Odessa Disturbance

NERC Event Analysis and Engineering

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Industry Webinar – October 2021

RELIABILITY | RESILIENCE | SECURITY




Opening Remarks

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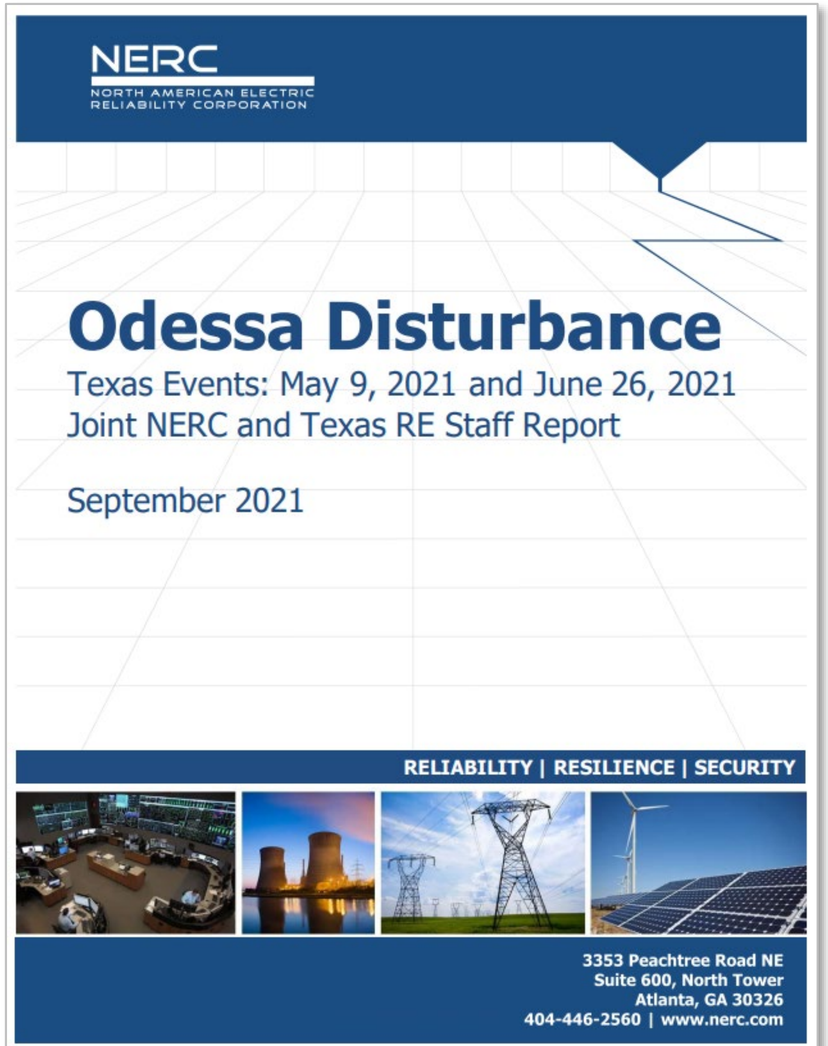
NERC Disturbance Reports and Alerts

Odessa Disturbance Report



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

Overview of Disturbances
and
Causes for Reduction of Solar PV Facilities

Analysis Process

- Situational awareness tools identified disturbance
  - Texas RE – low frequency alarm and deployment of reserves
  - NERC – FNET monitoring system
- Texas RE and ERCOT confirmed widespread solar PV reduction coincident with fault
- Registered as NERC Event Analysis Program Category 1i event
- ERCOT initiated RFIs to affected facilities
  - Follow-ups needed to clarify root causes of abnormal performance from a large number of resources after reviewing responses from the RFI
- NERC, Texas RE, and ERCOT worked jointly to engage affected GOs for facilities that reduced output **more than 10 MW**
  - ERCOT identified over 30 facilities that reduced power output

Overview of Events

May 9, 2021:

- 345 kV SLG fault (3 cycles)
  - Lightning arrester failure on GSU
- 1,340 MW loss of generation
  - 1,112 MW solar PV loss
    - 14 facilities (> 10 MW reduction)

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**

June 26, 2021:

- 345 kV SLG fault (3.5–4 cycles)
- 518 MW solar PV loss
- 5 facilities (> 15 MW reduction)

