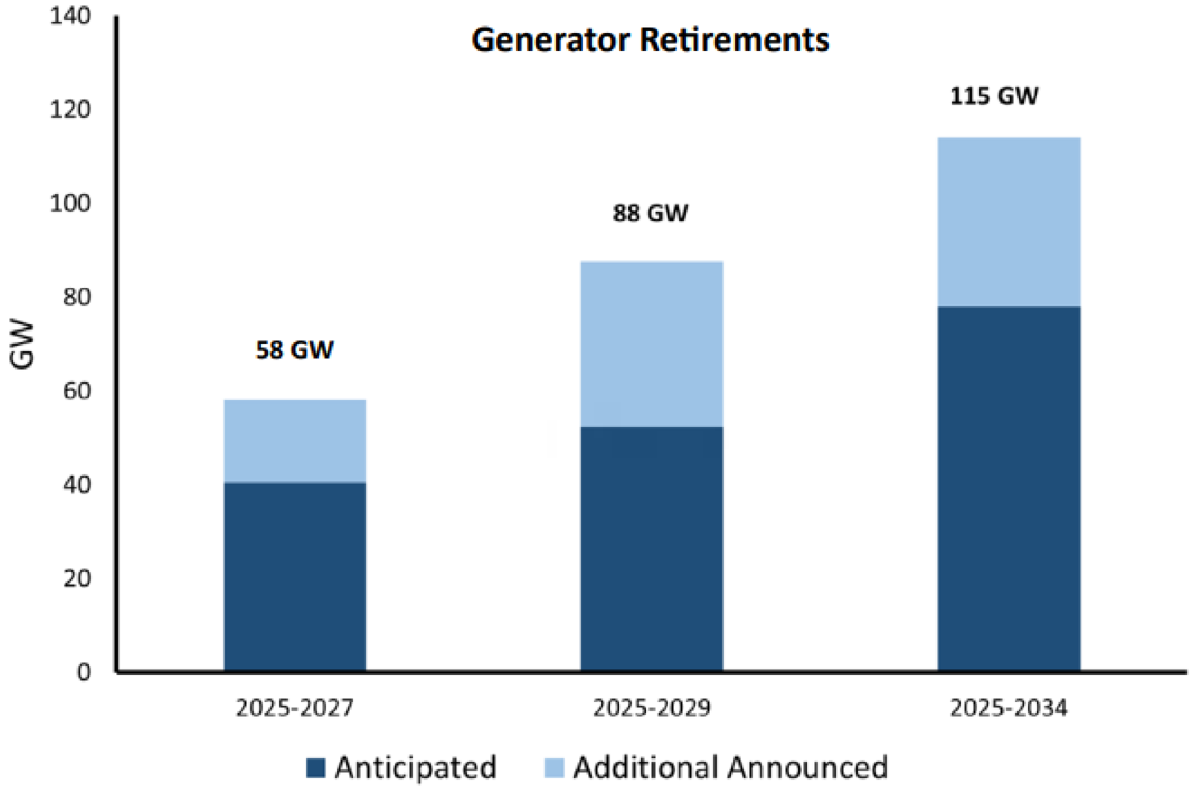
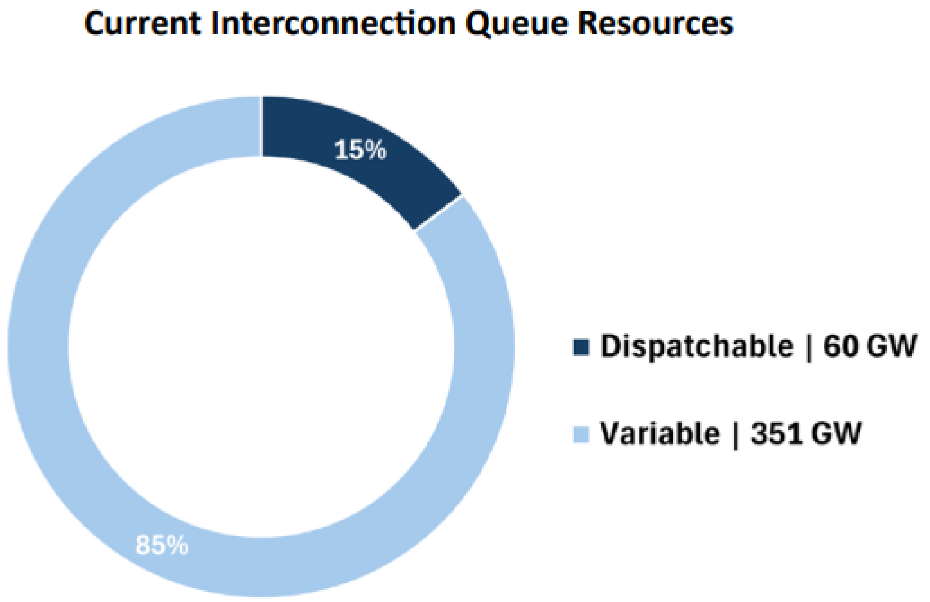
Essential Reliability Services to Meet the Needs of the Transforming Grid

Hasala Dharmawardena, Senior Engineer, NERC
NERC Industry Engagement Workshop
January 15, 2025

Background – Resource Adequacy





*NERC 2024 LTRA – Infographics NERC_LTRA_Infographic_2024.pdf

Essential Reliability Services in the Resource Mix

Past → Resource mix
- Synchronous Machine
- Slow and Bulky
- Robust

→ ERS are naturally included in resource → System Reliable

Future → Resource mix
- Inverter based resources
- Fast and Agile
- Fragile

→ ERS are not naturally included in resource → System Reliable?

