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IBR Modeling Update

Review of Findings and Recommendations from NERC Disturbance Reports and Guidelines

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ESIG Webinar Series – December 2022

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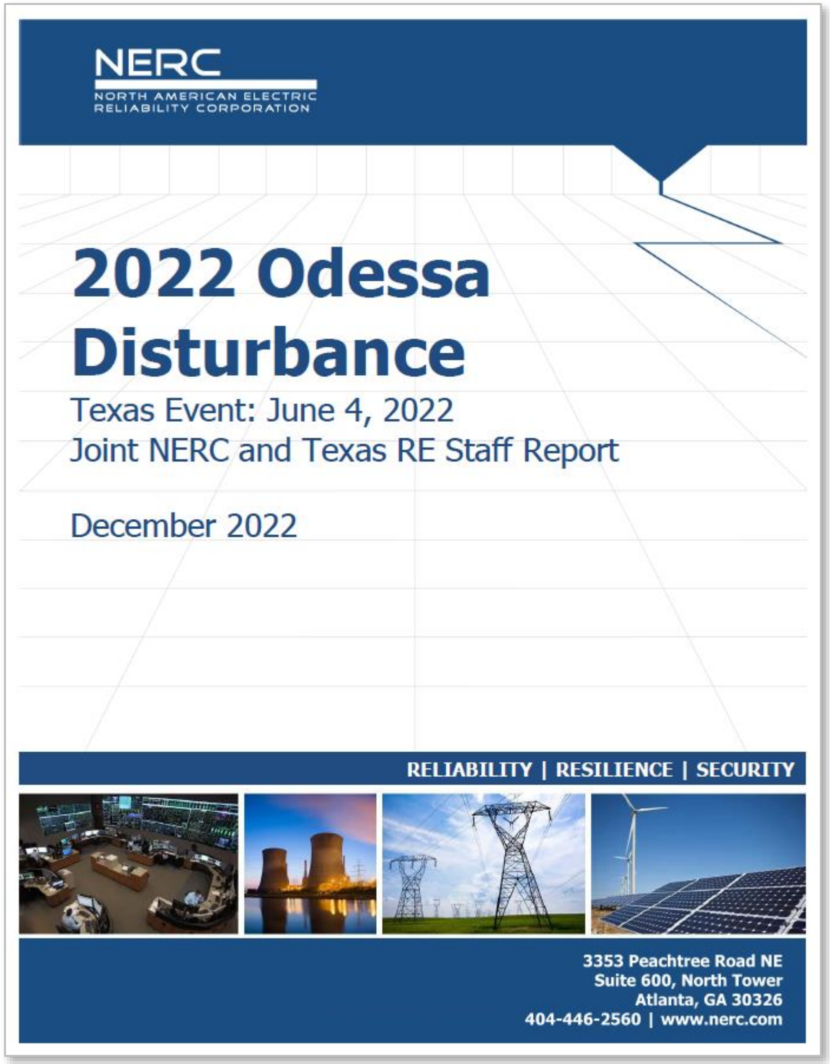
Odessa Disturbance Reports



