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NERC Inverter-Based Resource (IBR) Webinar:

Session 11: Overview of IBR Risk Mitigation and Next Steps

July 13, 2023

RELIABILITY | RESILIENCE | SECURITY

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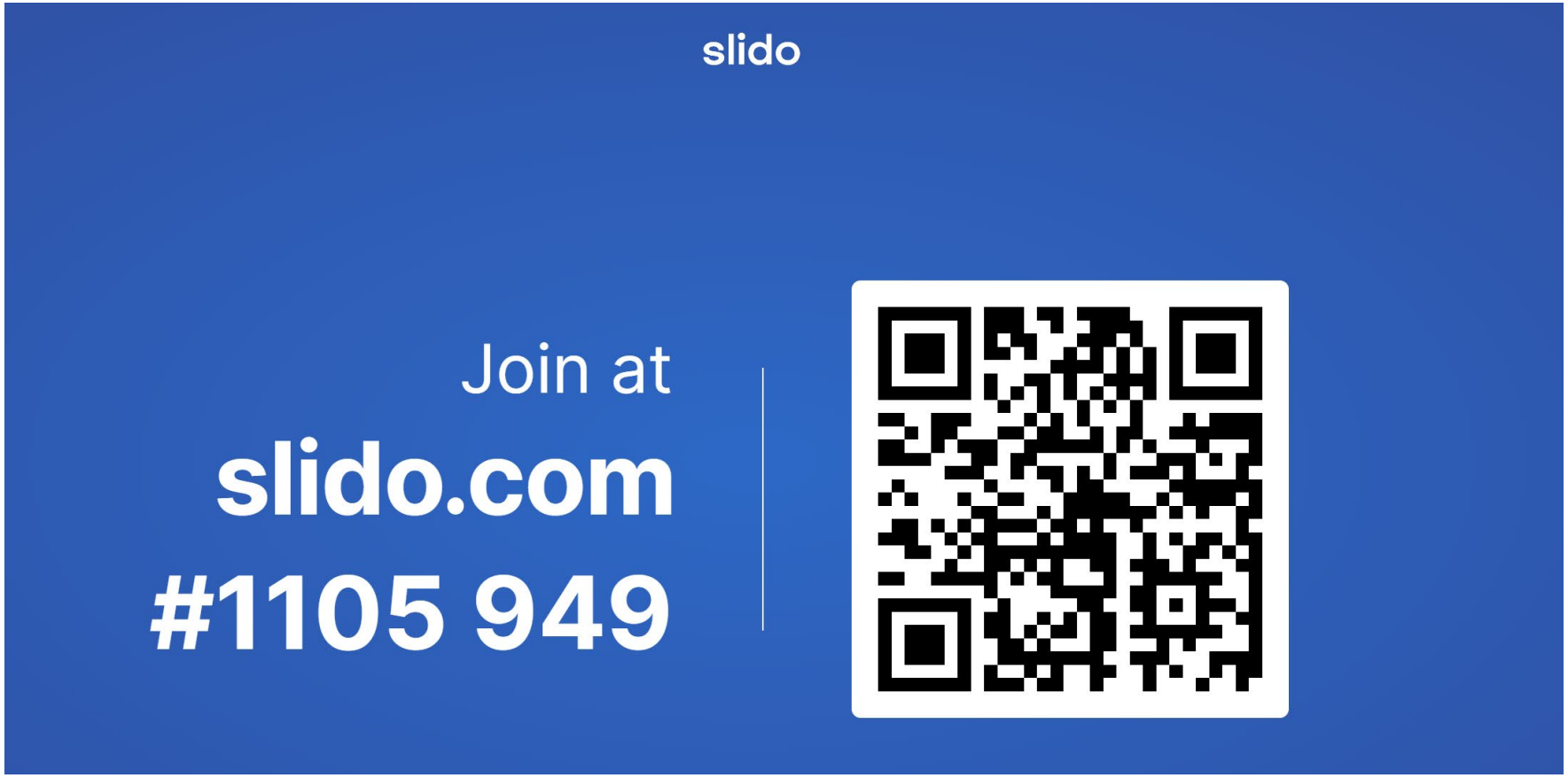

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Recap of the Webinar Series

Key Takeaways from Each Session

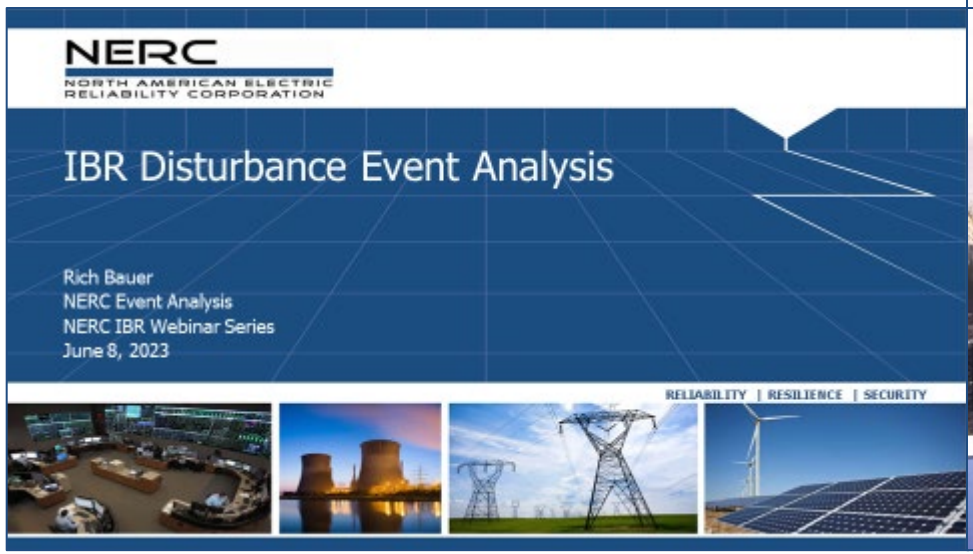
Alex Shattuck
Senior Engineer
Engineering & Security Integration (Engineering and Standards)
July 13, 2023

Webinar 1: Intro. to Inverter-Based Resources

- **Key Takeaways:**
  - The grid transformation is happening extremely quickly
  - High penetrations of IBR bring unique challenges that must be planned for and mitigated to ensure BPS reliability
  - Important to consider the difficulties of retrofitting
  - Grid forming IBR can help BPS reliability under high penetrations (grid forming BESS are already available and in operation internationally)

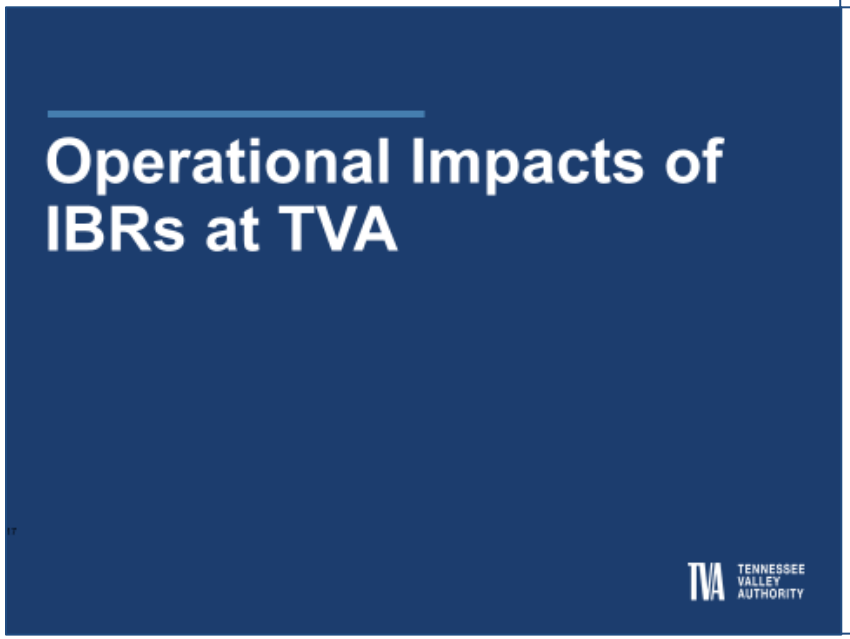
Webinar 2: NERC Disturbance Reports and Lessons Learned

- **Key Takeaways:**
  - The disturbance analysis process is extremely resource intensive and involves many organizations
  - Collaboration between all stakeholders is **key**
  - Pre- and post-fault data needs to be improved



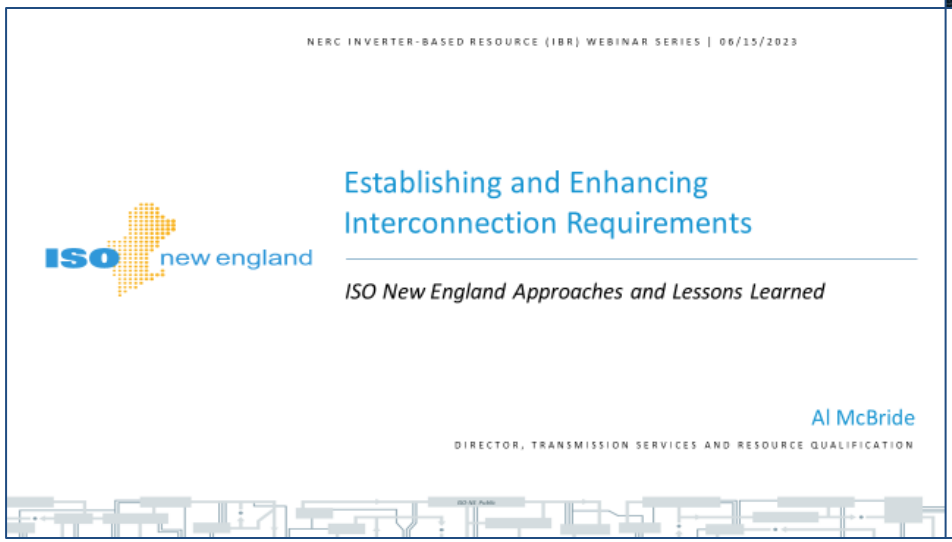
Webinar 3: Inverter-Based Resource Performance Issues

