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Bulk Power System Reliability with Increasing Inverter Technology

NERC Inverter-Based Resource Performance Working Group Update

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ESIG Spring Technical Workshop 2021

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1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

Southern California 8/16/2016 Event

June 2017

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

Initial Distribution: June 20, 2017

NERC identified a potential characteristic exhibited by some inverter-based resources, particularly utility-scale solar photovoltaic (PV) generators, which reduces power output during fault conditions on the transmission system. An example of this behavior has been observed during recent BPS disturbances, highlighting general risks to BPS reliability. With the event and expected increase of utility-scale solar resources, the issue of this reduction in power output from utility-scale power resources needs to be actively communicated and addressed by the industry. The industry should identify reliability preserving actions in the area of power system planning and operations to reduce the system reliability impact in the event of widespread loss of solar resources during faults on the power system.

For more information, see the [1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report](#).

About NERC Alerts:

Status: Acknowledgment Received by Midnight Eastern on June 27, 2017
Responsible: Issued by Midnight Eastern on August 15, 2017

 **PUBLIC:** No Restrictions
[View on Issuance](#)

Introduction: This recommendation provides specific actions NERC registered entities must consider taking to respond to a particular issue. Pursuant to Rule 354 of NERC's Code of Practice, NERC registered entities shall: (1) acknowledge receipt of this advisory within the NERC Alert System; and (2) report to NERC on the status of their activities in relation to this recommendation as provided below. For U.S. entities, NERC will compile the responses and report the results to the Federal Energy Regulatory Commission.

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900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

Southern California Event: October 9, 2017
Joint NERC and WECC Staff Report

February 2018

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

Initial Distribution: May 5, 2018

NERC has identified a potential characteristic of inverter-based resource performance during grid faults that could present potential risks to reliability of the BPS. As the penetration of inverter-based resources (generating solar PV) continues to increase in North America, these device characteristics need to be actively communicated. This Level 2 Industry Recommendation alerts industry to these behavior characteristics observed with BPS-connected solar PV resources, and provides recommended actions to address fault ride-through and timely restoration of constant frequency by all inverter-based resources connected to the BPS.

Although this NERC alert pertains specifically to solar PV resources, the same characteristics may exist for non-PV solar PV resources connected to the BPS regardless of installed generating capacity or interconnection voltage. Owners and operators of these facilities are encouraged to consult their system manufacturers, review inverter settings, and implement the recommendations described herein. While this NERC alert focuses on solar PV, we encourage similar activities for other inverter-based resources such as, but not limited to, battery energy storage and wind resources.

For more information, see the October 9, 2017 Level 2 [Final Dispatchable Report](#).

About NERC Alerts:

Status: Acknowledgment Received by Midnight Eastern on May 8, 2018
Responsible: Issued by Midnight Eastern on July 24, 2018

 **PUBLIC:** No Restrictions
[View on Issuance](#)

¹ These resources do not have the full electric system definition, and are generally less than 75 MW per connection to transmission and voltage.

² To the extent that inverter-based resources have implemented time or requirements that are from Section 402 of the FERC, NERC requests affected solar photovoltaic resources participate in response to this alert.

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April and May 2018 Fault Induced Solar Photovoltaic Resource Interruption Disturbances Report

Southern California Events: April 20, 2018 and
May 11, 2018
Joint NERC and WECC Staff Report

