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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Attachment #10.3
Return to Agenda

Blue Cut Fire and Canyon 2 Fire Disturbance Analyses

Ensuring Reliable Performance of the BPS

Rich Bauer
Associate Director Reliability Risk Management / Event Analysis

RELIABILITY | ACCOUNTABILITY




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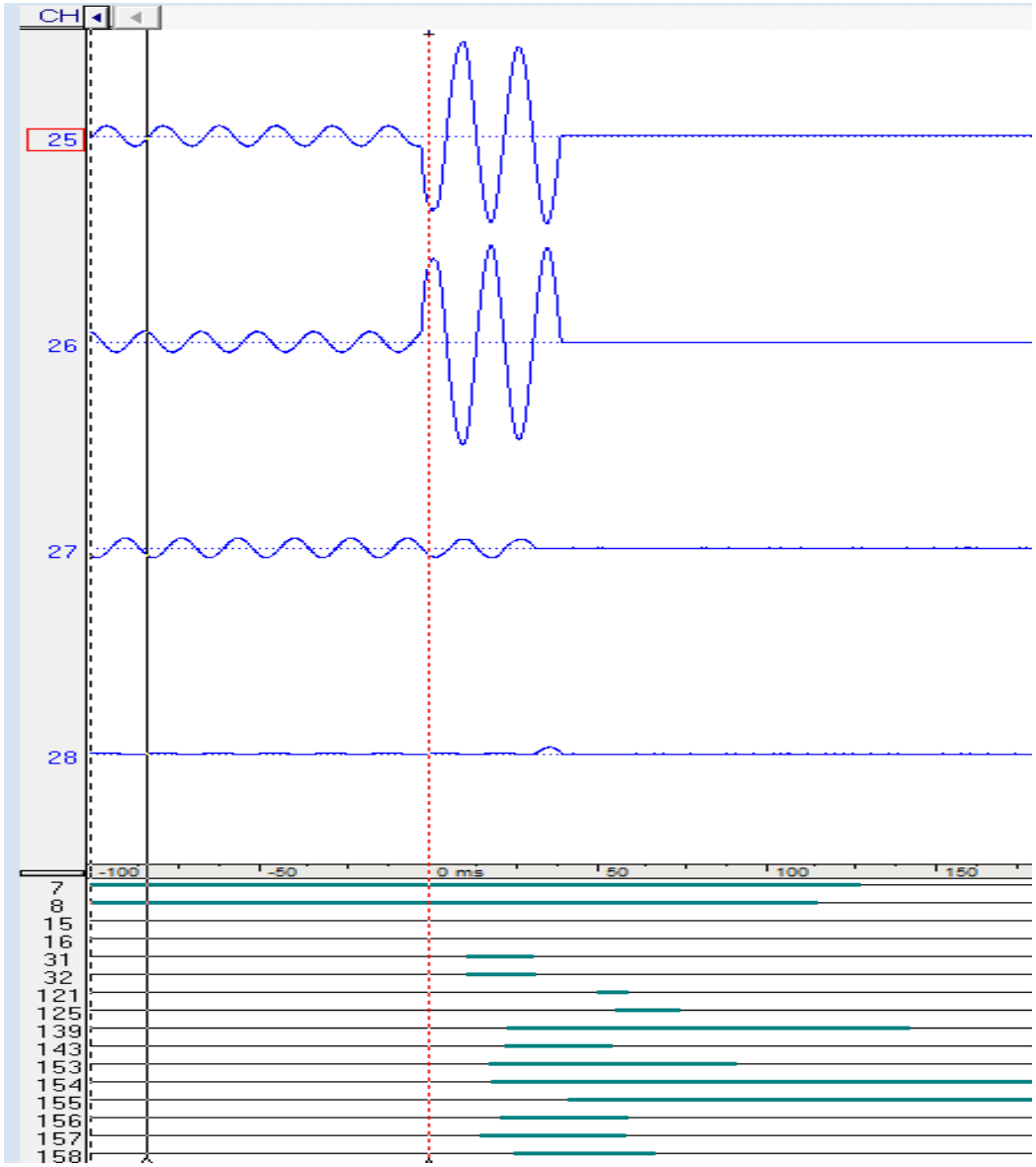
August 16, 2016
Blue Cut Fire Disturbance

Refresher on Key Findings and Recommendations

500kV Fault trace



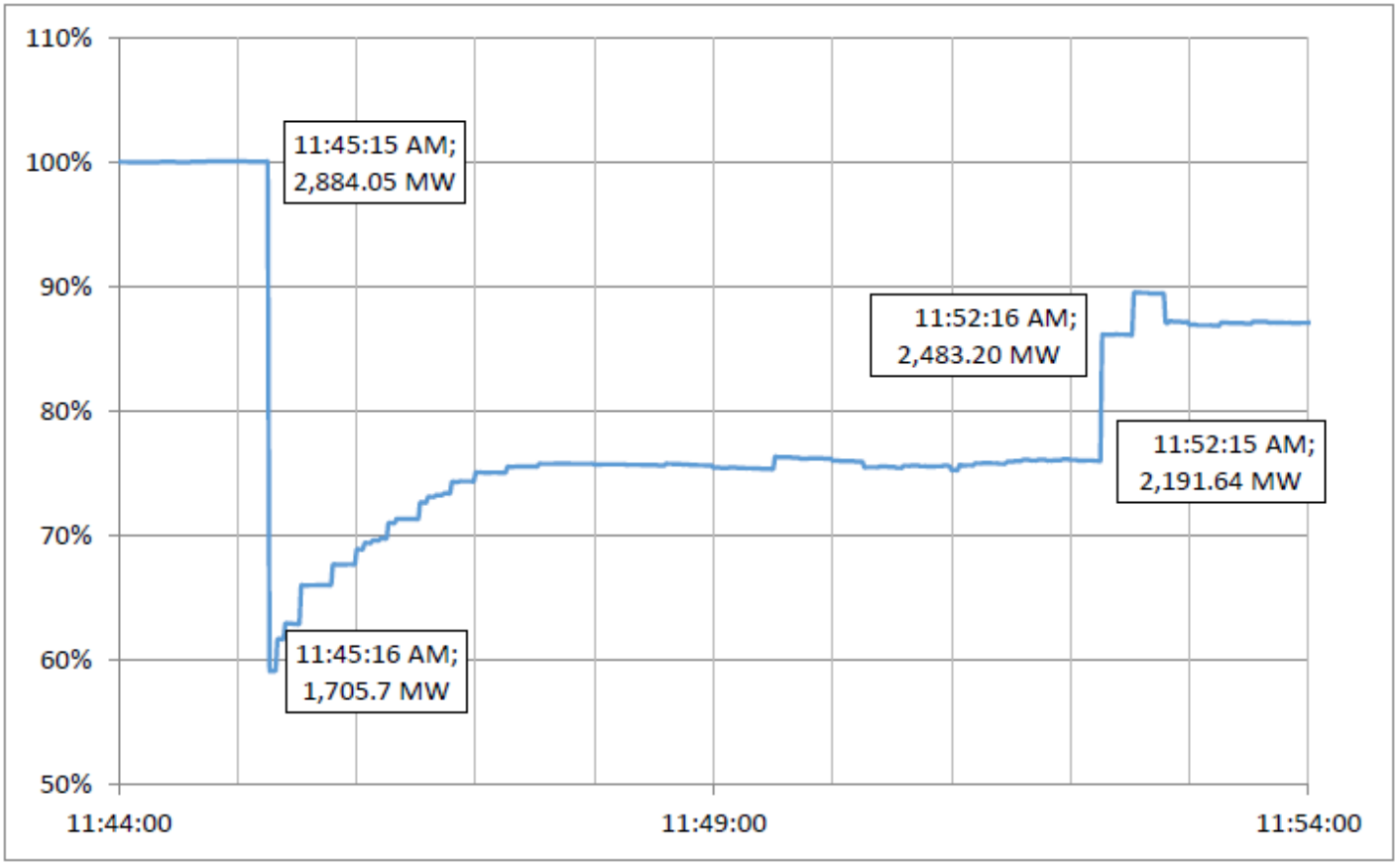
Phase A amps

Phase B amps

Phase C amps

Residual amps

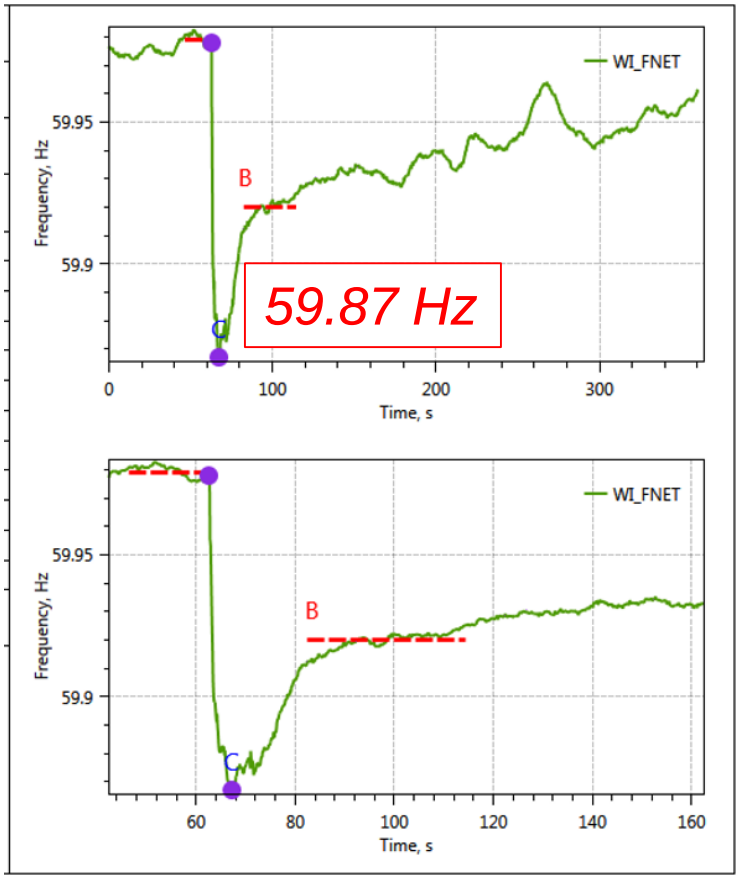
Solar Resource Loss

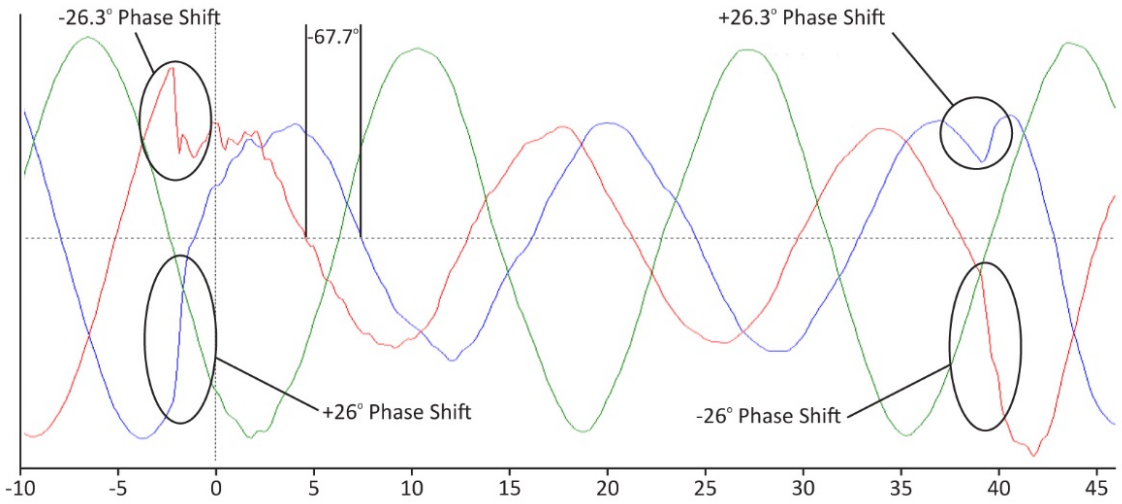


- 26 utility-scale (most at 500 kV and 230 kV) solar developments
- 10 different inverter manufacturers

Key Finding #1

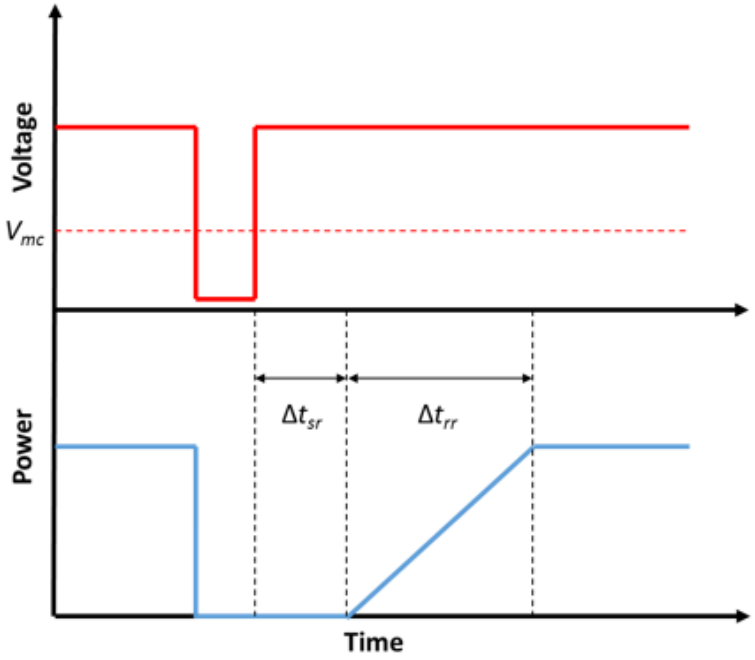
- Largest solar PV loss (~700 MW) due to underfrequency tripping
  - Inverter sensed near instantaneous frequency of < 57 Hz and tripped