Intentionally identifying, measuring, and planning for sufficient Essential Reliability Services (ERS) in the future resource mix is critical to ensuring long term system reliability

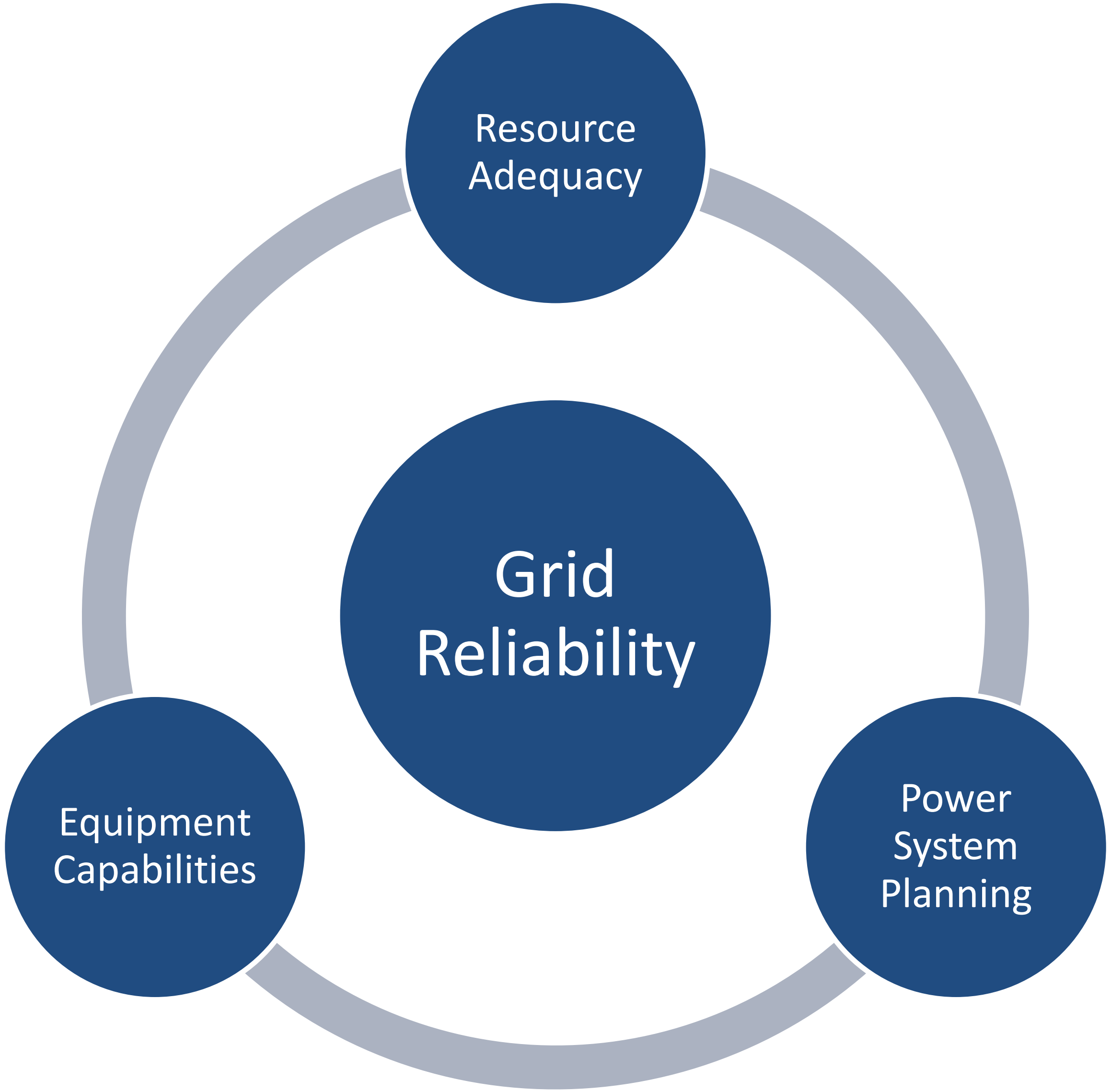
ERS are Dynamic – A Periodic Assessment is Important

