Are We Ready?

For High Penetrations of Inverter-Based Resources

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RELIABILITY | RESILIENCE | SECURITY




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NERC Disturbance Reports and Alerts

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

May 9 Fault Location and Affected Facilities

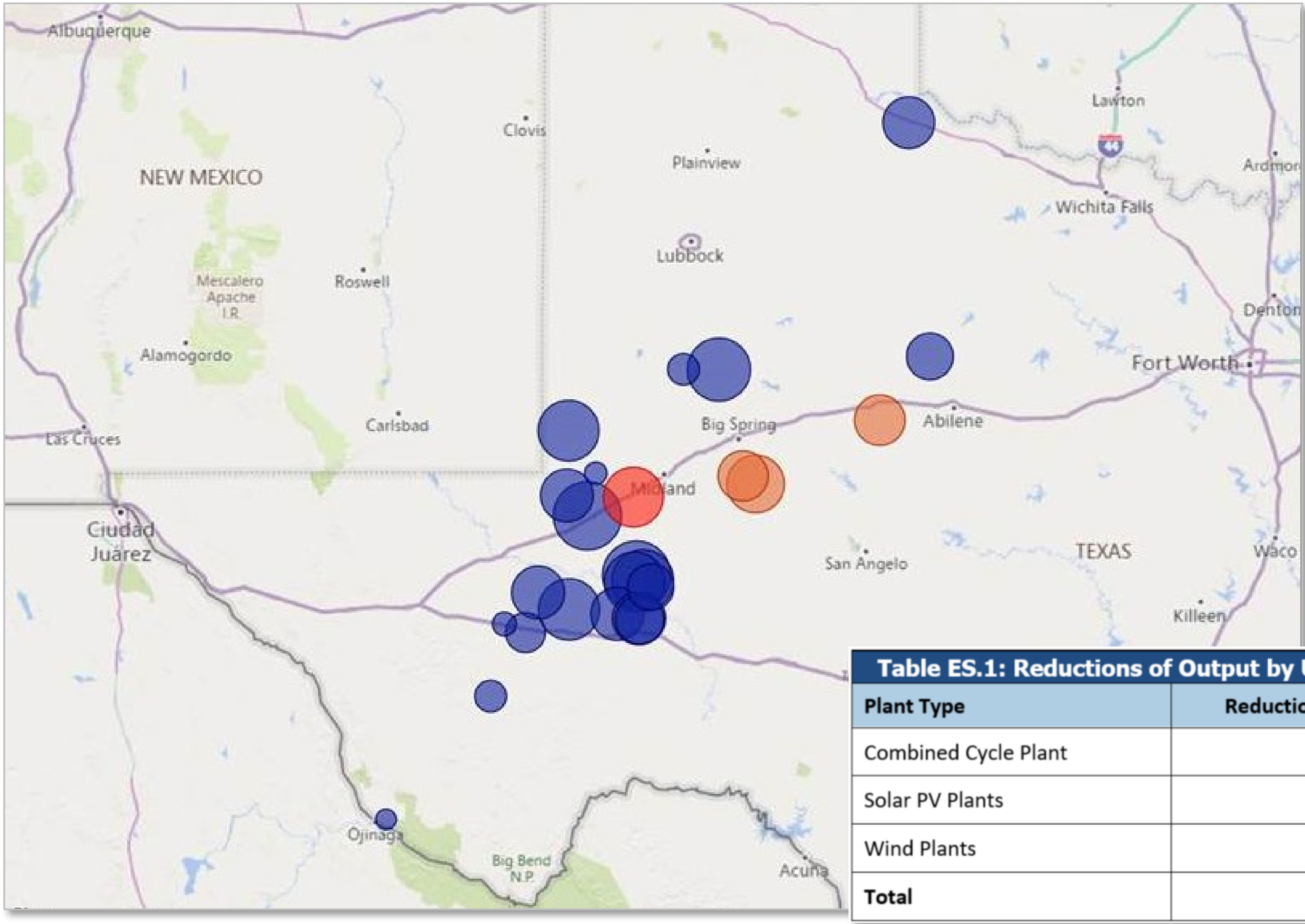
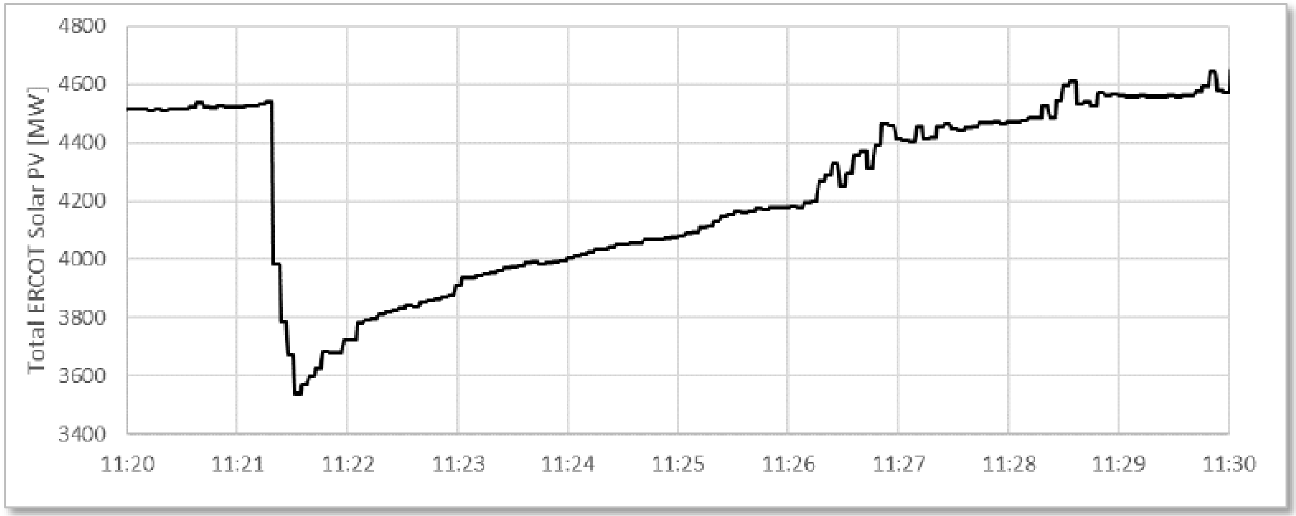