Key Finding #2

- Inverters have three modes of operation:
  - **Continuous Operation:** injecting current into the grid
  - **Trip:** cease injecting current, disconnect from grid, wait ~5 mins, automatically return to service if voltage and frequency within bounds
  - **Momentary Cessation:** momentarily cease injecting current during voltages outside continuous operating range – 0.9 to 1.0 pu)



NERC Alert I

- Level 2 NERC Alert – Industry Recommendation

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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) generation, which reduces power output during fault conditions on the transmission system. An example of this behavior has been observed during recent BPS disturbances, highlighting potential risks to BPS reliability. With the recent and expected increases of utility-scale solar resources, the causes of this reduction in power output from utility-scale power inverters needs to be widely communicated and addressed by the industry. The industry should identify reliability preserving actions in the areas 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 >>

Susceptible to Erroneous Frequency Calculations?			
	MW	Responses	Inverter units
Yes	6,244	74	7,148
No	10,527	76	7,230
Total	**16,771**	**150**	**14,378**

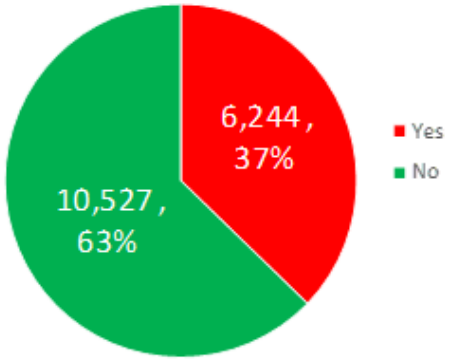


Figure 2: MW susceptible to Erroneous Frequency Calculations

Inverter cease output during abnormal voltages?			
	MW	Responses	Inverter units
Yes	14,113	119	11,821
No	2,657	31	2,557
Total	**16,771**	**150**	**14,378**

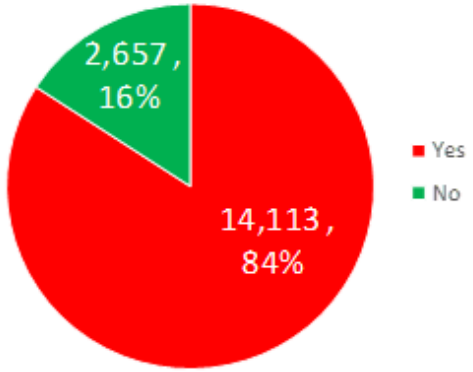


Figure 4: MW cease output during abnormal voltages

Joint Task Force Report Recommendation

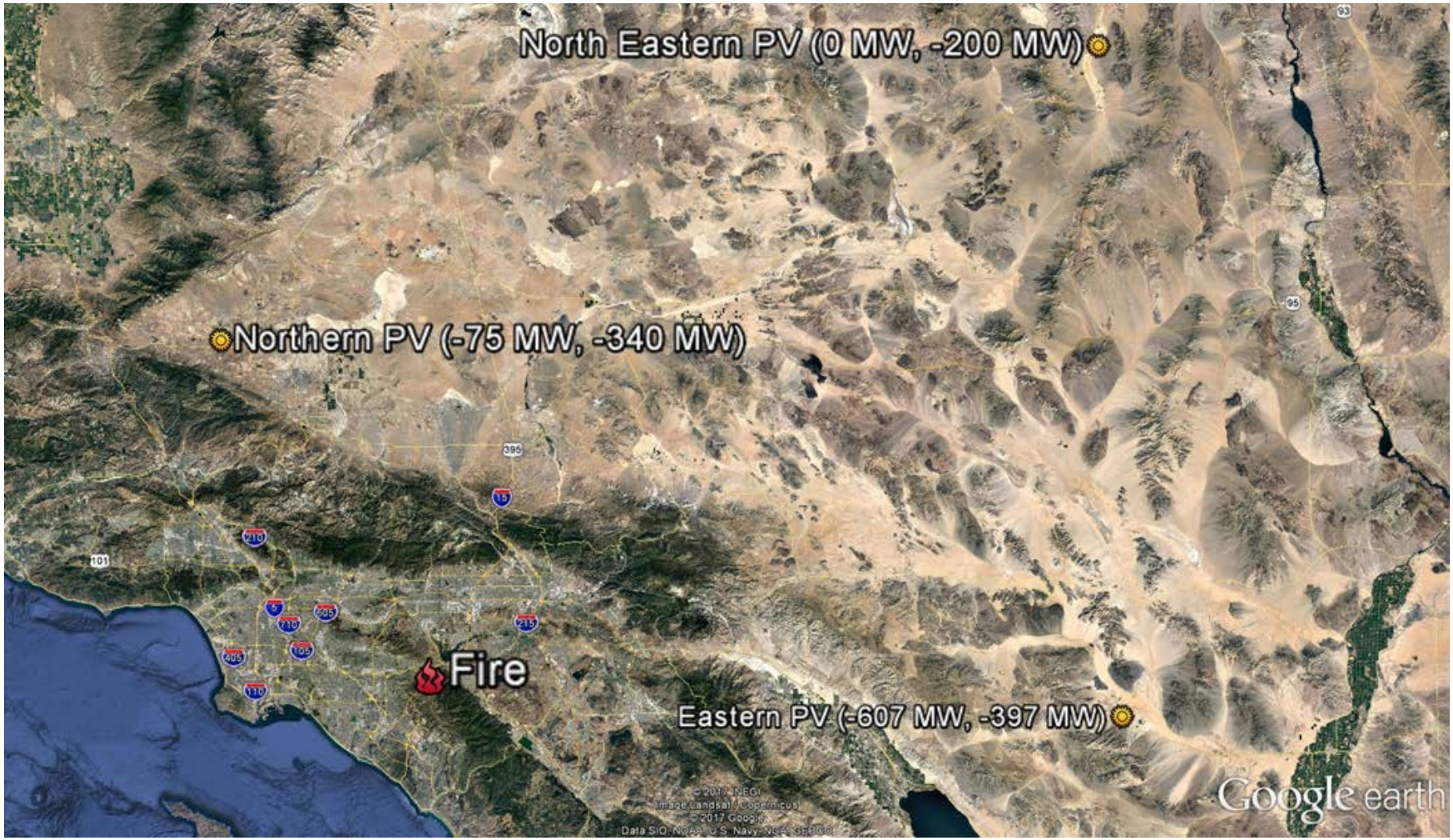
NERC should continue to perform further, in depth analysis of Momentary Cessation with higher penetrations of inverter connected resources to determine if that should be allowed for voltages less than 0.9 per unit or greater than 1.1 per unit. If current injection is required, the analysis should determine what type of current (active or reactive, positive – negative - zero sequence) should be injected at what voltage levels.

Inverter-based Resource Performance Task Force (IRPTF) created

October 9, 2017
Canyon 2 Fire Disturbance

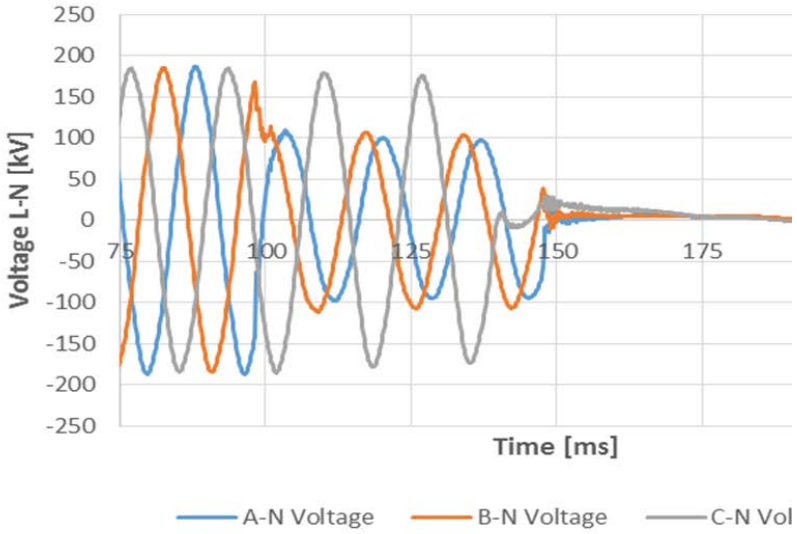
Key Findings and Recommendations

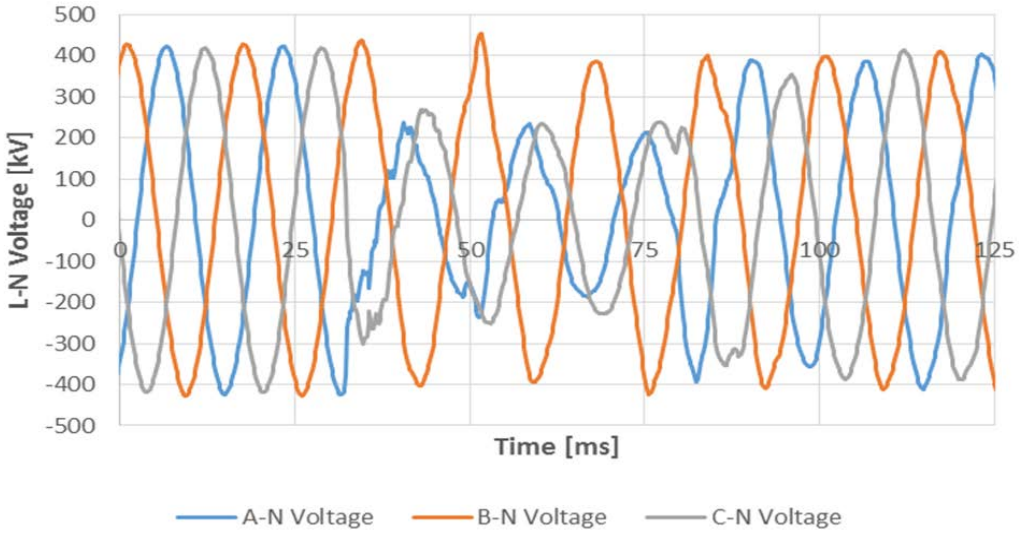
Map of Affected Area



Two Fault Events

Smoke-induced L-L fault events caused by Canyon 2 Fire…
Both fault cleared normally…