The BPS characteristics changes with time

The required type and amount of ERS changes with the BPS Characteristics

The mechanisms to account for ERS must also evolve

ERS Should be Included into the Planning Life Cycle



NERC Defined Essential Reliability Services

Frequency

Voltage

Ramping and Balancing

ERS Integration into Power Systems Planning and Operations

- Capability mandates for Equipment
  - Voltage (Reactive Power) Services – (FERC Order 827 - 2016)
  - Frequency (Primary Frequency Response) Services – (FERC Order 824- 2018)
- Standards
  - Long-term Planning
    - Transmission System Planning Performance Requirements (TPL-001-4)
  - Operational Planning and Real-time Operations
    - Resource Loss Protection Criteria of BAL-003 connects to ERS
      - IFRO* drives the frequency reserve requirements
    - Voltage and Reactive Control (Operations Planning) VAR-001-5

**IFRO=(RLPC-CLR)/Max Delta Freq/10*

Measuring Essential Reliability Services via System Properties

- Synchronous Inertial Response(SIR) at an Interconnection Level*
- Initial Frequency Deviation Following Largest Contingency
- Frequency Response at Interconnection Level *
- Overall System Reactive Performance
- System Strength- Short Circuit Level
- Reactive Capability on the System

- *NERC Essential Reliability Services Task Force Measures Framework Report – 2015*

**M-4/M-4.1 Interconnection Frequency Response/Inertia and Rate-of-Change-of-Frequency*

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NERC Led ERS Initiatives

2001

Interconnected Operation Services (IOS)

Balancing Services

- Resource Adequacy

2014-17

ERS WG - ERS Framework

Ramping (Duck Curve)

2018

Reactive Power

2020

Fast Frequency Response

- Inertia

2024

Massive integration of IBRs?

- Wide area stability
- New large loads

Essential Reliability Services – Next Steps

- Review of Essential Reliability Services Framework to meet the challenges of the transforming grid
  - Enhance Long Term Reliability Assessments
  - Enhance State of Reliability Report

Questions and Answers

To share your work or ideas for collaboration with us - hasala.dharmawardena@nerc.net

Questions and Answers

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Break

10:15 – 10:45 a.m.

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Panel Discussion: Grid Stability Challenges and Services from Inverter-Based Resources (IBRs)

Moderator: JP Skeath, NERC –Manager, Engineering & Security Integration, NERC
Todd Chwialkowski – EDF Renewables
Julia Matevosyan – ESIG
Deepak Ramasubramanian – EPRI
Kyle Thomas – Elevate Energy Consulting
Duncan Burt – Reactive Technologies

January 15, 2025

NERC

Industry Engagement Workshop

Grid Stability Challenges and Services from Inverter-Based Resources

Agenda

- EDFR Introduction
- Generator Challenges
- Opportunities

Todd Chwialkowski
Dir., Transmission Regulatory & Compliance

January 15, 2025

Overview

EDF Renewables North America is a project developer, owner, and operator with end-to-end solutions for every market…

As developer, owner and operator of one of the largest renewable energy portfolios and second largest project pipeline on the continent, EDF Renewables is active in every market across North America.

With our history of innovation, and deep experience developing and operating renewable energy assets, we bring a full-suite of solutions for grid-scale, distribution-scale, asset optimization and onsite energy.

Our outstanding capabilities allow us to utilize our in-house experts, providing maximal efficiency and end-to-end oversight of any size of energy project.

…with the capabilities, financial strength and global footprint to help you secure your energy future.