January 2019

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San Fernando Disturbance

Southern California Event: July 7, 2020
Joint NERC and WECC Staff Report

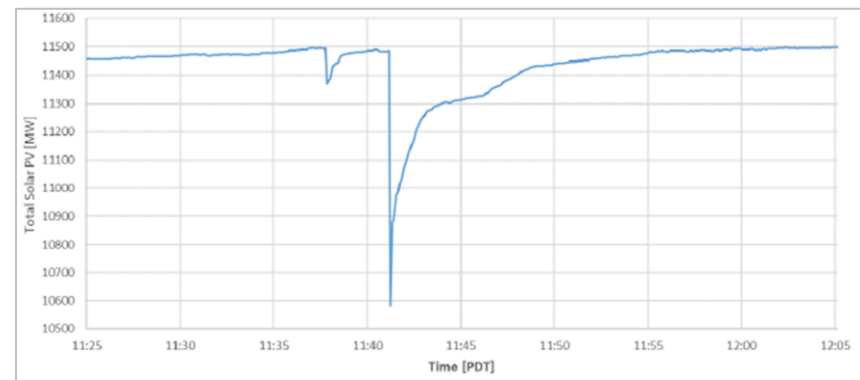
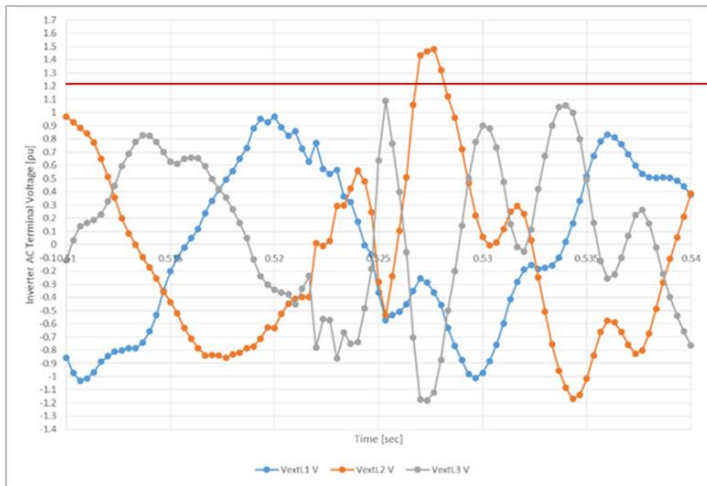
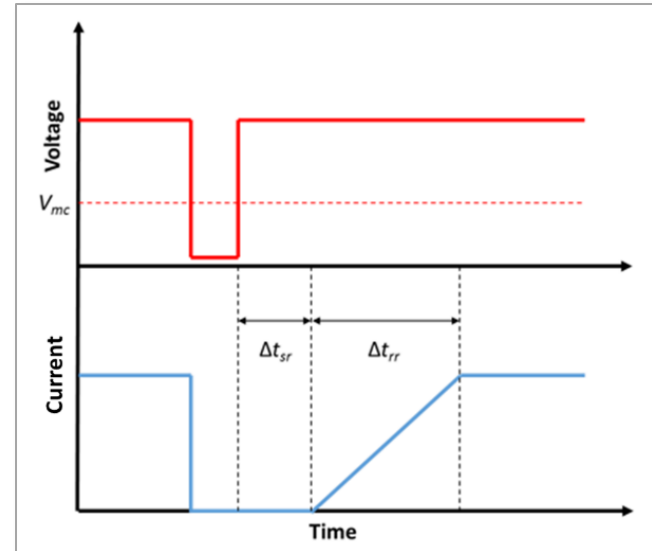
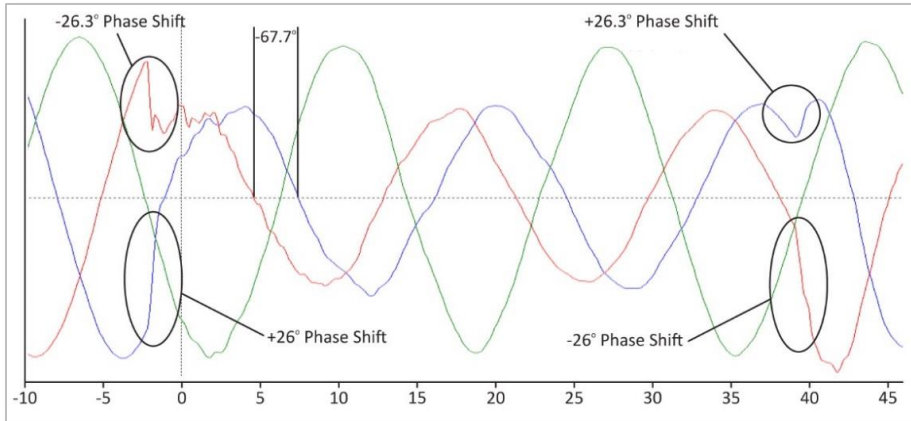
