NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Solar PV Disturbances

What We Need to Do to Get Ready for High Penetration Conditions

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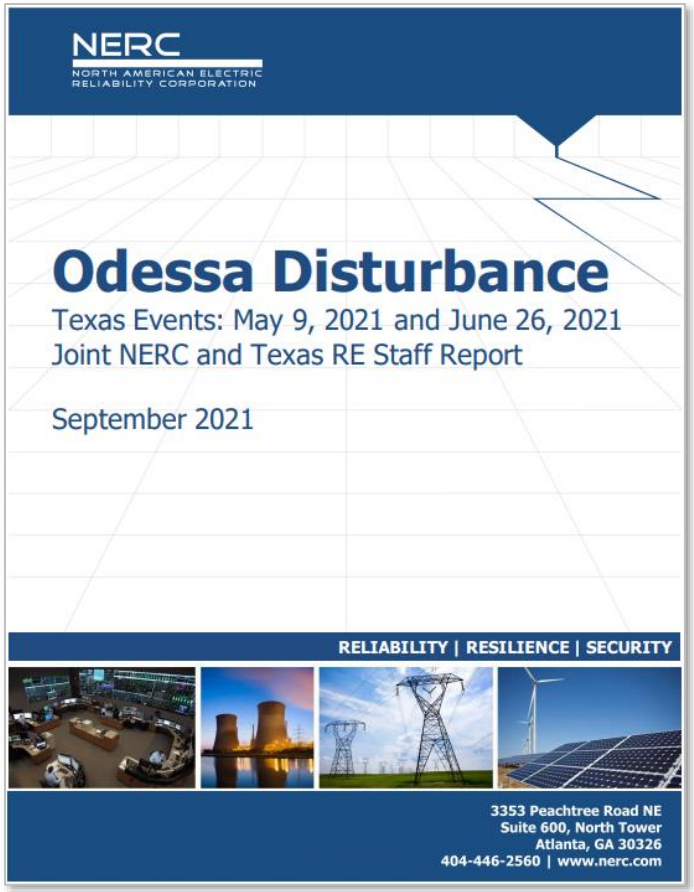
RELIABILITY | RESILIENCE | SECURITY




NERC Disturbance Reports and Alerts

https://www.nerc.com/pa/rrm/ea/Documents/Odessa_Disturbance_Report.pdf

Odessa Event Overview



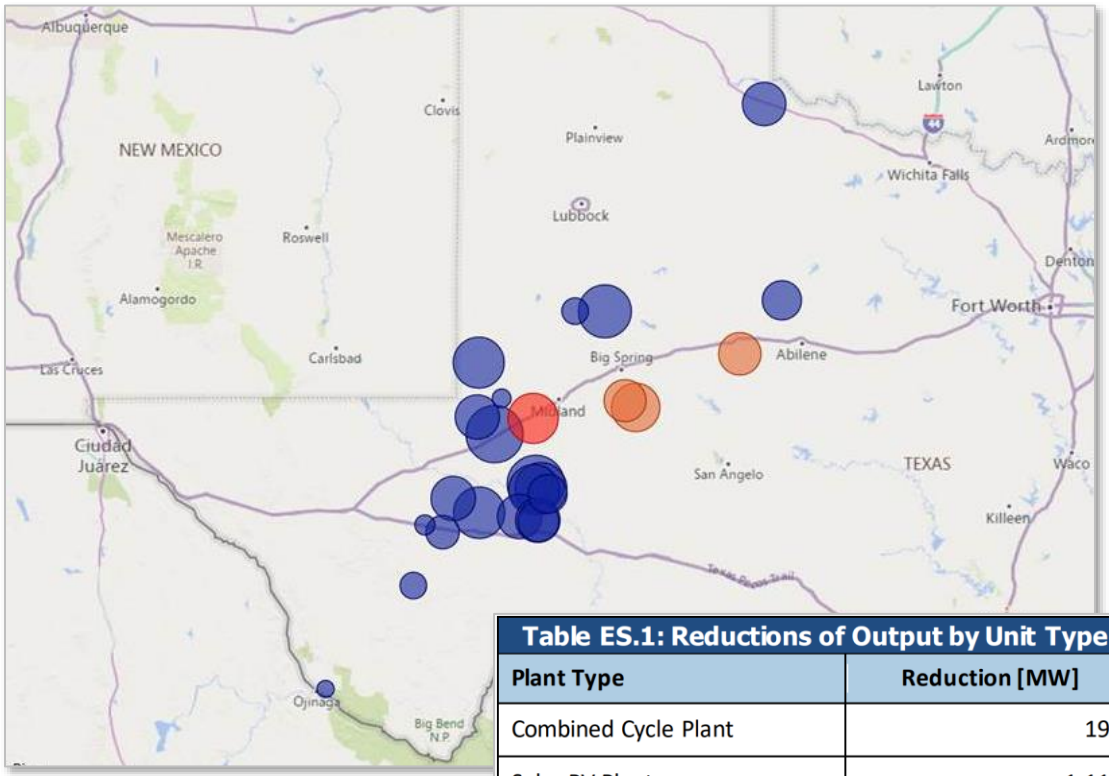
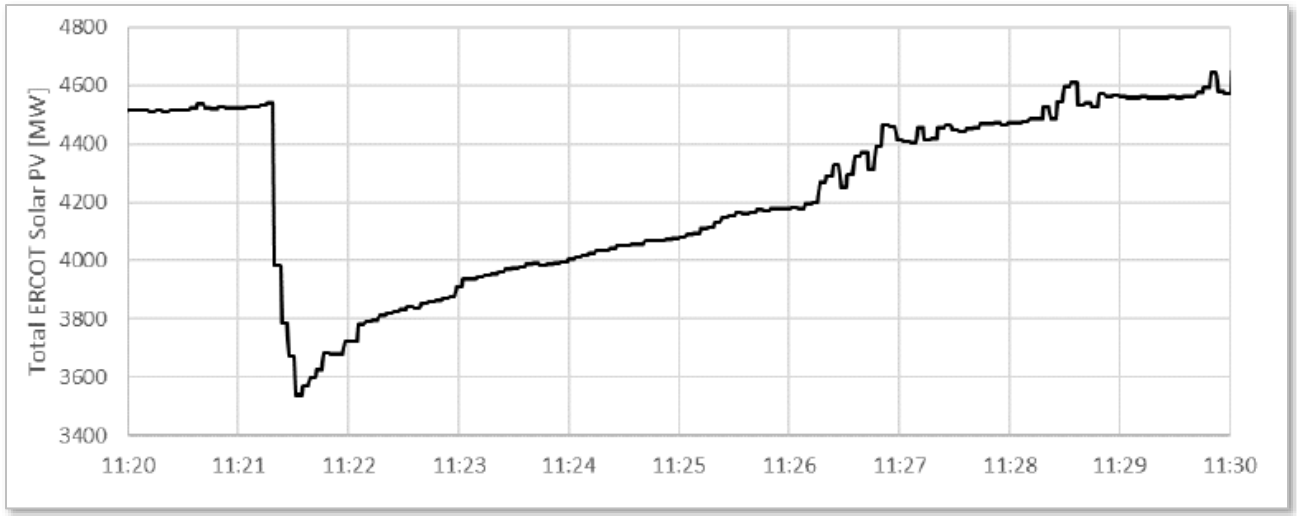