EDF Renewables North America

16 GW
developed

13 GW
service contracts

44 GW
pipeline

35+
years experience

1,650+
employees

Grid-Scale Power

Distribution-Scale Power

Onsite Solutions

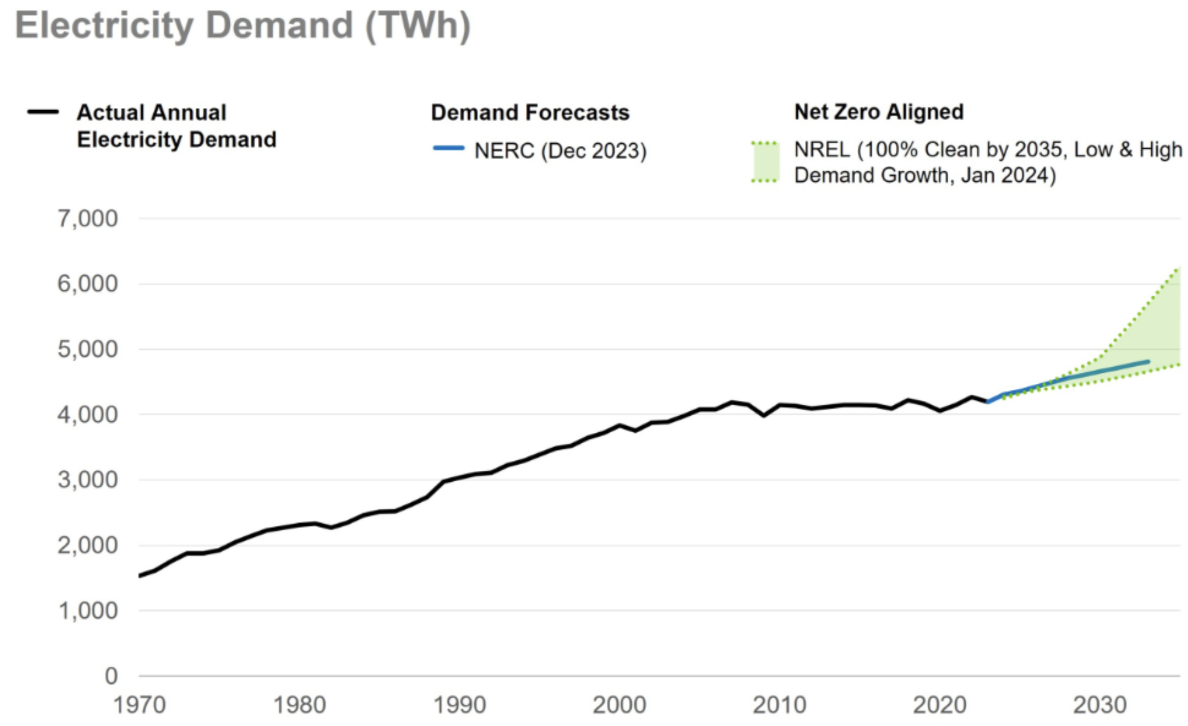
Asset Optimization

as of 12/31/22

edf renewables

Energy Demand & Study Cost Allocation

Figure 1: U.S. Electricity Demand (1970-2035)



The U.S. Department of Energy (DOE) has been anticipating and planning for rising electricity demand underscored by the nationwide goal to reach net-zero emissions economy-wide by 2050. To reach this goal, we expect at least a doubling in current electricity demand.

Why is this important to point out?
→ *Effective collaboration = Success with our goals!*

DOE: Clean Energy Resources to Meet Data Center Electricity Demand (Aug. 12, 2024)
https://www.energy.gov/policy/articles/clean-energy-resources-meet-data-center-electricity-demand#:~:text=The%20U.S.%20Department%20of%20Energy,doubling%20in%20current%20electricity%20demand

Reliability Opportunities

To date, NERC and ERCOT have proposed *retroactive implementation* (applies to both current generation and future projects). ISOs / RTOs are utilizing various strategies in their implementation of the IEEE2800-2022 requirements.

Current IBRs (Legacy Generation Plants):

- P & Q Capability
- Frequency and Voltage Ride-Through Capability
- Improved Data Monitoring and Reporting (e.g., ERCOT NOGRR-245, NERC PRC-028-1)
- Basic Modeling

IBRs in Development (Future Generation Plants):

- Grid Support Services
- P & [increased] Q Capability
- Faster Response to Events
- Enhanced Frequency and Voltage Ride-Through Capability
- Continued Response Over Longer Periods Of Time Before Tripping
- Grid Forming vs. Grid Following
- Increased Accuracy With Modeling

edF renewables

Thank You

Contact:

Todd.Chwialkowski@EDF-RE.com

NERC Panel: Grid Stability Challenges and Services from Inverter-Based Resources (IBRs)