May 9 Solar PV Profile and Reduction

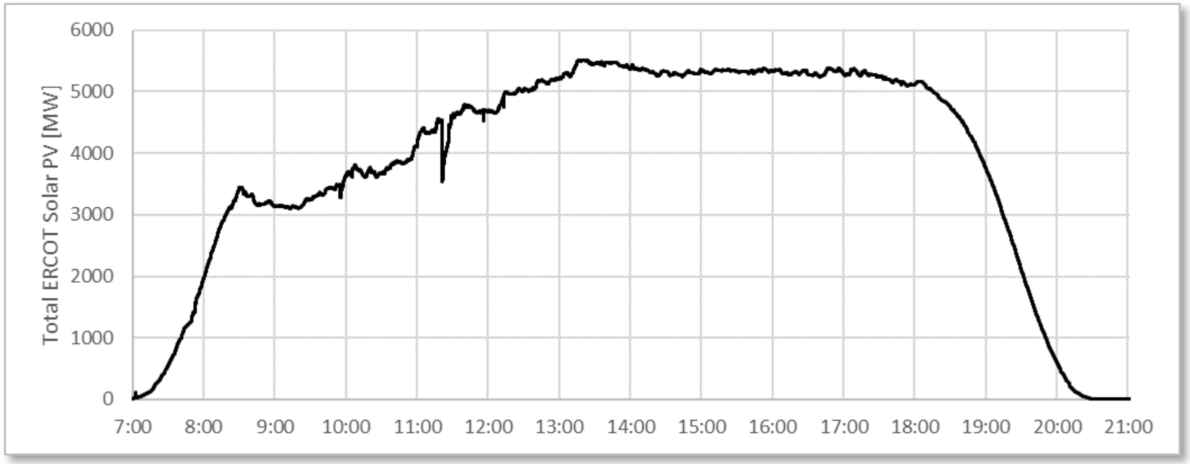
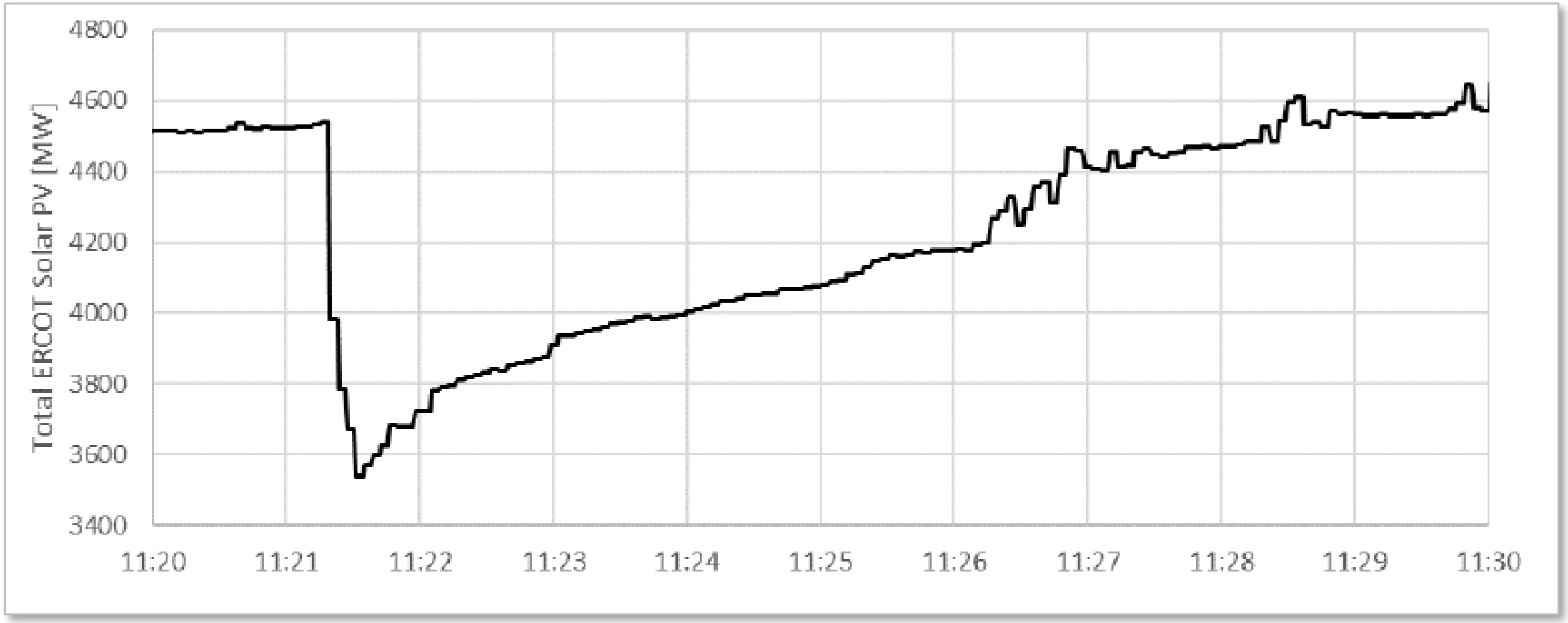


Table I.1: Predisturbance Resource Mix		
BPS Operating Characteristic	**MW**	**%**
Internal Net Demand	47,434	-
Solar PV Output	4,533	9%
Wind Output	15,952	34%
Synchronous Generation	26,383	56%