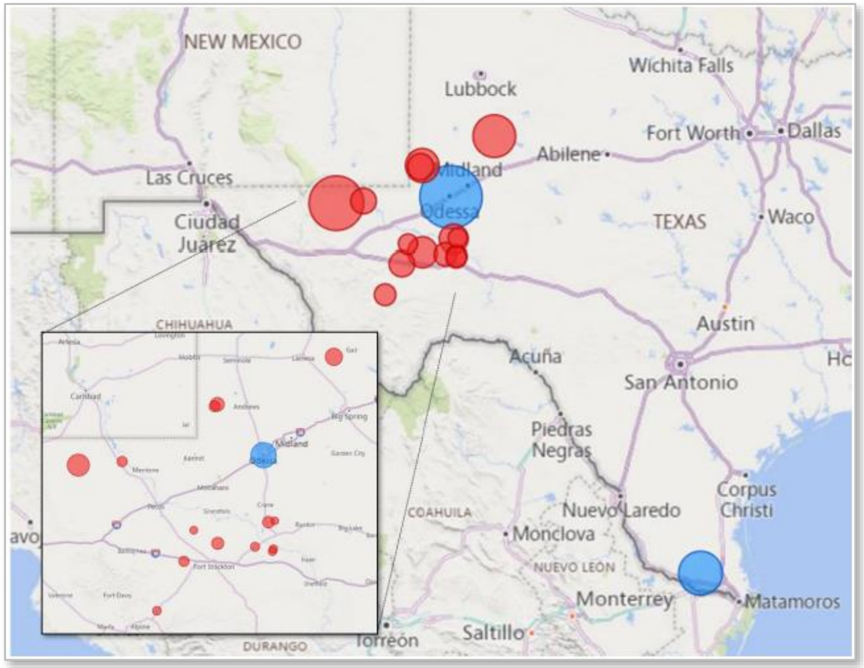
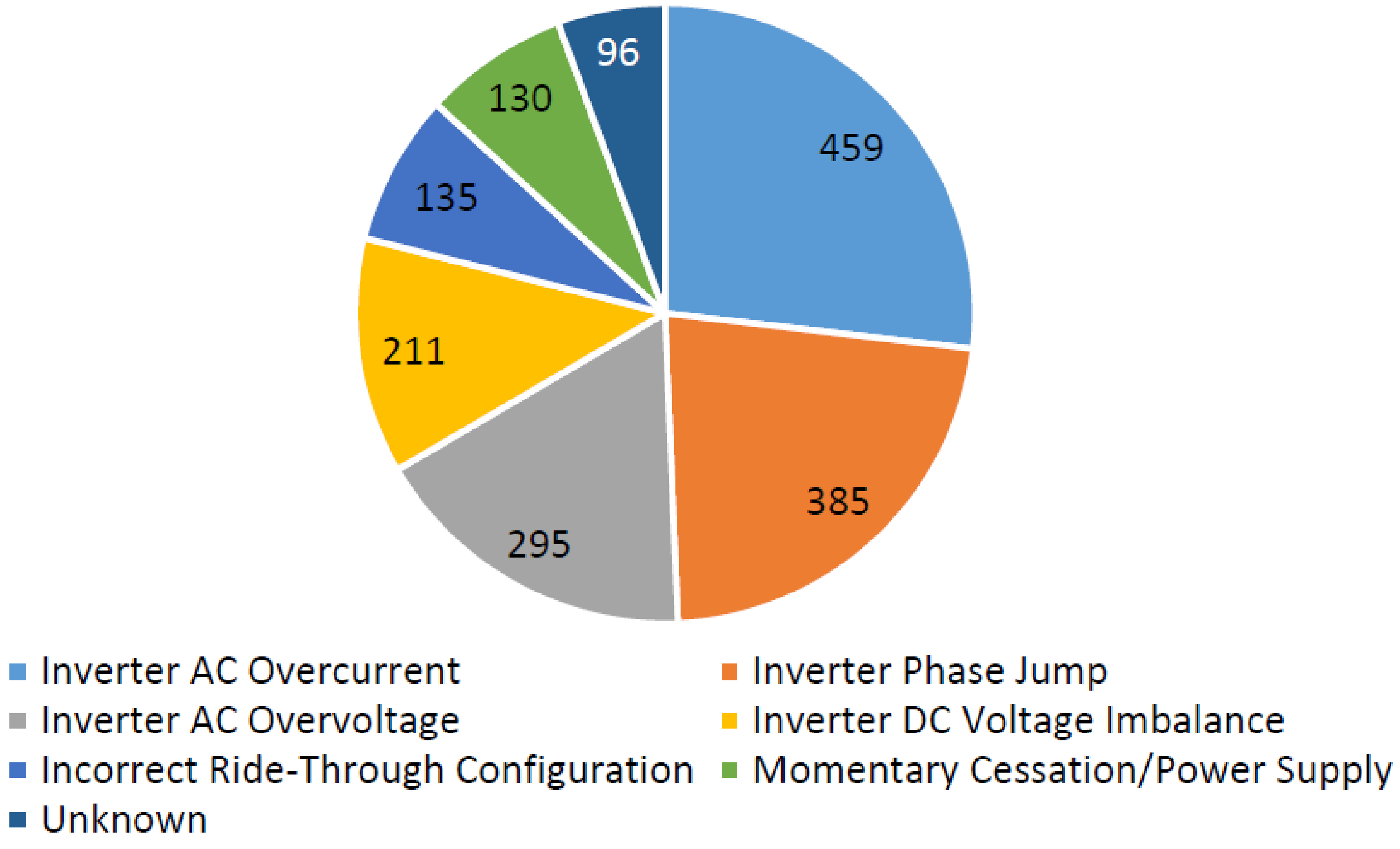


Table ES.1: Reductions of Output by Unit Type	
Plant Type	**Reduction [MW]**
Synchronous Generation Plants	844
Solar PV Plants	1,711
Total	**2,555**

https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_2022_Odessa_Disturbance_Report%20%281%29.pdf

Cause of Solar PV Reduction



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Cause of Solar PV Reduction

Table 1.1: Causes of Solar PV Active Power Reductions

Cause of Reduction	Odessa 2021 Reduction [MW]	Odessa 2022 Reduction [MW]
Inverter Instantaneous AC Overcurrent	–	459
Passive Anti-Islanding (Phase Jump)	–	385
Inverter Instantaneous AC Overvoltage	269	295
Inverter DC Bus Voltage Unbalance	–	211
Feeder Underfrequency	21	148*
Unknown/Misc.	51	96
Incorrect Ride-Through Configuration	–	135
Plant Controller Interactions	–	146
Momentary Cessation	153	130**
Inverter Overfrequency	–	–
PLL Loss of Synchronism	389	–
Feeder AC Overvoltage	147	–
Inverter Underfrequency	48	–
Not Analyzed	34	–

* In addition to inverter-level tripping (not included in total tripping calculation.)
** Power supply failure

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Review of Affected Solar Plants