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

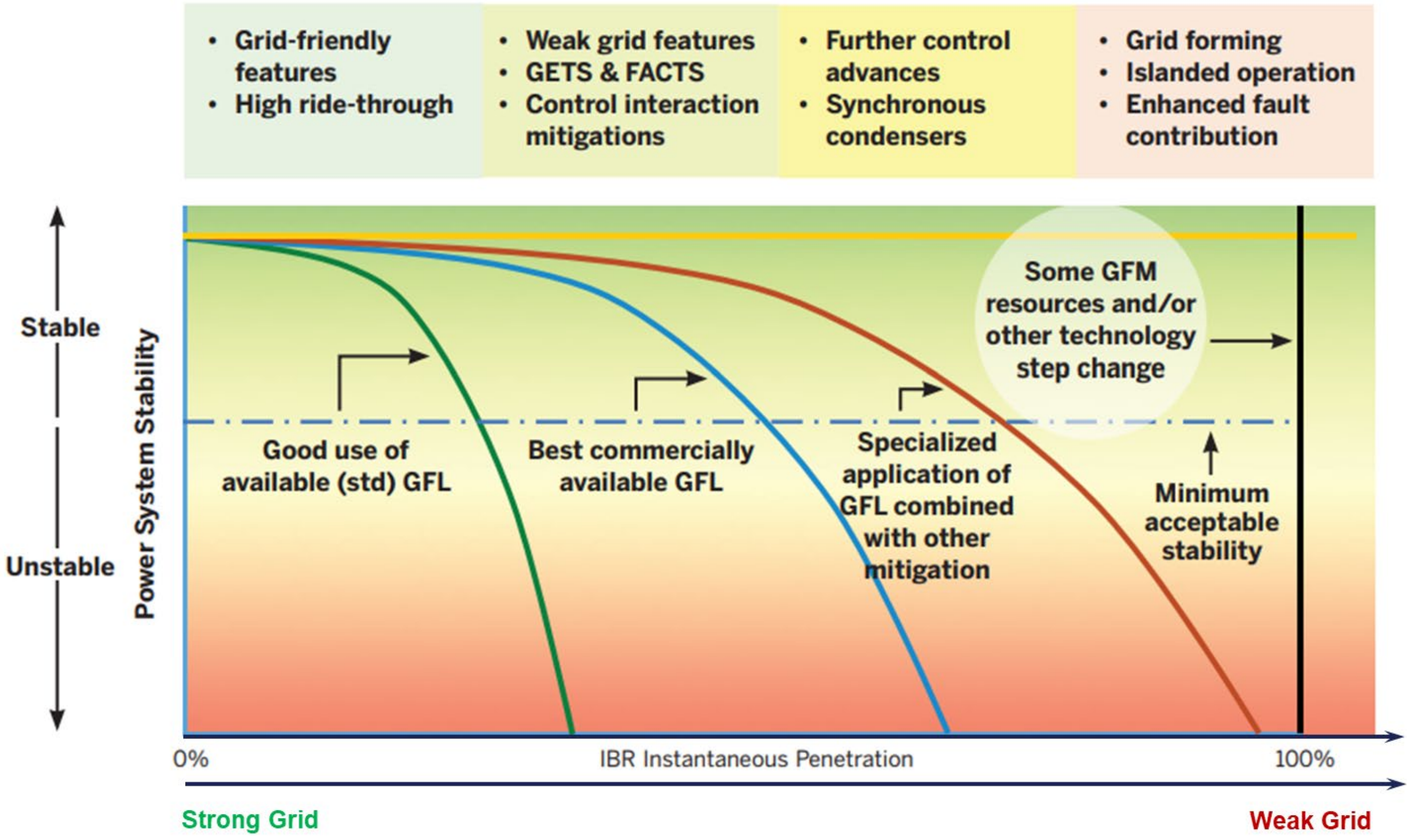
Julia Matevosyan

Associate Director and Chief Engineer

ESIG

05/21/2024

Evolution of Grid Services from IBRs



- *Majority of the inverters today are "grid-following"*
- *They read the voltage and frequency of the grid, lock onto that, and inject power aligned with that signal.*
- *That signal comes from synchronous generators.*
- *The further wind and solar generation pockets are from synchronous generation, the "weaker" the grid.*
- *The signal is then easily perturbed by power injection from wind and solar resources, making it hard for inverters to lock onto it correctly.*
- *This may lead to local instability issues.*

EPRI

Essential reliability services for future power networks

Together…
Shaping the
Future of Energy®

Deepak Ramasubramanian
Senior Technical Leader
dramasubramanian@epri.com

NERC IBR Technical Workshop
15th January 2025

Categories of services that IBRs can provide to network

Fast & stable response to events

Help maintain voltage

Help maintain frequency

Robust fault ride through

Network benefits when devices work as a team

Blackstart capability

Network requires a star player

EPRI

Services from IBRs mapped to needs of the system

Need of network	Service that IBR can provide
Synchronization	Synchronization torque/phase jump mitigation
	First swing mitigation
	Phase jump ride-through
	PLL Stability Support
Frequency Control	Frequency containment
	Inertial response/limiting RoCoF
	Frequency stabilization
	Frequency recovery
Voltage control	Voltage containment
	Mitigate voltage collapse
	Fault ride-through
	Mitigate unbalance and harmonics
Damping	Damp sub-synchronous oscillations (SSO)
	Damp super-synchronous oscillations
Protection	Detect and locate faults
Restoration	Black start
	Cold load pick up
	Island operation

Table from [1]

Points to note:

- Need to identify situations where the service is important/can be tested
- Not every service is required at all points in time

[1] B. Chaudhuri, D. Ramasubramanian, J. Matevosyan, M. O'Malley, N. Miller, T. Green and X. Zhou, "Rebalancing Needs and Services for Future Grids: System Needs and Service Provisions With Increasing Shares of Inverter-Based Resources," in IEEE Power and Energy Magazine, vol. 22, no. 2, pp. 30-41, March-April 2024

Technical requirements and utilization of capability

No grid services – grid following

Legacy IBR

- Injects active power at unity power factor
- Provides no grid support services

Conventional IBR

- Has capability to provide both frequency and voltage response
- Typically, full delivery of response over multiple seconds

Enhanced IBR

- Delivers full frequency and voltage response within 1s of event
- As a group, could survive loss of last synchronous machine