Table ES.1: Reductions of Output by Unit Type

Plant Type	Reduction [MW]
Combined Cycle Plant	192
Solar PV Plants	1,112
Wind Plants	36
Total	**1,340**

May 9 Solar PV Profile and Reduction



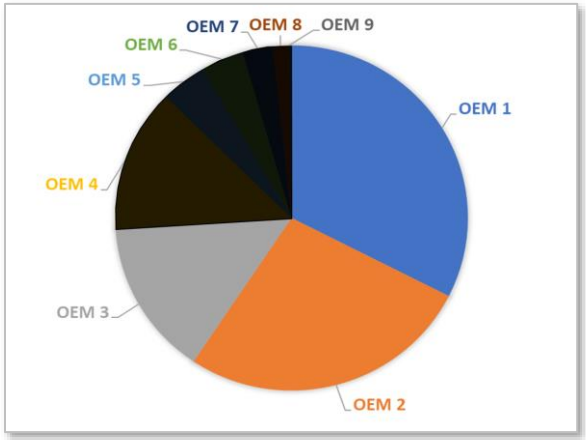
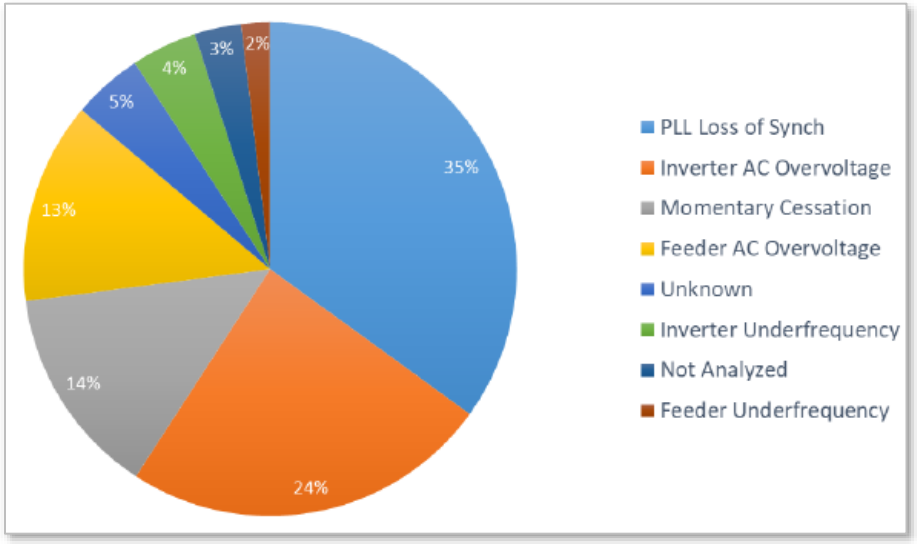


Table 1.1: Causes of Reduction

Cause of Reduction	Reduction [MW]
PLL Loss of Synchronism	389
Inverter AC Overvoltage	269
Momentary Cessation	153
Feeder AC Overvoltage	147
Unknown	51
Inverter Underfrequency	48
Not Analyzed	34
Feeder Underfrequency	21