*ERCOT was importing 566 MW through dc ties

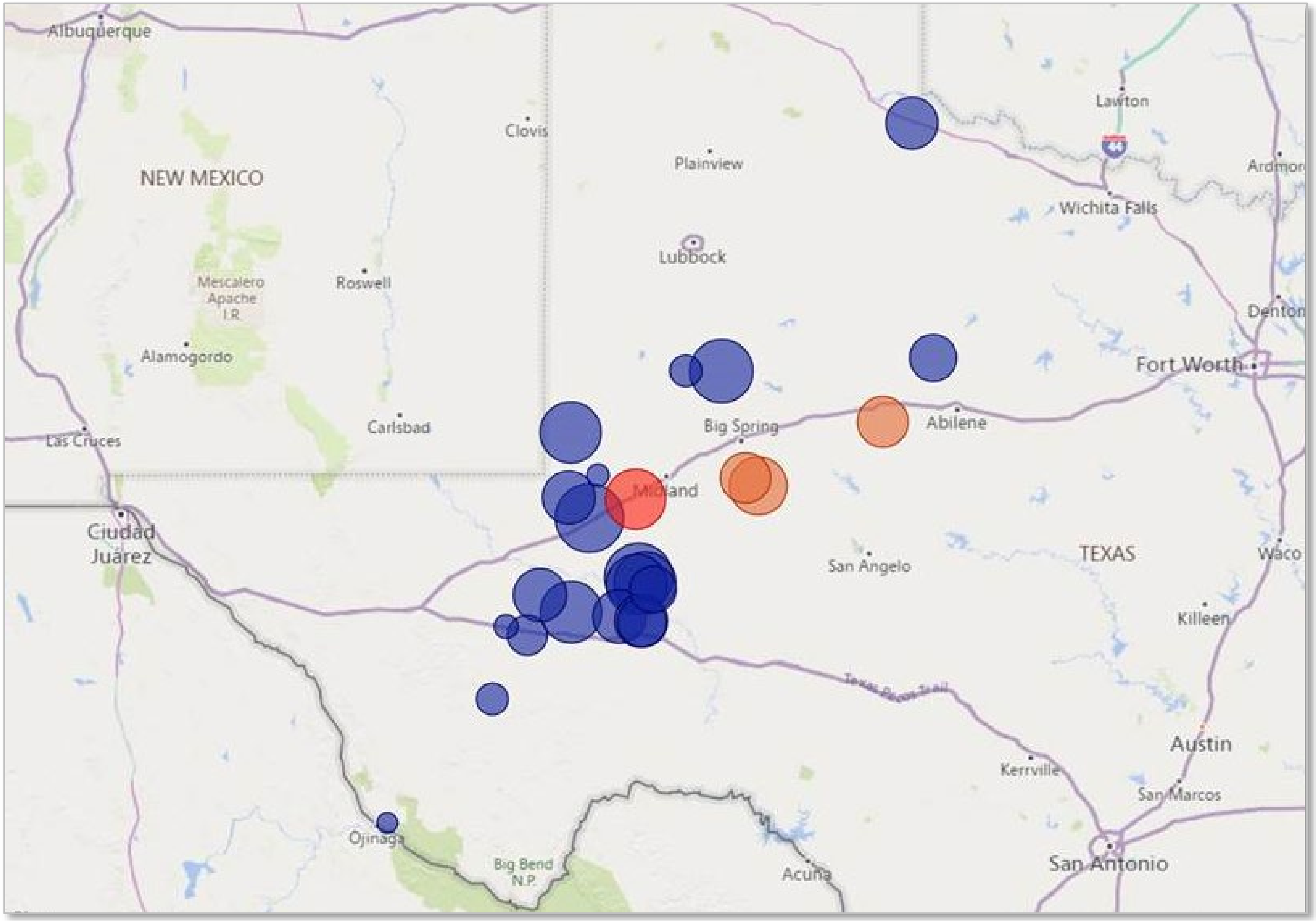


Growing Solar PV Portfolio

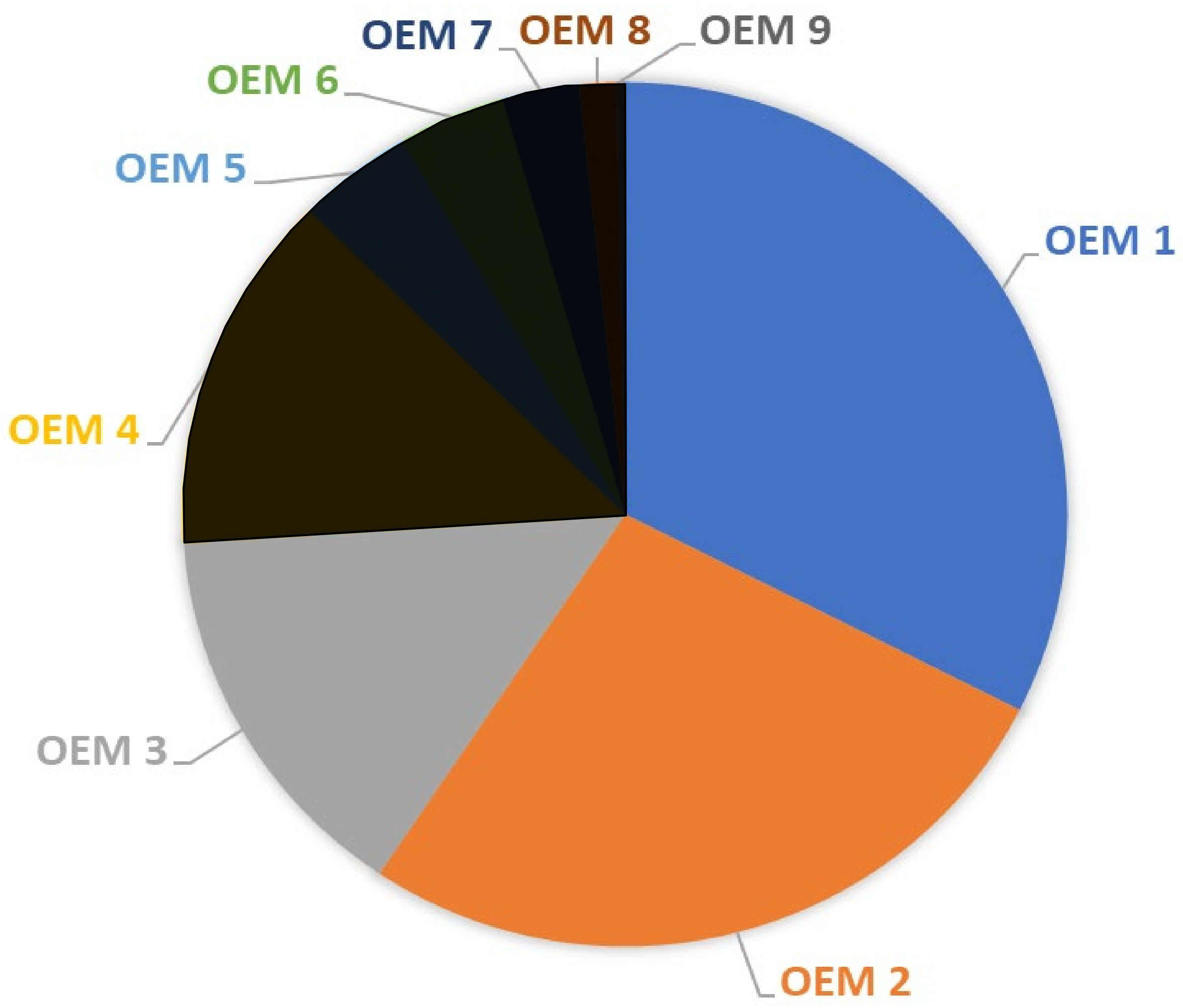
- Magnitude of reduction highlights importance of ensuring all BPS-connected inverter-based resources are operating in a manner that ensures reliable operation of the BPS