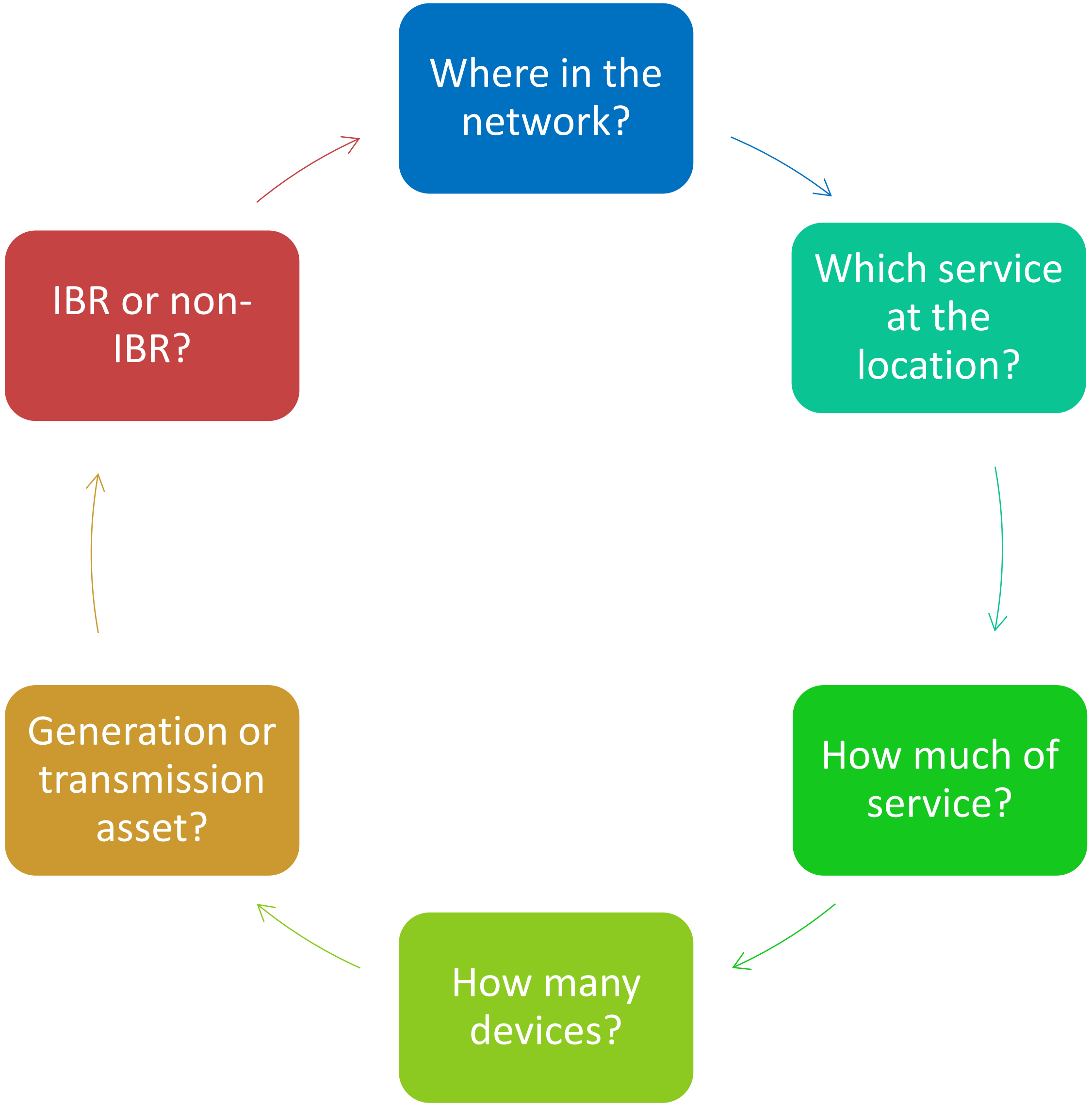
Future IBR

- Is capable of blackstart
- A single IBR could ride through extreme load-gen mismatch

All grid services – grid forming

IBR – Inverter based resource

Questions that can be asked for requisite services



Planning and operation of a system with high IBRs requires an evaluation of capability *and deliverability of performance from various devices in the network*

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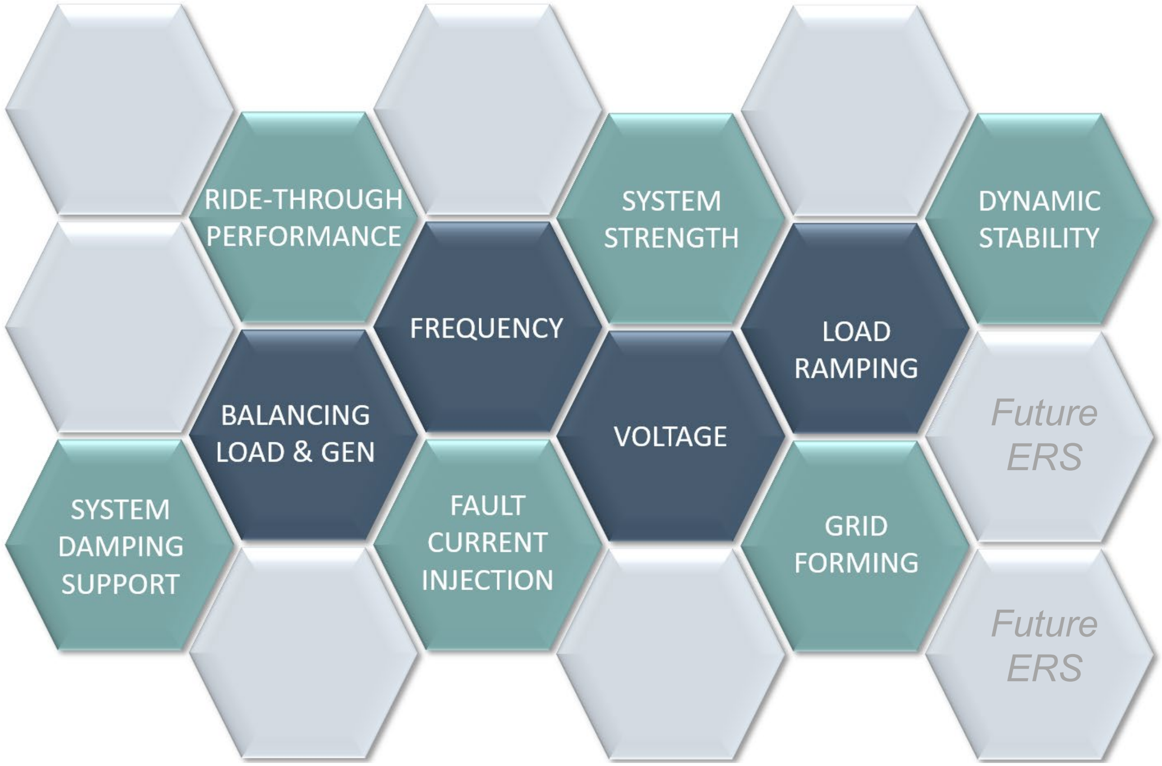
NERC Panel: Grid Stability Challenges and Services from Inverter-Based Resources (IBRs)