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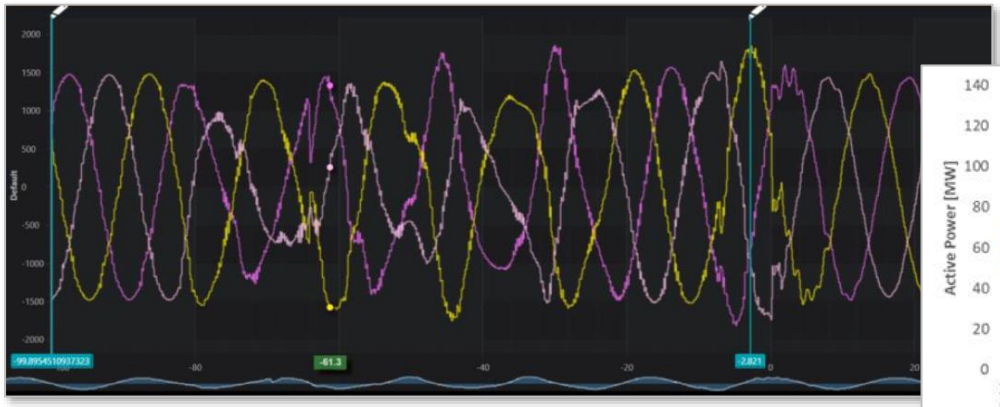
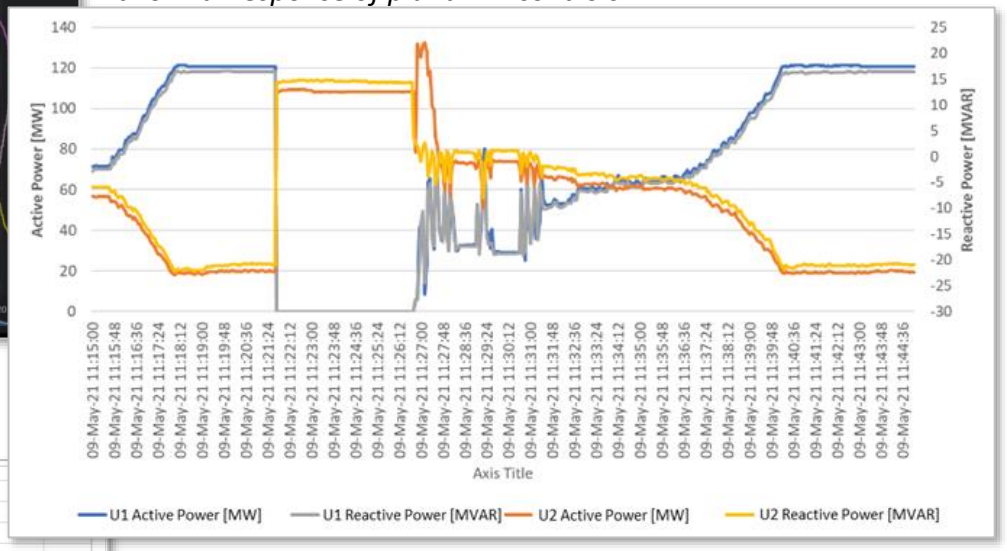
Solar PV Performance Issues