Table ES.1: Reductions of Output by Unit Type	
Plant Type	**Reduction [MW]**
Combined Cycle Plant	192
Solar PV Plants	1,112
Wind Plants	36
Total	**1,340**

May 9 Solar PV Profile and Reduction



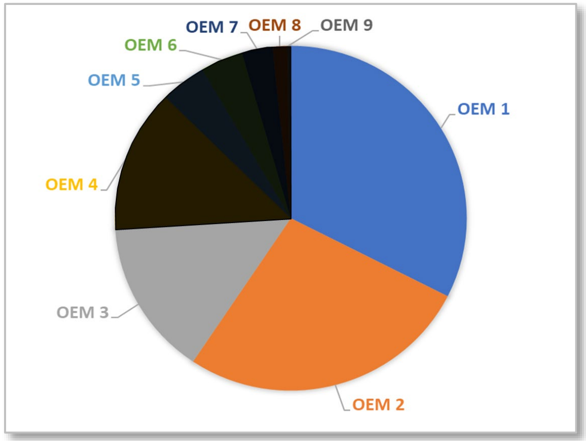
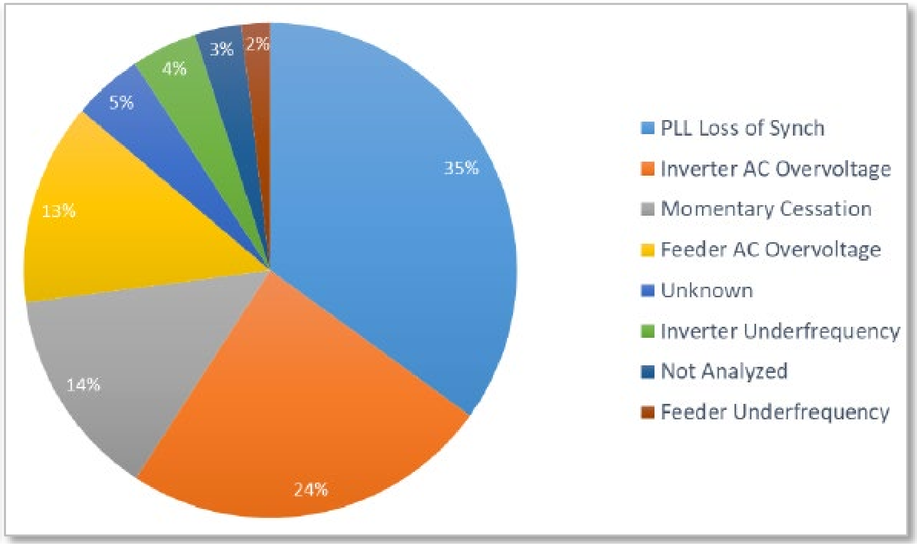
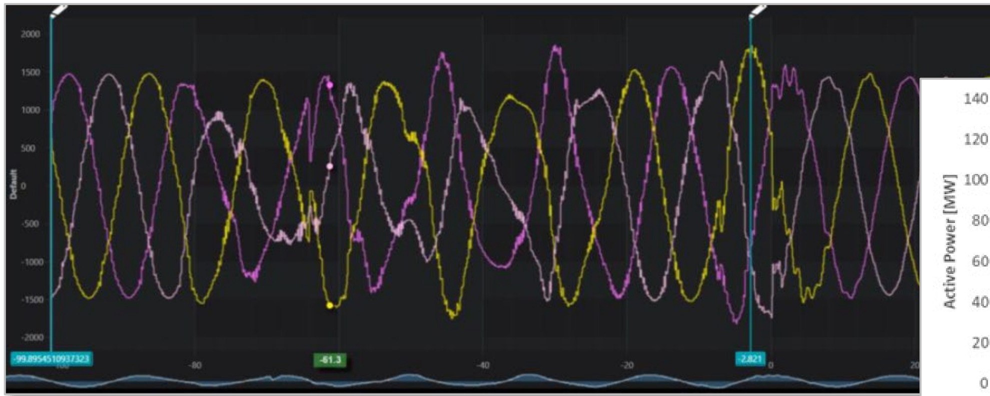
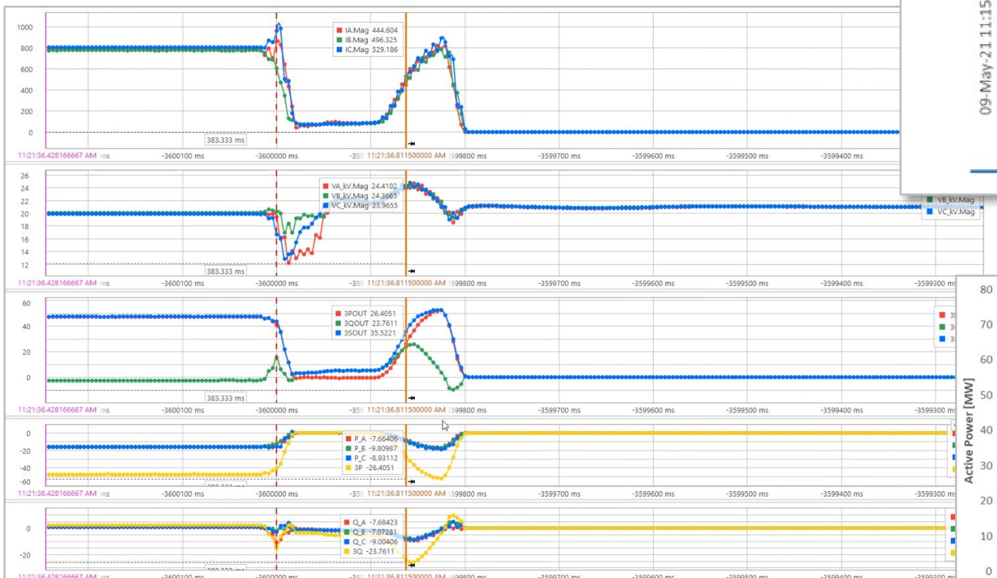