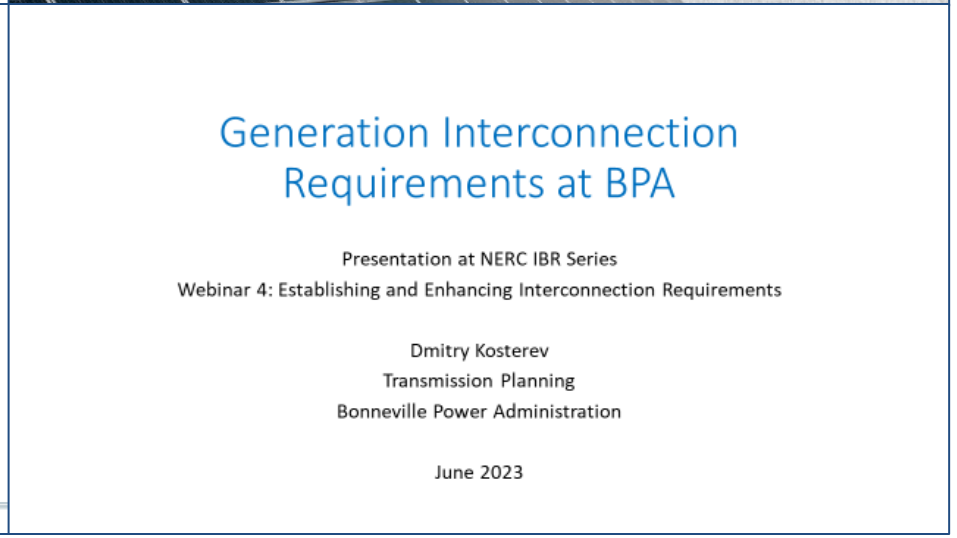
- **Key Takeaways:**
  - Develop NERC standards on a risk-based approach to help improve IBR performance
  - Considerations need to be made for existing facilities
  - Models need to match what is installed
  - Comissioning process improvements have driven improvements



Webinar 4: Establishing and Enhancing Interconnection Req.

- **Key Takeaways:**
  - Standardization of a technical minimum set of interconnection requirements can help all stakeholders
  - Model performance and parameter attestations can improve interconnection process quality
  - EMT requirements have already started to be implemented
  - More resources and industry knowledge are needed

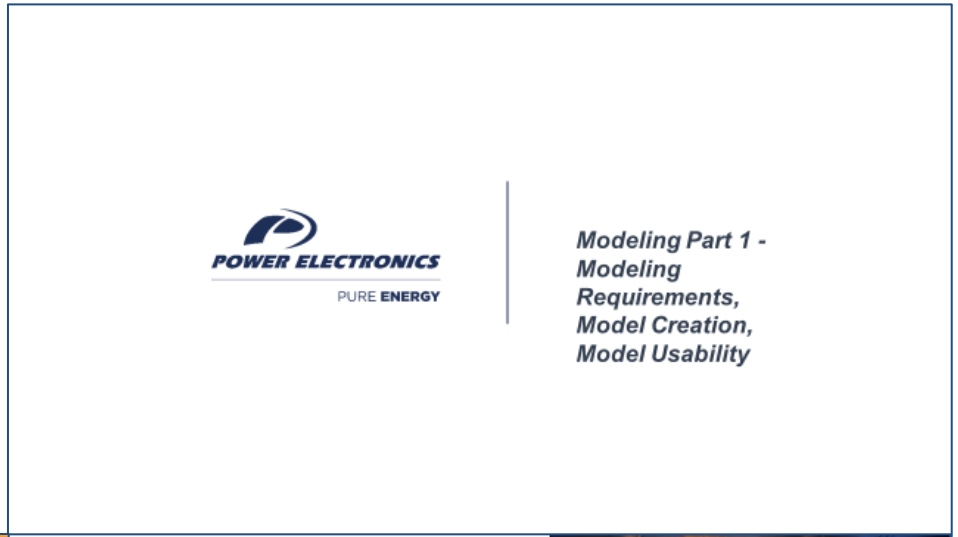


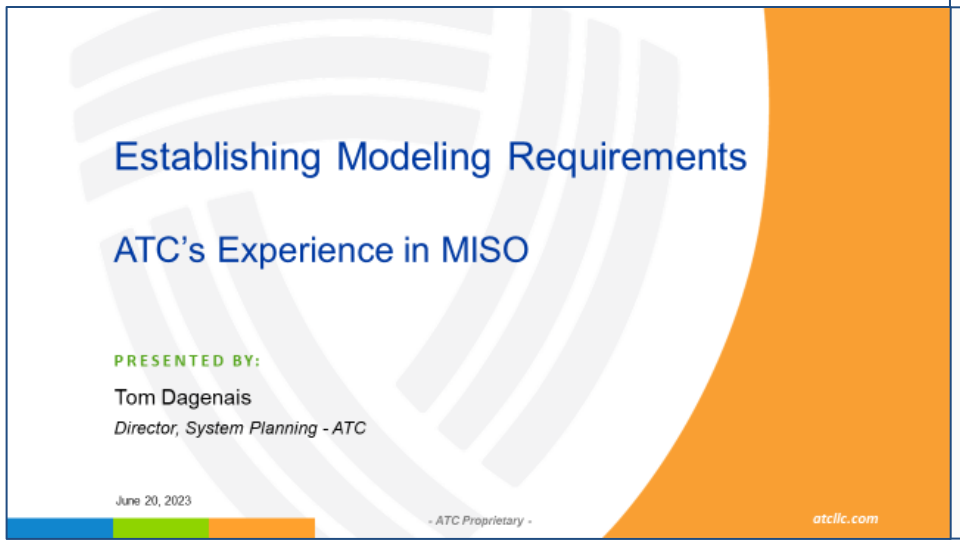


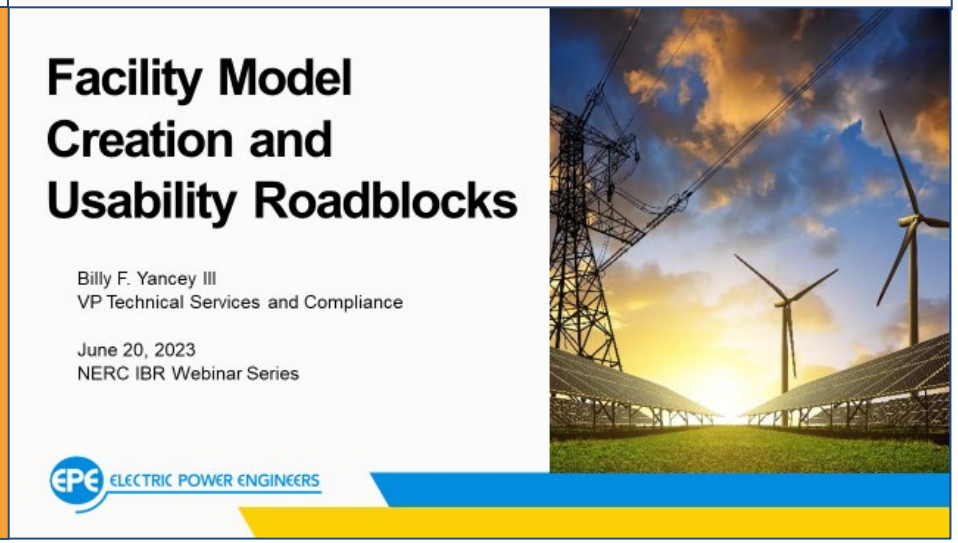
IEEE PES Power & Energy Society® | IEEE

Webinar 5: Modeling 1 – Modeling Req., Model Creation/Usability

- **Key Takeaways:**
  - Model requirements are needed to drive changes in manufacturer models
  - Significant work takes place between manufacturer model and interconnection model
  - Model usability and parameter verification will be key moving forward