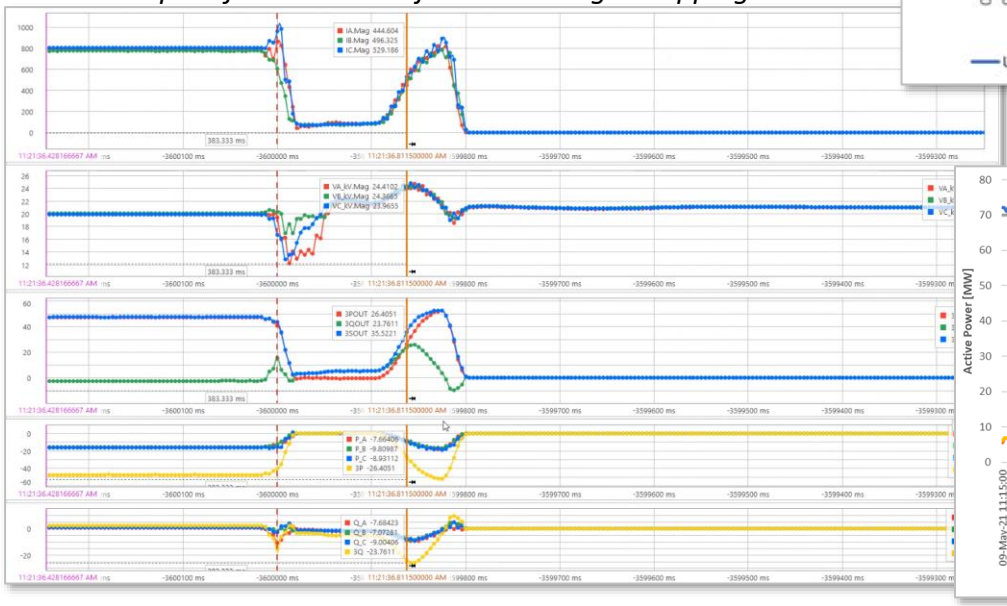
Sub-cycle AC overvoltage tripping



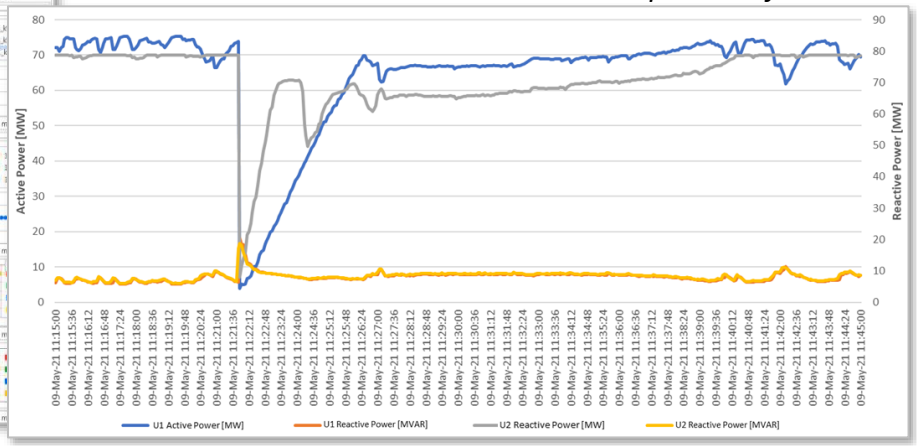
Abnormal response of plant PFR controls



Abnormal post-fault current injection leading to tripping



Plant controller interactions with inverter response to fault



Objective Facts

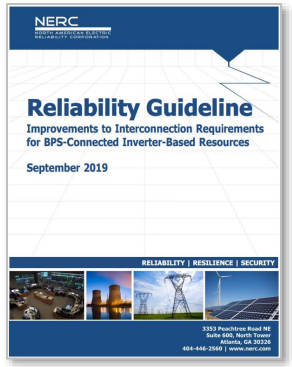
- BPS-connected solar PV resources continue to be interconnected in an unreliable manner
  - Abnormal performance during BPS fault events has resulted in widespread tripping, disconnection, and power reduction from these resources
- The positive sequence dynamic models used to study the interconnection of these resources are inadequate to identify these causes of tripping
- The EMT models that can capture these issues are either not being provided to the TP/PC or have modeling deficiencies
- Industry not adopting the strong recommendations in NERC reliability guidelines
  - Particularly related to improvements to interconnection requirements

Review of Modeling Situation

- ERCOT models did not represent actual behavior of facilities involved in disturbance
- Existing positive sequence models will not capture the majority of tripping observed
- EMT models and simulations needed to identify ride-through issues during interconnection process
- Existing EMT models supplied to ERCOT likely have model quality issues
- Detailed model quality review needed for both positive sequence and EMT models to ensure they reflect as-built facility protection and controls

Odessa Report Recommendations

- #1: Industry Needs to Take Action – Adopt NERC Reliability Guidelines



- #2: Need improvements to FERC Generator Interconnection Procedures and Agreements

- #3: Need significant enhancements to NERC Reliability Standards

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 MW solar PV resources in ERCOT
  - Additional 790 MW in commissioning process
- **End of August:** 8,900 MW solar PV resources in the ERCOT
  - Additional 1,000 MW in commissioning process
- **Near Future:** 25,000 MW solar PV resources with signed interconnection agreements in ERCOT generation interconnection queue between now and 2023

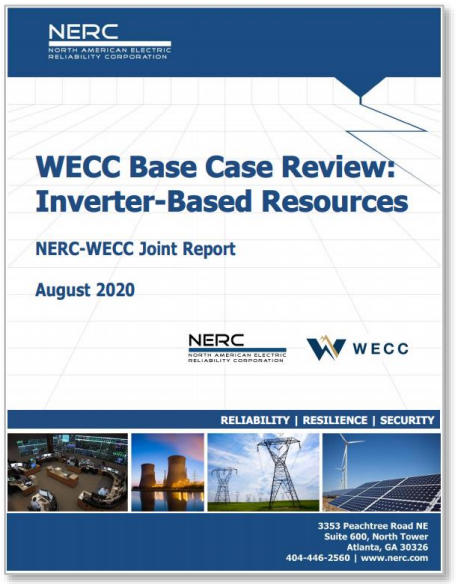
Focus on Modeling and Studies: The Root of All Reliability Issues

"Why was this not identified prior to interconnection?"

Positive Sequence Model Limitations

Table 2.1: Solar PV Tripping and Modeling Capabilities and Practices		
Cause of Tripping	**Can Be Accurately Modeled in Positive Sequence Simulations?**	**Can Be Accurately Modeled in EMT Simulations?**
Erroneous frequency calculation	No	Yes
Instantaneous* ac overvoltage	No	Yes
PLL loss of synchronism	No	Yes
Phase jump tripping	Yes	Yes
DC reverse current	No	Yes
DC low voltage	No	Yes
AC overcurrent	No	Yes
Instantaneous* ac overvoltage—feeder protection	No	Yes
Measured underfrequency—feeder protection	No	No**