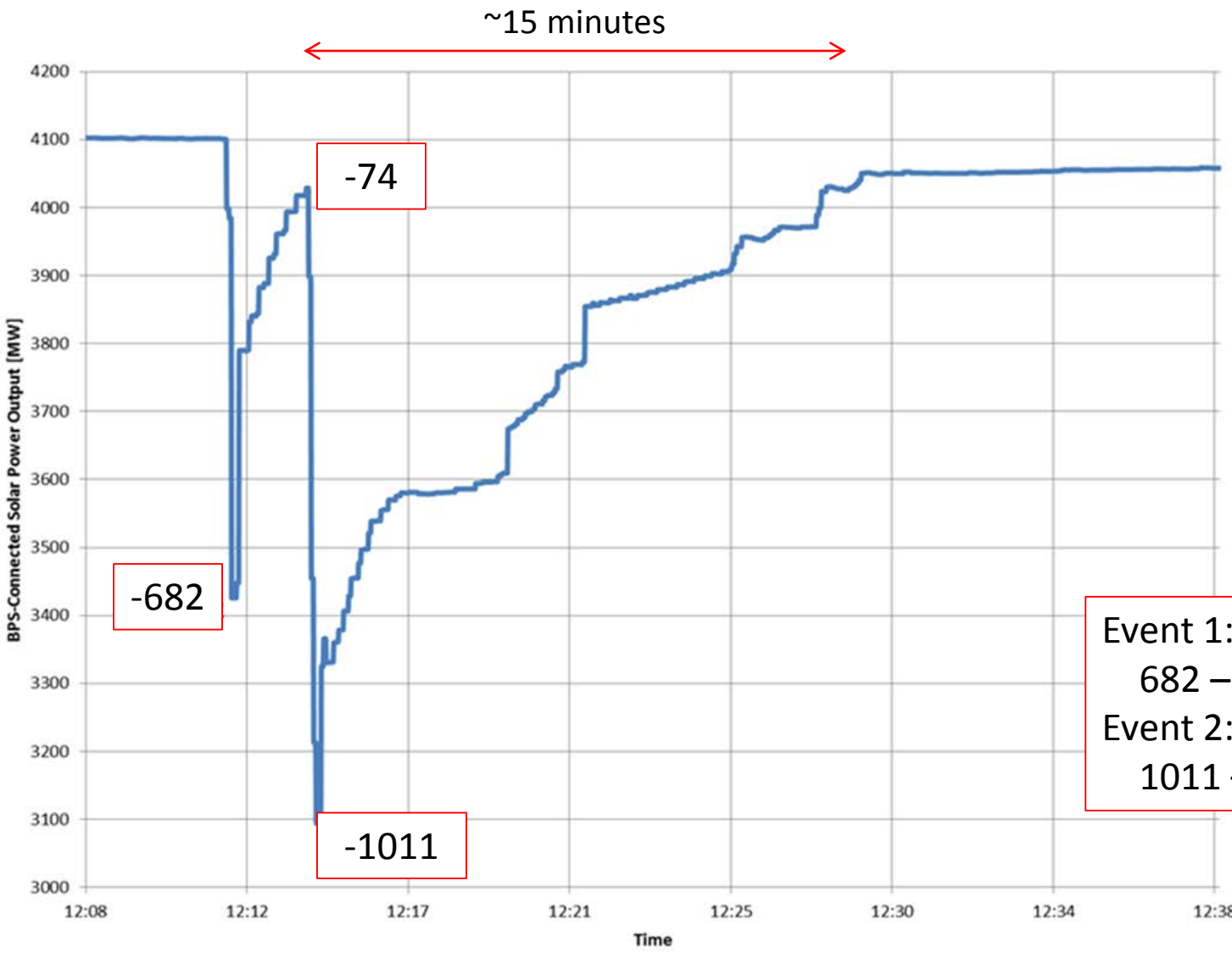




<u>Fault Event 1:</u>
220 kV
L-L Fault
< 3 cycle clearing

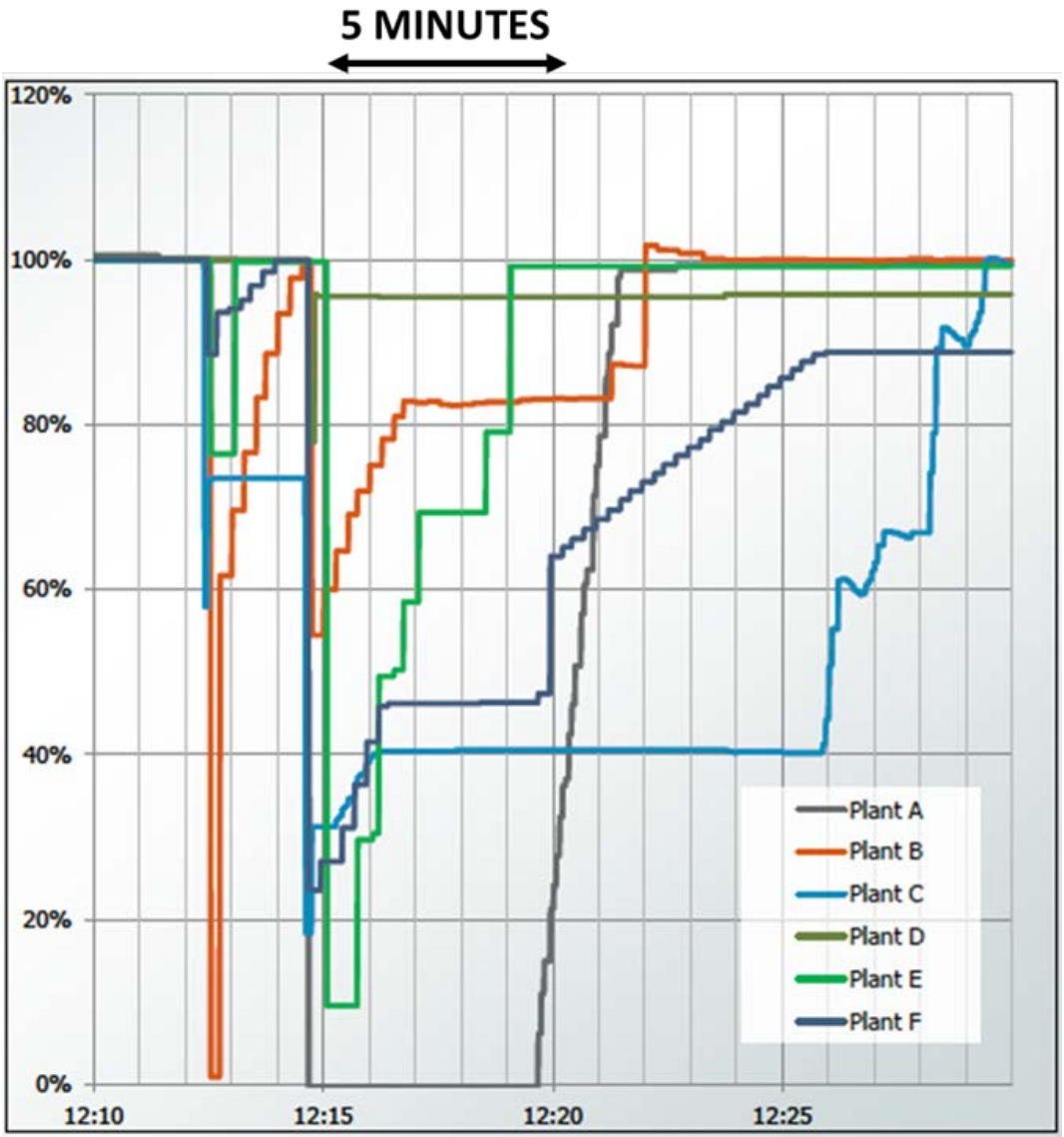
<u>Fault Event 2:</u>
500 kV
L-L Fault
< 3 cycle clearing

Aggregate SCE Solar PV Performance SCADA Data



Event 1:
682 – 0 = 682 MW
Event 2:
1011 – 74 = 937 MW

Solar PV Outputs



Key Findings

1. No erroneous frequency tripping
2. Continued use of momentary cessation
3. Ramp rate interactions with return from momentary cessation
4. Interpretation of PRC-024-2 voltage ride-through curve
5. Instantaneous voltage tripping and measurement filtering
6. Phase lock loop synchronization issues
7. DC reverse current tripping
8. Transient interactions and ride-through considerations

Key Findings #1

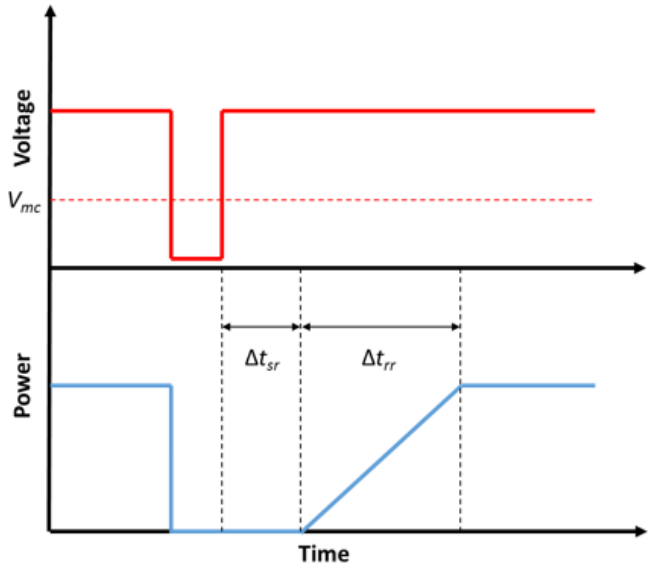
No erroneous frequency tripping

- Alert recommended GOPs and GOs ensure inverter controls do not erroneously trip on instantaneous frequency measurements
- By October 9, 2017 event, 97% of inverter manufacturer's BPS-connected fleet had been updated
- Mitigating actions by inverter manufacturer and GOs appear to have worked

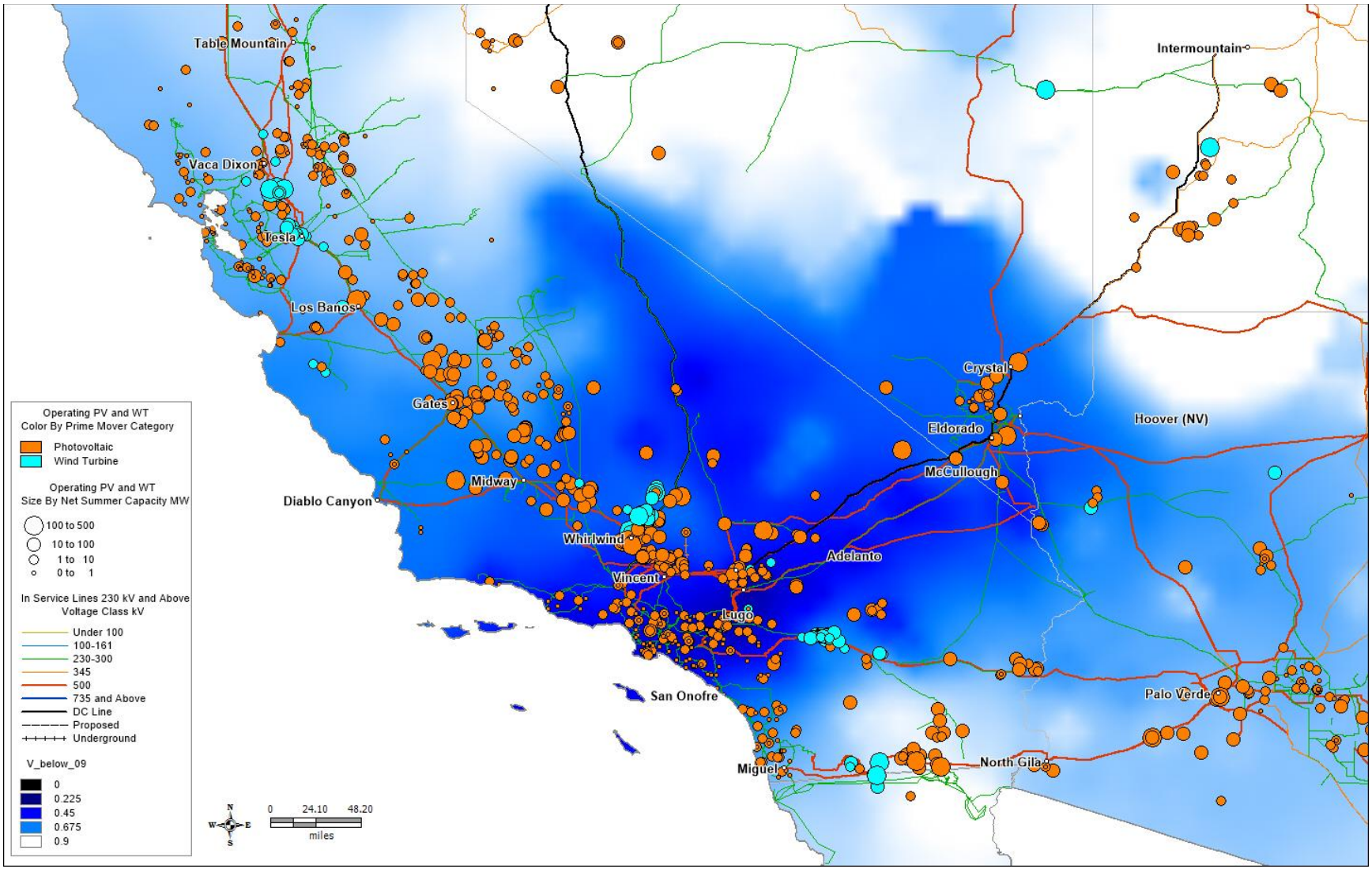
Key Findings #2

Continued use of momentary cessation

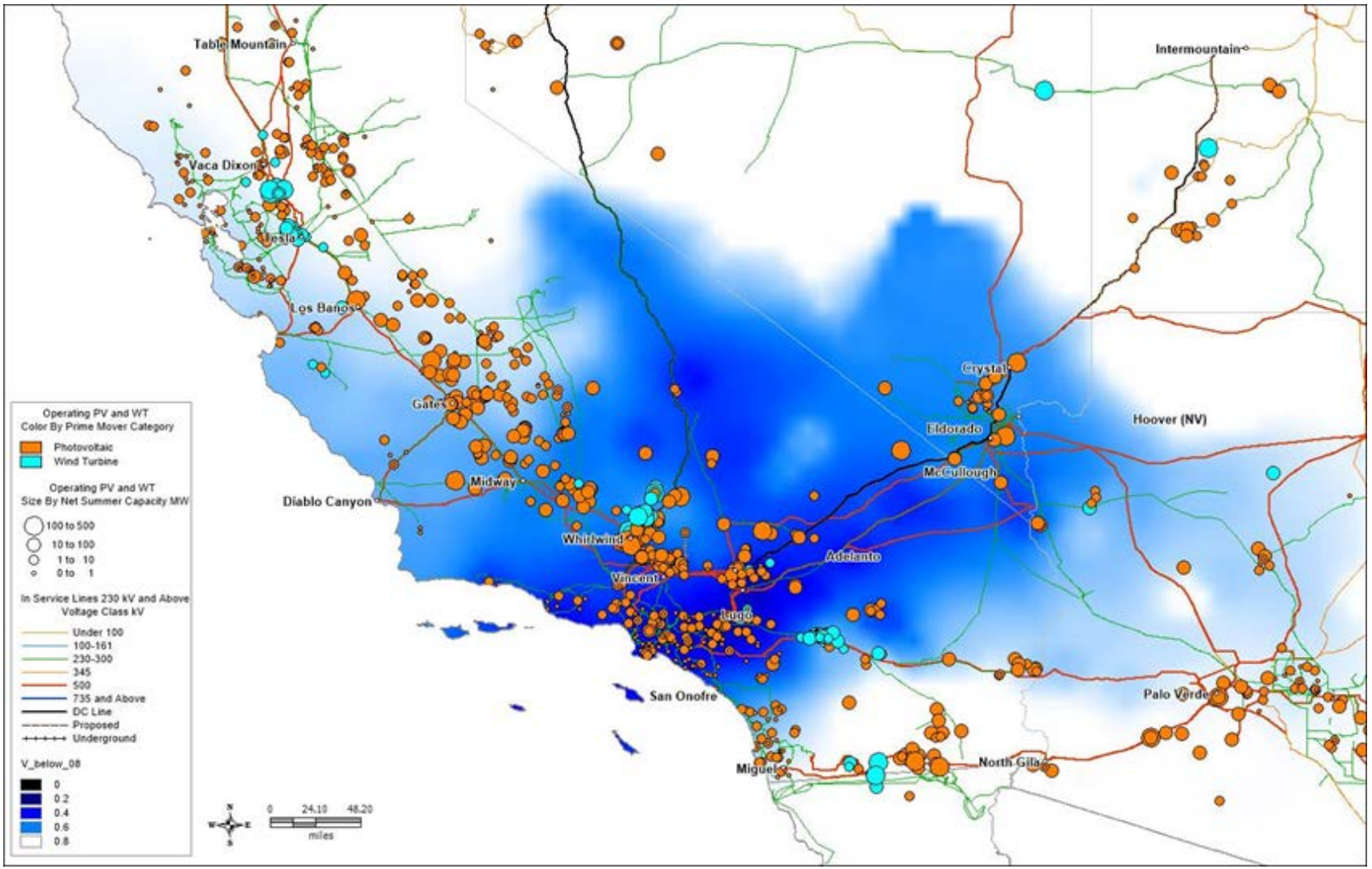
- Most inverters use momentary cessation (V < 0.9 pu)
- Recovery of current following momentary cessation varies, relatively slow for grid dynamics
- Blue Cut Fire recommendation – interim solution
- NERC IRPTF studies – new recommendation