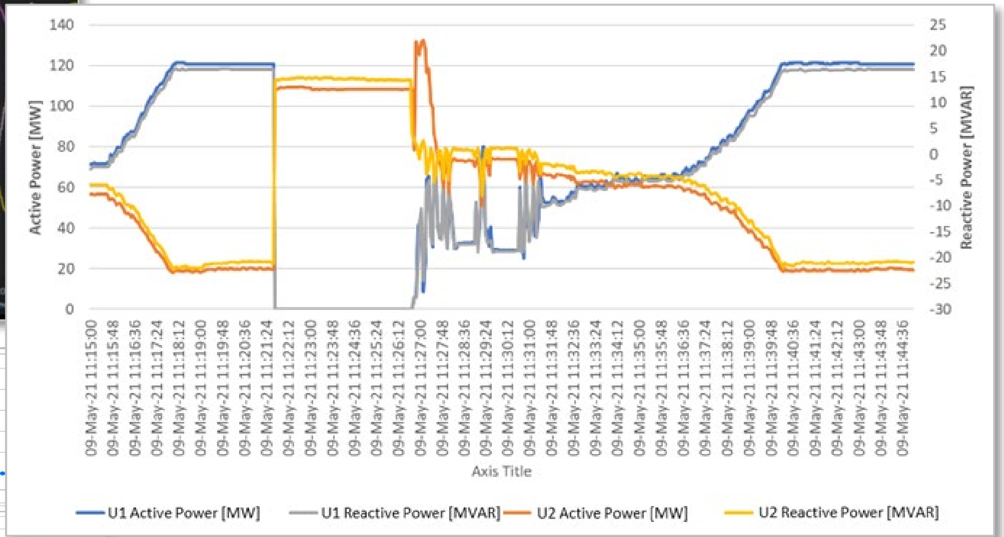
Table 1.1: Causes of Reduction	
Cause of Reduction	Reduction [MW]
PLL Loss of Synchronism	389
Inverter AC Overvoltage	269
Momentary Cessation	153
Feeder AC Overvoltage	147
Unknown	51
Inverter Underfrequency	48
Not Analyzed	34
Feeder Underfrequency	21

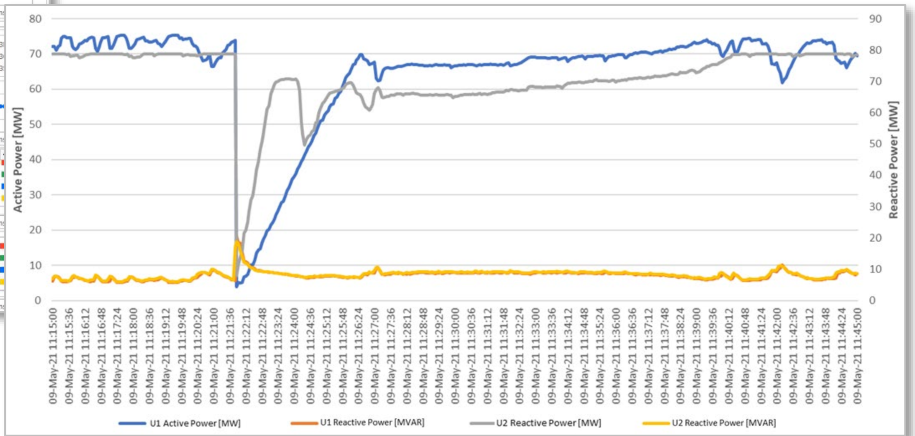


Reliability Issues









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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

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

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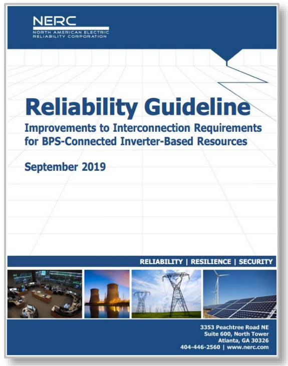
Odessa Report Recommendations