Table A.1: Review of Solar PV Facilities

Facility ID	Capacity [MW]	Reduction [MW]	POI Voltage [kV]	In-Service Date	Cause of Reduction
Plant B	152	133	138	June 2020	Inverter phase jump (passive anti-islanding) tripping.
Plant C	126	56	345	November 2020	Inverter phase jump (passive anti-islanding) tripping.
Plant E	162	159	138	May 2021	Inverter ac overvoltage tripping.
Plant U	143.5	136	138	August 2021	Inverter ac overvoltage tripping; feeder underfrequency tripping.
Plant F	50	46	69	September 2017	Unknown.
Plants I & J	304	196	345	June 2020	Inverter phase jump (passive anti-islanding) tripping.
Plant V	253	106	345	July 2021	Inverter dc voltage imbalance tripping.
Plants K & L	157.5	130	138	September 2016	Momentary cessation/inverter power supply failure.
Plant M	155	146	138	March 2018	Inverter dc voltage imbalance tripping; incorrect inverter ride through configuration.
Plant N	110	35	138	March 2017	Unknown.
Plant O	50	15	138	November 2016	Unknown.
Plant P	157.5	10	138	August 2017	Inverter ac overcurrent tripping.
Plant Q	255	12	138	December 2020	Inverter ac overcurrent tripping.
Plant R	268	261	138	June 2021	Inverter ac overcurrent tripping.
Plant S	100	94	138	December 2019	Inverter dc voltage imbalance tripping.