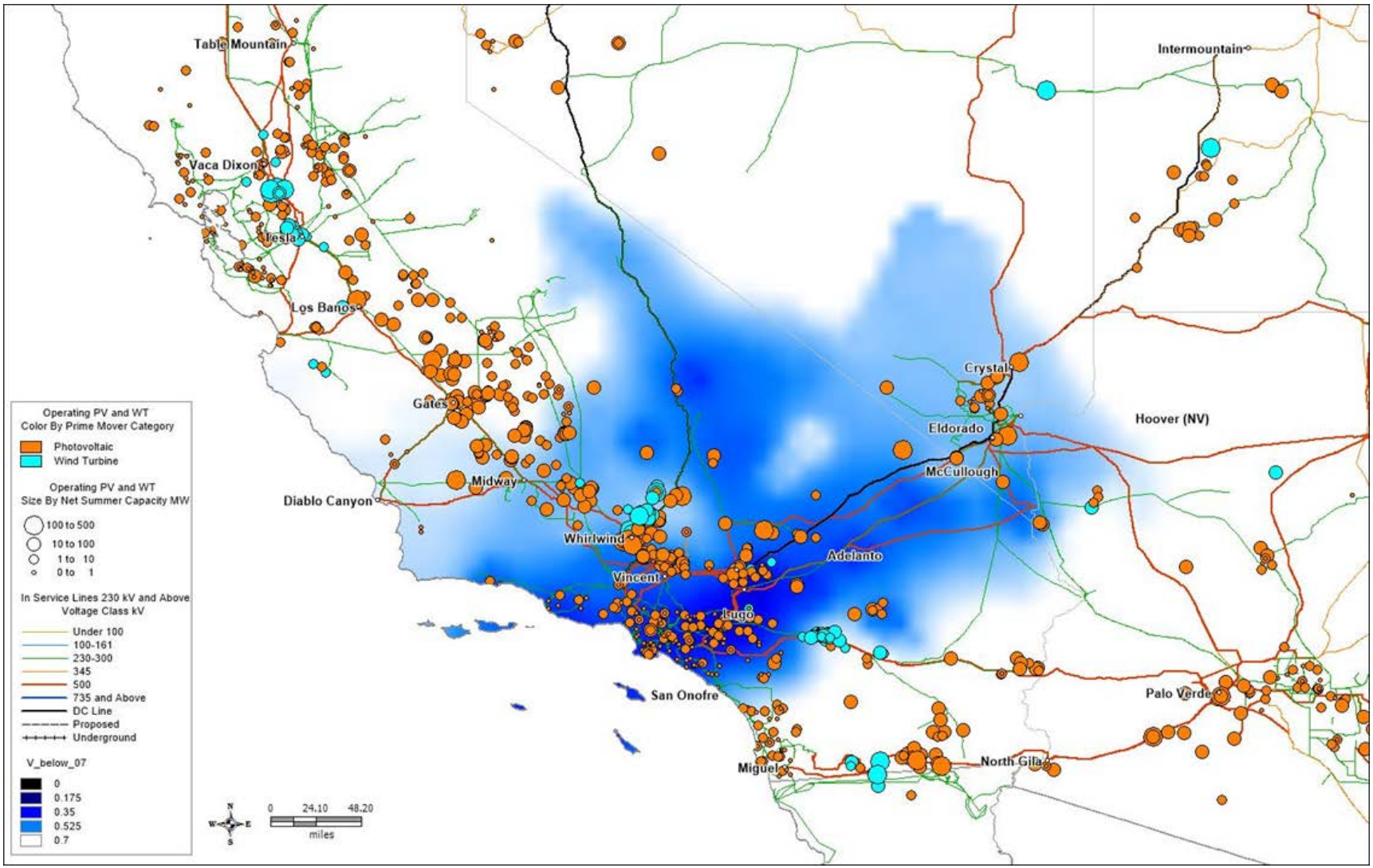
Clarification and Recommendation for Momentary Cessation



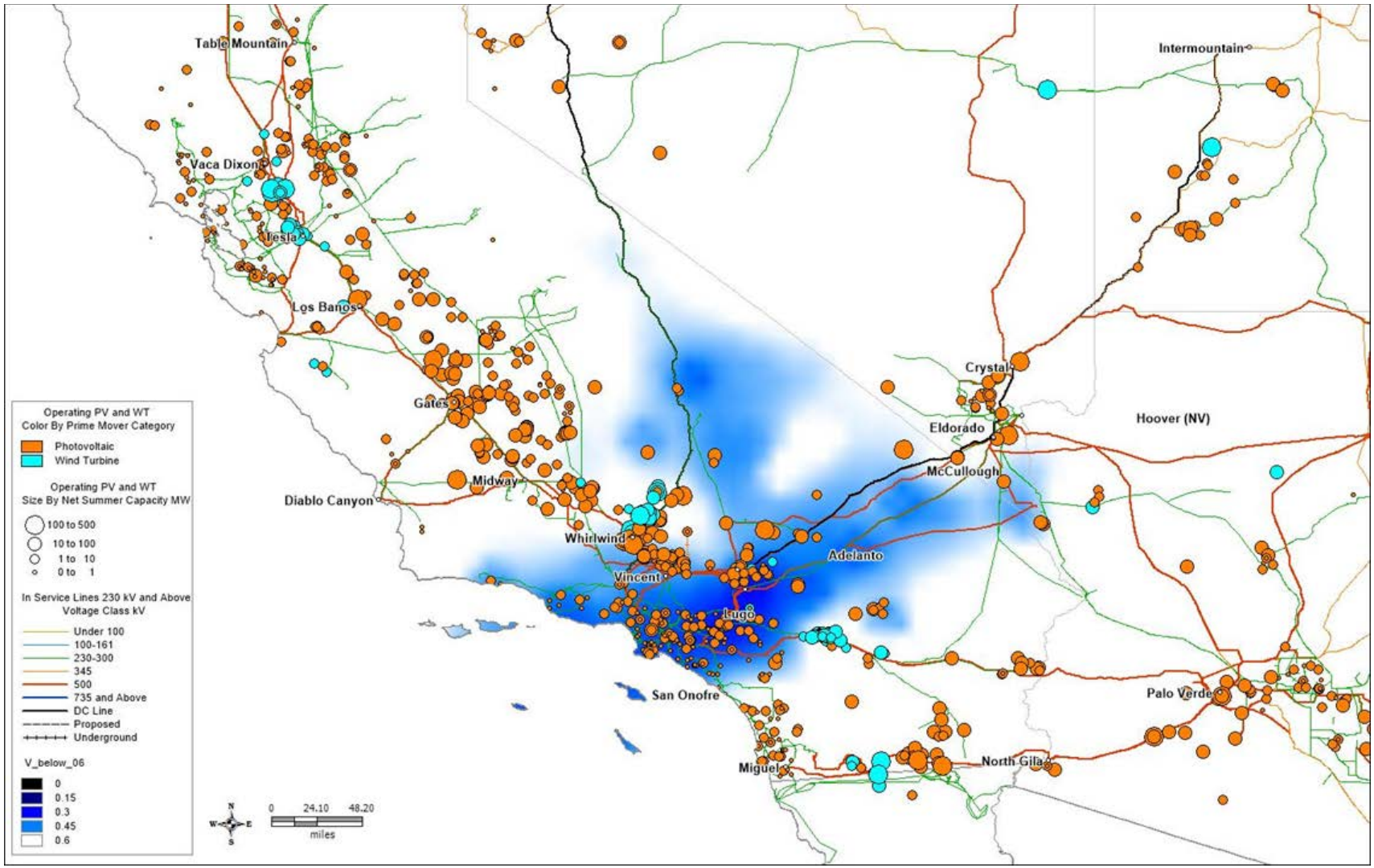
Clarification and Recommendation for Momentary Cessation



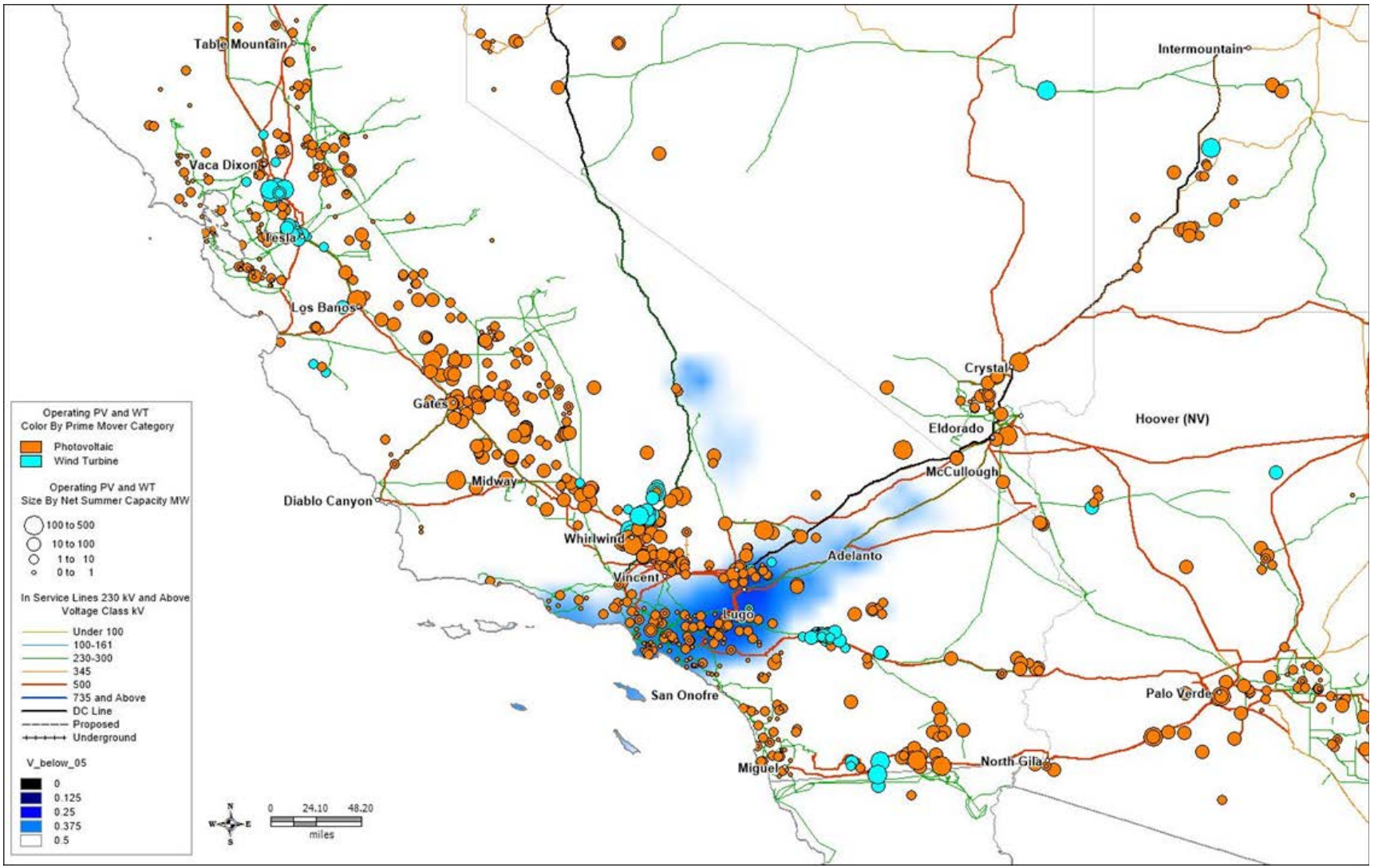
Clarification and Recommendation for Momentary Cessation