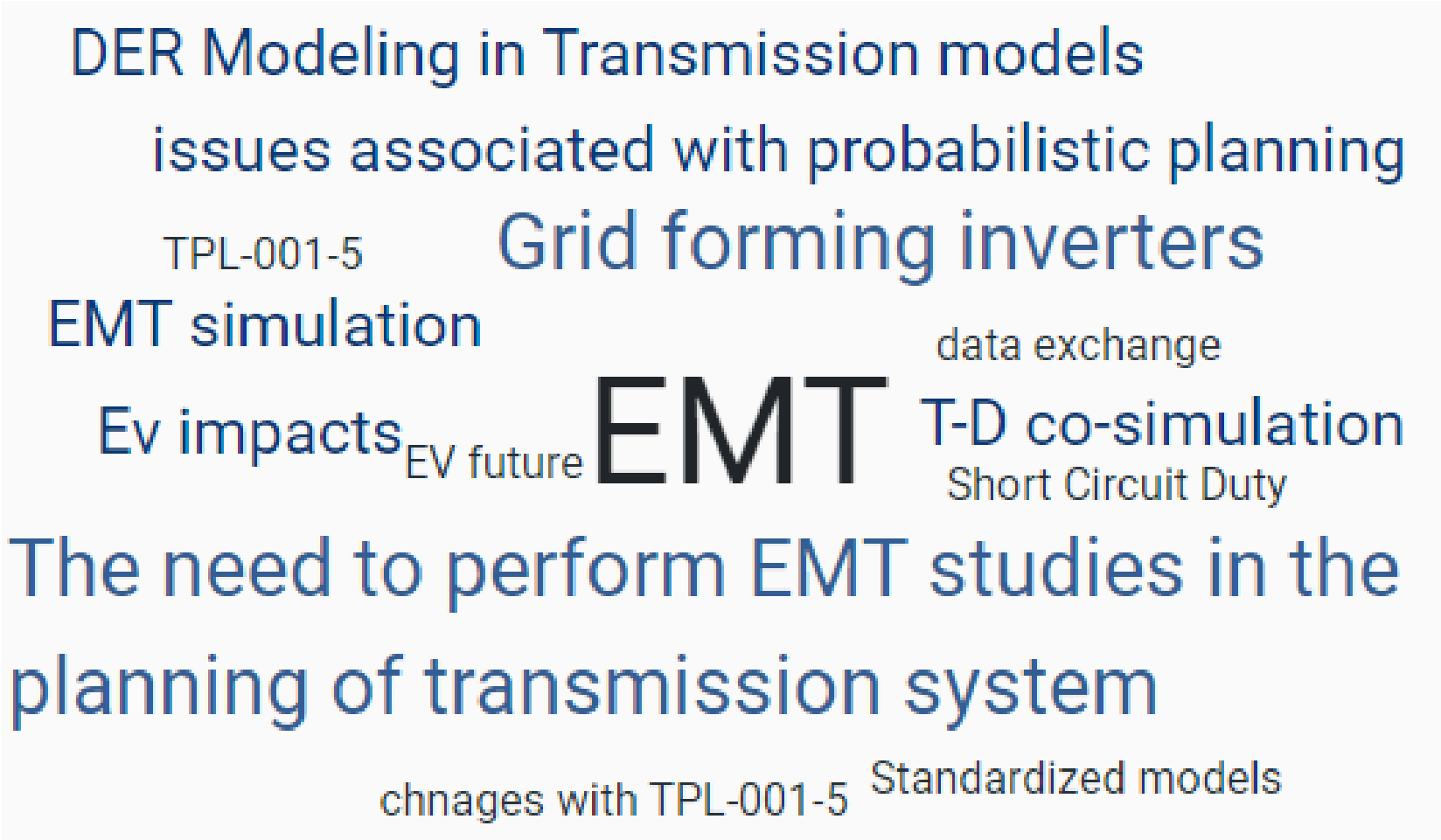
* Sub-cycle ** Due to very limited protective relay models in EMT today



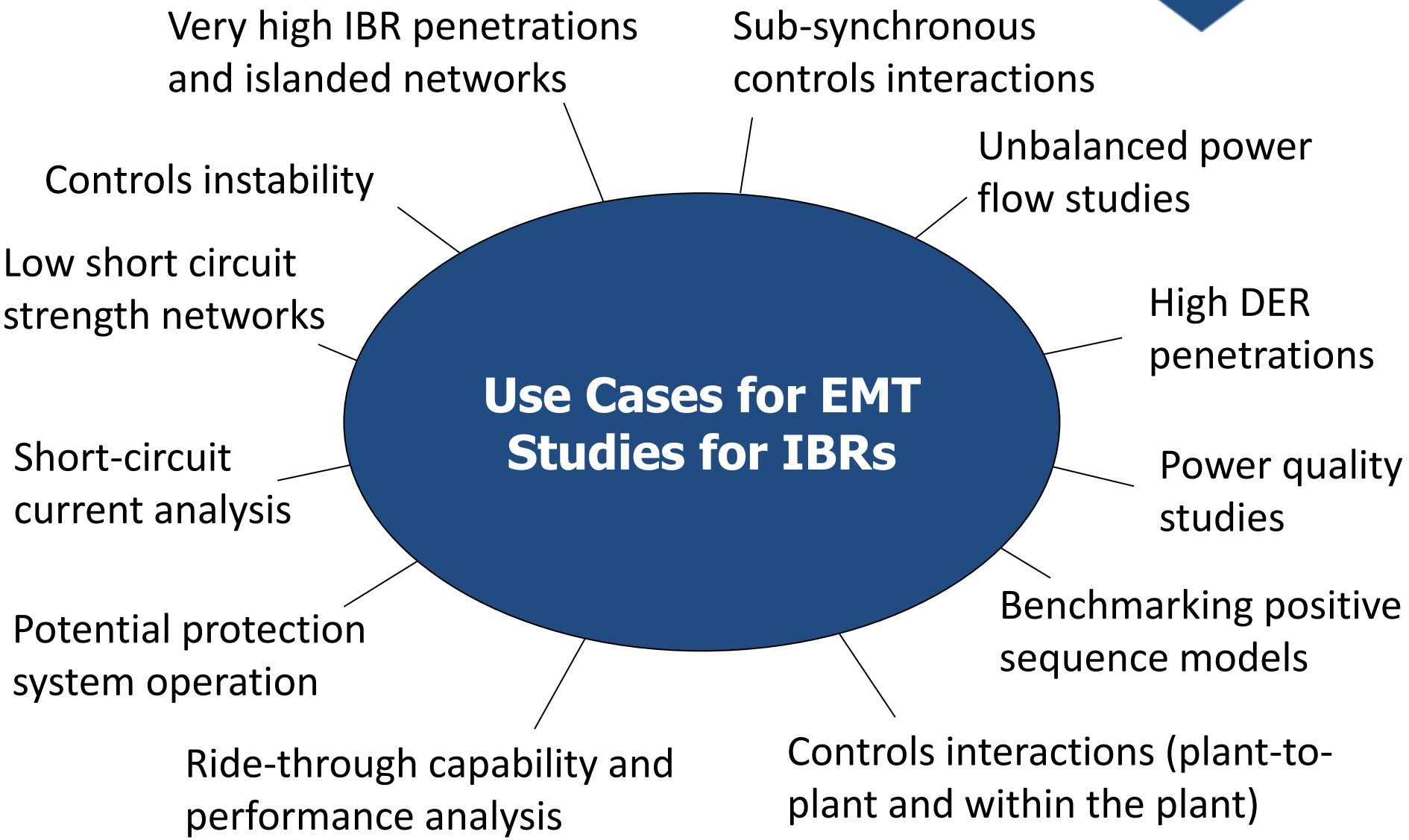
- There remains a need for accurate positive sequence studies … but …
- Majority of tripping across *all* events analyzed by NERC cannot be accurately simulated in positive sequence studies today
  - Most commonly performed during interconnection process
- Significant amount of models in planning cases are incorrectly parametrized
- Strong need for EMT studies moving forward