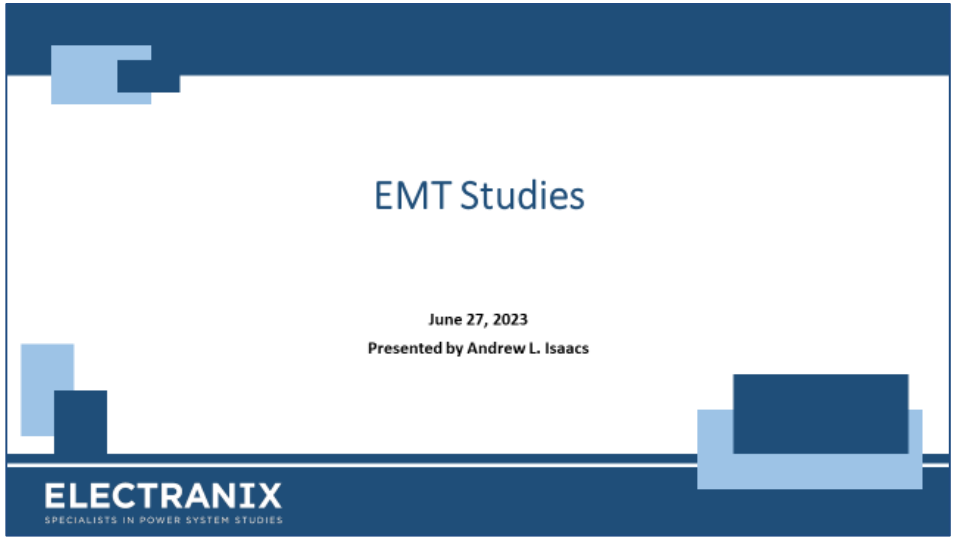


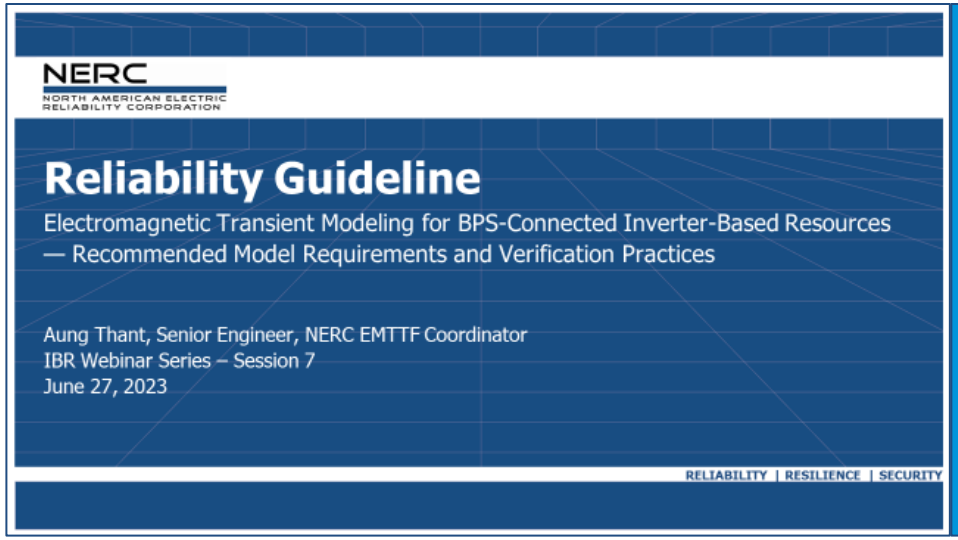
Webinar 6: Modeling 2 – Model Quality and Benchmarking

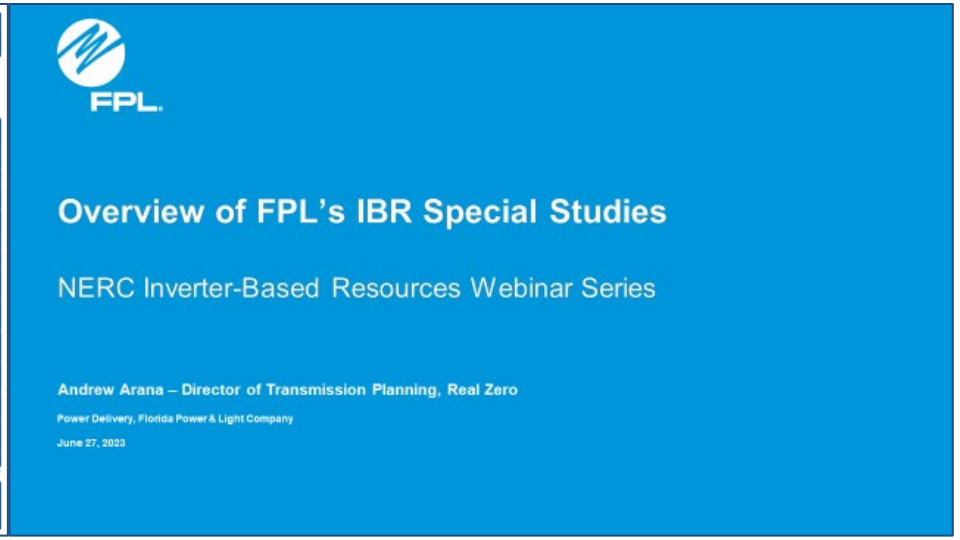
- **Key Takeaways:**
  - Great examples of model quality testing and verification are in place currently in some areas
  - Benchmarking models between themselves and actual performance is not impossible, but requires significant focus
  - Standardized performance requirements could help manufacturers and developers minimize design changes

Webinar 7: EMT, Special Studies, Interconnection Studies

- **Key Takeaways:**
  - EMT studies are going to continue to be more essential for BPS reliability
  - Some regions are already utilizing EMT models and studies to increase reliability and study special scenarios
  - NERC and other Industry organizations are working to provide knowledge and best practices to assist in this transition

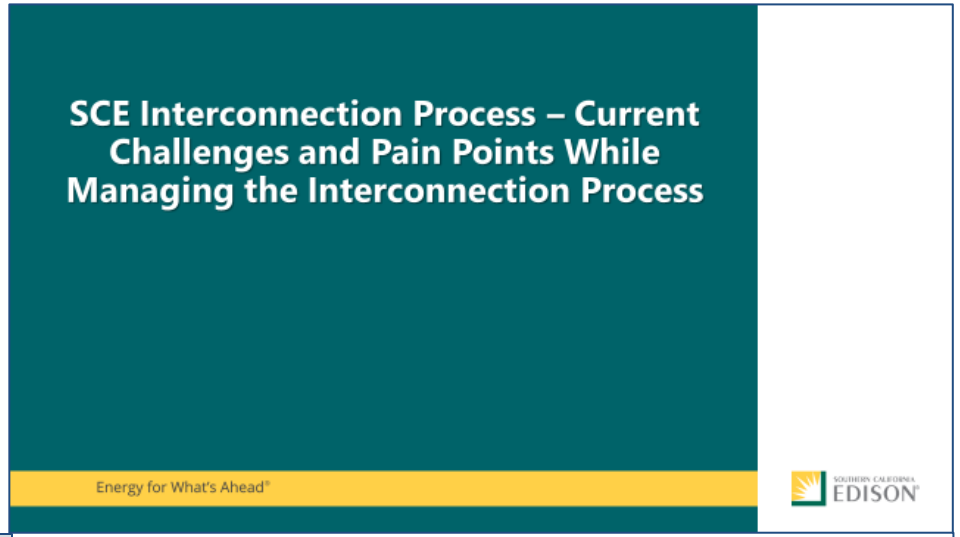


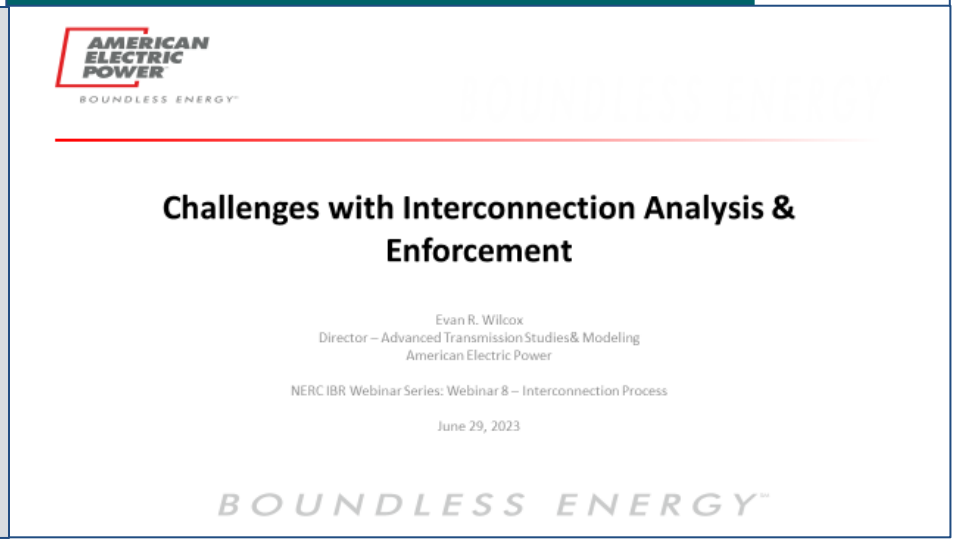




Webinar 8: Interconnection Process

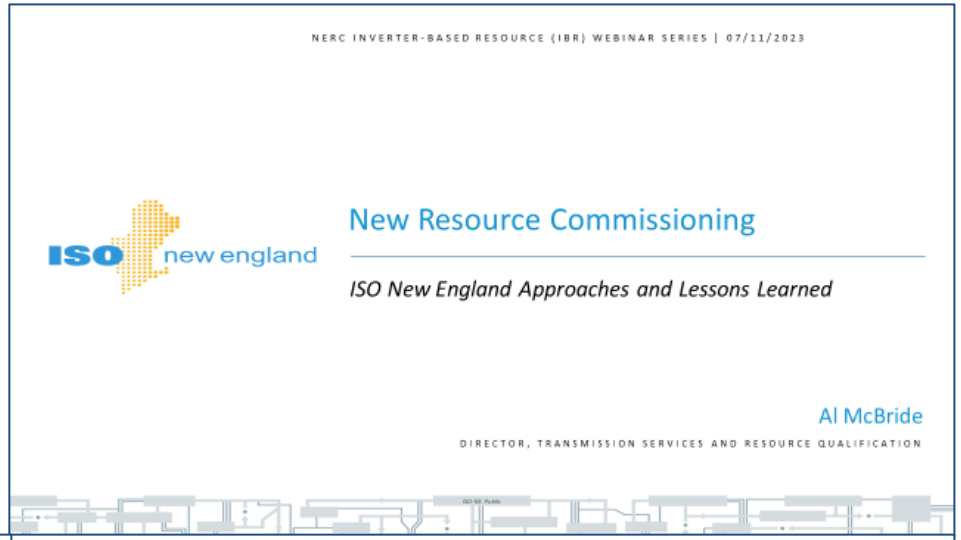
- **Key Takeaways:**
  - IEEE 2800-2022 can help industry create interconnection requirements as it provides technical minimum IBR performance requirements
  - The interconnection process is extremely long and resource intensive
  - Difficult to manage process time and detailed engineering work