- **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

Fault Location and Affected Facilities

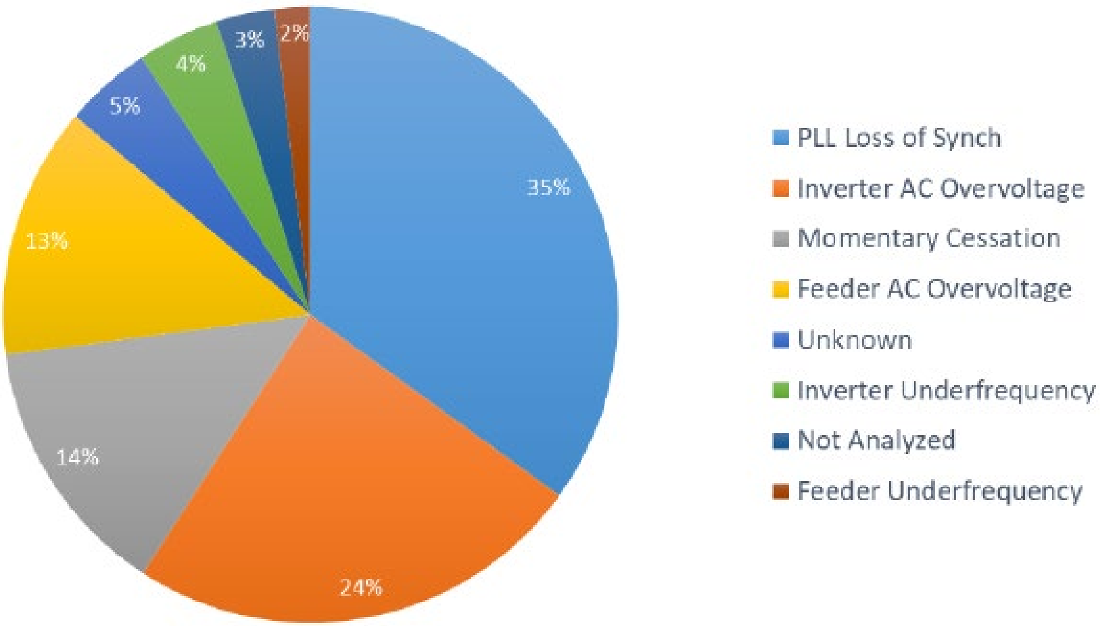


Affected Solar PV Inverter OEMs



Cause of Solar PV 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



PLL Loss of Synchronism

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PLL Loss of Synchronism	389
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- Two BES facilities – reductions of 239 MW and 150 MW
- Attributable to one inverter OEM
  - Identified in multiple prior events analyzed by NERC
  - "Tripping on phase jump protects against PLL instability"
- *Systemic concern for facilities with this inverter type*

- Existing facilities with this inverter OEM likely susceptible to tripping
  - Inverters issue fault code and shut down – function separate from "ride through settings"
  - Default setting of 10 degree voltage phase angle shift

- Inverter OEM removing this trip function from inverters at existing facilities *only upon request*; shipping newer inverters with function disabled

AC Overvoltage – Inverter-Level

Table 1.1: Causes of Reduction

Cause of Reduction	Reduction [MW]
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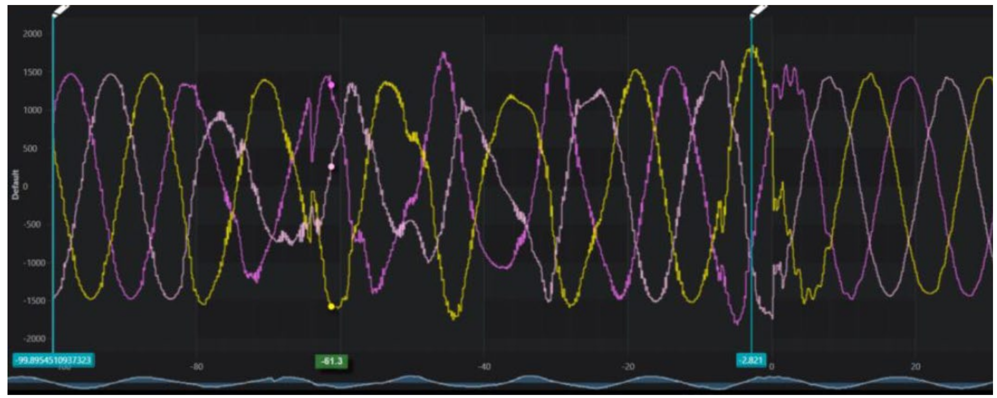

- POI oscillography data shows voltage within PRC-024-3 voltage “no trip” curve
- Inverter experiences spikes (instantaneous peak) above 1.3 pu at terminals
- 1.3 pu threshold hard-coded by OEM; separate from HVRT settings configurable by plant personnel (used to demonstrate compliance with PRC-024-3).
- Settings cannot be modified for any existing facilities
  - AC overvoltage tripping for this OEM will likely continue to occur in future
- PRC-024-3 not adequate protection to ensure IBRs ride through faults and support BPS post-fault (essential reliability service)
  - Identified in nearly all solar PV disturbances analyzed by NERC

AC Overvoltage – Feeder-Level

Table 1.1: Causes of Reduction

Cause of Reduction	Reduction [MW]
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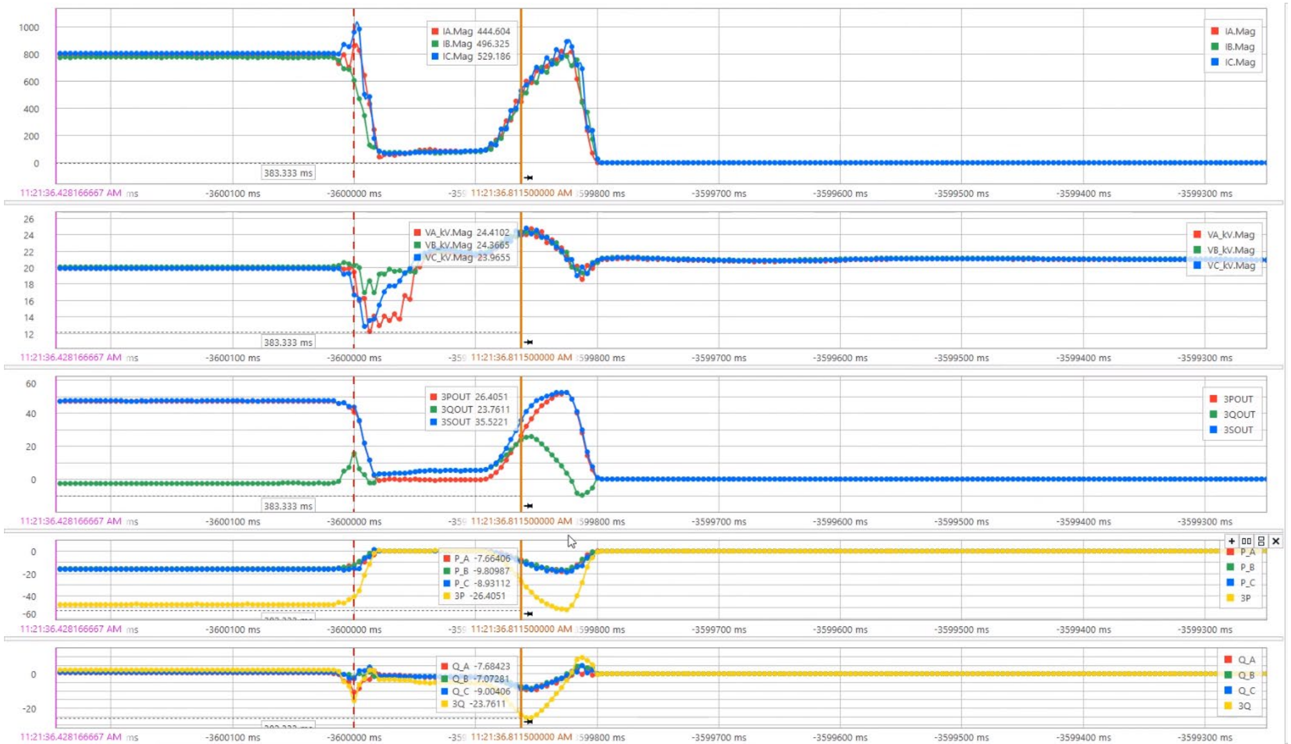