Plant T	187	176	138	September 2021	Inverter ac overcurrent tripping; feeder underfrequency tripping.
TOTAL		**1,711**			

* Naming convention of facilities is a continuation of the 2021 Odessa Disturbance; therefore, plant numbering is not necessarily alphanumeric but does match the labeling used in the 2021 Odessa Disturbance.

* Denotes plants that went into commercial operation in late 2020 onward

> 900 MW reduction

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Growing Solar PV Portfolio

- Magnitude of reduction highlights importance of ensuring all BPS-connected inverter-based resources are operating in a manner that ensures reliable operation of the BPS

- **Time of Event:** ~~7,200~~ 8,660 MW solar PV resources in ERCOT
  - Additional ~~790~~ 3,010 MW in commissioning process
- **Near Future:** ~~25,000~~ 28,850 MW solar PV resources with signed interconnection agreements in ERCOT generation interconnection queue between now and 2023

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Positive Sequence vs. EMT Modeling Capabilities

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

Can the Models Recreate the Cause of Reduction?

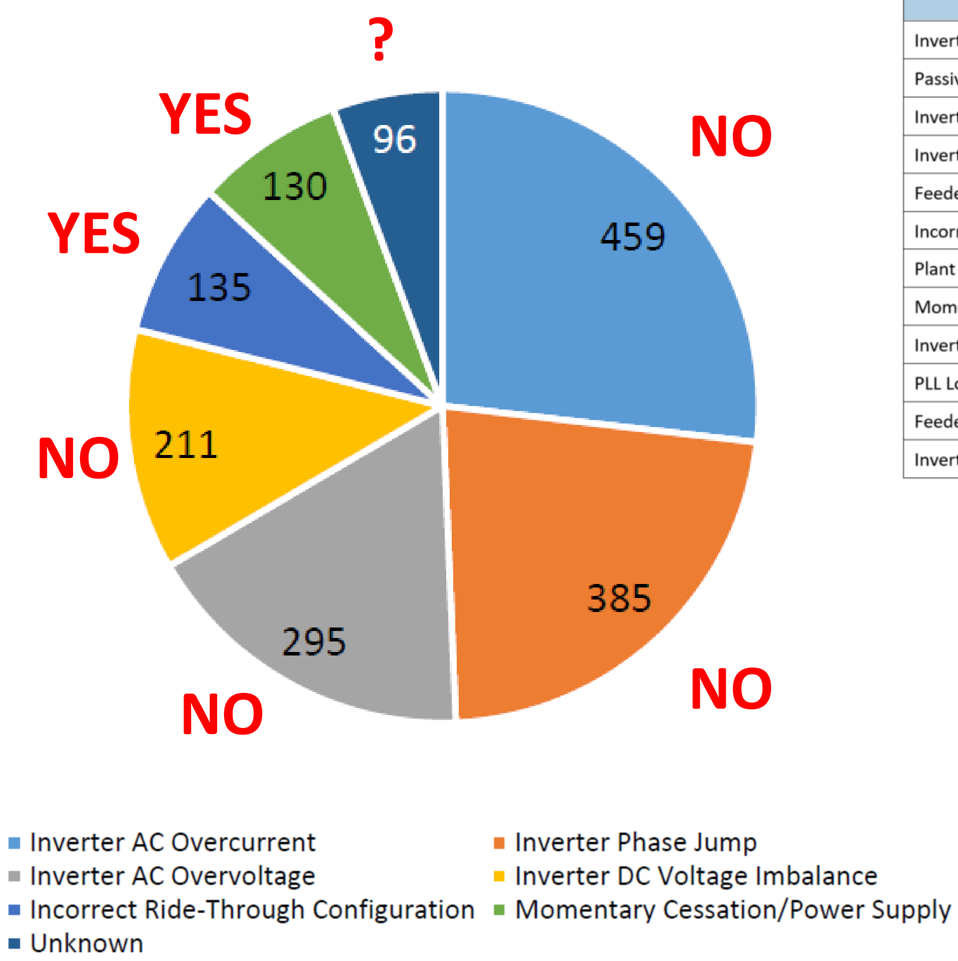
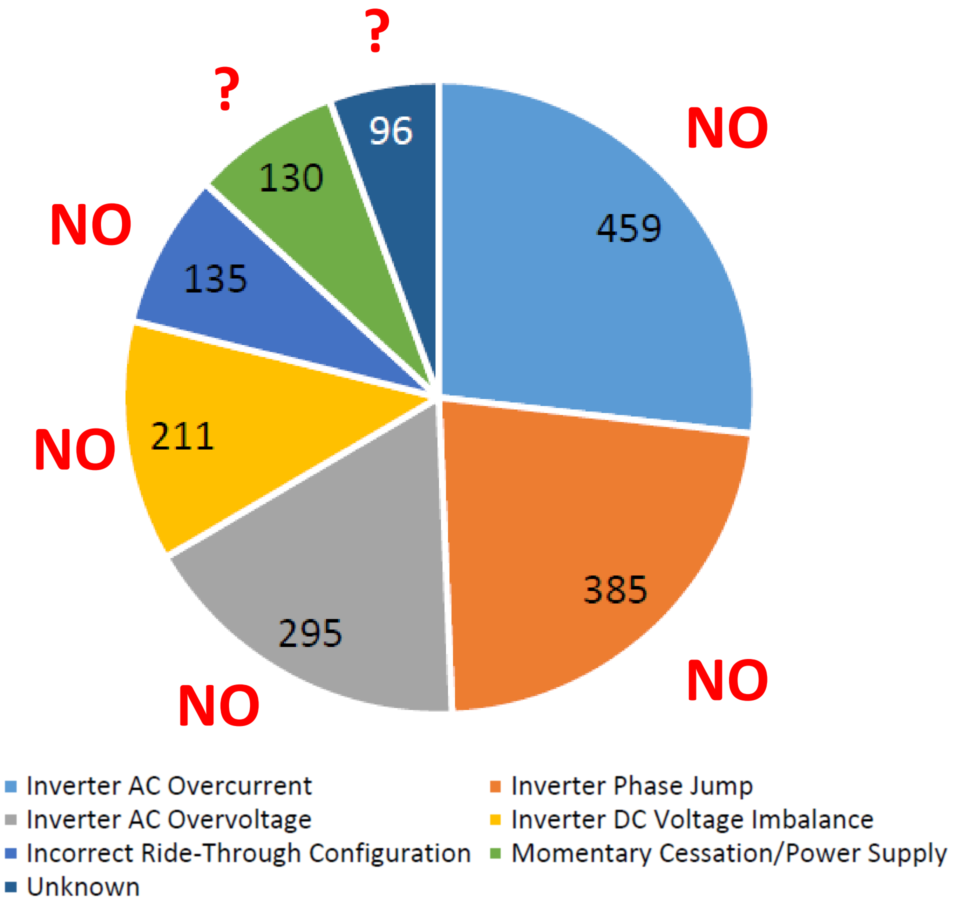