Clarification and Recommendation for Momentary Cessation

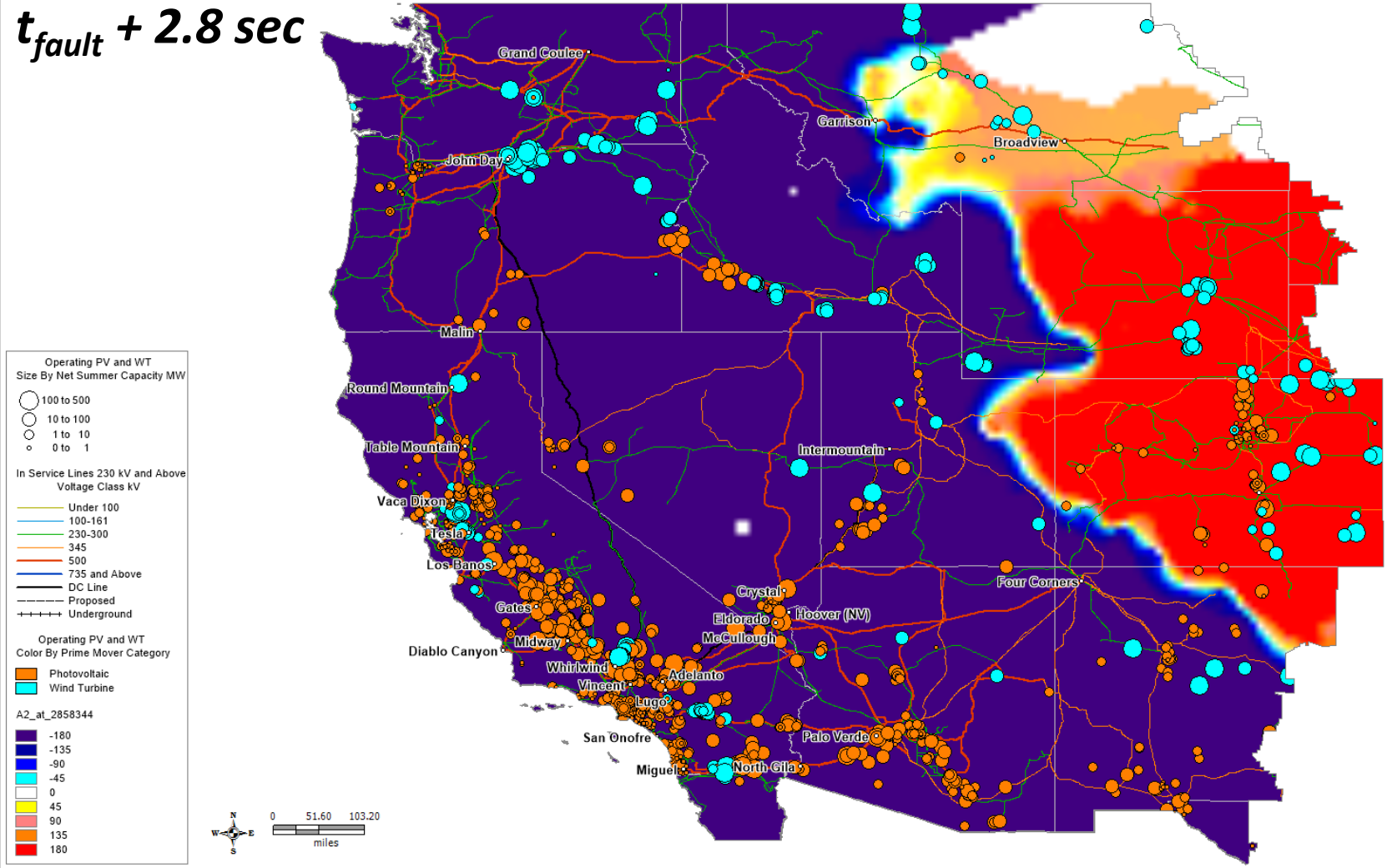


Clarification and Recommendation for Momentary Cessation



Clarification and Recommendation for Momentary Cessation

t_{fault} + 2.8 sec

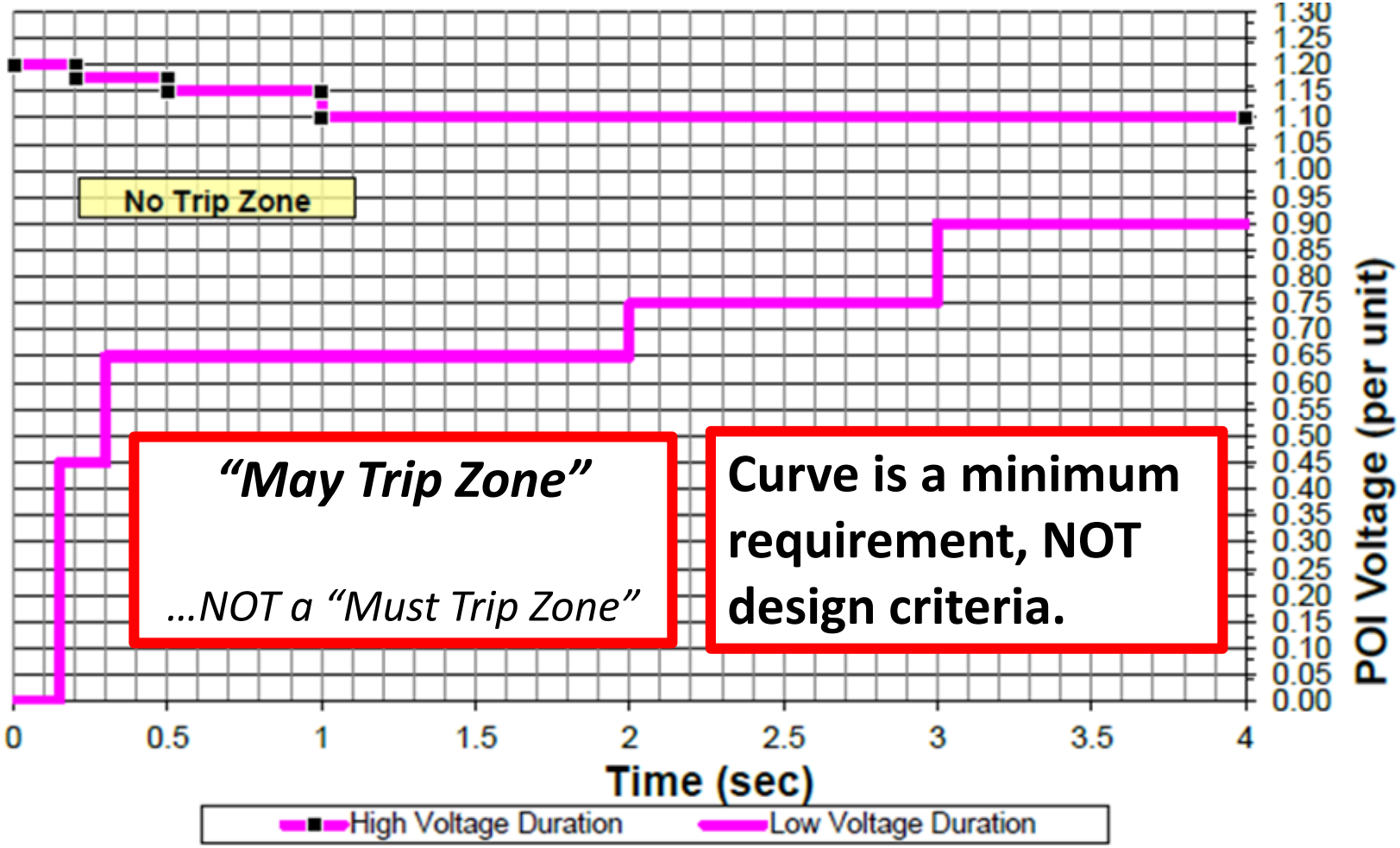


Momentary Cessation Recommendation Moving Forward

- Generator Owners should coordinate with their inverter manufacturer(s) to **eliminate momentary cessation (MC) to the greatest extent possible**.
- For inverters where MC cannot be eliminated (e.g., use another form of ride-through mode), MC settings should be changed by:
  - Reducing the MC low voltage threshold to the lowest value possible.
  - Reducing the recovery delay to the smallest value possible (e.g., on the order of 1-3 electrical cycles).
  - Increasing the active power ramp rate to at least 100% per second (e.g., return to pre-disturbance active current injection within 1 second).
  - Setting reactive current priority upon recovery (if applicable) should eliminate the use of MC on all inverters that are capable of continuous current injection during abnormal voltages.

Key Findings #4

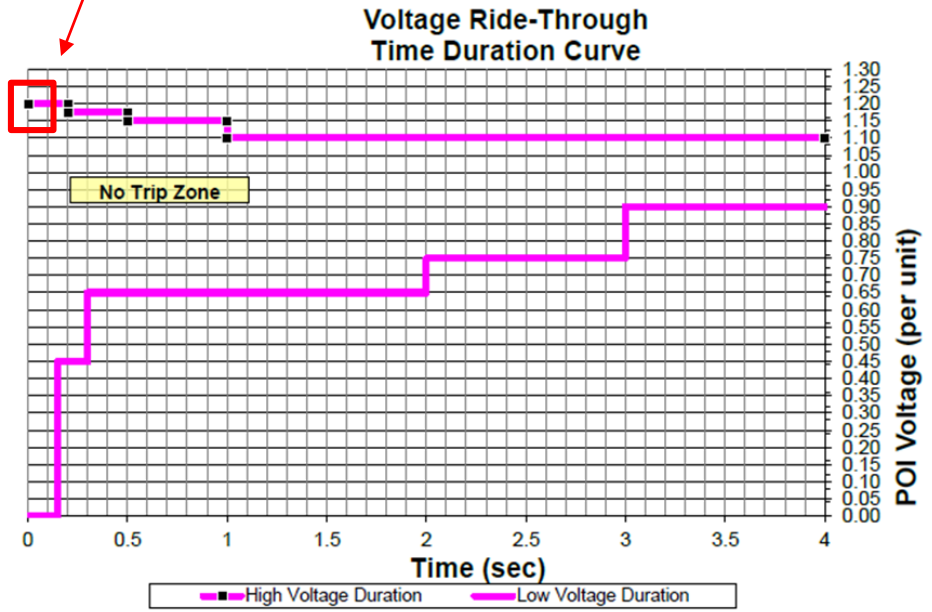
Interpretation of PRC-024-2 voltage ride-through curve



Key Findings #5

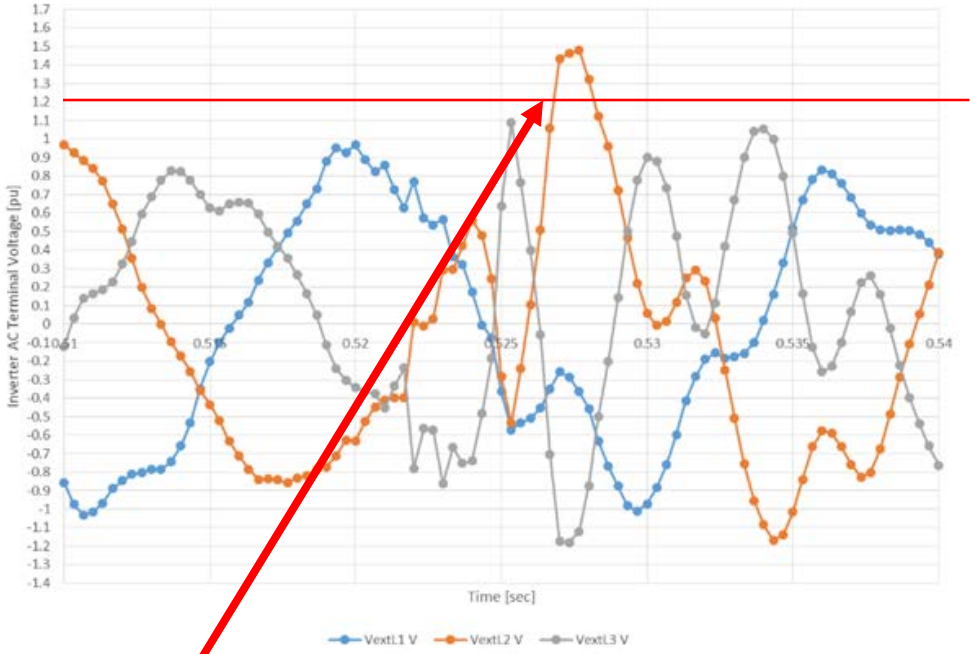
Instantaneous voltage tripping and measurement filtering

High Voltage Ride Through Duration		Low Voltage Ride Through Duration	
Voltage (pu)	Time (sec)	Voltage (pu)	Time (sec)
≥ 1.20	Instantaneous Trip	≤ 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



Key Findings #5

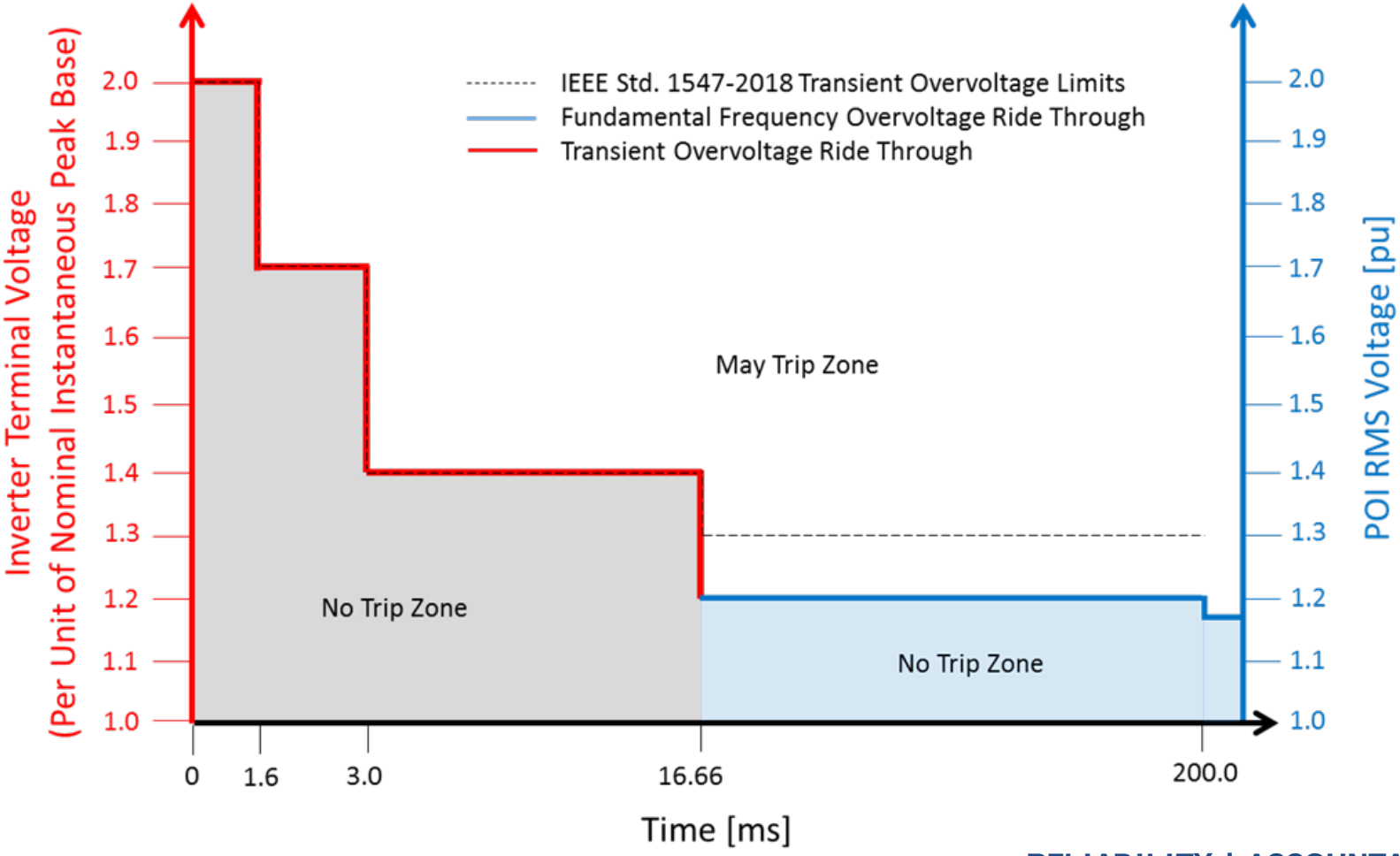
Instantaneous voltage tripping and measurement filtering