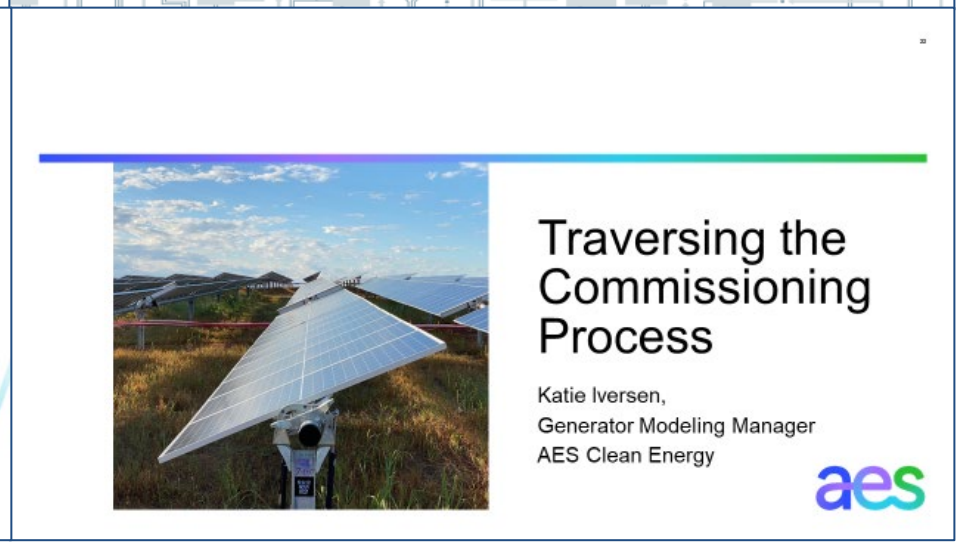




Webinar 9: Commissioning

- **Key Takeaways:**
  - Development of verification/validation requirements can help commissioning checks
  - Collaboration is key, many stakeholders participate in the commissioning process and must understand “big picture” to ask the right questions and drive collaboration
  - Scoping and contracting should have reliability and requirements in mind





Webinar 10: IBR Registration and Reliability Standards Enhancements

- **Key Takeaways:**
  - NERC has been directed by FERC to complete modifications to its registration process (12 mo.), identify owners and operators of IBRs that are connected to the BPS (24 mo.), and complete registration of unregistered IBR Owners and Operators (36 mo.)
  - NERC Standards are currently undergoing numerous enhancements to better address the nuances of IBR

Questions and Answers After All Presentations

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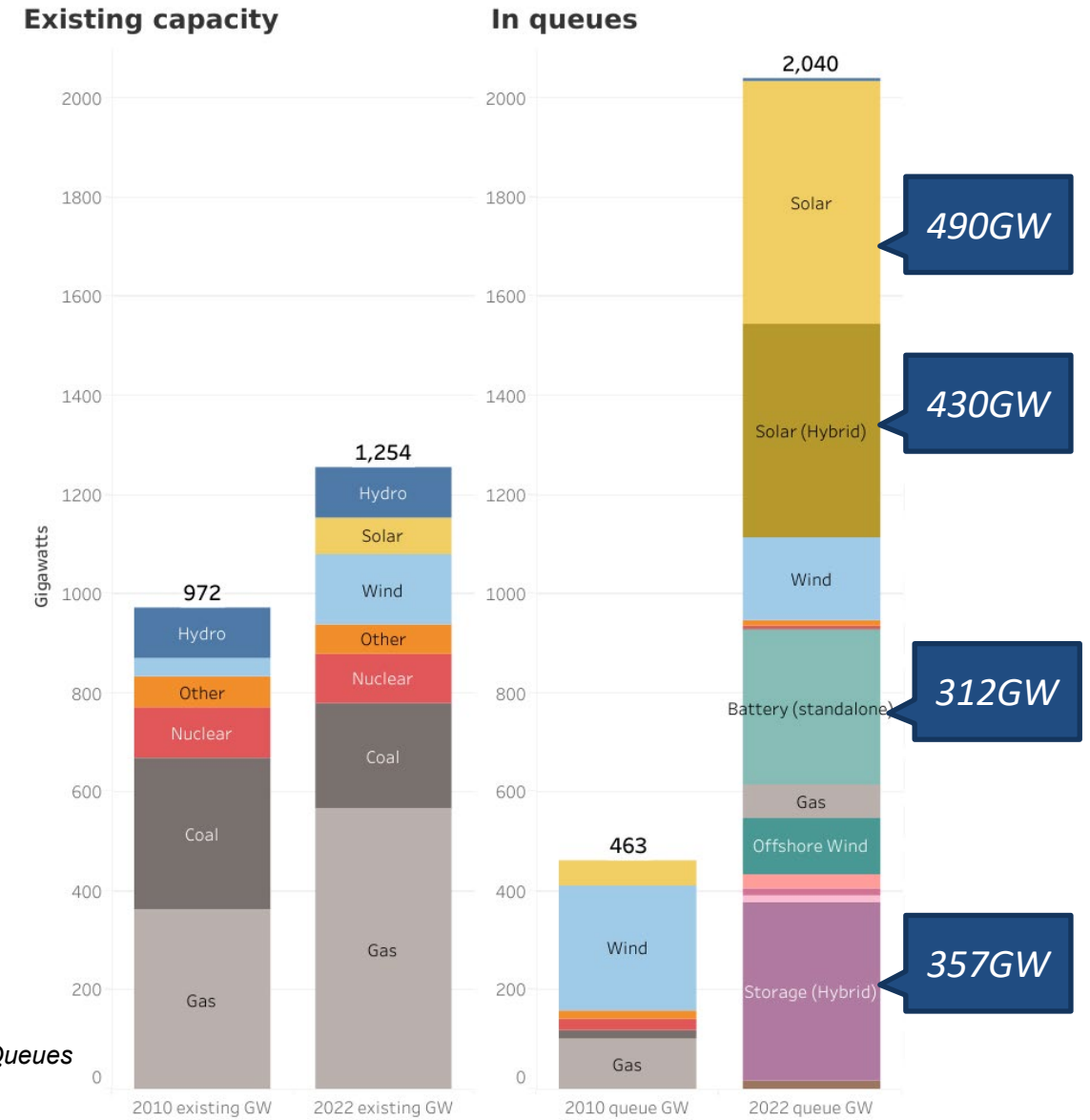
Risk Mitigation Activities

Solving for BPS Reliability

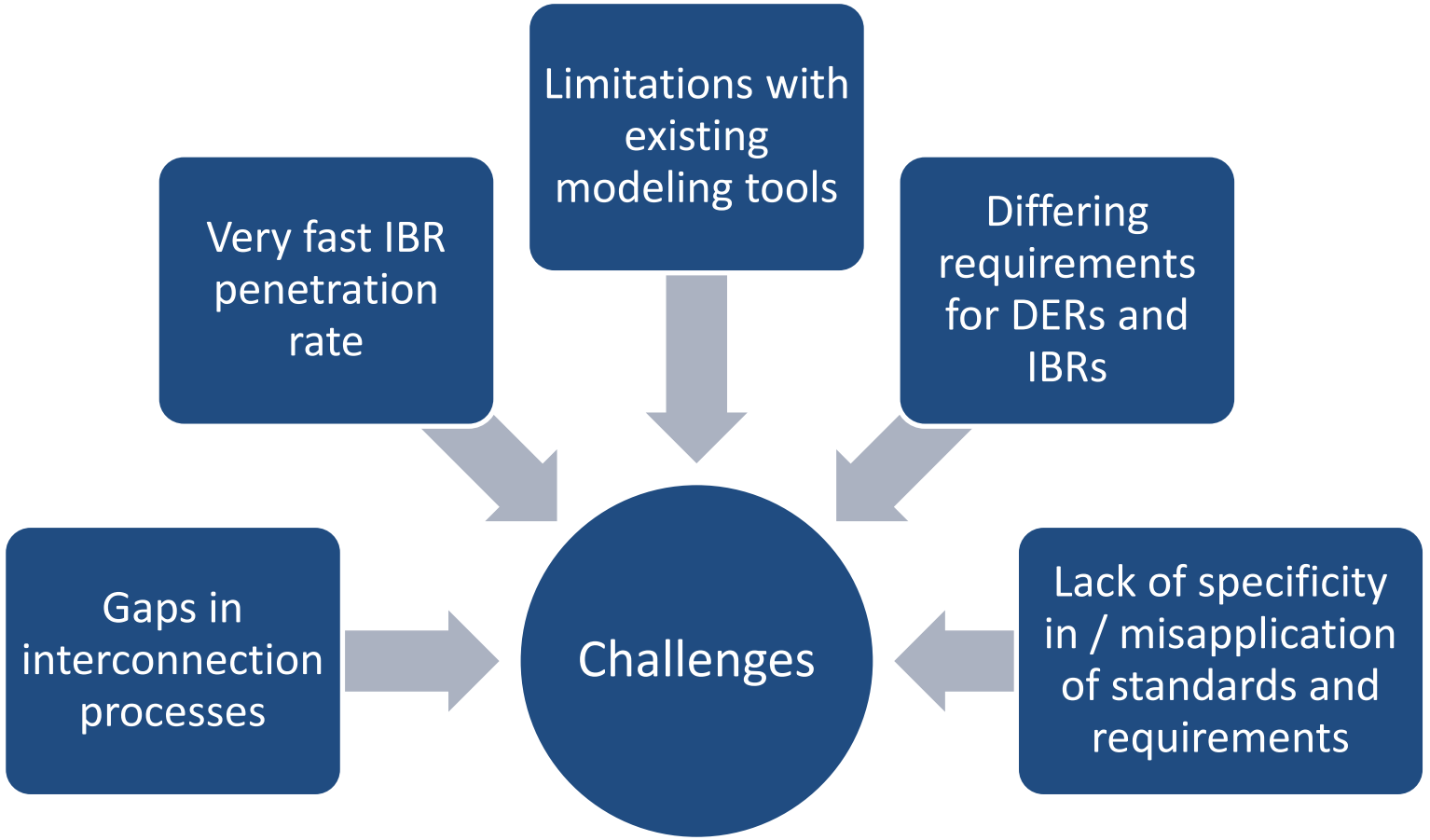
Aung Thant, Senior Engineer
IBR Webinar Series
July 13, 2023