Table 3.1: Solar PV Tripping and Modeling Capabilities and Practices

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

Do the Models Recreate the Cause of Reduction?



…Synch Gen Involved? No

- Transformer differential protection
- AVR manual mode

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Do the Models Recreate the Cause of Reduction?

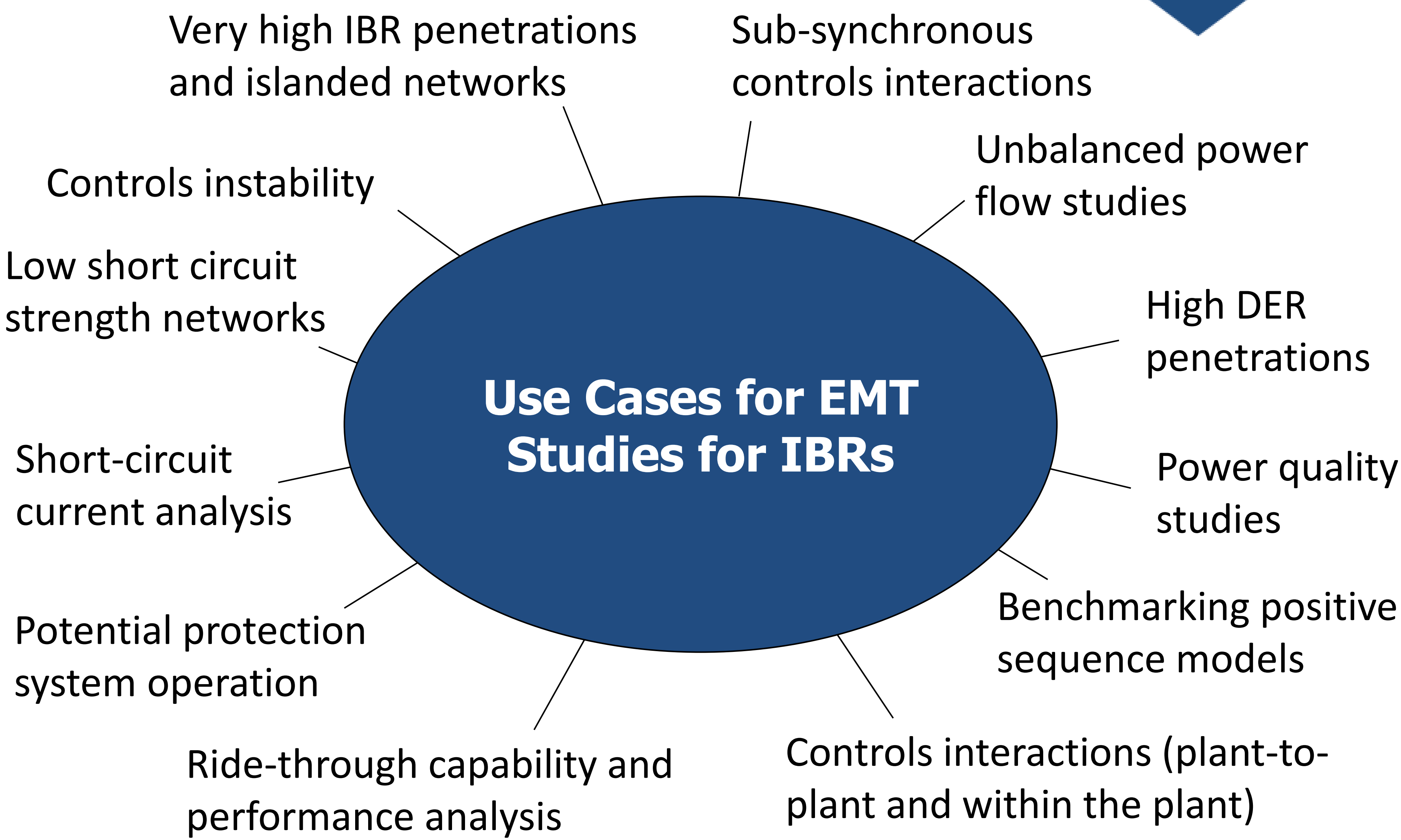
ERCOT's answer…

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

Takeaways and Recommendations

Inverter-Based Resource Modeling Moving Forward

Takeaway #1: EMT Modeling



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Takeaway #1: EMT Modeling

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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:	EMT Models in NERC MOD, TPL, and FAC Standards		
Date Submitted:	June 8, 2022		
SAR Requester			
Name:	Allen Schriver, NextEra Energy (NERC IRPS Chair) Julia Matevosyan, ESIG (NERC IRPS Vice Chair)		
Organization:	NERC Inverter-Based Resource Performance Subcommittee (IRPS)		
Telephone:	Allen – 561-904-3234 Julia – 512-994-7914	Email:	allen.schriver@fpl.com julia@esig.energy
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	
Industry Need (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. Transmission Planners (TP) and Planning Coordinators (PC) are concerned about the lack of accurate modeling data and the need to perform electromagnetic transient (EMT) studies during the interconnection process and long-term planning horizon. The growth of inverter technology has pushed conventional planning tools to their limits in many ways, and TPs and PCs are now faced with the need to conduct more detailed studies using EMT models for issues related to inverter-based resource integration issues. This SAR proposes including EMT models and studies in planning-related NERC Standards to ensure reliable operation of the BPS moving forward. See attached supporting paper for more details.			

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Reliability Guideline

Electromagnetic Transient Modeling for BPS-Connected Inverter-Based Resources – Model Requirements and Verification Processes

December 2022

DRAFT

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3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

Takeaway #1: EMT Modeling

- Establish EMT modeling requirements **now**
  - Require for all newly connecting BPS-connected inverter-based resources
  - Details matter – clear, consistent, explicit, and detailed requirements
    - All control modes, settings, and protections that could affect the electrical output of the facility
- Establish EMT model quality checks **now**
  - Model quality ≠ plant performance
  - Enforce model quality checks during interconnection studies
  - Require sufficient verification documentation to ensure model quality
  - Integrate into commissioning activities
- Develop processes for determining when EMT studies are needed **now**
  - Pockets of inverter-based resources, low short circuit strength areas, etc.

Takeaway #2: Use of Positive Sequence Models

- Do we still need positive sequence models? **Yes!**
  - Interconnection-wide base cases, wide-area analyses, EMT difficulties
- Significant need to improve positive sequence modeling
  - Need high-quality, verified positive sequence models
  - Inability to capture many IBR performance issues
- Require **both**: user-defined model + standard library model
- **Benchmark** models
  - EMT → user-defined pos seq → standard library pos seq
  - Require explanations for any differences
- NERC Acceptable Model List **does not preclude** use of UDMs
  - NERC actively updating our acceptable model list for additional clarity
- **Models need to match actual equipment installed in field!**

Takeaway #3: Quality of Positive Sequence Models

- Quality = model accuracy, fidelity, usability, efficiency, etc.
  - Model must match actual equipment installed in field!
- MOD-026-1 and MOD-027-1 **undergoing significant revision**
  - Small disturbance testing does NOT lead to a validated/accurate model
- **Using acceptable models ≠ an accurate model**
  - Default parameters pervasive across industry
    - Defaults = matching software manual defaults, matching OEM defaults, matching other OEM models, matching majority of other projects, curve fitting to match MOD-026/-027 small disturbance tests
- "Generic" models are making it through the interconnection study process and into interconnection-wide base cases
- Standard library models more common than UDMs
  - Most **OEMs strongly favor UDMs** to actually match real equipment
  - OEMs will provide whatever required to **meet minimum obligations**