- Voltage driven high by abnormal inverter controls during and after fault
- All feeder protection at one facility set to trip on inst phase ac overvoltage
  - Set at 1.2 pu – directly on PRC-024-3 curves
- Review team questioned need for this feeder-level protection
  - Plant personnel unable to clarify what the voltage protection was protecting

Momentary Cessation

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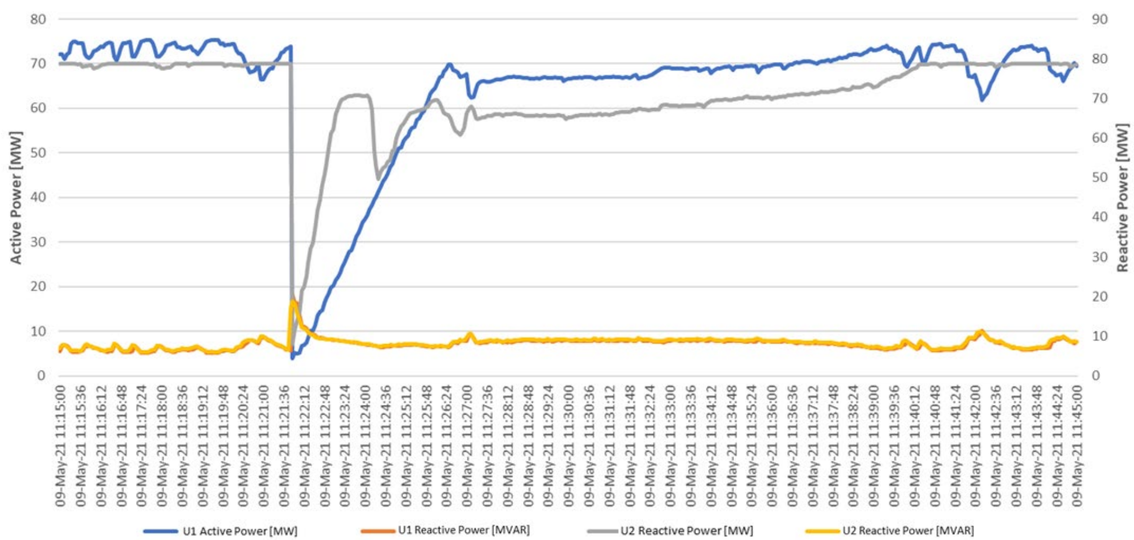

- Legacy inverters at one plant – momentary cessation below 0.9 pu voltage
  - Inverters should recover to predisturbance output relatively quickly when voltage recovers
- Plant-level controller interactions – slowed recovery to BA ramp rate limits
- Not appropriate use of these limits; negatively impacting system stability
- Not meeting recommended performance in NERC reliability guidelines

Underfrequency – Inverter and Feeder

Table 1.1: Causes of Reduction	
Cause of Reduction	Reduction [MW]
PLL Loss of Synchronism	389
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Unknown	51
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Feeder Underfrequency	21

- Inverter-Level:
  - One facility had all inverters trip on "grid underfrequency"
  - Grid frequency did not fall outside of the PRC-024-3 boundaries
  - Inverters likely erroneously tripped on a poorly measured or calculated frequency signal
- Feeder Underfrequency:
  - One feeder-level relay operated
  - NERC followed up with relay OEM to perform root cause analysis
    - Newer relay version used at this facility, set with very fast measurement window
    - Relay OEM modifying adjustable window to eliminate problem; not systemic

Other

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

Table 1.1: Causes of Reduction

- Unknown Cause (51 MW):
  - One facility had insufficient data to perform any useful root cause analysis; the cause of reduction remains unknown.

- Not Analyzed (34 MW):
  - All other combined reductions in solar PV output (not meeting ERO Enterprise analysis threshold) accounted 34 MW

Misinterpretations of PRC-024-3

```
<GRID PROTECTION> (1/3)

LEVEL & TIME
      OVR4:    125.0%
         3:    118.0%         2.00sec
         2:    116.0%         3.00sec
         1:    112.0%         5.00sec
      UVR1:     88.0%        20.00sec
         2:     70.0%        10.00sec
         3:     60.0%         5.00sec
         4:     45.0%         1.00sec
```

** The area outside the "No Trip Zone" is not a "Must Trip Zone."*

Voltage Boundary Data Points

High Voltage Duration		Low Voltage Duration	
Voltage (pu)	Minimum Time (sec)	Voltage (pu)	Minimum Time (sec)
≥1.200	0.00	<0.45	0.15
≥1.175	0.20	<0.65	0.30
≥1.15	0.50	<0.75	2.00
≥1.10	1.00	<0.90	3.00
<1.10	4.00	≥ 0.90	4.00

Table 1

- Protection set either directly or very close to PRC-024-3 boundaries
- Inverter-level protection not coordinated with POI conditions (per PRC-024-3 req’s)
- GO unsure whether inverter protection set to equipment capability or to PRC-024-3 curve
  - Consultant often hired to design station protection and not interpreting standards appropriately
  - Insufficient technical staff on site to interpret results – simply install what consultant recommends

- Systemic and significant misinterpretations of the standard
- Recent minor revisions to PRC-024-3 not fulfilling necessary resource performance
- Poorly coordinated protection systems, causing unreliable performance from solar PV resources