Motivation

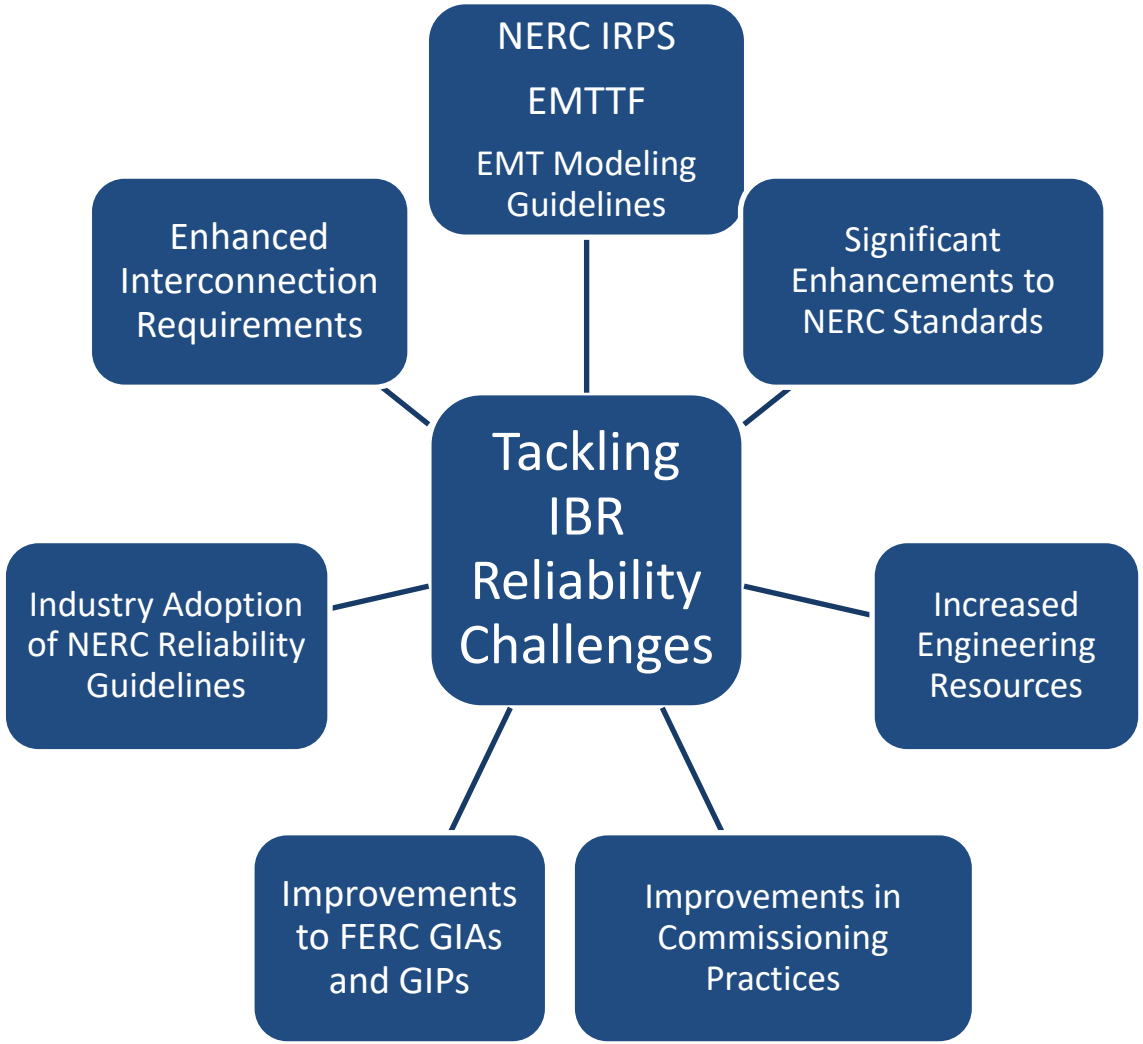


Source: LBL.GOV
Generation, Storage, and Hybrid Capacity in Interconnection Queues

Challenges Today



Industry Response



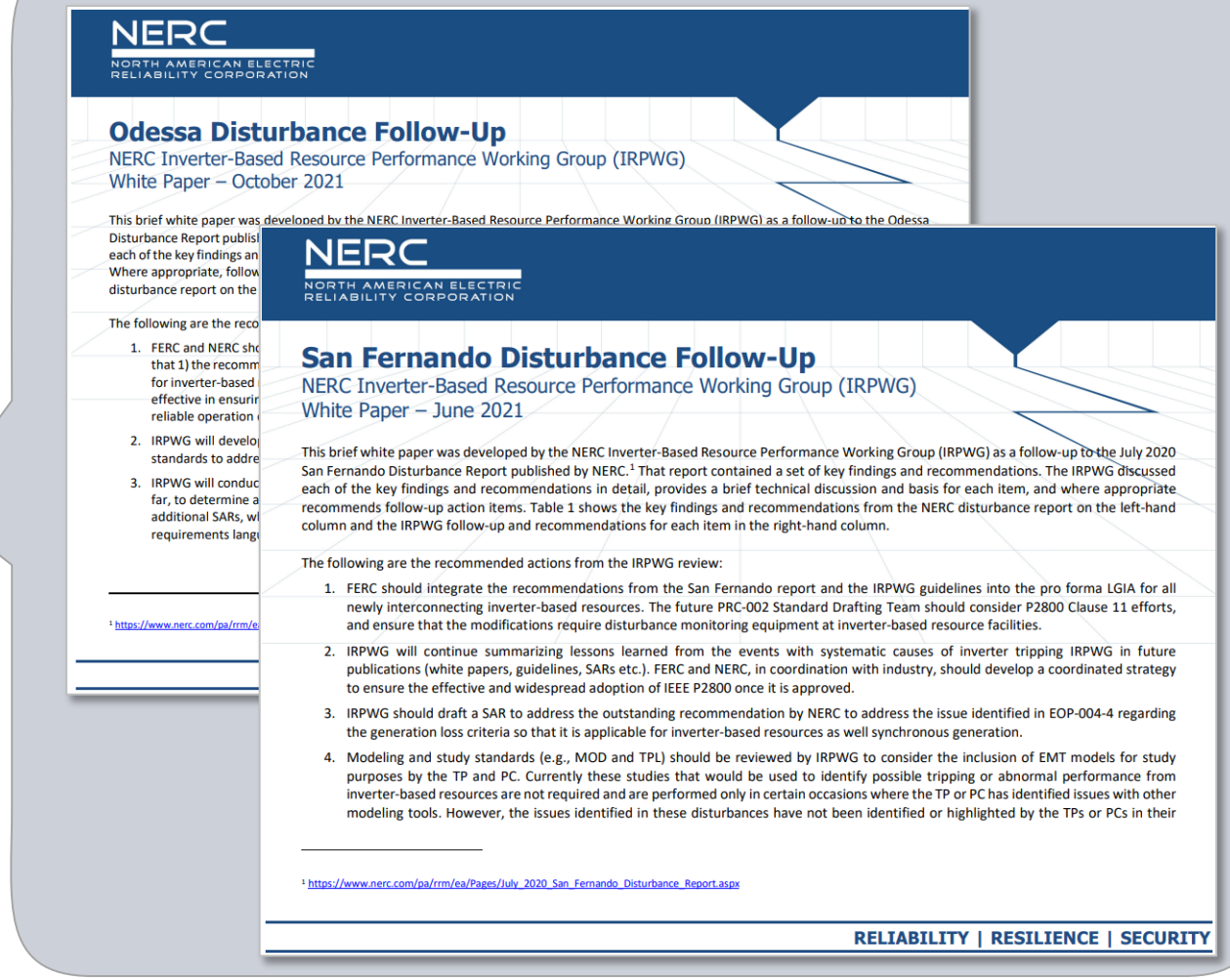
NERC IBR Strategy

Risk Analysis	Interconnection Process Improvements	Best Practices and Education	Regulatory Enhancements
Event Analysis	Improvements to GIAs and GIP	Reliability Guidelines	NERC Standards Projects
Disturbance Reports	Enhanced Interconnection Requirements	Webinars and Workshops	BES Definition Review
Alerts	Modeling and Study Improvements	Outreach and Engagement	Inverter-Specific Requirements and Standards
Lessons Learned	IEEE 2800-2022	Emerging Reliability Risk Issues	Risk-Based Compliance

NERC IBR Strategy

Risk Analysis

- Event Analysis
- Disturbance Reports
- Alerts
- Lessons Learned



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Odessa Disturbance Follow-Up
NERC Inverter-Based Resource Performance Working Group (IRPWG)
White Paper – October 2021

This brief white paper was developed by the NERC Inverter-Based Resource Performance Working Group (IRPWG) as a follow-up to the Odessa Disturbance Report publis
each of the key findings an
Where appropriate, follow
disturbance report on the

The following are the reco

1. FERC and NERC sh
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for inverter-based
effective in ensurir
reliable operation
2. IRPWG will develo
standards to addre
3. IRPWG will conduc
far, to determine a
additional SARs, w
requirements lang

[1] https://www.nerc.com/pa/rrm/e

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San Fernando Disturbance Follow-Up
NERC Inverter-Based Resource Performance Working Group (IRPWG)
White Paper – June 2021

This brief white paper was developed by the NERC Inverter-Based Resource Performance Working Group (IRPWG) as a follow-up to the July 2020 San Fernando Disturbance Report published by NERC.[1] That report contained a set of key findings and recommendations. The IRPWG discussed each of the key findings and recommendations in detail, provides a brief technical discussion and basis for each item, and where appropriate recommends follow-up action items. Table 1 shows the key findings and recommendations from the NERC disturbance report on the left-hand column and the IRPWG follow-up and recommendations for each item in the right-hand column.