Takeaway #4: Take Model Quality Checks Seriously

- Model quality checks should be established **industry-wide**
  - Mitigate pervasive nature of genericized models being used
- Model quality checks should include:
  - Attestations from OEMs (OEM models)
  - Validation reports – factory acceptance tests, HIL testing, etc.
  - Attestations from GOs or consultants (plant model)
  - Documentation proving as-built settings
  - Version control and change management processes
  - Commissioning steps dedicated to modeling
  - True-up by transmission planner during process

Takeaway #5: Model Quality vs. Plant Performance

- **Model quality:** checks accuracy and validity of model provided
- **Plant performance:** checks whether plant reliably interconnects to local system
- **Industry mixing the two – MAJOR PROBLEM!**
  - NERC told "model quality tests are not supposed to check model accuracy"
  - Inherently incentivizes developers, GOs, and OEMs to provide **models that "look good" but don't match actual equipment**
- **Differentiate** these steps, be explicit in requirements for both
- Multiple instances of OEM complaints, GO/GOP explanations, and TP/PC acknowledgements that **models (intentionally) do not match actual equipment**
  - Failure of true-up during interconnection study process

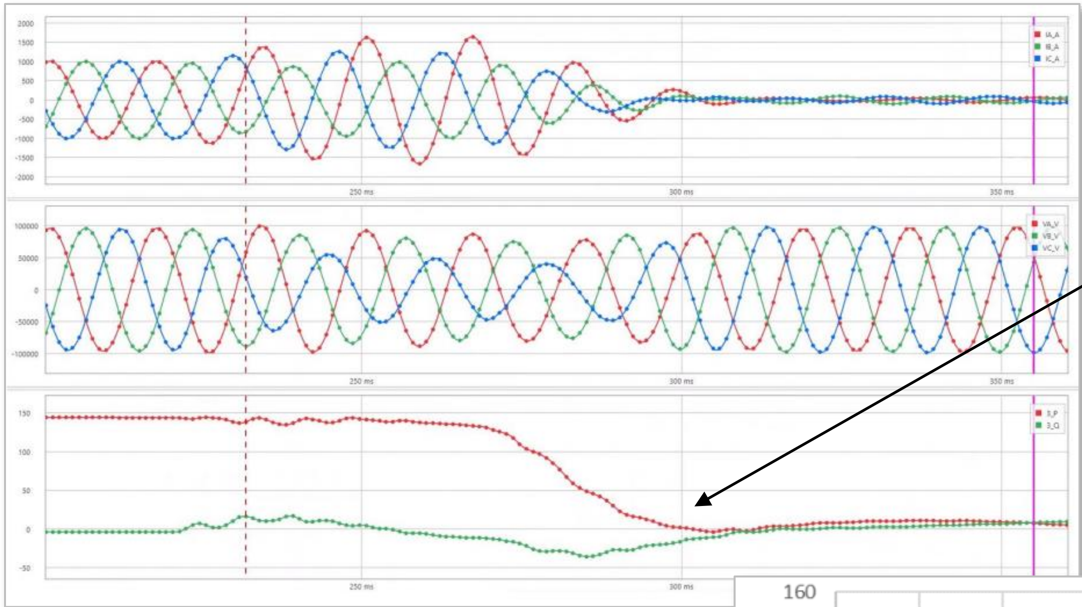
Takeaway #6: Model Quality Issues Abound

- **Example 1:** Site voltage tripping issues; OEM models, replicates, and mitigates issue with limiter logic in inverter and PPC
  - Site-specific, OEM-verified UDM provided by OEM to developer in EMT and pos seq; customer submitted standard library model to TP
    - "Easier to get TP/PC approval; we need to start producing MWs to make money"
- **Example 2:** Site parameter verification
  - OEM provided site-specific, verified EMT and pos seq models to developer
  - Standard library model parameterized with "best guess mapping" (no simulations, just assumptions) submitted because TP template for verification reports uses standard library models as examples
- **Example 3:** Complex site with multiple OEMs and 3rd party PPC
  - Detailed EMT and UDM pos seq studies by OEM(s) for site design
  - Standard library models submitted by developer – no coordination between controllers, no parameter verification, easy passing TP requirements with standard library model; no checking verification of actual equipment
- **Example 4:** Developer knowingly provides generic model that "looks good" to pass TP requirements, not model supplied by OEM(s)
- **Example 5:** Developer or GO uses false assumption that UDMs are not allowed and submits model not verified by OEM and passes TP requirements