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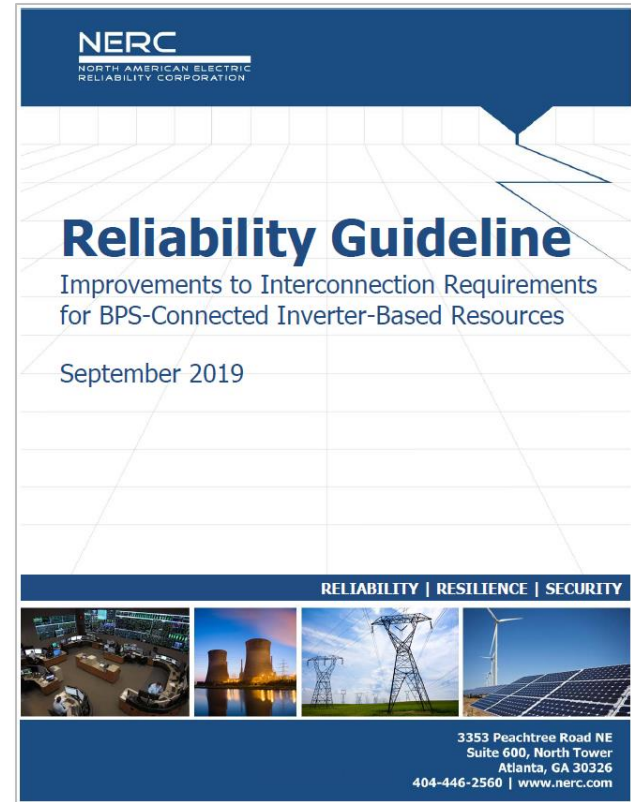
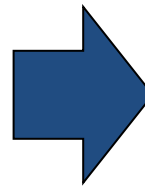
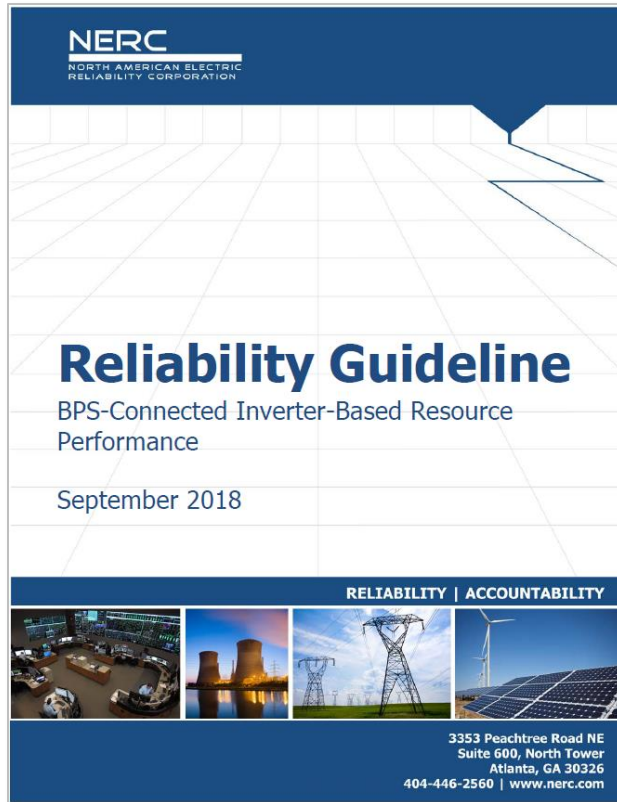
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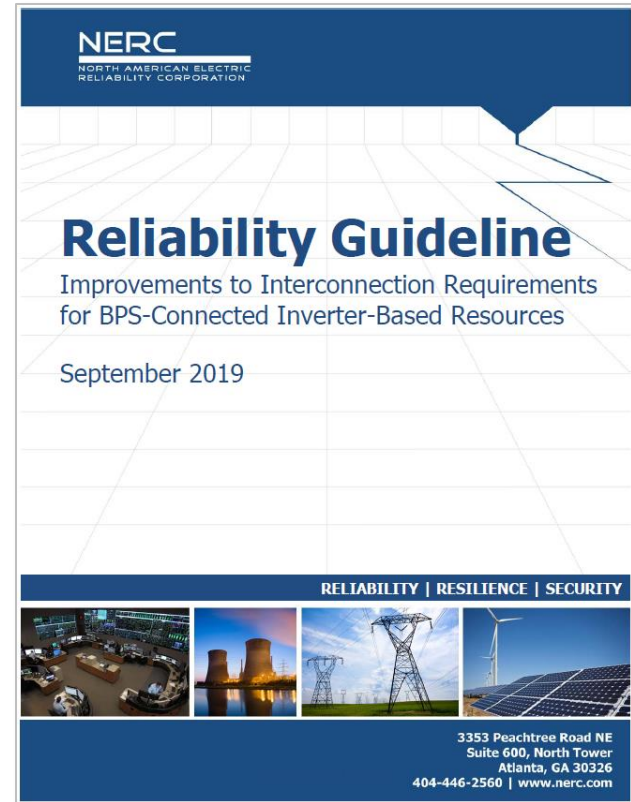
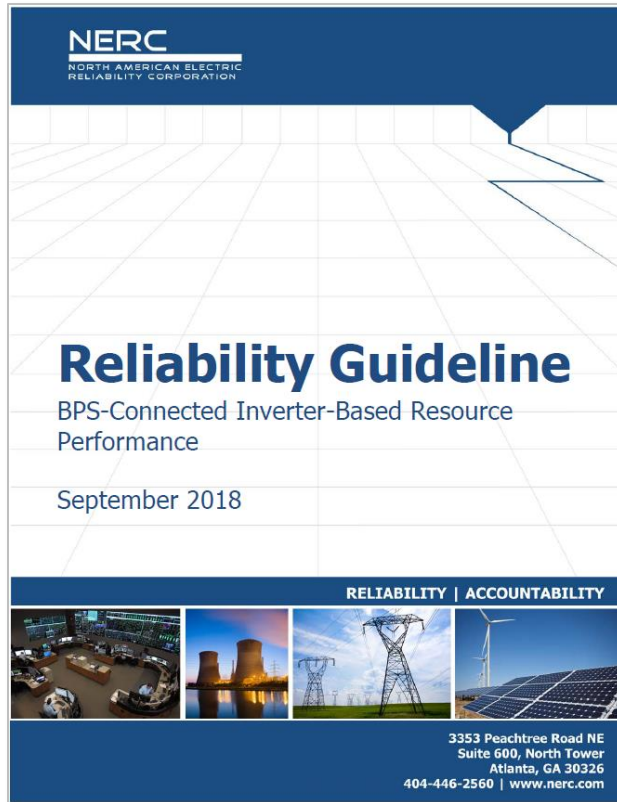