Major Gaps of PRC-024-3

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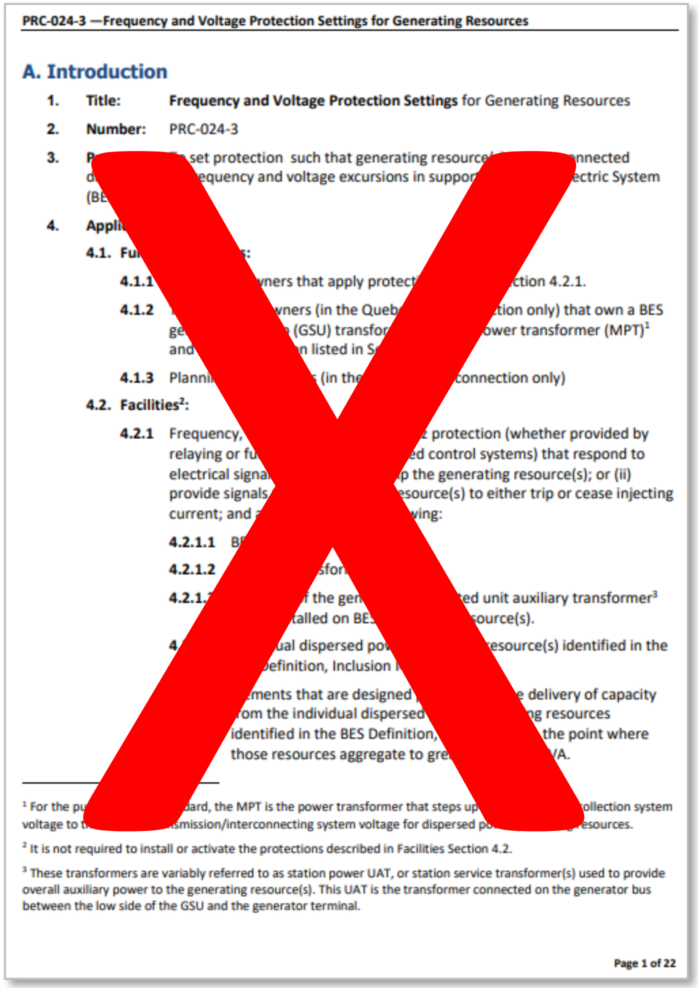
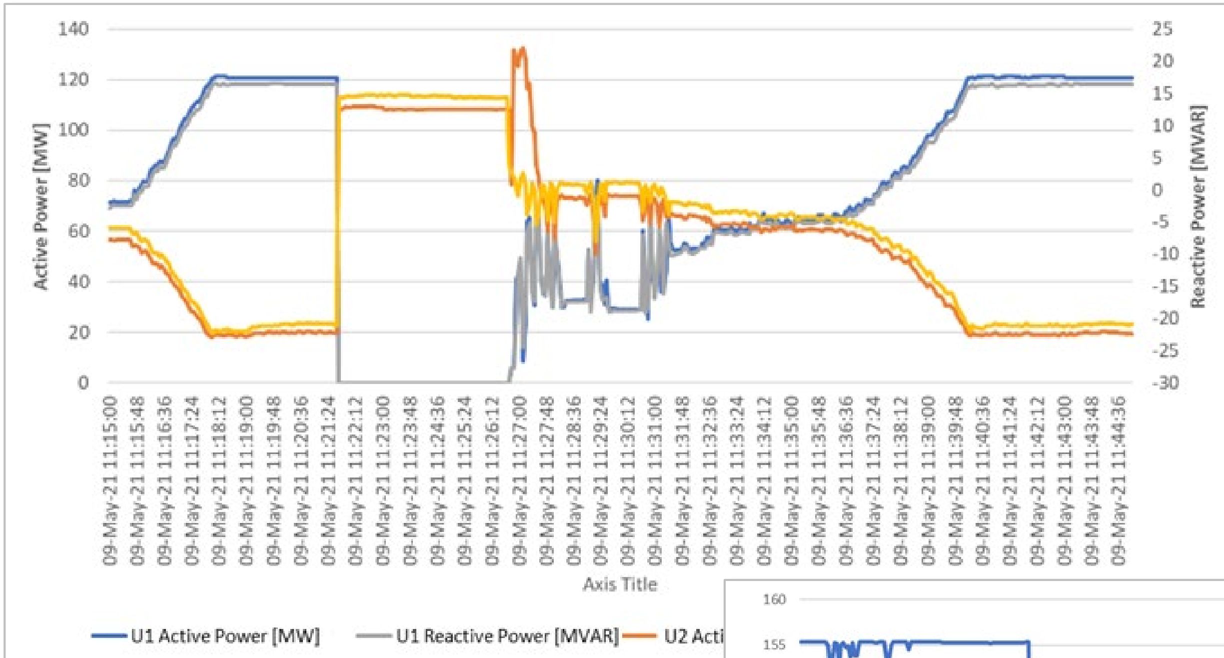
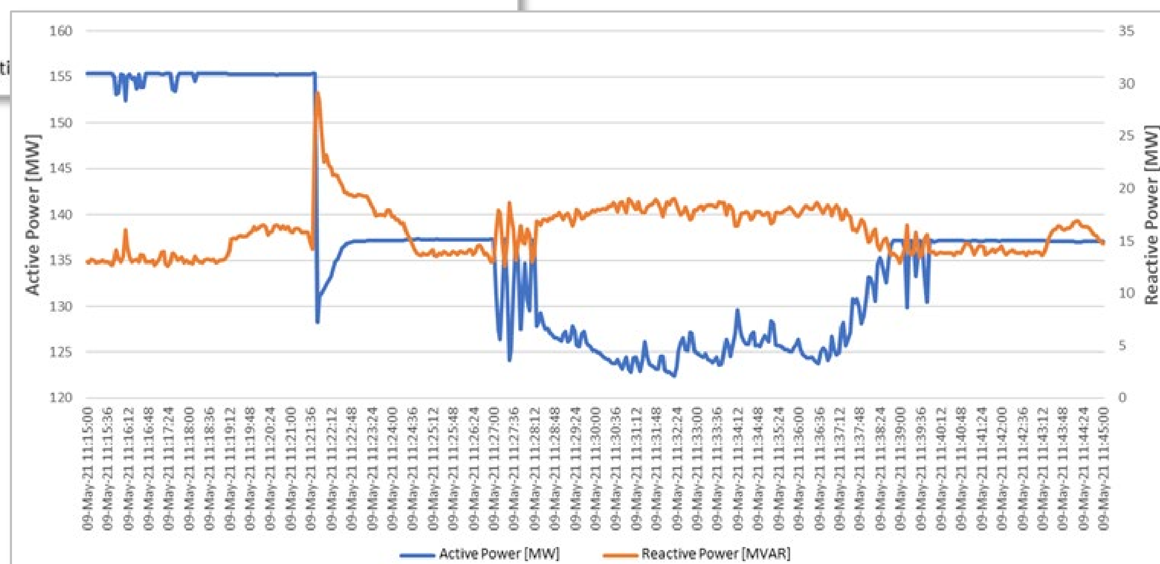