Takeaway #7: Interconnection Study Process

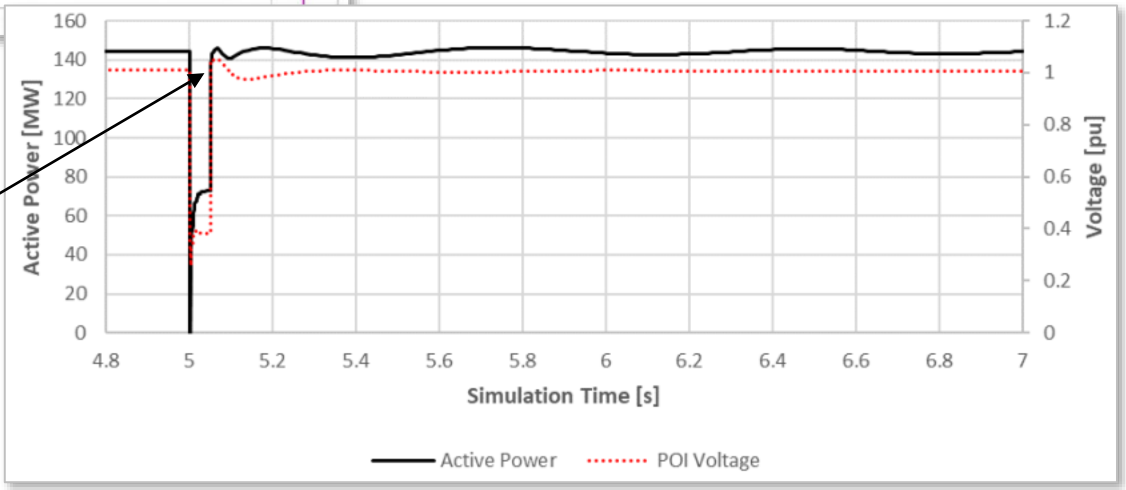
- **Interconnection studies using default models are as good as useless to BPS reliability**
  - Failure to identify plant ride-through problems
  - Failure to detect unreliable operation issues – controls instability, control interactions plant ride-through problems, inability to provide essential reliability services, etc.
- **Check model quality (using model quality checks) throughout interconnection studies**
  - Model submission during interconnection request
  - Updates at time of System Impact Studies
  - Confirmation at Interconnection Agreement signing
  - Accountability to performance against model provided afterwards
  - Confirmation of expected as-built settings pre-commissioning
  - Verification at time of commissioning – model matches reality

Takeaway #8: These Issues Are for All IBRs



- **Real World:** P goes to zero *after* fault clearing, slow ride-through recovery
- **EMT Study (not shown):** showed similar recovery trend

- **Positive Sequence Study (balanced fault):** P returns to pre-disturbance nearly instantaneously; does not show post-fault dynamics



THIS IS NEW WIND THAT UNDERWENT DETAILED EMT STUDIES!

NERC Activities

IBR Risk Mitigation – Modeling and Studies

NERC IBR Strategy

Risk Analysis

- Event Analysis
- Disturbance Reports
- Alerts
- Lessons Learned

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

Regulatory Enhancements

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

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NERC DER Strategy

DER Modeling
- Data Collection
- Modeling Tools
- Verification
- Modeling Usage

Studies Incorporating DER
- Planning Studies
- Design Criteria
- Operations Planning

Operational Impacts of DER
- T-D Impacts
- Aggregator
- Protection Systems
- Decentralization

Regulatory Considerations
- Aggregator
- NERC Standards Enhancements
- Cybersecurity
- Training

Strong Foundation of Coordination between
Regulatory Agencies: FERC, NARUC, CER
Industry Stakeholders: SPIDERWG, RSTC, SC, NATF, EEI, ESIG
Ongoing Research and Design: EPRI, National Labs, Academia

NERC Disturbance Reports

Planned Upcoming Reports:

- BESS-Related Events in California in 2022

https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx

Ramping Up EMT Activities

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Reliability Guideline

Electromagnetic Transient Modeling for BPS-Connected Inverter-Based Resources – Model Requirements and Verification Processes

December 2022

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NERC EMT Task Force

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Electromagnetic Transient (EMT) Modeling Task Force

Scope Document

1st Draft: November 2022

Purpose

The purpose of the Electromagnetic Transient Modeling Taskforce (EMT-TF) is to support and accelerate industry adoption of EMT modeling and simulation in their interconnection and planning studies of bulk power system (BPS)-connected inverter-based resources (IBR).[1] The EMT-TF will provide guidance and useful references to TPs and PCs embarking on the EMT modeling and simulation to more adequately assess the system impacts and reliability risks of interconnecting IBRs. The EMT-TF will also focus on developing technical documents to support BPS planning under increasing penetrations of BPS-connected inverter-based resources.

NERC-IEEE EMT Effort

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IEEE PES Power & Energy Society

Statement of Work

Joint IEEE-NERC Technical Report on EMT Modeling and Studies for Inverter-Based Resources

July 2022

Future NERC Alerts

- Level 2 NERC Alerts – Recommendations to Industry
  - Recommends specific action be taken by registered entities. A response from recipients, as defined in the alert, is required.
- Inverter-based resource performance risks
  - Inverter performance issues
  - Plant controller interaction issues
  - Plant protection setting issues
- Inverter-based resource modeling risks
  - Plant positive sequence dynamic models
  - Plant EMT models
  - Interconnection study models vs. interconnection-wide models
  - Model verification and quality testing

NERC Standards Under Development

Inverter-Based Resource Performance Enhancements:

- Project 2021-04 Modifications to PRC-002-2
- Project 2020-02 Modifications to PRC-024 (Generator Ride-Through)
- Project 2020-06 Verification of Models and Data for Generators
- Project 2021-01 Modifications to MOD-025 and PRC-019
- Project 2022-04 EMT Modeling
- Project 2021-02 Modification to VAR-002
- (Future Project) Updates to EOP-004
- (Future Project) IBR Performance Issues