Inst. Voltage [pu nominal peak]	Samples	Time [sec]	Cycles
> 1.1	5	0.00167	0.1
> 1.2	4	0.00133	0.08
> 1.3	4	0.00133	0.08
> 1.4	3	0.00100	0.06

Key Findings #5
IRPTF Recommended HVRT

Instantaneous voltage tripping and measurement filtering



Next Steps and Future Work

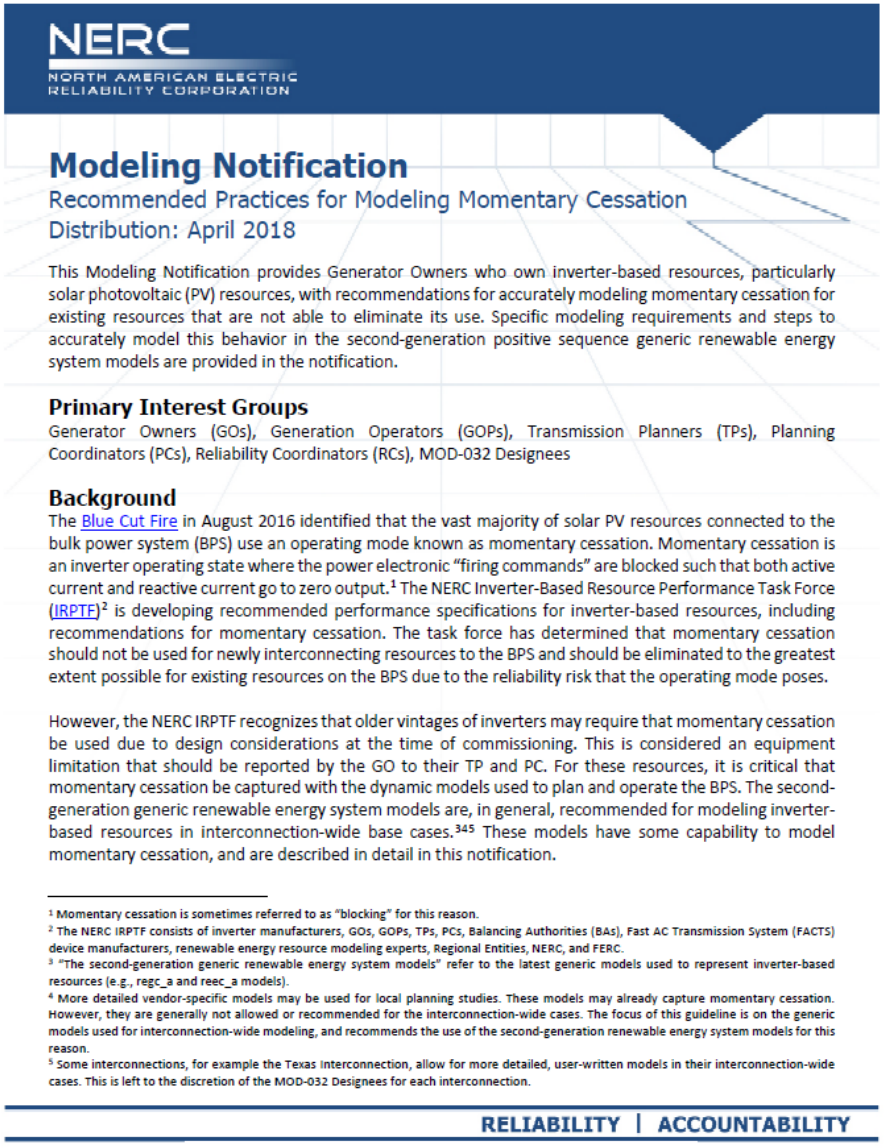
- Disturbance Report – published February 21, 2018
- Informational webinar – held February 15, 2018
- NERC Alert – issued May 1, 2018
- Reliability Guideline on Inverter-Based Resources Performance – coming soon
- Ongoing informational webinars – Q2-Q4 2018
- NERC-NATF-EPRI-UVIG Webinar Series on Inverter-Based Resources – Q2-Q3 2018 (posted on NERC Calendar)
- Technical Workshop – planned for Q3 or Q4 2018

NERC Alert

- Issued May 1
- Level 2 Alert – Industry Recommendation
- Topics covered:
  - Modeling improvements for existing equipment/controls NEEDED
  - Momentary cessation mitigation – performance improvements
  - Updated controls modeling improvements needed
  - Ramp rate interactions
  - DC reverse current
  - Transient overvoltage data collection

NERC SAMS Modeling Notification

- Guidance on how to model momentary cessation



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Modeling Notification

Recommended Practices for Modeling Momentary Cessation
Distribution: April 2018

This Modeling Notification provides Generator Owners who own inverter-based resources, particularly solar photovoltaic (PV) resources, with recommendations for accurately modeling momentary cessation for existing resources that are not able to eliminate its use. Specific modeling requirements and steps to accurately model this behavior in the second-generation positive sequence generic renewable energy system models are provided in the notification.

Primary Interest Groups

Generator Owners (GOs), Generation Operators (GOPs), Transmission Planners (TPs), Planning Coordinators (PCs), Reliability Coordinators (RCs), MOD-032 Designees

Background

The Blue Cut Fire in August 2016 identified that the vast majority of solar PV resources connected to the bulk power system (BPS) use an operating mode known as momentary cessation. Momentary cessation is an inverter operating state where the power electronic "firing commands" are blocked such that both active current and reactive current go to zero output.[1] The NERC Inverter-Based Resource Performance Task Force (IRPTF)[2] is developing recommended performance specifications for inverter-based resources, including recommendations for momentary cessation. The task force has determined that momentary cessation should not be used for newly interconnecting resources to the BPS and should be eliminated to the greatest extent possible for existing resources on the BPS due to the reliability risk that the operating mode poses.

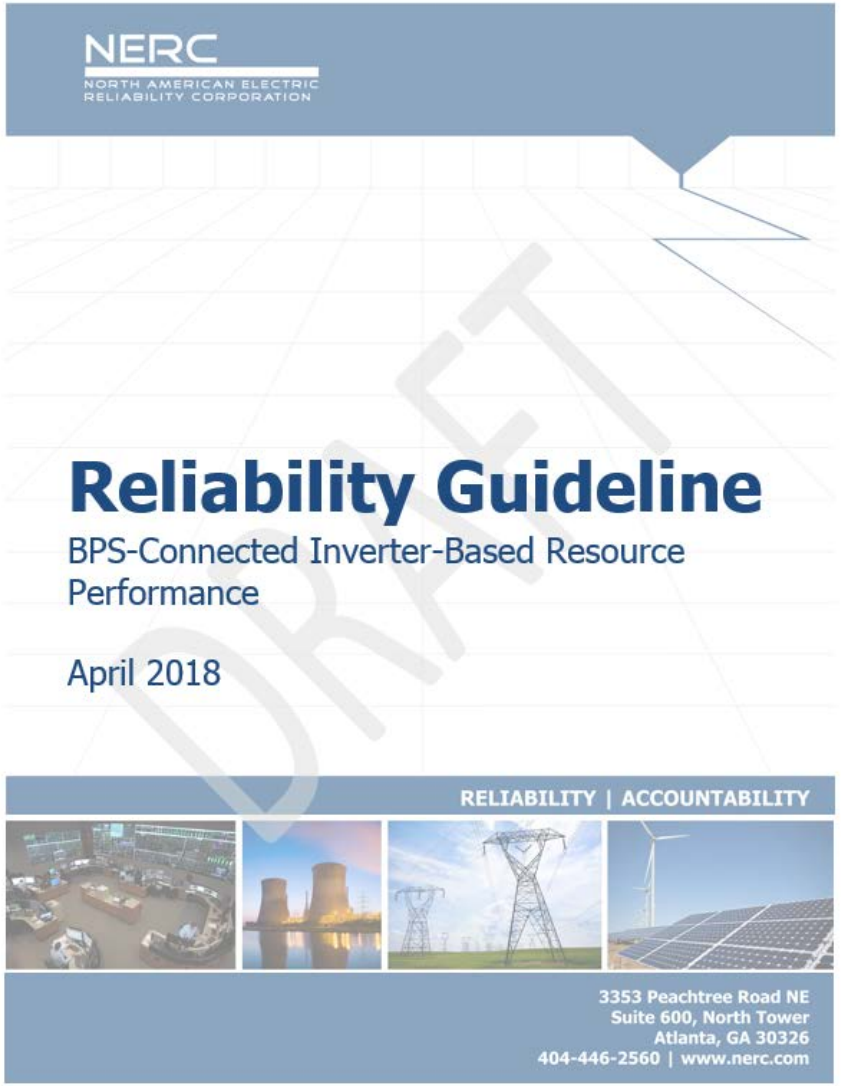
However, the NERC IRPTF recognizes that older vintages of inverters may require that momentary cessation be used due to design considerations at the time of commissioning. This is considered an equipment limitation that should be reported by the GO to their TP and PC. For these resources, it is critical that momentary cessation be captured with the dynamic models used to plan and operate the BPS. The second-generation generic renewable energy system models are, in general, recommended for modeling inverter-based resources in interconnection-wide base cases.[3][4][5] These models have some capability to model momentary cessation, and are described in detail in this notification.

[1] Momentary cessation is sometimes referred to as "blocking" for this reason.
[2] The NERC IRPTF consists of inverter manufacturers, GOs, GOPs, TPs, PCs, Balancing Authorities (BAs), Fast AC Transmission System (FACTS) device manufacturers, renewable energy resource modeling experts, Regional Entities, NERC, and FERC.
[3] "The second-generation generic renewable energy system models" refer to the latest generic models used to represent inverter-based resources (e.g., regc_a and reec_a models).
[4] More detailed vendor-specific models may be used for local planning studies. These models may already capture momentary cessation. However, they are generally not allowed or recommended for the interconnection-wide cases. The focus of this guideline is on the generic models used for interconnection-wide modeling, and recommends the use of the second-generation renewable energy system models for this reason.
[5] Some interconnections, for example the Texas Interconnection, allow for more detailed, user-written models in their interconnection-wide cases. This is left to the discretion of the MOD-032 Designees for each interconnection.

RELIABILITY | ACCOUNTABILITY

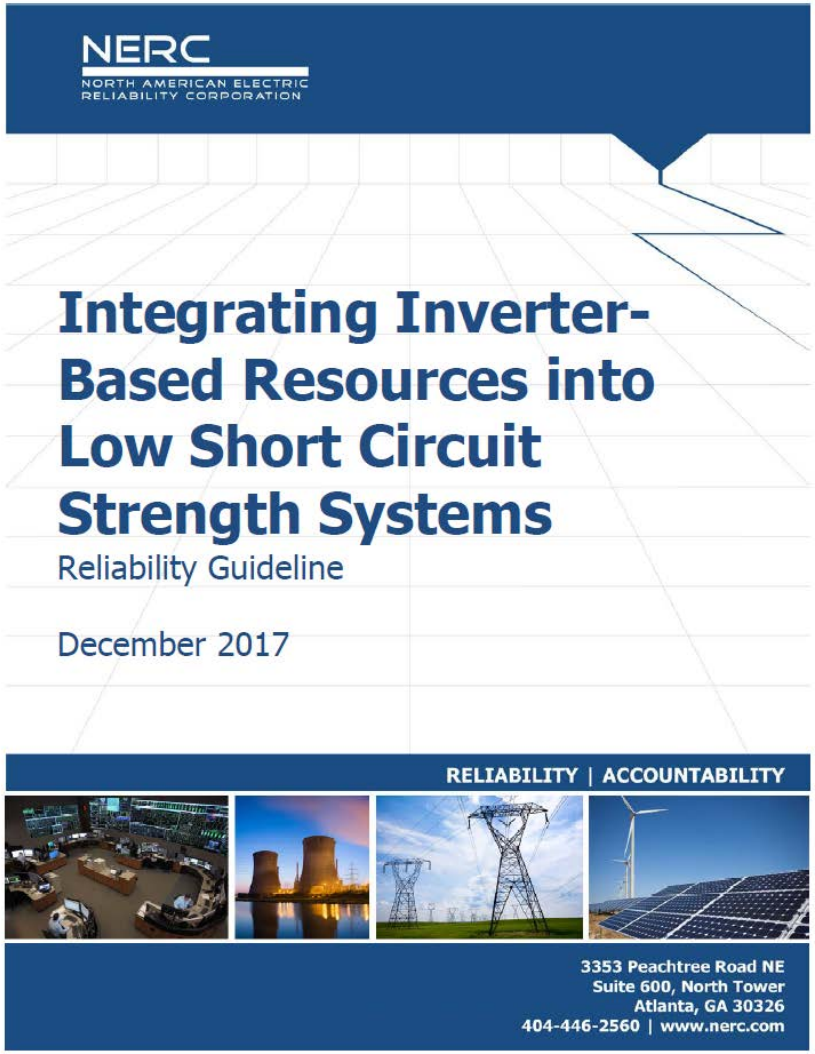
NERC Reliability Guideline:
Inverter-Based Resource Performance

- Comprehensive document outlining best practices for IBR
- Posted for comment (ended 6/30/2018)
- Anticipate PC approval in September