- #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

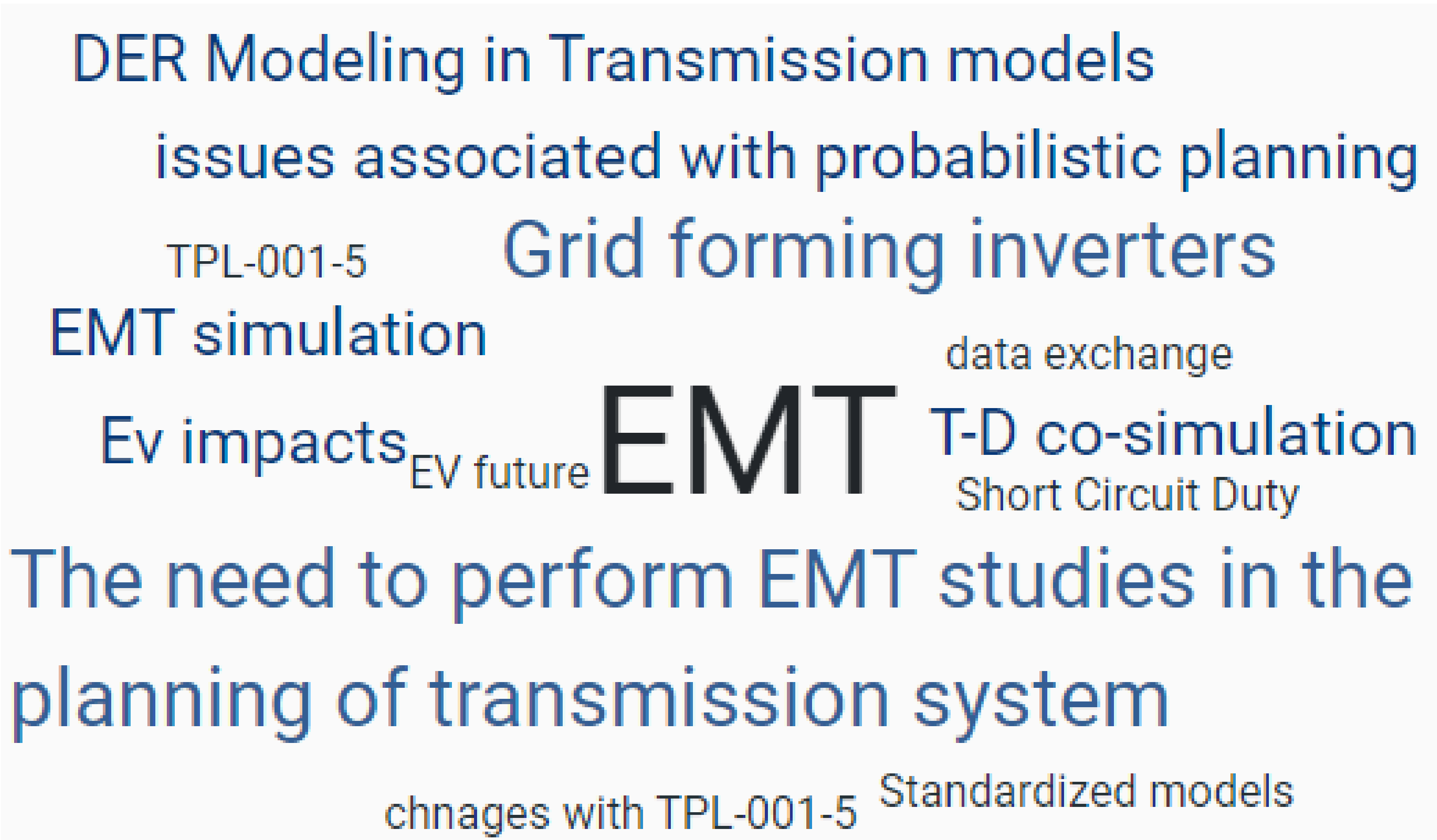
Growing Solar PV Portfolio

- 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

Topics for Future

From NERC/NATF/EPRI Workshop