Topics for Future

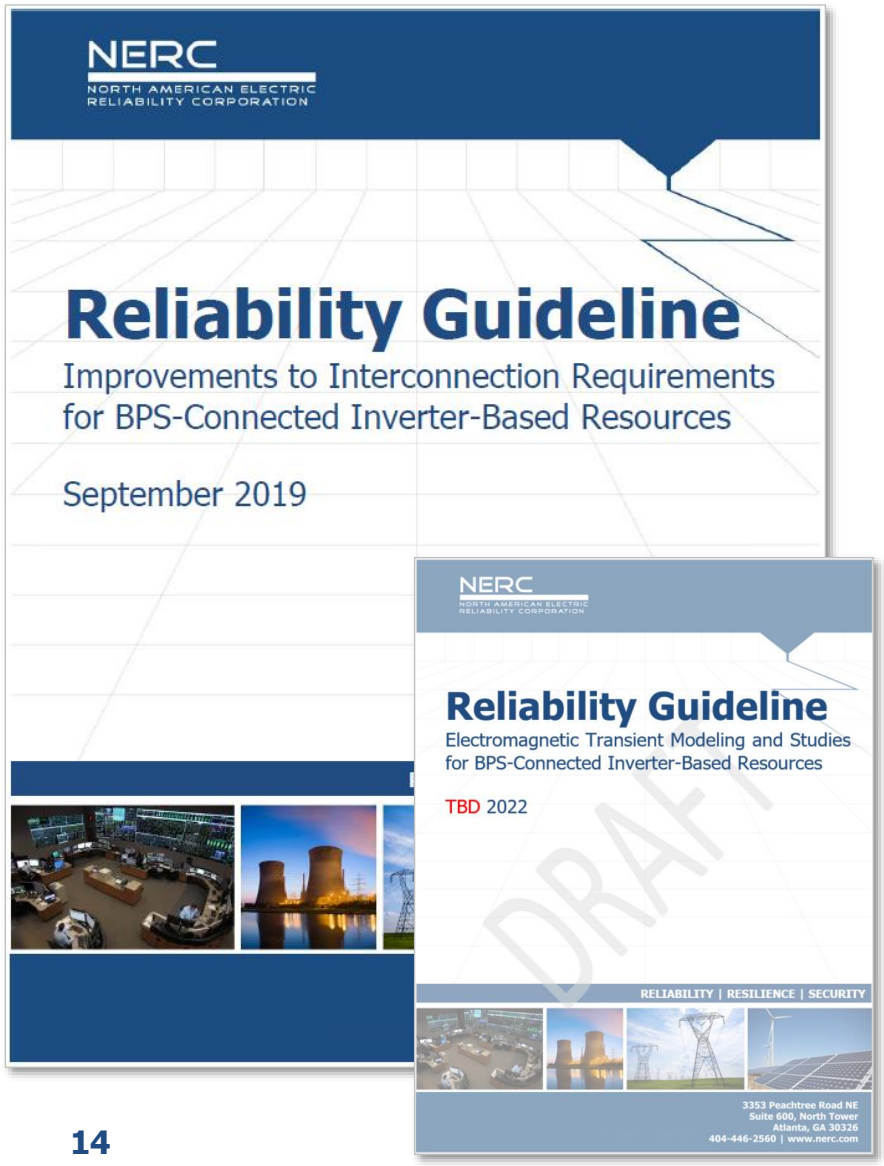
From NERC/NATF/EPRI Workshop



Possible Studies using EMT Models



EMT Modeling and Studies

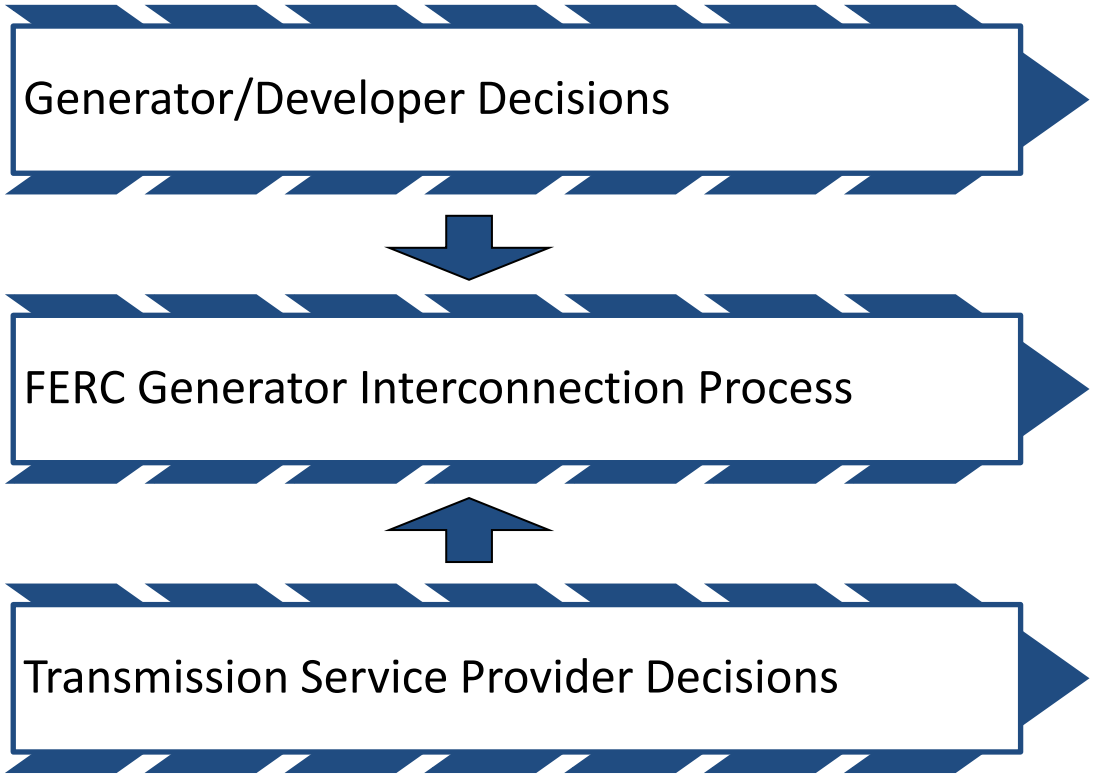


- Future grid conditions will demand the increased use of EMT modeling and studies
- Industry lacking in expertise, tools, processes, and experience to perform EMT studies at scale
- Innovation needed to move the needle for skillset development and tools adoption
- Step 1: Establish EMT modeling requirements
- Step 1a: Establish EMT model quality checks

Growing List of Modeling Issues

- Transmission entities taking models at face value with no analysis of model quality
  - Unintentionally incorrect models (parameterization) used and never questioned
  - Intentionally incorrect models used to get through interconnection process easily
  - EMT models using generic representations
  - Transmission entities lack resources, time, and/or expertise to analyze vast number of models for interconnection requests
- Interconnection studies not picking up reliability issues
  - Positive sequence studies mostly, will not identify ride-through problems
  - Detailed EMT studies without accurate models of protection