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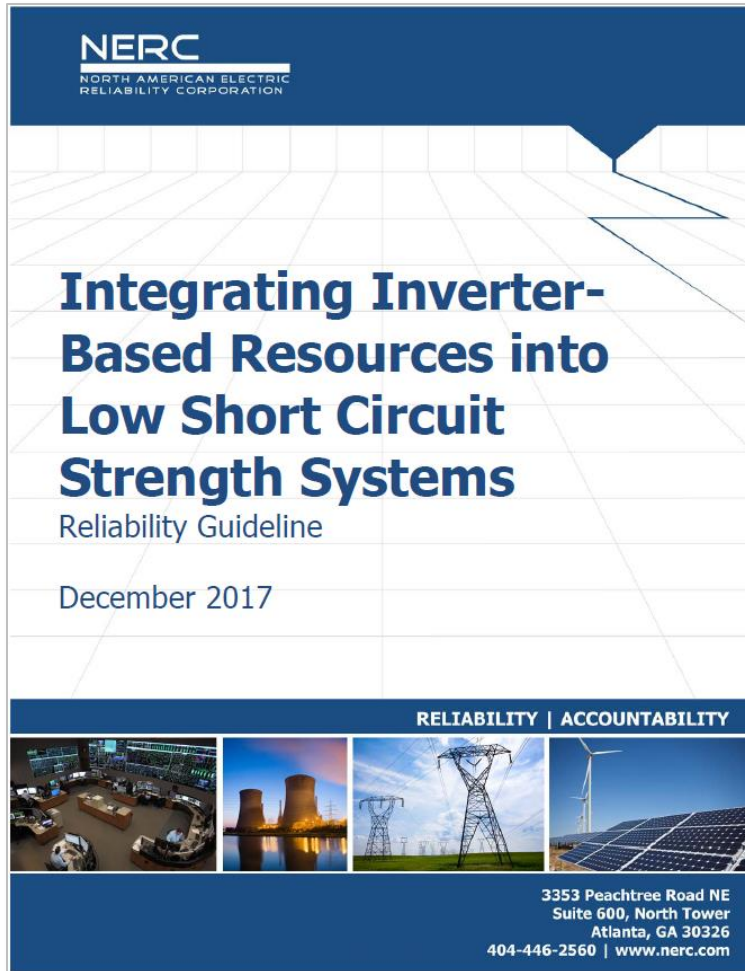
Understanding Abnormal Inverter Performance on the BPS