Positive Sequence Model Limitations

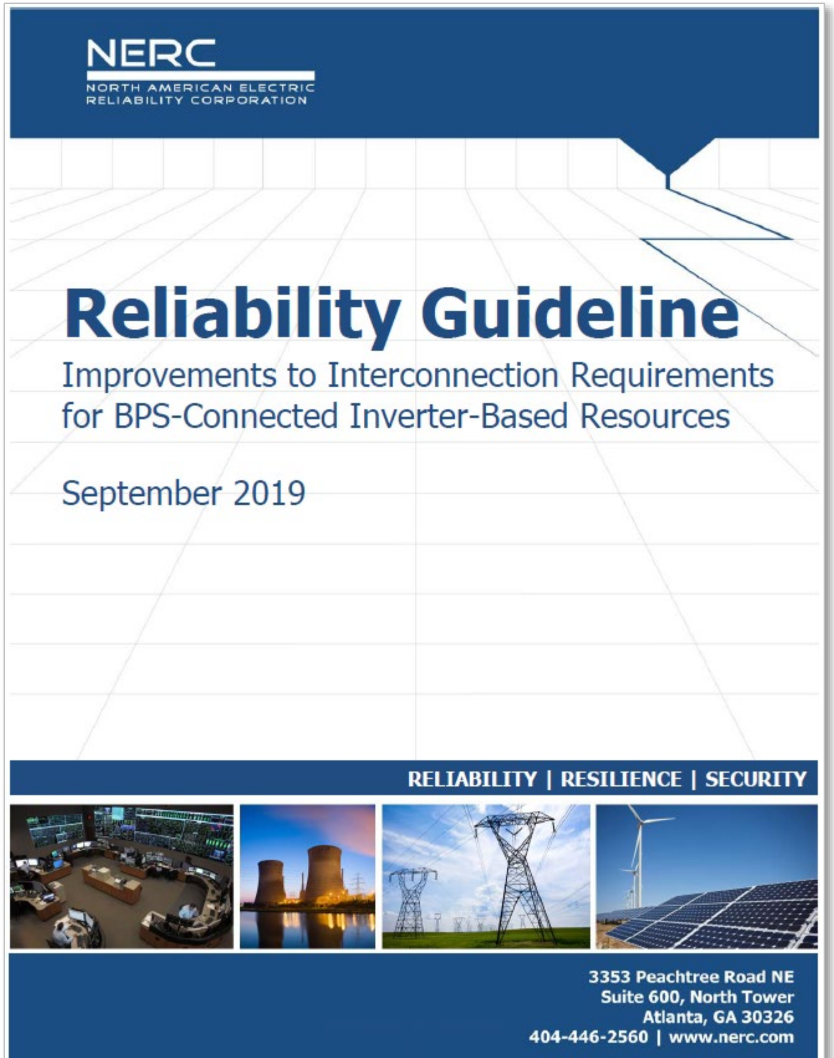
Table 2.1: Solar PV Tripping and Modeling Capabilities and Practices

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