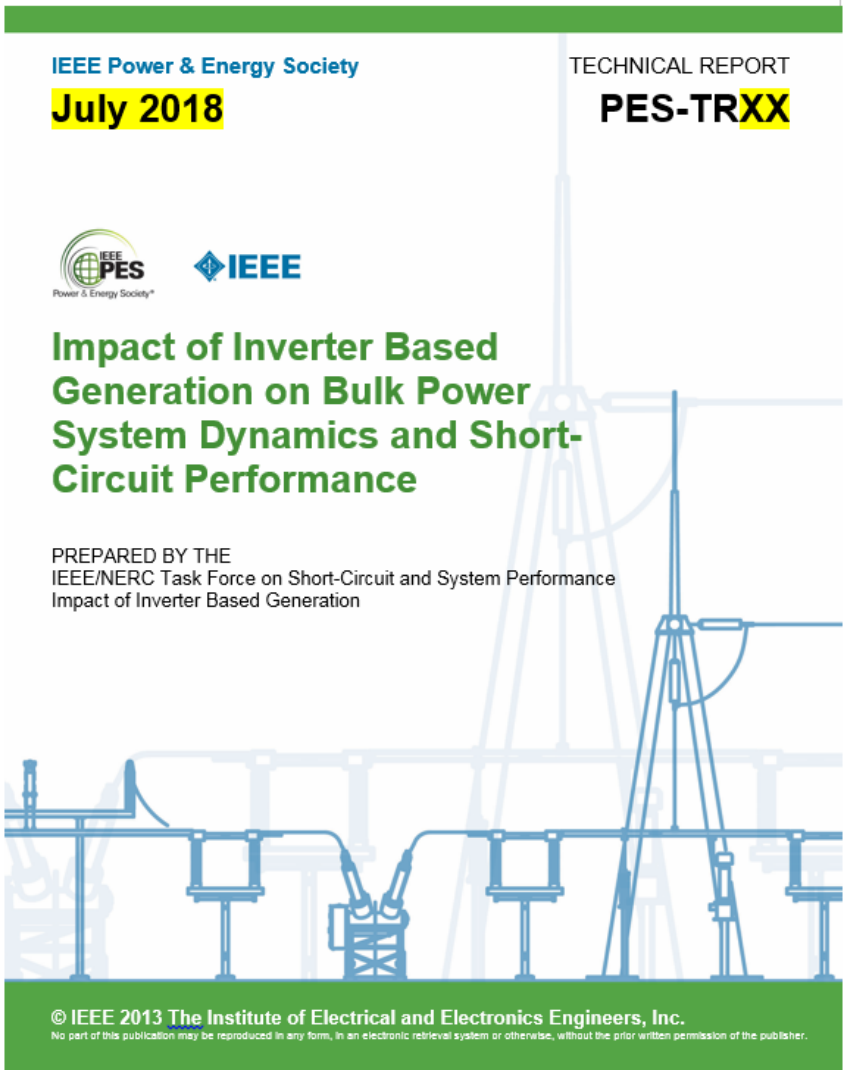
NERC Reliability Guideline: IBR in Low Short Circuit Strength

- Identifying a “weak grid” condition
  - Qualitatively and quantitatively
- Use of metrics
- Issues associated with “weak grids”
  - Voltage stability issues
  - Controls interactions
  - Controls instability
  - Ride-through capability
- Planning study considerations
- Coordination

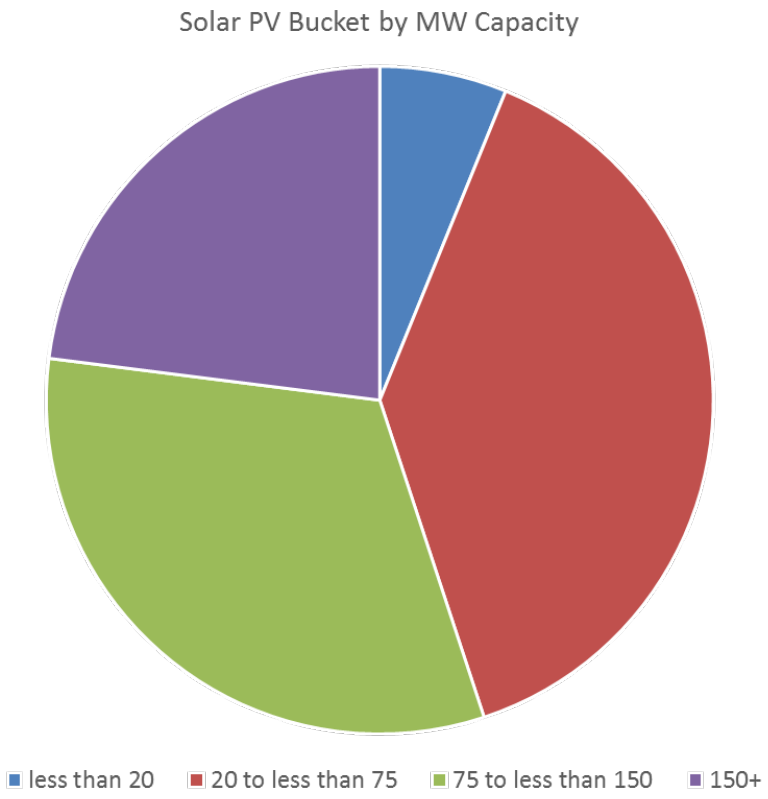


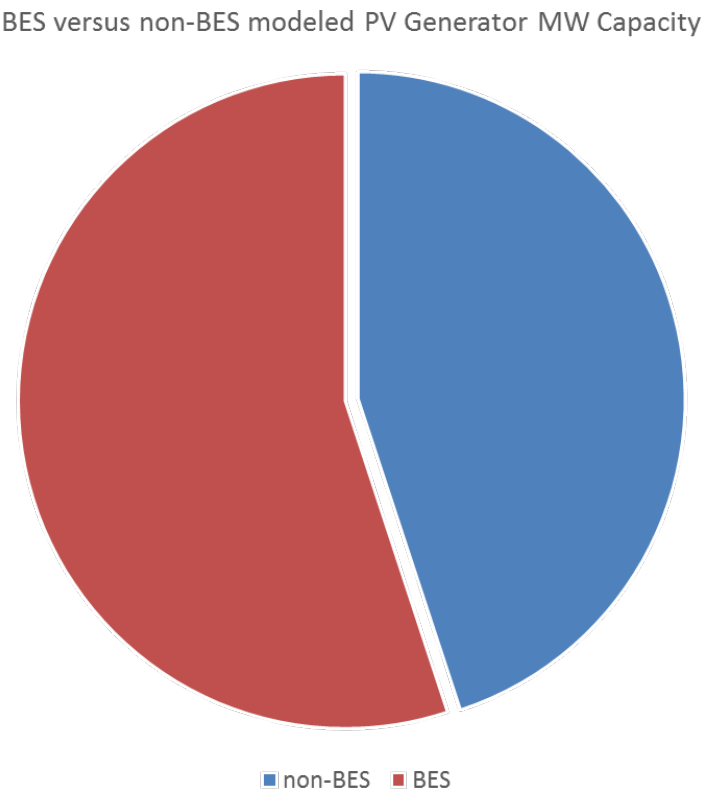
NERC / IEEE Joint Effort

- Issues related to large penetration of inverter-based resources
  - Controls
  - Modeling
  - Planning
  - Operations
- Protective relay issues
  - Inverter-based fault current
  - Relay element response
  - Relay scheme selection
  - Short circuit study issues



2018 Planning Case Analysis

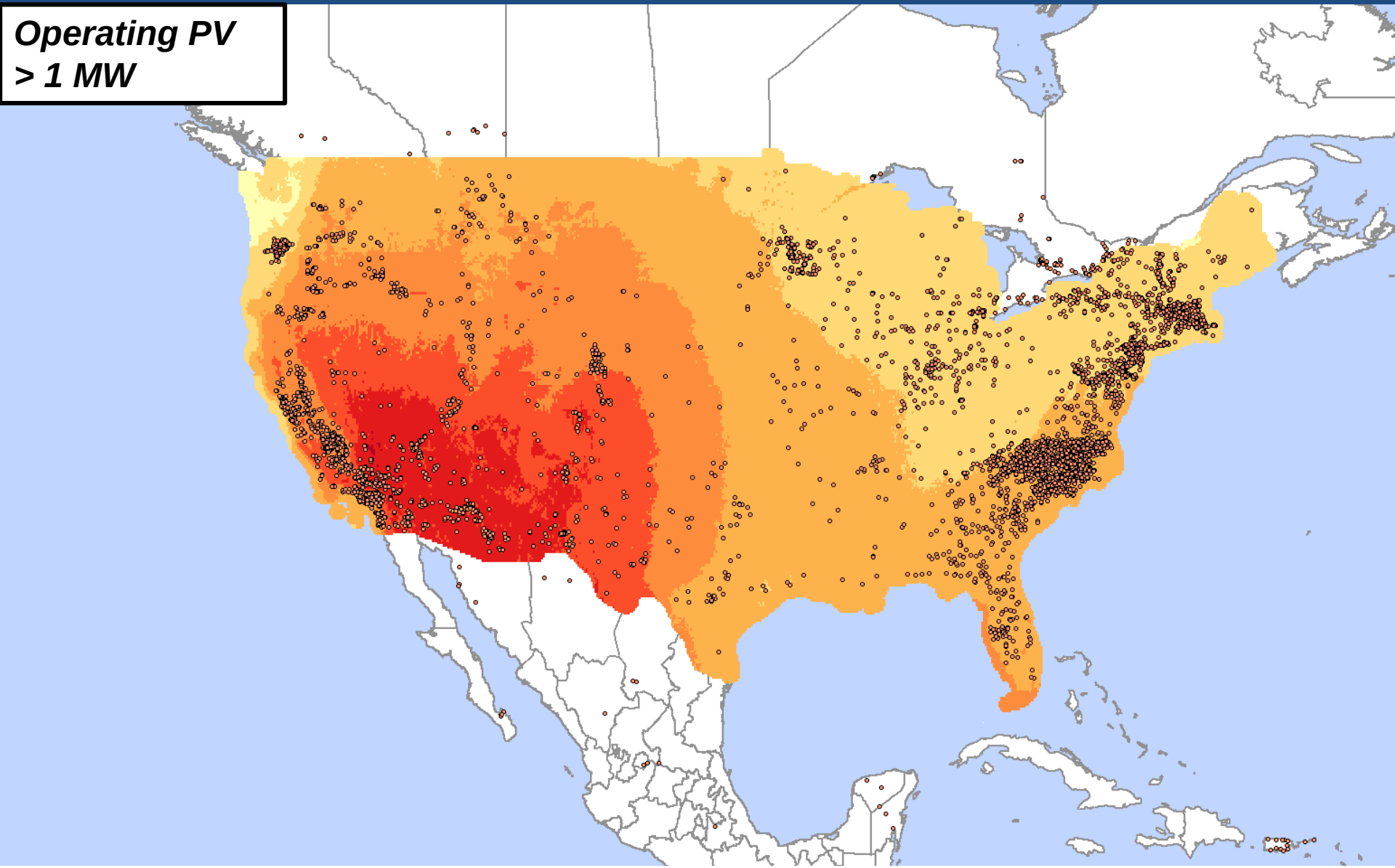




* These are not official registration numbers. Illustrative purposes only.

Operating PV Visualization

Operating PV
> 1 MW



Operating PV Visualization

Operating PV
> 75 MW

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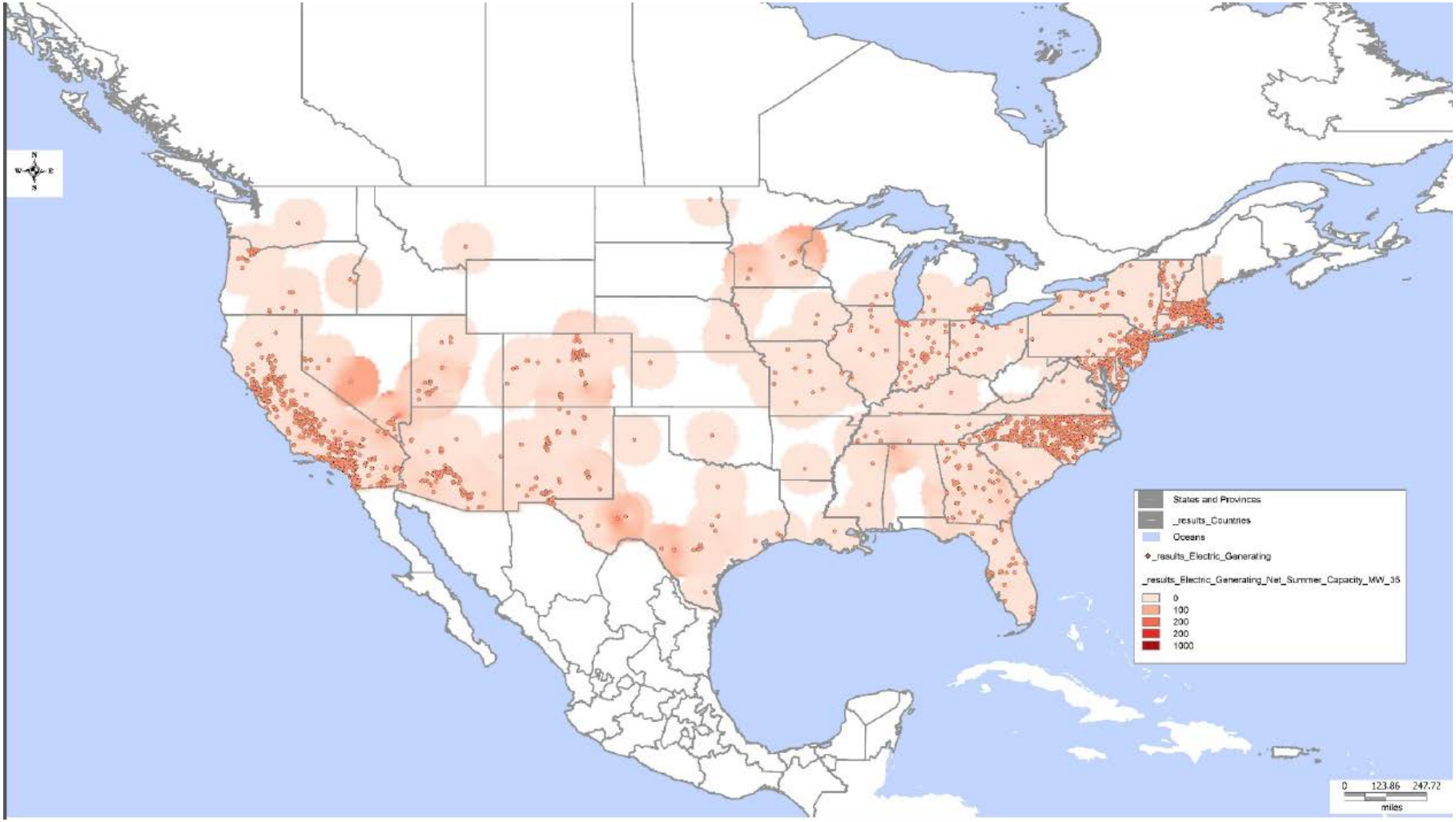
Current solar production