P2800 - Standard for Interconnection and Interoperability of Inverter-Based Resources (IBR) Interconnecting with Associated Transmission Electric Power Systems



Key Takeaways

Inverter Manufacturer and Relay Manufacturer Coordination Meeting
April 2019

NERC facilitated an in-depth technical discussion between inverter manufacturers, protective relay manufacturers, and industry experts related to current injection of bulk power system (BPS)-connected inverters during fault conditions and potential impacts and solutions for BPS protection schemes.¹ The following key takeaways, recommendations, and next steps were an outcome of this discussion.

General Takeaways

- Industry needs to collectively speak in terms of phase unbalance rather than sequence components, to better understand the underlying issues regarding current injection during faults. Sequence components are a tool for analyzing unbalanced three-phase power systems, and are derived from phase quantities.
- Protection engineers setting protective relay settings do not generally use electromagnetic transient (EMT) simulation programs. Short-circuit programs typically used by protection engineers do not accurately represent the dynamic response of inverter-based resources during the first few cycles after fault inception as the phase and sequence components.
- The injection of negative sequence current (I₂) events is beneficial for existing protection, possible, and in the future, should maintain the phases and faulted phases both in voltage and between sequence voltages and currents, and is consistent with conventional power system.
- Inverter-based resources respond to faults by controlled inverter response generally does (measurement and processing time delay) from cycles of a severe² fault, the response from in necessary sequence currents for protective setting primary protection in a heavily inverter.
- The concept of critical clearing time may need inverter-based resources continue to displace

¹ This was a follow-up to the work related to the IEEE Technical Report and Short-Circuit Performance. Available: <http://resourcecenter.ieee.org>
² Negative sequence current supports reliable BPS operation. For example, unbalanced faults (avoiding overvoltages).
³ Typically either a very low terminal voltage, severe voltage distortion
⁴ The inverter response is highly dependent on factors including fault type

IEEE Power & Energy Society
July 2018

TECHNICAL REPORT
PES-TR68



Impact of Inverter Based Generation on Bulk Power System Dynamics and Short-Circuit Performance

PREPARED BY THE
IEEE/NERC Task Force on Short-Circuit and System Performance
Impact of Inverter Based Generation

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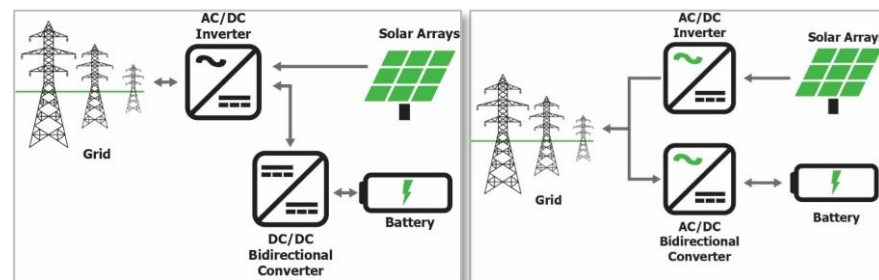
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Reliability Guideline