Primary Frequency Response Controls Issues





Modifications to Default Restart Times

- Most commonly, solar PV facilities experiencing a “minor fault” event undergo a 5-min disconnection with automatic restart timer and ramp back to pre-disturbance levels
  - 5-min restart observed across all solar PV disturbances analyzed by NERC
- In this event, some facilities experienced a trip and were able to return to service following the trip in a relatively short time period
  - E.g., around 30 seconds to a couple minutes
  - Demonstrates that timers can be modified and are being modified by some asset owners
- NERC Reliability Guidelines specifically cover this issue
  - *“TOs, in coordination with their BA, should specify the expected performance of inverter-based resources following a tripping event. This may include automatic reconnection after a predefined period of time or may include manual reconnection by the BA. Ramp rates during return to service conditions should be specified as well…”*
- However, ERCOT has not implemented any return to service specification following the recommendations outlined in the NERC Reliability Guideline

Updates to Misoperation Analysis

- Majority of solar PV owners and operators unaware of their abnormal performance until RC, BA, TOP, Regional Entity, or NERC identifies a widespread issue.
- Leading to more common widespread solar PV reductions to fault events than is necessary or warranted
- PRC-004-6 is unclear as to whether it requires any analysis or reporting of large reductions in inverter-based resource facilities caused by either protection or controls
- Standards revisions needed to address this lack of analysis and lack of action to mitigate these issues ahead of widespread events

June 26 Disturbance

June 26, 2021:

- 345 kV SLG fault (3.5–4 cycles)
- 518 MW solar PV loss
- 5 facilities (> 15 MW reduction)

Table C.2: Comparison of Events

Facility ID	MW Capacity	Cause of Reduction – May 9	May 9 Reduction [MW]	Cause of Reduction – June 26	June 26 Reduction [MW]
Plant I	154	Inverter tripping on instantaneous ac overvoltage	205	Inverter tripping on ac overcurrent and ac undervoltage	131
Plant J	150				129
New Plant 1	126.5	No reduction	0	"No Modules" Fault Code – Unknown Cause	113
New Plant 2	126.5				110
Plant M	155	Feeder breaker tripping on instantaneous ac overvoltage	147	Inverter tripping on instantaneous ac overvoltage tripping	143*

Discussion on Modeling and Studies
The Real Root Cause of These Events

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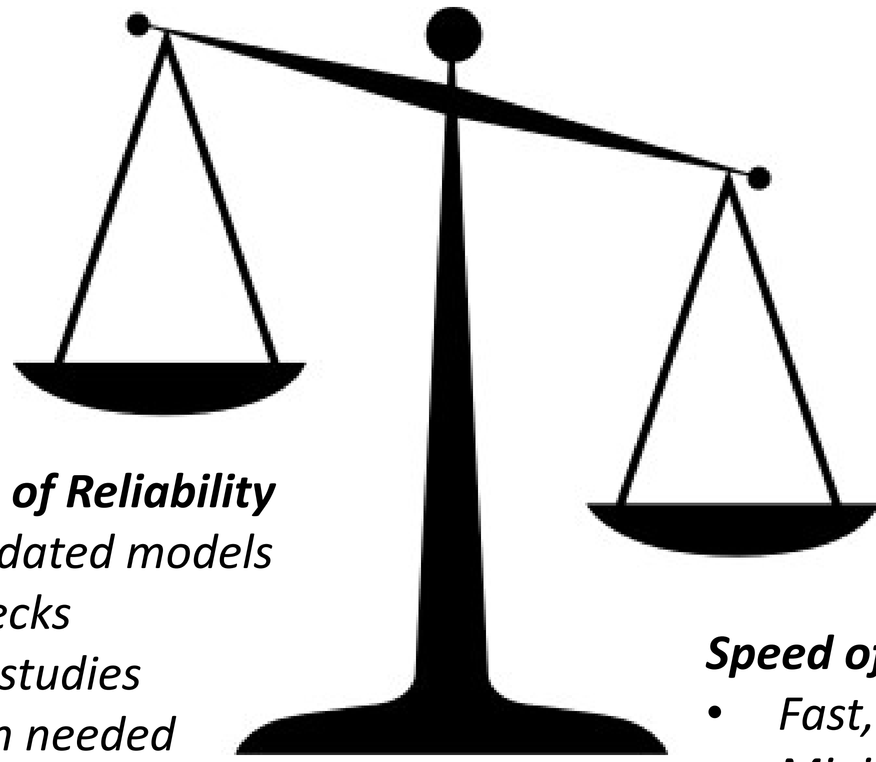
Balancing Act

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*

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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
- EMT simulations can pick up all these types of tripping
- Strong need for EMT studies moving forward

ERCOT Review of Models

Table 2.2: Positive Sequence Models for Affected Facilities		
Resource	**Standard Library Model**	**User-Defined Model**
Wind	1	2
Solar PV	16	2

Table 2.3: EMT Models for Affected Facilities		
Resource	**Available EMT Model**	**No EMT Model**
Wind	2	1
Solar PV	15	3

- ERCOT using mostly positive sequence standard library models
- ERCOT has required EMT models since 2016
  - Have EMT models for most affected facilities
- ERCOT improved model quality requirements in March 2021
  - Models received prior to this date are likely questionable in quality – detailed model quality review needed