The following are the recommended actions from the IRPWG review:

1. FERC should integrate the recommendations from the San Fernando report and the IRPWG guidelines into the pro forma LGIA for all newly interconnecting inverter-based resources. The future PRC-002 Standard Drafting Team should consider P2800 Clause 11 efforts, and ensure that the modifications require disturbance monitoring equipment at inverter-based resource facilities.
2. IRPWG will continue summarizing lessons learned from the events with systematic causes of inverter tripping IRPWG in future publications (white papers, guidelines, SARs etc.). FERC and NERC, in coordination with industry, should develop a coordinated strategy to ensure the effective and widespread adoption of IEEE P2800 once it is approved.
3. IRPWG should draft a SAR to address the outstanding recommendation by NERC to address the issue identified in EOP-004-4 regarding the generation loss criteria so that it is applicable for inverter-based resources as well synchronous generation.
4. Modeling and study standards (e.g., MOD and TPL) should be reviewed by IRPWG to consider the inclusion of EMT models for study purposes by the TP and PC. Currently these studies that would be used to identify possible tripping or abnormal performance from inverter-based resources are not required and are performed only in certain occasions where the TP or PC has identified issues with other modeling tools. However, the issues identified in these disturbances have not been identified or highlighted by the TPs or PCs in their

[1] https://www.nerc.com/pa/rrm/ea/Pages/July_2020_San_Fernando_Disturbance_Report.aspx

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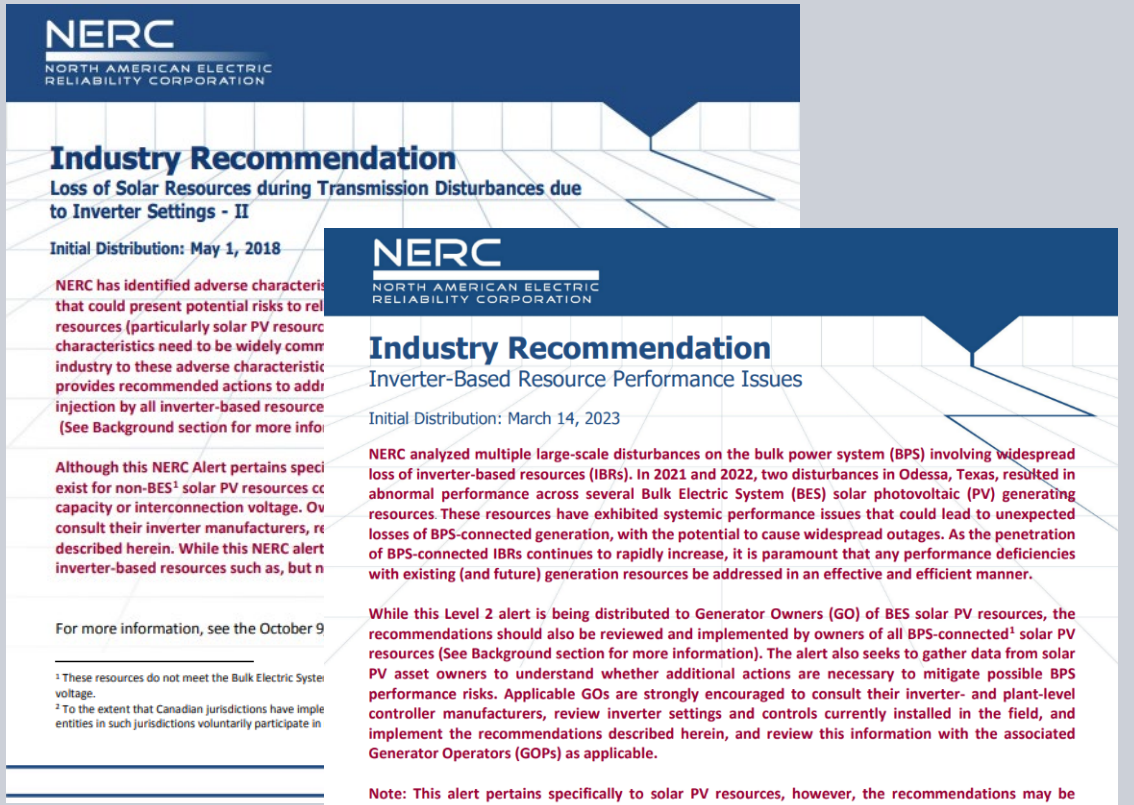
NERC IBR Strategy

Risk Analysis

- Event Analysis
- Disturbance Reports
- Alerts
- Lessons Learned



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Industry Recommendation
Loss of Solar Resources during Transmission Disturbances due to Inverter Settings - II

Initial Distribution: May 1, 2018

NERC has identified adverse characteris
that could present potential risks to rel
resources (particularly solar PV resourc
characteristics need to be widely comm
industry to these adverse characteristic
provides recommended actions to addr
injection by all inverter-based resource
(See Background section for more infor

Although this NERC Alert pertains speci
exist for non-BES[1] solar PV resources c
capacity or interconnection voltage. Ov
consult their inverter manufacturers, re
described herein. While this NERC alert
inverter-based resources such as, but n

For more information, see the October 9

[1] These resources do not meet the Bulk Electric Syste
voltage.
[2] To the extent that Canadian jurisdictions have imple
entities in such jurisdictions voluntarily participate in

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Industry Recommendation
Inverter-Based Resource Performance Issues

Initial Distribution: March 14, 2023

NERC analyzed multiple large-scale disturbances on the bulk power system (BPS) involving widespread loss of inverter-based resources (IBRs). In 2021 and 2022, two disturbances in Odessa, Texas, resulted in abnormal performance across several Bulk Electric System (BES) solar photovoltaic (PV) generating resources. These resources have exhibited systemic performance issues that could lead to unexpected losses of BPS-connected generation, with the potential to cause widespread outages. As the penetration of BPS-connected IBRs continues to rapidly increase, it is paramount that any performance deficiencies with existing (and future) generation resources be addressed in an effective and efficient manner.

While this Level 2 alert is being distributed to Generator Owners (GO) of BES solar PV resources, the recommendations should also be reviewed and implemented by owners of all BPS-connected[1] solar PV resources (See Background section for more information). The alert also seeks to gather data from solar PV asset owners to understand whether additional actions are necessary to mitigate possible BPS performance risks. Applicable GOs are strongly encouraged to consult their inverter- and plant-level controller manufacturers, review inverter settings and controls currently installed in the field, and implement the recommendations described herein, and review this information with the associated Generator Operators (GOPs) as applicable.

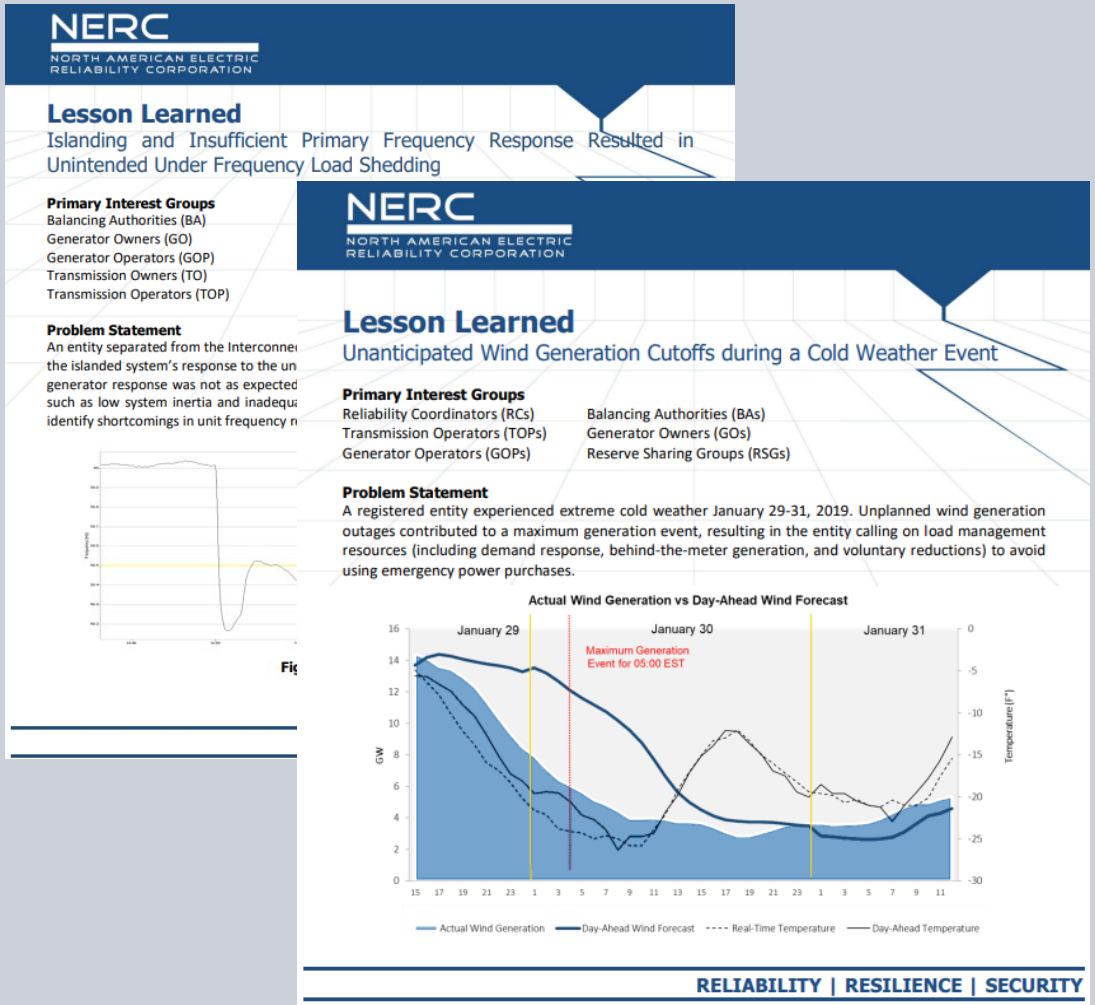
Note: This alert pertains specifically to solar PV resources, however, the recommendations may be applicable to BPS-connected battery energy storage systems (BESS). This alert does not pertain to wind resources as the observed performance issues are different.