NERC Standards Under Development

NERC Standards Under Development

Distributed Energy Resource Enhancements:

- Project 2022-02 Modifications to TPL-001-5.1 and MOD-032-1
- (Future Projects) SPIDERWG Standards Review White Paper
  - BAL-003
  - EOP-004 and EOP-005
  - FAC-001 and FAC-002
  - MOD-031
  - PRC-006
  - TOP-001 and TOP-002 and TOP-003 and TOP-010

[NERC Standards Under Development]

FERC Directives: IBR Registration and Standards

NEWS RELEASES

FERC Proposes IBR Standards, Registration to Improve Grid Reliability

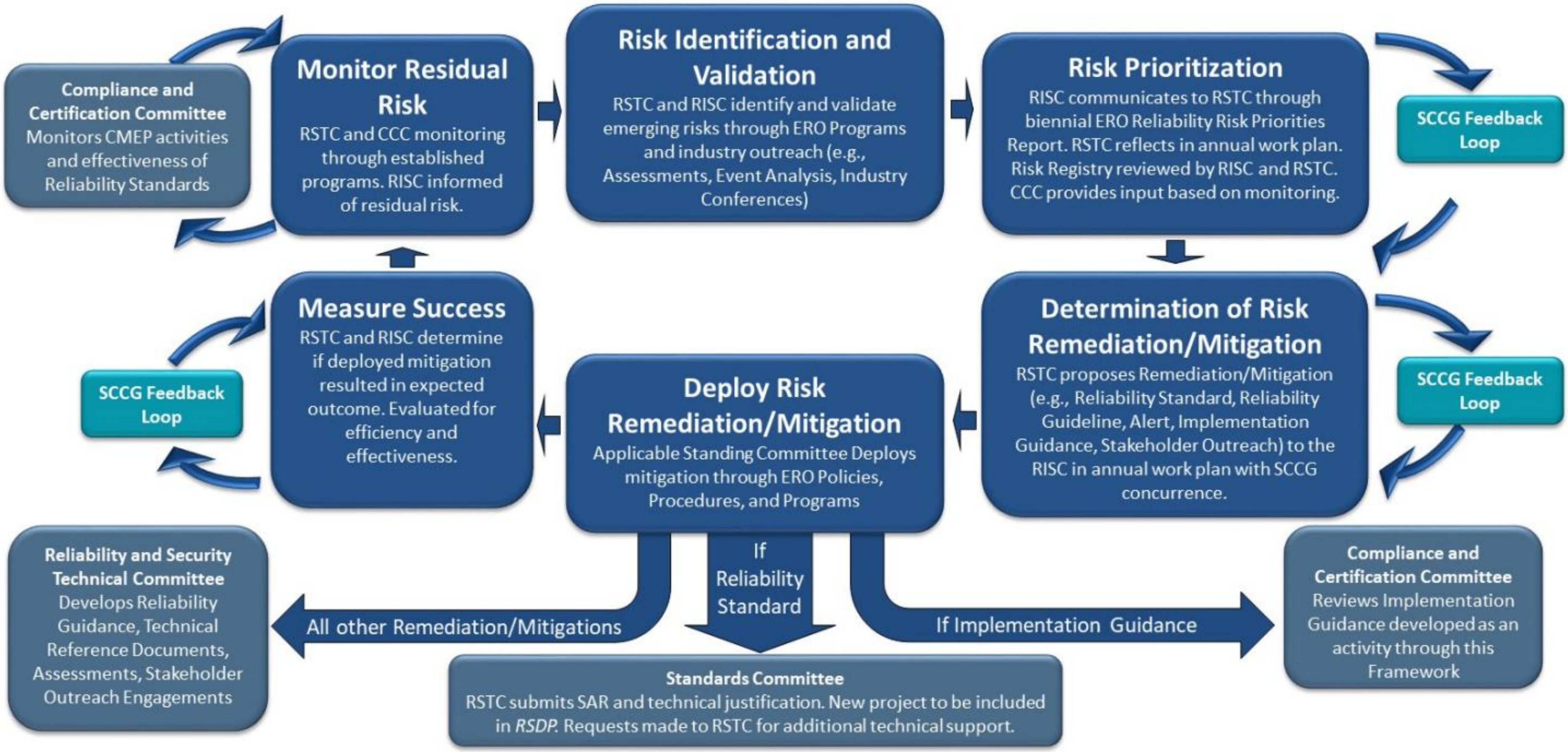
November 17, 2022

Item E-1, E-2, E-3 | E-2 Table of Cited NERC IBR Resources | Presentation

FERC took several actions today focused on inverter-based resources (IBRs), including proposing that new mandatory standards be developed to enhance the reliability of the bulk electric system.

https://www.ferc.gov/news-events/news/ferc-proposes-ibr-standards-registration-improve-grid-reliability

ERO Risk Management Framework



2021 ERO Reliability Risk Priorities Report

Questions and Answers

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Director, Engineering and Security Integration
ryan.quint@nerc.net

Feel free to reach out if interested in participating in the NERC IRPWG!