Kyle Thomas, PE

January 15, 2025

Essential Reliability Services (ERS) Going Forward

- The grid today relies on the physical, inherent properties of synchronous generators to maintain reliability, *which go beyond the current defined ERS*
- IBRs do not have these same inherent properties, so additional ERS may need to be defined to ensure that these are required and implemented by IBRs in their software & controls



Future ERS for IBRs

Current ERS

ELEVATE ENERGY CONSULTING

Expanded Set of Essential Reliability Services with Increasing Levels of IBRs

Essential Reliability Services (ERS) Going Forward

- NERC can help ensure that the industry is collectively ensuring an *adequate level of reliability* by assessing and requiring that there is an adequate amount of all the expanded, necessary ERS from IBRs

- To do this, we need accurate and validated models from all resources during the interconnection process to allow us to run these ERS assessments under high IBR scenarios
  - Must have this clearly defined in advance of interconnections so that right services, models, studies, and equipment can have requirements in place and implemented on the system

ELEVATE ENERGY CONSULTING

ELEVATE

ENERGY CONSULTING

kyle.thomas@elevate.energy

Grid Stability:

Challenges and Services from IBRs

Solutions for a fast-evolving power grid

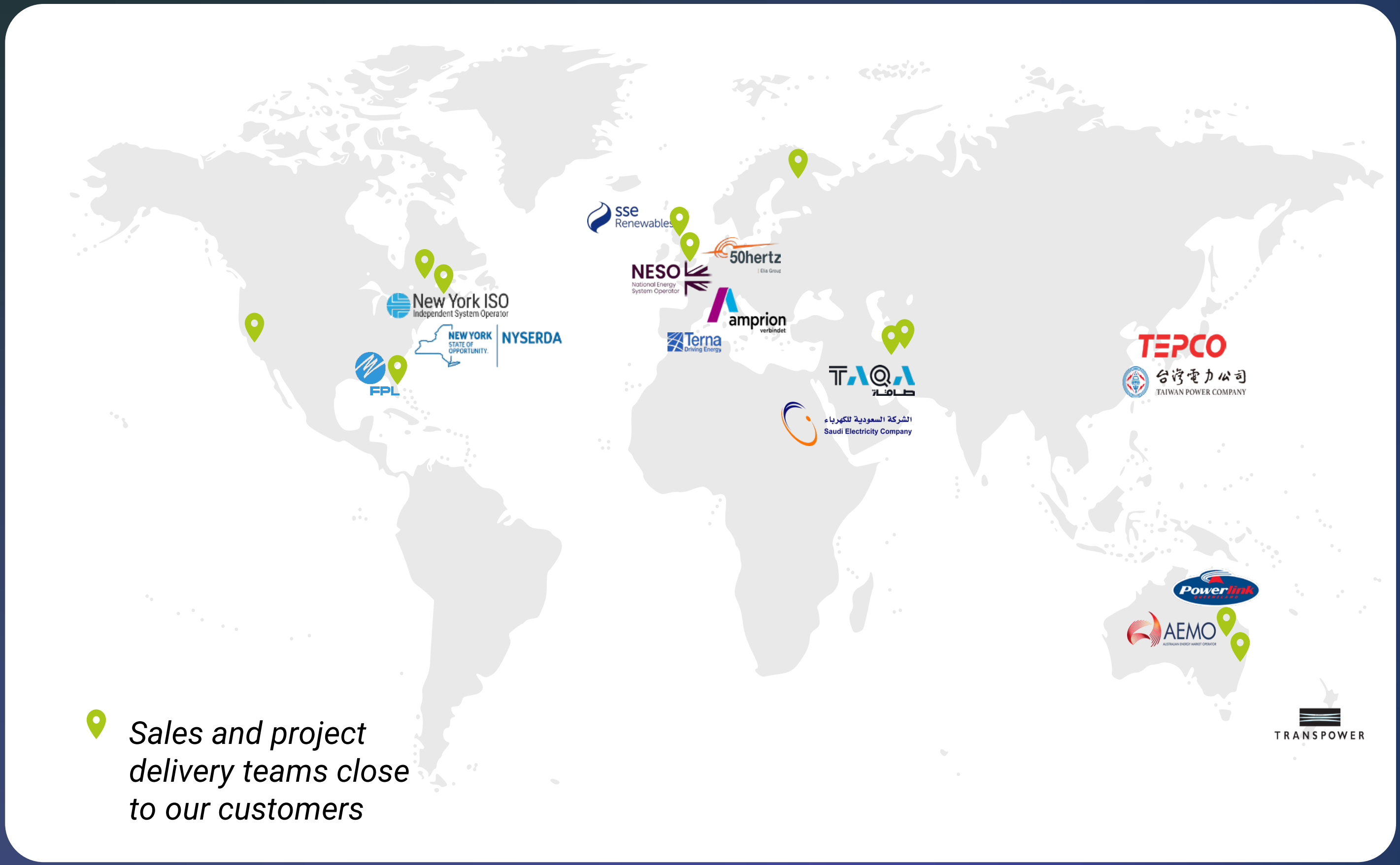
Reactive Technologies

Duncan Burt

Chief Strategy Officer

duncanb@reactive-technologies.com

We enable transmission and distribution grid operators to measure grid inertia and system strength to accelerate the transition to a low-carbon grid, safer and faster.



To Tackle Global Grid Challenges

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

*"As the penetration of wind and solar on the system increases, operation of the system becomes significantly more complex. The **power system is being operated closer to its known limits** more frequently, with increasingly variable and uncertain supply and demand, and **declines in system strength and inertia**."*

NESO
National Energy System Operator

*"Zero carbon operation of the electricity system means a **fundamental change to how our system was designed to operate**; integrating newer technologies right across the system… **using new smart digital systems** to manage and control the system in real-time."*

*"It is recommended that system operators perform **inertial measurements** to get an **accurate, real-time** view of inertia levels to replace guesswork and conservative estimates."*

entsoe