For more information, see the NERC Major Event Analysis Reports webpage. All recipients are strongly encouraged to read the findings from these reports, particularly the 2021 Odessa Disturbance report and the 2022 Odessa Disturbance report.

NERC IBR Strategy

Risk Analysis

- Event Analysis
- Disturbance Reports
- Alerts
- Lessons Learned



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Lesson Learned
Islanding and Insufficient Primary Frequency Response Resulted in Unintended Under Frequency Load Shedding

Primary Interest Groups
Balancing Authorities (BA)
Generator Owners (GO)
Generator Operators (GOP)
Transmission Owners (TO)
Transmission Operators (TOP)

Problem Statement
An entity separated from the Interconnec
the islanded system's response to the un
generator response was not as expected
such as low system inertia and inadequa
identify shortcomings in unit frequency r

Fig

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Lesson Learned
Unanticipated Wind Generation Cutoffs during a Cold Weather Event

Primary Interest Groups
Reliability Coordinators (RCs)
Transmission Operators (TOPs)
Generator Operators (GOPs)
Balancing Authorities (BAs)
Generator Owners (GOs)
Reserve Sharing Groups (RSGs)

Problem Statement
A registered entity experienced extreme cold weather January 29-31, 2019. Unplanned wind generation outages contributed to a maximum generation event, resulting in the entity calling on load management resources (including demand response, behind-the-meter generation, and voluntary reductions) to avoid using emergency power purchases.

Actual Wind Generation vs Day-Ahead Wind Forecast

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NERC IBR Strategy

Risk Analysis

- Event Analysis
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- Alerts
- Lessons Learned

Interconnection Process Improvements

- Improvements to GIAs and GIP
- Enhanced Interconnection Requirements
- Modeling and Study Improvements
- IEEE 2800-2022

- Many IBR-related risks comes from generator interconnect process challenges
- Recommended FERC overhaul & modernize Interconnection Process to address systemic issues
- Highlighted need for significant revision to pro-forma LGIA and LGIP
- NERC has responded to FERC NOPR RM22-12-000 with a work plan
  - to develop new or modified Reliability Standards that address the following reliability gaps related to inverter-based resources (IBR):
  - data sharing;
  - model validation;
  - planning and operational studies;
  - performance requirements

NERC IBR Strategy

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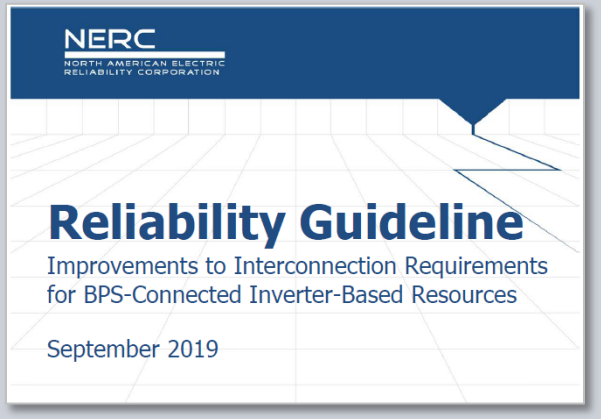
- In 2019, NERC published Reliability Guideline: Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources
  - Strong recommendations for significant enhancement to TO interconnection requirement per NERC FAC-001
  - Modeling and study requirement per NERC FAC-002
  - Pillar for IEEE 2800-2022 and NERC IBR activities
- NERC continues to see many applicable entities have not implemented the recommendations but instead rely on pro forma GIA with ad-hoc modification



NERC IBR Strategy

Risk Analysis

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Interconnection Process Improvements

- Improvements to GIAs and GIP
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- Interconnection process challenges led to modeling and study gaps when assessing BPS reliability for newly connecting IBR
- NERC continues to see systemic modeling error in positive sequence dynamic models that are pervasive in interconnection-wide planning cases
- Mismatch in model vs actual performance
- EMT studies increasingly becoming necessary -> EMTTF
- NERC RSTC endorsed SAR for model quality & EMT requirement for FAC, MOD, TPL stds

NERC IBR Strategy

Risk Analysis

- Event Analysis
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Interconnection Process Improvements

- Improvements to GIAs and GIP
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- Modeling and Study Improvements
- IEEE 2800-2022

- NERC is supporting adoption of IEEE 2800-2022 and actively participate in development of 2800.2 – Testing standard

NERC IBR Strategy

Interconnection Process Improvements

- Improvements to GIAs and GIP
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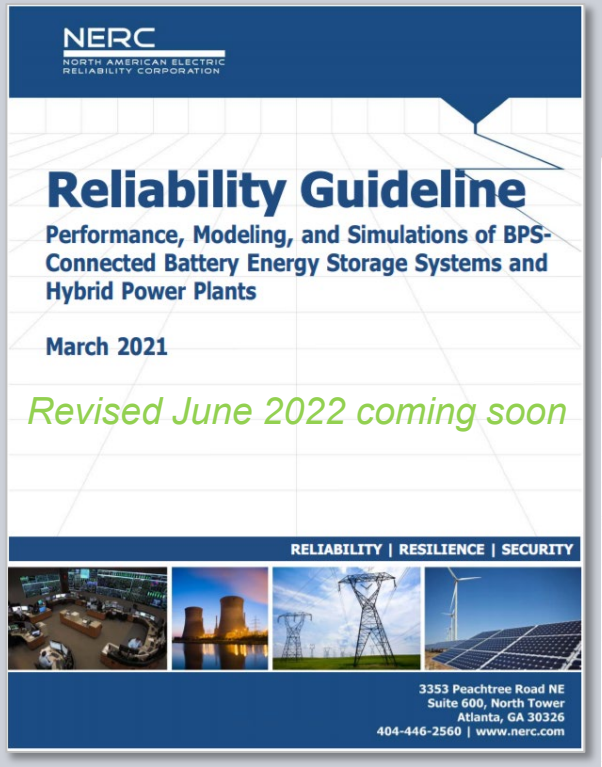
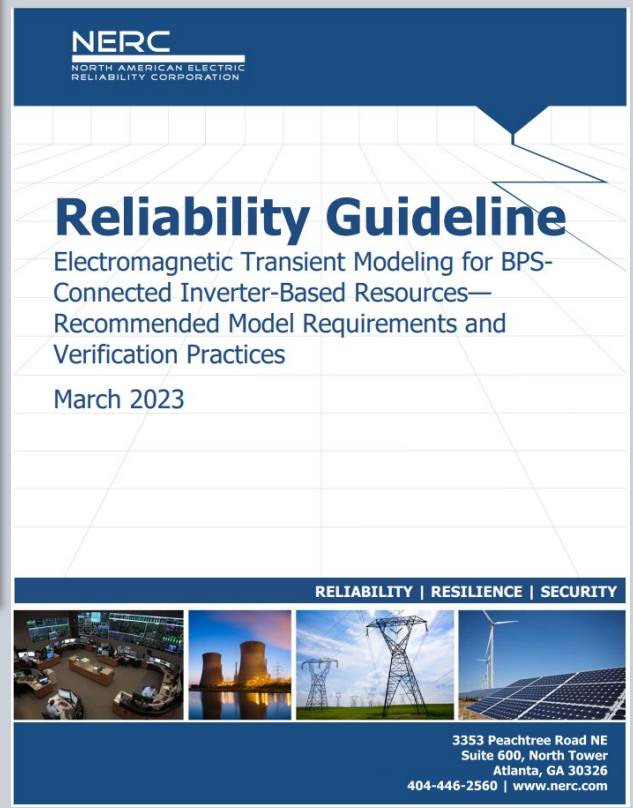
- Modeling and Study Improvements
- IEEE 2800-2022

Best Practices and Education

- Reliability Guidelines
- Webinars and Workshops
- Outreach and Engagement
- Emerging Reliability Risk Issues





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Interconnection Process Improvements

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- IEEE 2800-2022

Best Practices and Education

- Reliability Guidelines
- Webinars and Workshops
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In the works:

- **Reliability Guideline – EMT Studies**
- **Reliability Guideline – Recommended Approaches to Interconnection Studies for BPS-Connected IBRs**
- **White Paper – Grid Forming Roadmap and Functional Specifications**
- **White Paper – Gap Analysis of Any IBR Related Issues Not Addressed by Existing NERC Standards**
- **White Paper – BPS-Connected IBR Commissioning Best Practices**

NERC IBR Strategy

Interconnection Process Improvements

- Improvements to GIAs and GIP
- Enhanced Interconnection Requirements
- Modeling and Study Improvements
- IEEE 2800-2022

Best Practices and Education

- Reliability Guidelines
- Webinars and Workshops
- Outreach and Engagement
- Emerging Reliability Risk Issues

- Keep industry aware of our efforts underway in areas of IBR integration
- IBR initiatives are now located directly under Initiative tab on the main NERC webpage
- By presenting our IBR strategy at every opportunity, like this
- RGs are the most commonly downloaded doc on NERC website
- Dist. Report, webinars and joint industry webinars on IBR related topics are heavily advertised and have over 1000 participants dialing in
- NERC IRPS meetings have over 150 dial-in every month
- Continue to leverage industry partnership with NAGF, NATF, EPRI, ESIG and IEEE 2800 leadership team
- IBR Webinar series has been well attended