  - Inappropriate use of EMT models, or overestimation of model quality
  - Studies disabling protection and modifying controls without OEM involvement
- Systemic modeling errors during interconnection and in planning studies
  - Defaults models used in interconnection studies, never get updated or restudied during interconnection process
  - Generator owners making changes to equipment without seeking prior approval (models not getting updated)
- Little to no performance validation to compare expected performance (based on model) with actual performance (based on events) – this is NOT “model validation”

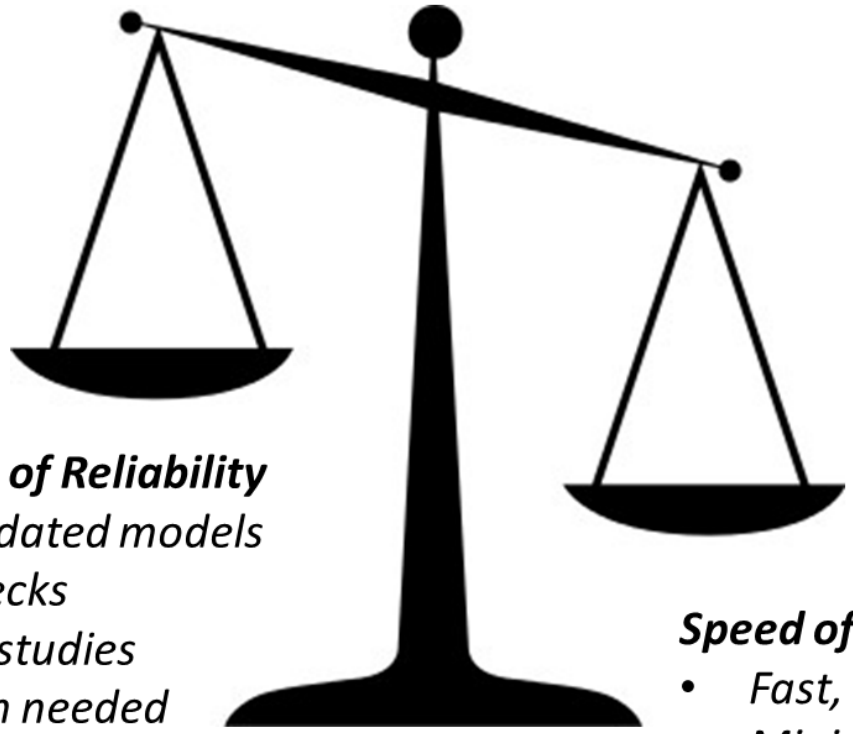
Complex Generator Interconnection Process – Modeling and Studies



- Complex process
- Inconsistent modeling and study requirements
- Lack of clarity at time of request
- Changes in equipment and settings throughout process
- Short timeline to run detailed studies, if needed
- Lack of transparency and "sign-offs" on critical decisions
- Lack of mutual agreement and understanding about equipment settings/models
- Process improvements needed
  - Difficult for both generation and transmission sides

"Why was this not identified during interconnection studies?"