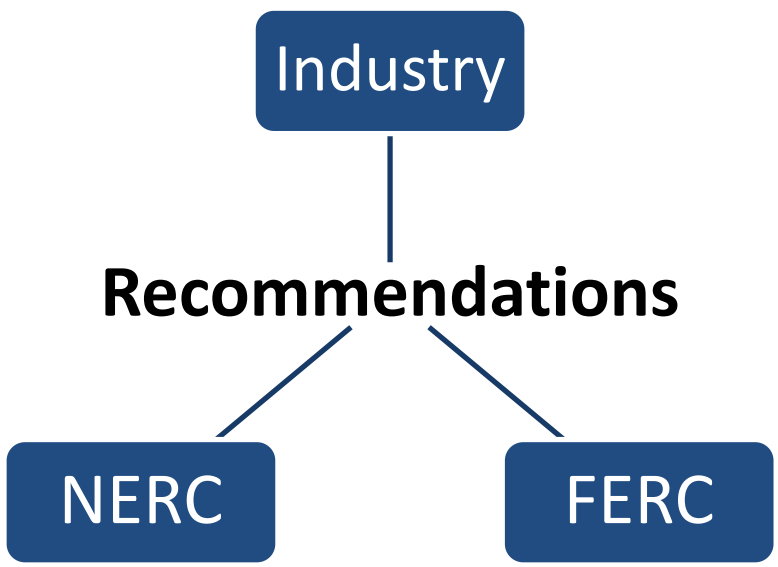
Review of Modeling Situation

- 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

NERC Recommendation

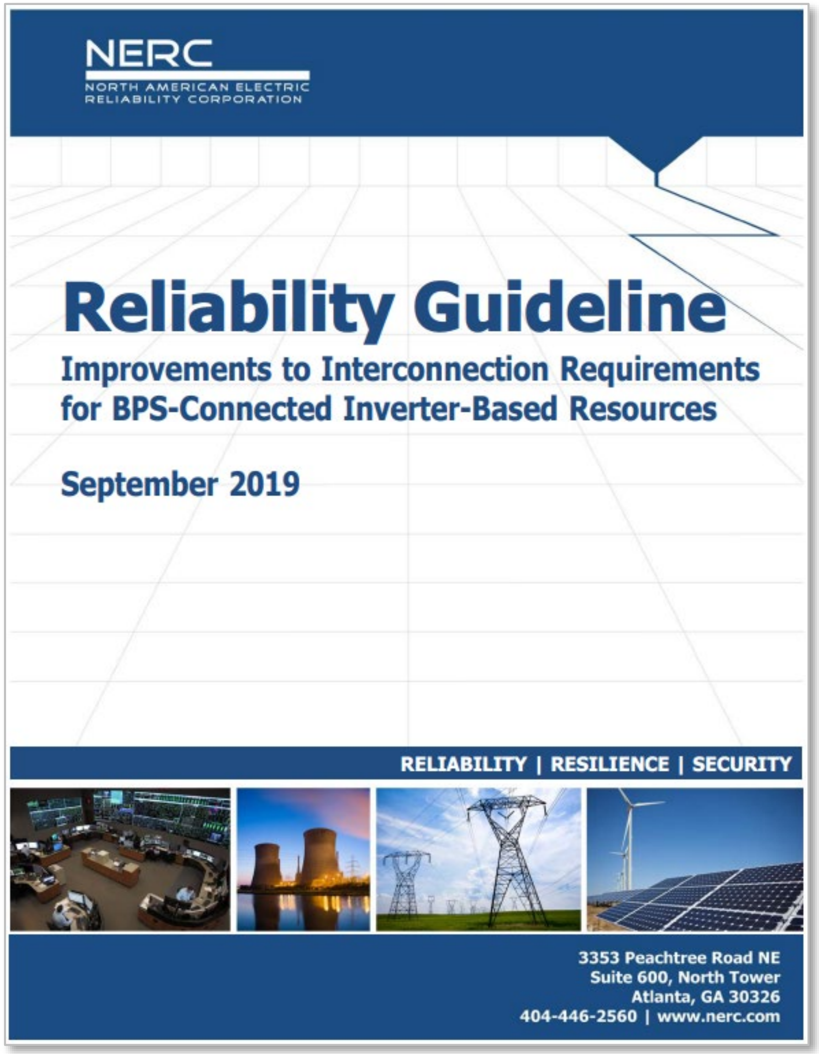
- Most causes of solar PV reduction in *all* events analyzed by NERC cannot be properly represented in positive sequence dynamic models
- High quality, vendor-specific EMT models required to identify causes of tripping
- EMT studies should be required as part of interconnection study process
  - Ensure all resources can reliably operate once connected to the BPS ***prior to*** resource being interconnected
- Resources that experience abnormal performance once connected should be subject to performance validation against submitted models
  - Discrepancies should be reported to the TP, PC, BA, RC, and NERC
  - Corrective action plans should be implemented as soon as possible
- Performance validation feedback loop should be created in a NERC Reliability Standard
  - Ensure reliable operation of BPS with growing levels of inverter-based resources

Key Findings and Recommendations



Recommendation #1: Adopt the Reliability Guidelines

- IRPWG guidelines widely known and used across industry
- However, industry not adopting recommendations contained within the guidelines (comprehensively).
- All GOs, GOPs, developers, and equipment manufacturers should adopt the performance recommendations.
- All TOs should establish (or improve) clear and consistent interconnection requirements for BPS-connected inverter-based resources
  - NERC FAC-001 and FAC-002



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Recommendation #2: Improve the FERC GIP/GIA

- Inverter-based resources are being interconnected in an unreliable manner
- Significant improvements needed to FERC Generator Interconnection Process and Generator Interconnection Agreement
- Need comprehensive requirements that must be met during interconnection process
  - Should ensure reliable operation of resources ***prior to*** commercial operation
  - Poor models, inadequate studies, gaps in performance requirements
- Needs to be addressed in GIP and GIA; should not be left up to individual interconnecting TOs using only NERC FAC-001-3

Recommendation #3: Improve NERC Reliability Standards

- Significant enhancements needed to NERC Reliability Standards to address gaps in modeling, studies, and performance of BES inverter-based resources
  - Strong technical justification based on multiple disturbance reports
- NERC strongly recommends the RSTC to ensure development of SARS to address the following performance issues:
  - Performance Validation Standard Needed
  - Ride-Through Standard to Replace PRC-024-3
  - Analysis and Reporting for Abnormal Inverter Operations
  - Monitoring Data Improvements
  - Inverter-Specific Performance Requirements

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Recommendation #3: Improve NERC Reliability Standards

- NERC strongly recommends the RSTC to ensure development of SARS to address the following modeling/studies issues:
  - Requirements for Accurate EMT Models at Time of Interconnection – Update FAC-001 and FAC-002
  - Update NERC MOD-032 to Include EMT Modeling
  - Updates to Ensure Model Quality Checks and Model Improvements

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Recommendation #4: ERCOT-Specific Follow-Ups

- Adoption of Reliability Guideline Content
- Follow-Up with all Solar PV Resources in Texas Interconnection
- Detailed Model Quality Review
- System Model Validation Effort
- Gap Analysis of Interconnection Study Process

Questions and Answers

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