NERC IBR Strategy

Interconnection Process Improvements

- Improvements to GIAs and GIP
- Enhanced Interconnection Requirements
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- IEEE 2800-2022

Best Practices and Education

- Reliability Guidelines
- Webinars and Workshops
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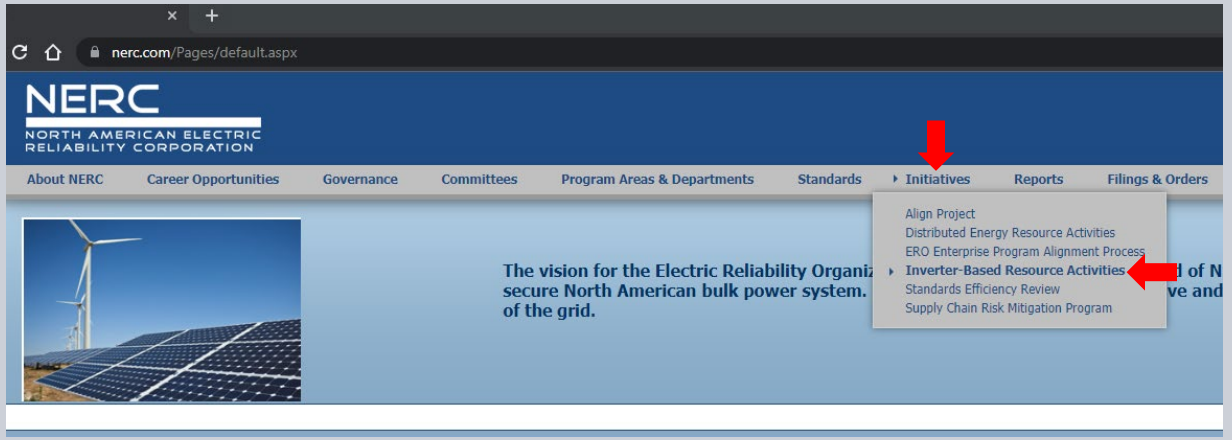

NERC IBR Strategy

Best Practices and Education

- Reliability Guidelines
- Webinars and Workshops
- Outreach and Engagement
- Emerging Reliability Risk Issues

Regulatory Enhnacements

- NERC Standards Projects
- BES Definition Review
- Inverter-Specific Requirements and Standards
- Risk-Based Compliance

- **Project 2023-02 Performance of IBRs:** Specific to IBRs to ensure that IBR facility owners with resources operating (based on protection or controls) in an unreliable and unexpected manner identify these events, analyze them, and determine if corrective actions
- **Project 2020-02 Modifications to PRC-024 (generator ride-through):** to ensure IBR ride-through performance
- **Project 2023-01 EOP-004 IBR Event Reporting:** to ensure that reporting of widespread inverter-based disturbances are reported to the ERO Enterprise
- **Project 2022-04 EMT Modeling:** to ensure TP/PC have the models and tools necessary to conduct reliability studies for IBR
- **SAR – Revisions to FAC-001 and FAC-002 (IRPS work plan item currently underway):** to ensure that the standards provide sufficient strength such that any performance issues that do not meet the established interconnection requirements are corrected

Next Steps

- Elevated the inverter risk issues within the ERO risk framework
- Agile NERC Standards development activities
  - Comprehensive ride-through standard
  - New performance validation standard
  - Additional IBR-related standards activities
- Disturbance investigation and analysis
  - 2022 California BESS event
  - 2023 Utah PV event
  - 2023 Texas wind event
- Level 2 NERC Alert(s) to understand extent of condition of IBR performance
  - Performance issues and modeling issues (currently underway)
  - IBR modeling deficiencies (planned Q4 2023)

Next Steps (cont.)

- Execute IBR Registration Work Plan
- NERC IRPS Priorities
  - Interconnection studies best practices
  - Commissioning best practices
  - Gap analysis on NERC standards
- EMTTF Activities
  - EMT modeling and studies guidance
  - Repository of reference materials
  - EMT Boot Camps and other industry outreach

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Webinar Stats and Closeout

July 13, 2023

Webinar Series Quick Facts

- Average registration: 2421
- Average attendance: 1087
- Number of speakers/panelists: 30
- Number of organizations: 20
- Hours of content: 11
- Most Punctual: Peter Heidrich
- Least Punctual: Ryan Quint
- Recordings of all sessions will be posted on the NERC website
  - Slides for all sessions will be posted
  - FAQ from each session's Q&A will be posted

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Webinar Series: Inverter-Based Resources

June 6 – July 13, 2023 | 4:00 – 5:00 pm Eastern Time

Please register for each day you are planning to attend:

Webinar 1: Introduction to Inverter-Based Resources
Tuesday, June 6, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 2: NERC Disturbance Reports and Lessons Learned
Thursday, June 8, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 3: Inverter-Based Resource Performance Issues
Tuesday, June 13, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 4: Establishing and Enhancing Interconnection Requirements
Thursday, June 15, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 5: Modeling Part 1 – Modeling Requirements, Model Creation, Model Usability
Tuesday, June 20, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 6: Modeling Part 2 – Model Quality, Model Benchmarking
Thursday, June 22, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 7: Studies – EMT, Special Studies, Interconnection Studies
Tuesday, June 27, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 8: Interconnection Process
Thursday, June 29, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 9: Commissioning
Tuesday, July 11, 2023 | 4:00 p.m. – 5:0

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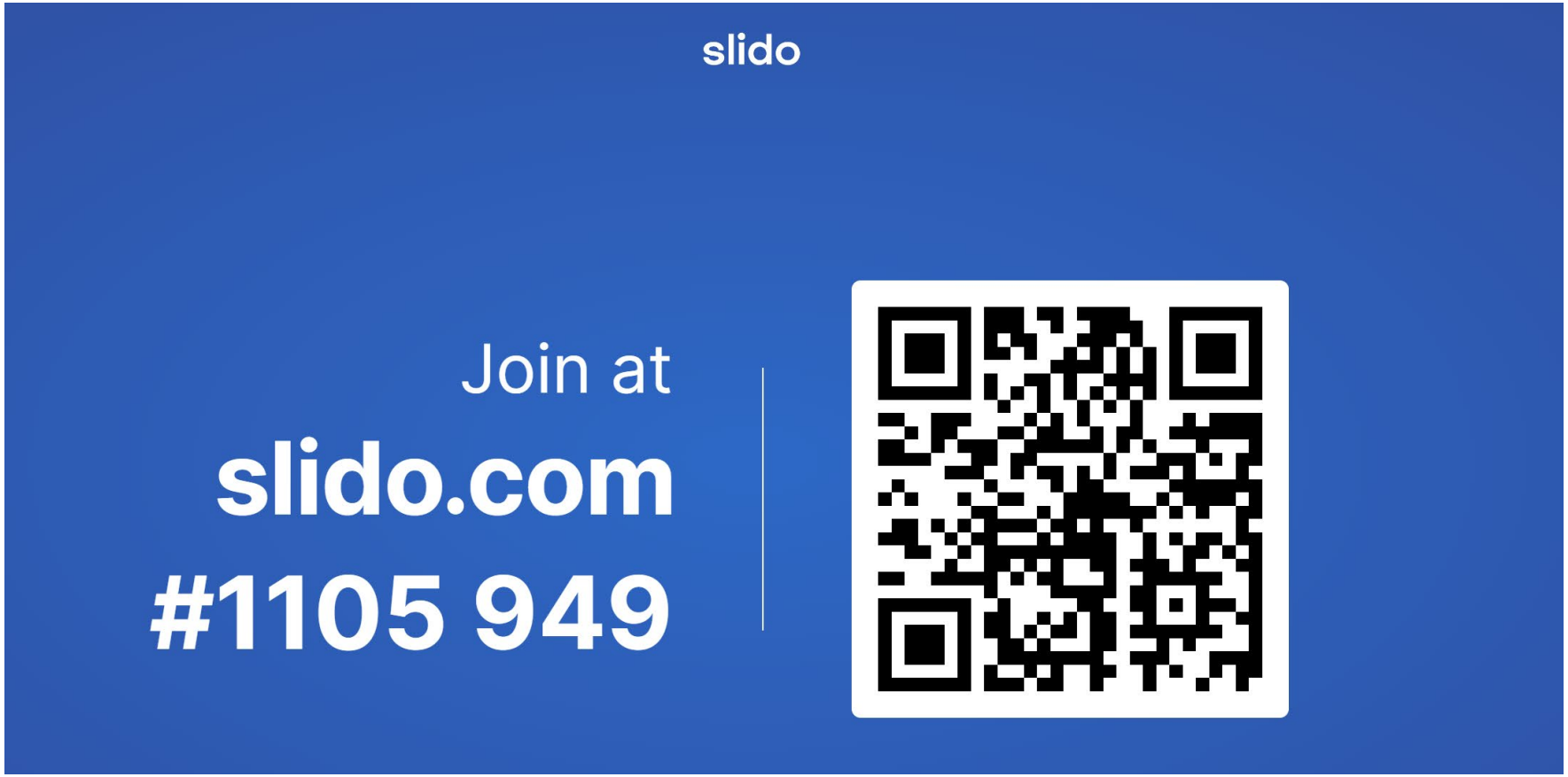
Webinar 10: IBR Registration and Reliability Standards Enhancements
Wednesday, July 12, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link

Webinar 11: Overview of IBR Risk Mitigations and Next Steps
Thursday, July 13, 2023 | 4:00 p.m. – 5:00 p.m. Eastern | Webinar Registration Link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Questions and Answers

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