Under Conditions of High Penetrations of Inverter-Based Resources…



Adequate Assurance of Reliability

- *Accurate and validated models*
- *Model quality checks*
- *Detailed stability studies*
- *EMT studies when needed*

Speed of Interconnection

- *Fast, effective, streamlined*
- *Minimal re-work*
- *Clear modeling requirements*
- *Quick studies*

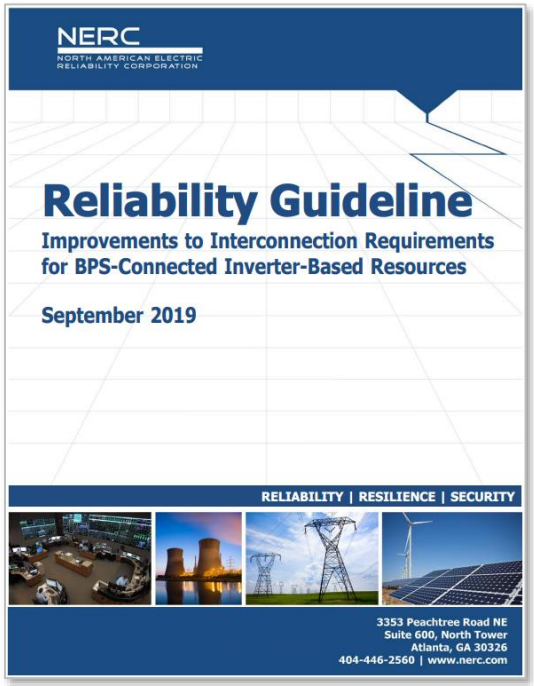
ERO Recommendations

"Why this matters to everyone…and what we can take away from this."

Recommendations for Transmission Owners

Recommendation:

- Comprehensively adopt the recommendations in this NERC reliability guideline
- Act (quickly) to significantly strengthen your interconnection requirements related to inverter-based resources
  - Clarity and consistency needed
  - Shore up gaps in unreliable performance
  - Then VERIFY that performance with models – transparent analysis



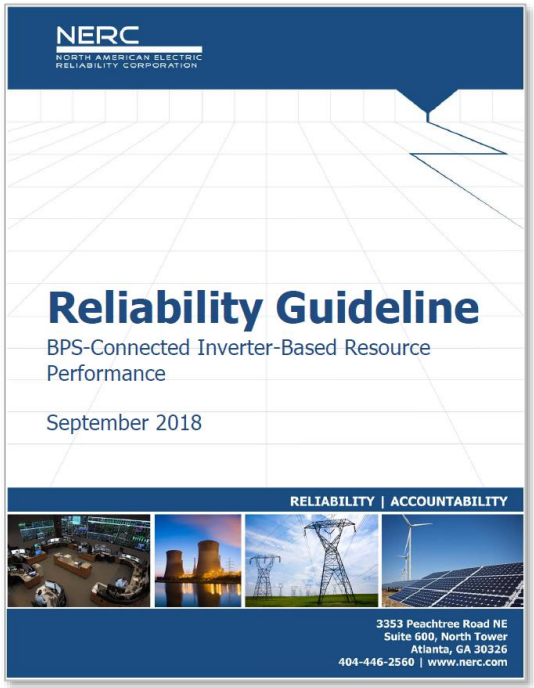
Risk Assessment Questions:

- Have you *comprehensively* adopted the reliability guideline? If not, why?
- Have performance requirements been established to mitigate the known risks described in the NERC disturbance reports (at a minimum)?
- What challenges are you facing in improving interconnection requirements?

Recommendations for Generator Owners/Operators

Recommendation:

- Adopt this NERC reliability guideline – mitigate known reliability issues
- Strengthen contractual agreements with OEMs and vendors – incorporate language to address known risks
- Ask questions to transmission entities when lacking clarity
- Help ensure models represent as-built equipment
- Improve monitoring and analysis of plant performance



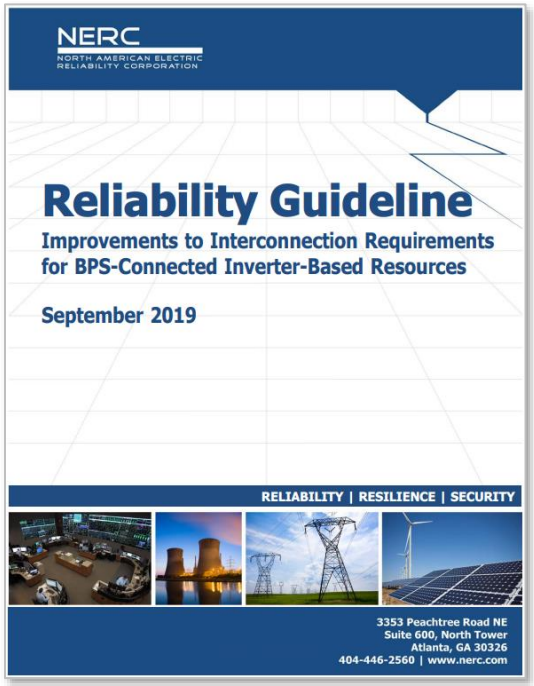
Risk Assessment Questions:

- Are you analyzing and reporting performance (tripping) during faults?
- Have you *comprehensively* adopted the guideline recommendations? Have you addressed performance issues from the reports and guidelines?
- Have you improved modeling practices to help address systemic modeling gaps?

Recommendations for Transmission Planners

Recommendation:

- Comprehensively adopt recommendations in this NERC reliability guideline
  - Improve modeling and data collection processes
  - Establish EMT modeling requirements
  - Establish strong ***model quality check requirements***
- Conduct model quality checks on all plant models provided
- Proactively correct deficient models
- Identify plants performing differently than models – seek corrective action



Risk Assessment Questions:

- Have you established and implemented model quality checks?
- Are you certain that the models match as-built equipment (or planned equipment)?
- Have you *comprehensively* adopted the guideline recommendations?
- Is plant performance validation being conducted after major disturbances?

Questions and Answers

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