- 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

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

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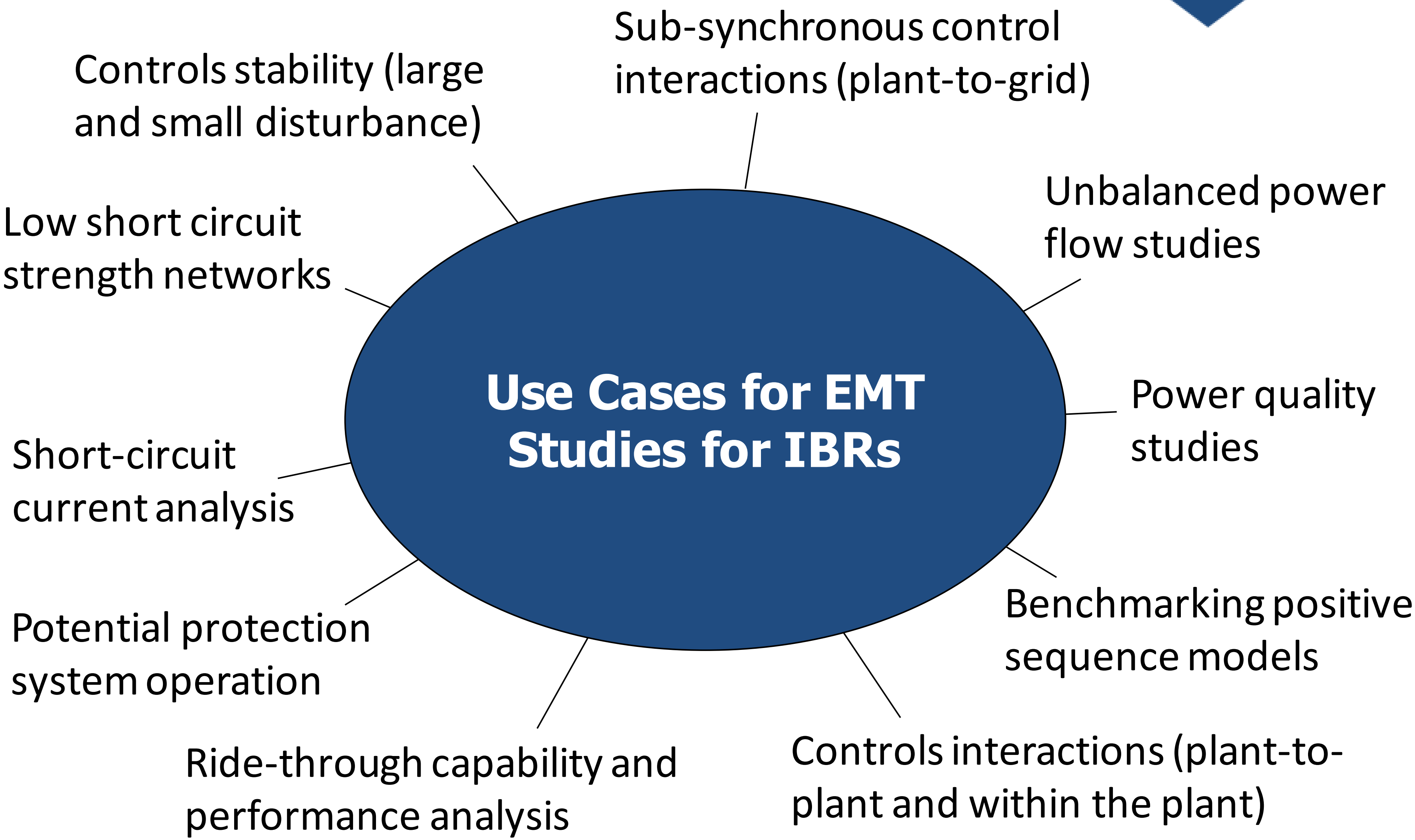
Possible Studies using EMT Models