*"Decreasing levels of inertia – as a result of the large-scale integration of renewable sources – **pose long-term challenges to frequency stability of the transmission system, with possible impacts on the resilience of the future system**."*

Observations and Mitigations

Frequency behavior increasingly localized	Reduced damping and more oscillations	Voltage stability issues linked to low SCL	More aggressive regional transients/RoCof	New Constraints for inertia /voltage /stability
Detailed /local regional security modelling	Modelling can replicate but can still be poor at predicting due to complexity	Continuous measurement of Inertia & SCL/Voltage	Fast control helps but can create oscillations	Development of stability/ Grid Forming (GFM) standards

You wouldn't operate the grid without measuring and modelling voltage and current.

Today, it's crucial to measure inertia and system strength for the IBR grid of tomorrow.

reactive technologies

Thank You!

Net Zero – Safer, Faster.

SLIDO

- Option 1
  - Navigate in browser to www.slido.com
  - Enter Event Code: NERC901
  - Email address requested on entry
    – so we can respond to all questions!

- Option 2:
  - You may also scan this QR code
    to be auto-directed to the event

Lunch
12:00 – 1:00 p.m.

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Panel Discussion: Best Practices on IBR Modeling and Validation

Moderator: Rich Bauer, Principal Engineer, Event Analysis, NERC
Miguel Acosta – Vestas
Chris Milan – Crestcura
Sebastian Achilles – GE Vernova
Larry Truong – TMEIC
Rajni Burra – Terabase Energy

Moderated by

Perfect World

Interconnection Request

- → Submit ***<u>Accurate</u>*** Model
  - → Study Model
    - → Construct
      - → Install Equipment Representative of Model
        - → Commission Test to validate Accurate Equipment Model

Perfect World

Interconnection Request

- Submit ***Accurate*** Model
  - Study Model
    - Construct
      - Install Equipment Representative of Model
        - Commission Test to validate Accurate Equipment Model
          - Changes? Differences?

Perfect World

Let’s talk about how do we achieve that Perfect World and what are some Best Practices for how to accomplish that?

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Break
2:30 – 2:45 p.m.

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Panel Discussion: IBR Modeling Challenges

Moderator: Alex Shattuck, ESIG
Todd Chwialkowski – EDF Renewables
Katie Iversen – S Power
Mohamed Khabit – Invenergy
Zhi Qu – EPE Consulting
Farhad Yahyaie – Elevate Energy Consulting
David Marshall – Southern Company

Questions and Answers

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Closing Remarks

Latrice Harkness, Director, Engineering, NERC
NERC Industry Engagement Workshop
January 15, 2025