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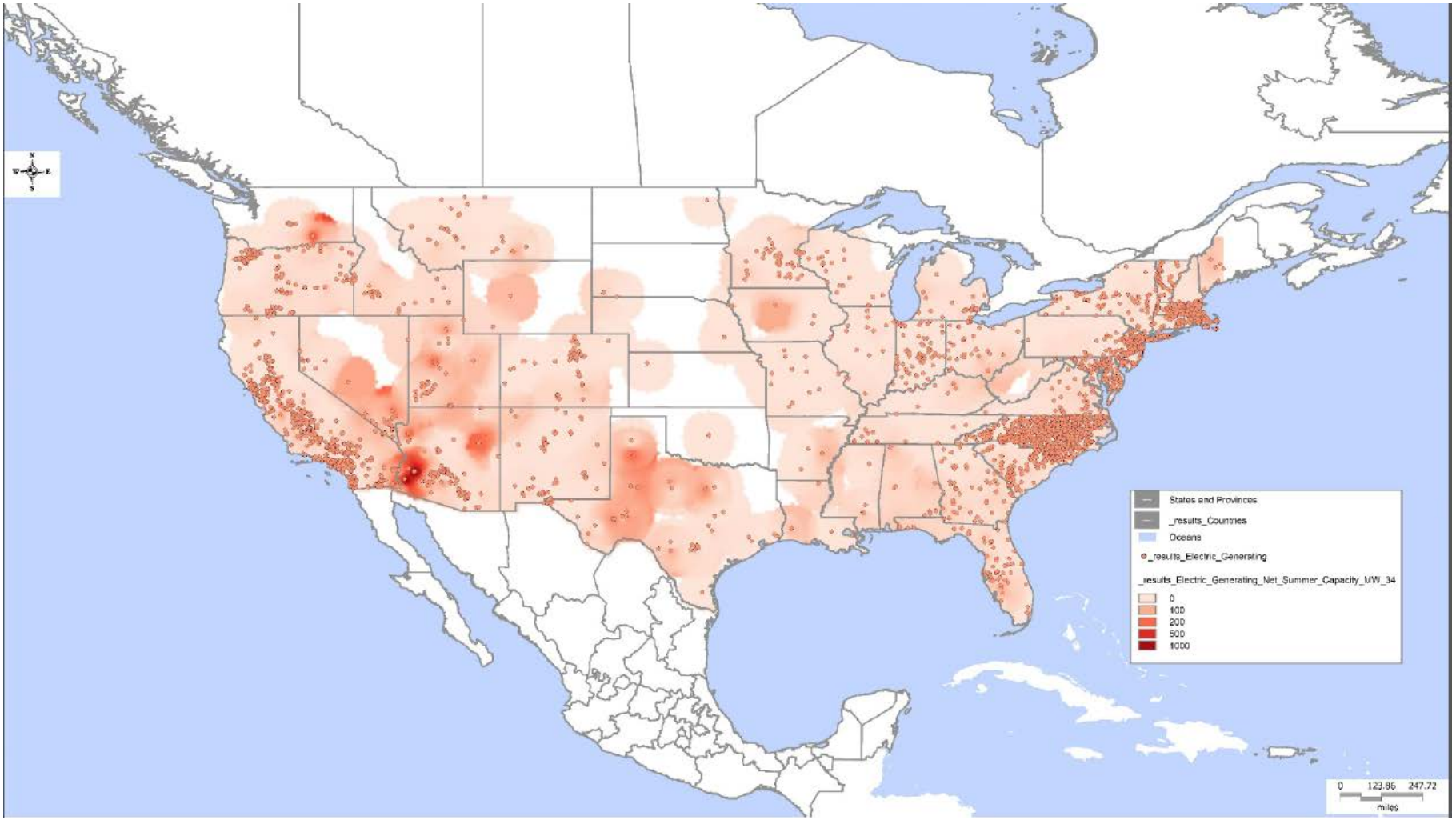
Current and planned solar production



Relevant Links

- Blue Cut Fire Disturbance Report: http://www.nerc.com/pa/rrm/ea/Pages/1200-MW-Fault-Induced-Solar-Photovoltaic-Resource-Interruption-Disturbance-Report.aspx
- Canyon 2 Fire Disturbance Report: http://www.nerc.com/pa/rrm/ea/Pages/1200-MW-Fault-Induced-Solar-Photovoltaic-Resource-Interruption-Disturbance-Report.aspx
- Webinar on Both Disturbances: http://www.nerc.com/pa/rrm/ea/Pages/1200-MW-Fault-Induced-Solar-Photovoltaic-Resource-Interruption-Disturbance-Report.aspx
- NERC Events Analysis: http://www.nerc.com/pa/rrm/ea/Pages/default.aspx
- NERC Alerts: http://www.nerc.com/pa/rrm/bpsa/Pages/Alerts.aspx
- NERC IRPTF Page: http://www.nerc.com/comm/PC/Pages/Inverter-Based-Resource-Performance-Task-Force.aspx

Questions and Answers

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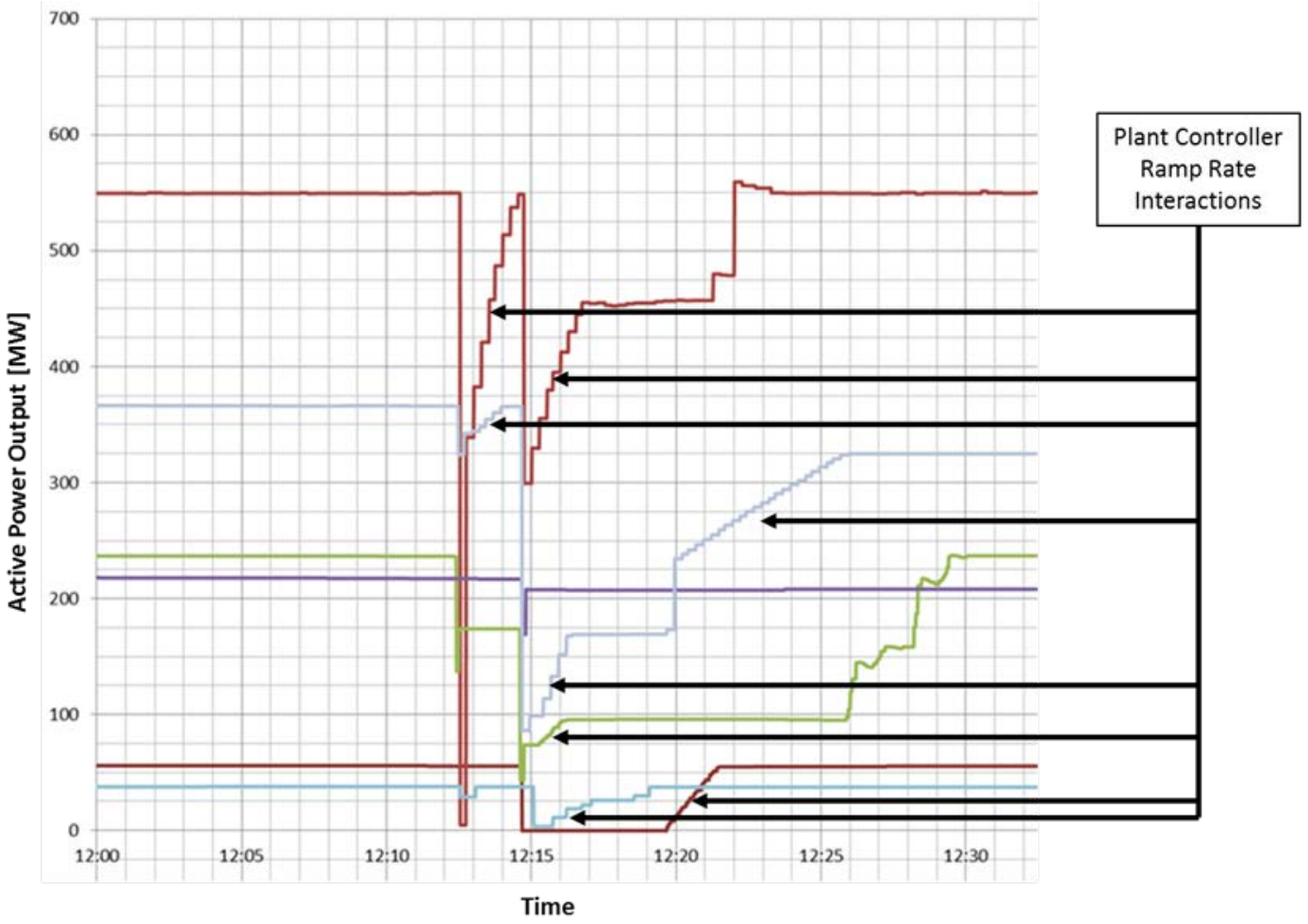
Key Findings #3

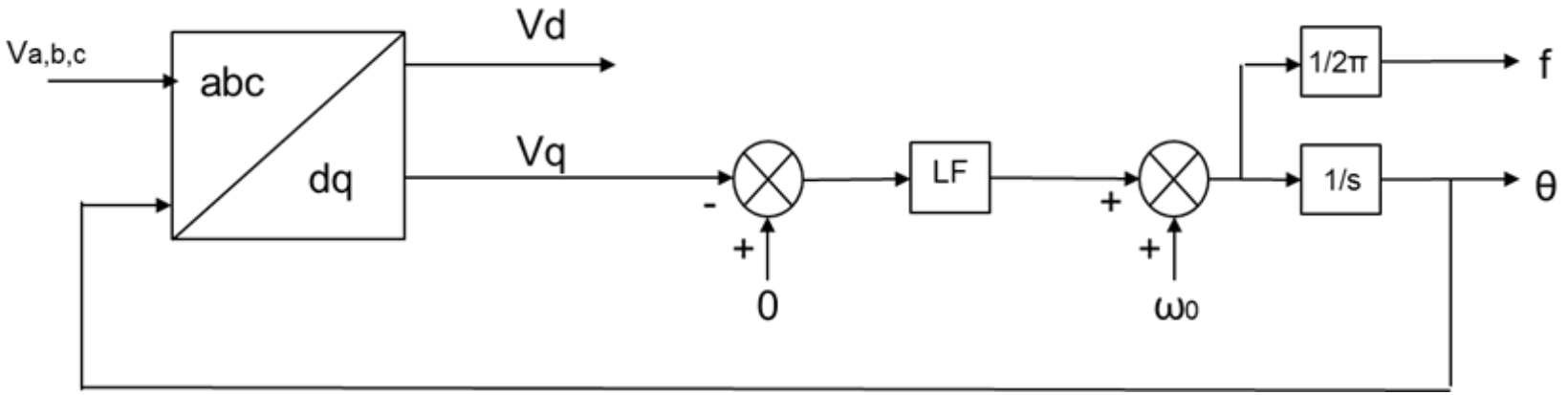
Ramp rate interactions with return from momentary cessation



Key Findings #6

Phase lock loop synchronization issues

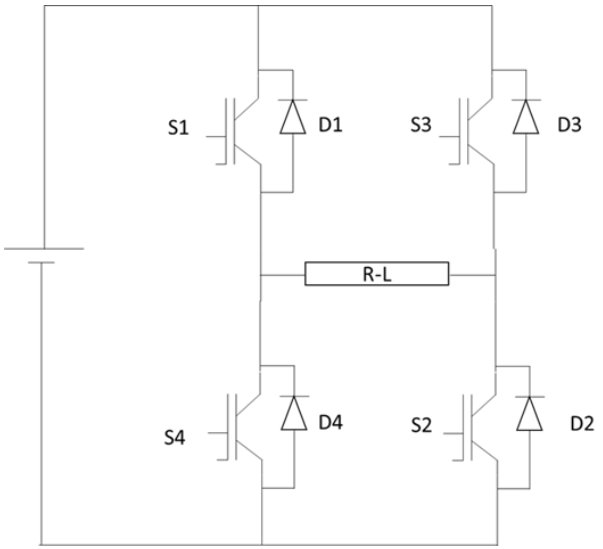
- Grid voltage phase jumps occur (e.g., during faults)
- Inverter PLLs should be robust to withstand BPS phase jumps
- Should not result in inverter tripping or momentary cessation
- Advanced controls should enable “PLL ride-through” rather than tripping

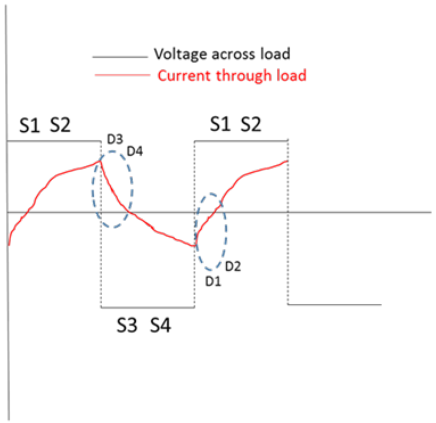


Key Findings #7

DC reverse current tripping

- Anti-parallel diodes dissipate energy, mitigate voltage spikes
- Can conduct if forward biased (AC voltage > DC voltage)
- UL 1741 requires testing and detection, no specified trip settings
- DC reverse current detection protects panels, not inverter
- Very sensitive settings for one plant





Key Findings #8

Transient interactions and ride-through considerations

- Interactions between momentary cessation, in-plant shunt capacitors, transient voltages, harmonics, etc., that are not sufficient understood
- Requires detailed electromagnetic transient (EMT) studies needed