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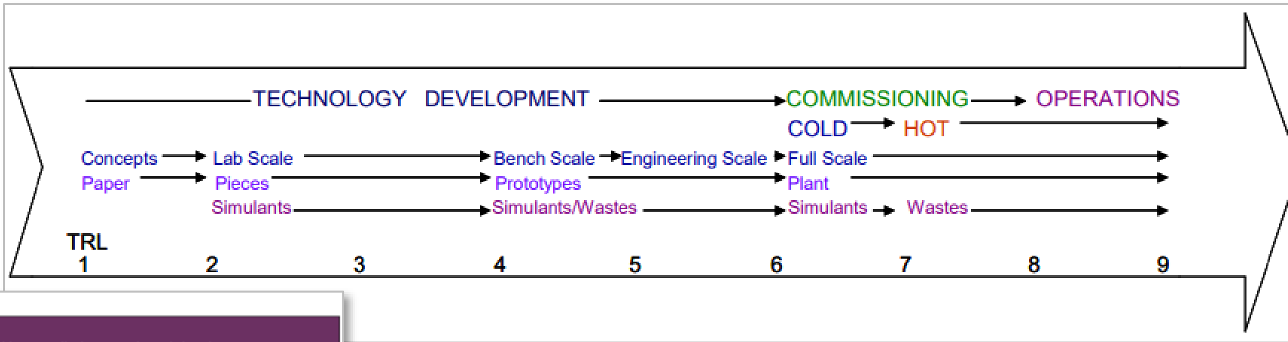
Grid Forming Inverters Technology

- Technically a TRL = 9 *(commercially available)*
- Realistically a TRL = 5ish…
  - What is it?
  - Is there a widely adopted definition?
  - How does it work exactly?
  - How is it to be modeled?
  - How is it to be studied?
  - What situations should it be deployed?
  - Are policymakers and regulators educated on its proper use?
  - How is it being incentivized or leveraged?
  - Who needs to be involved in its adoption and integration?
  - How are we handling its reliability, security, and resilience through its entire lifecycle?

Conventional Technology Readiness



Source: US DOE

Technology readiness level (TRL)	Description
1 Basic principles observed and reported	Scientific research begins to be translated into applied research and development. Examples include paper studies of a technology's basic properties.
2 Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3 Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4 Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively low fidelity compared with the eventual system. Examples include integration of ad hoc hardware in the laboratory.
5 Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include high fidelity laboratory integration of components.
6 System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in its relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7 System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requirement demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, a vehicle, or space).
8 Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9 Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: US GAO

Missing Element of Technology Readiness

Technology readiness level (TRL)	Description
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Source: US GAO

Technology Readiness Level 10

Technology fully integrated with existing systems, processes, procedures, and practices across wide range of industry sectors. All necessary stakeholders understand the technology and have the tools and capabilities needed to properly and effectively leverage the technology for actual use in real-time systems. Proper recommended practices, regulations, policies, incentives, use cases, etc., (as applicable) are established and adopted widely by industry stakeholders.

- Missing systems integration aspect of new technology
- Proving a technology in a real system is not the end, it is the beginning…

Questions and Answers

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