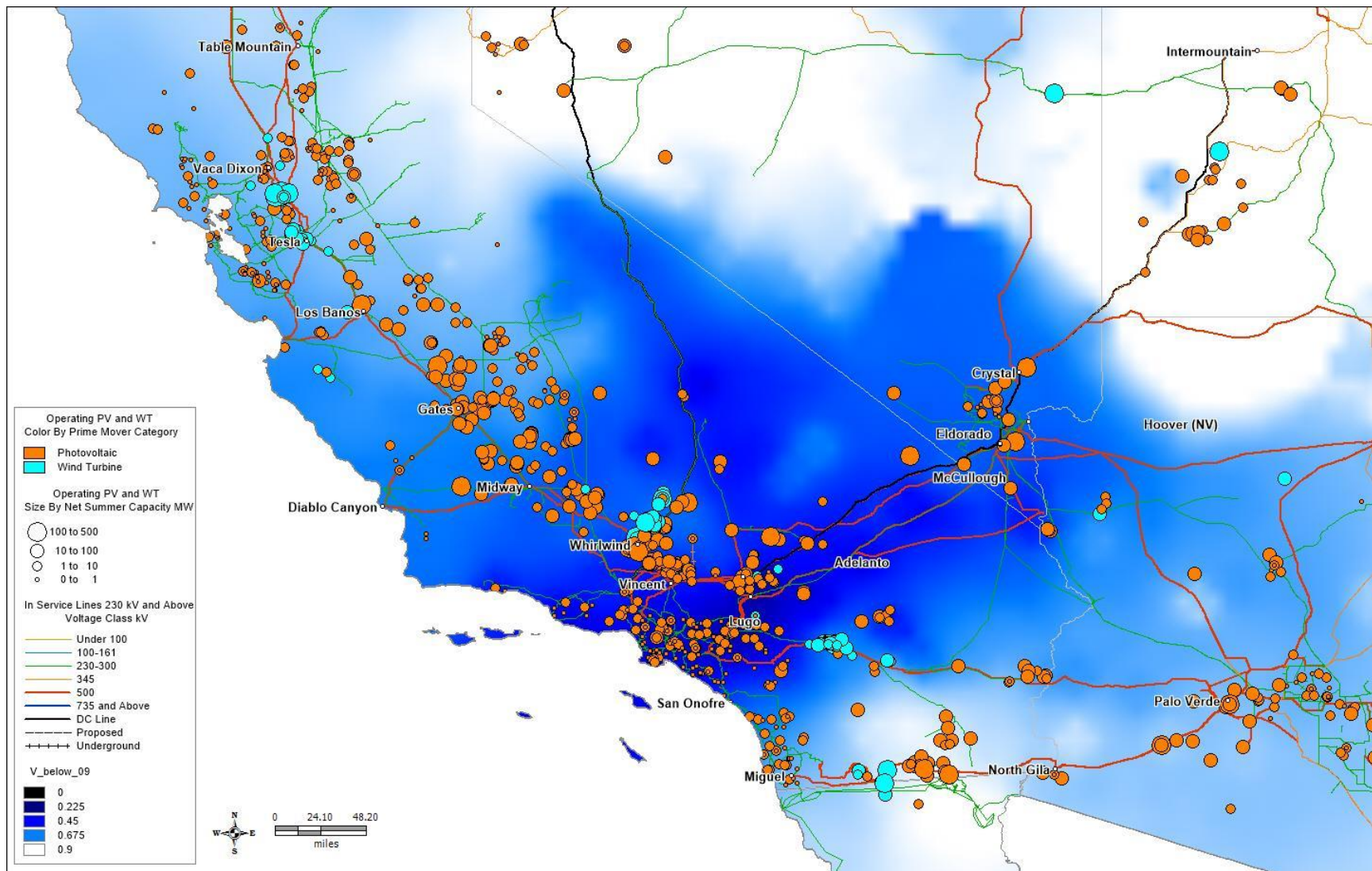
Performance, Modeling, and Simulations of BPS-Connected Battery Energy Storage System and Hybrid Power Plants

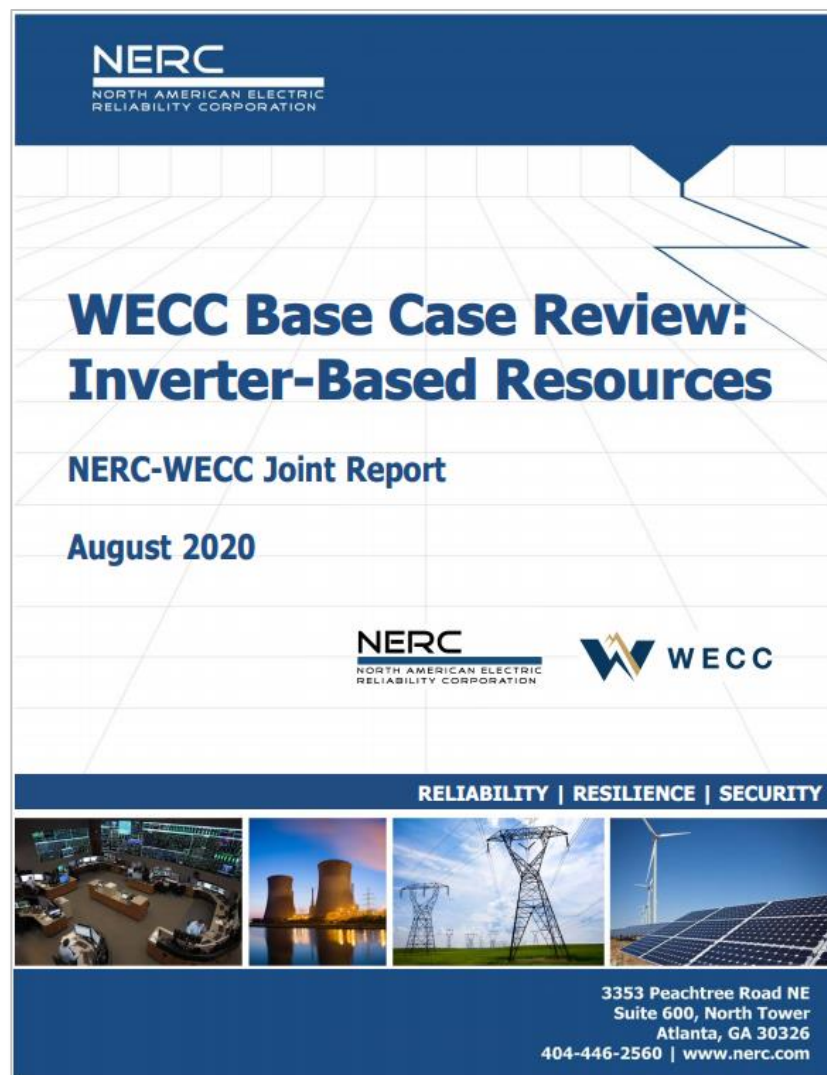
March 2020

DRAFT



Momentary Cessation – NERC Alert I





The Evolving Landscape



New Equipment and Capabilities

Maturing Equipment Standards

Evolving Inverter Technology

Tax Credits and Incentives

Climate Change Policies

Rising Cybersecurity Concerns

Wildfires and Extreme Weather

Fuel Source Interdependencies

Multi-Sector Electrification

Microgrids and Demand-Side Changes

Interconnection Study Complexity

Challenges with Data Collection

Systemic Modeling Issues

Limited Data Availability

Lack of Qualified Personnel

Disparate Requirements and Studies

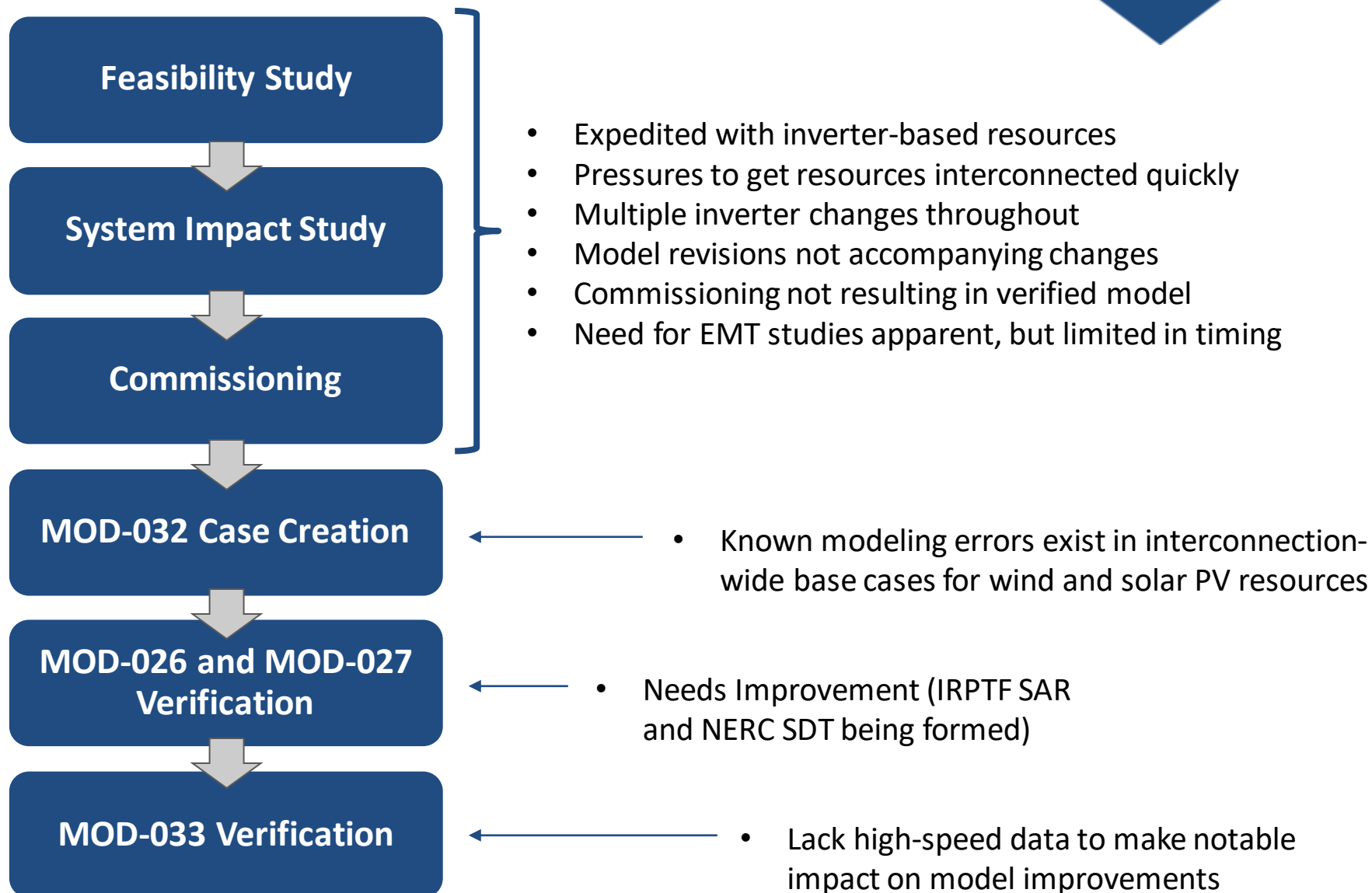
Need for Certainty in World of Variability

Growing Unknown Unknowns

Need for Energy Assurance and Resilience

Focus on Compliance Rather Than Reliability

Improvements Needed to Interconnection Process



Adapting to Change and Mobilizing Quickly Enough to Keep Up...

- Sufficient and comprehensive data collection
- Accurate and verified models
- Streamlined interconnection process
- Suitable and adequate studies prior to interconnection
- Ability to accurately identify future reliability issues
- Sufficient time to develop solutions
- Holistic solutions that create resilience
- Ensuring mitigation of boundary-spanning risks

- Are we designing an energy system that has *assurance* of its energy supply? Particularly under extreme circumstances?
- Are we planning and designing a future grid that is as *resilient* as possible?
- Are we *confident* in our resource mix to handle extreme weather and other extreme events?
- Do we *fully* understand the new technologies being presented on the market?
- Are we *configured organizationally* to even study the right things anymore?
- Are the ways in which decisions are made *relevant* in a world of variability, uncertainty, and extremes?
- Do we truly believe that our *security posture* is sufficient to handle the growing risk of cyber threats to our critical infrastructure?



Questions and Answers

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