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Blue Cut Fire and Canyon 2 Fire Disturbance Analyses

Key Findings and Recommendations

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RELIABILITY | ACCOUNTABILITY




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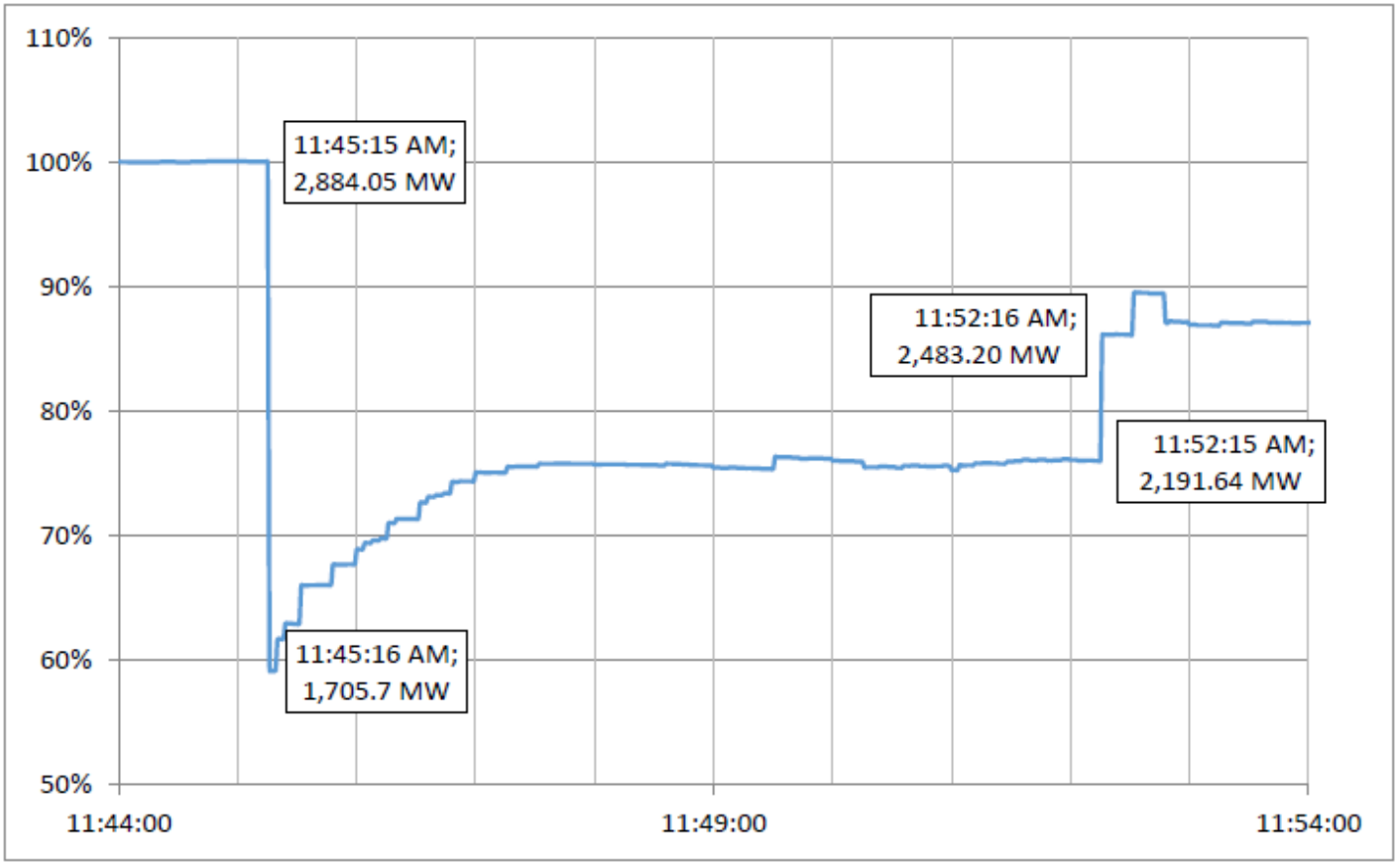
August 16, 2016
Blue Cut Fire Disturbance

Refresher on Key Findings and Recommendations

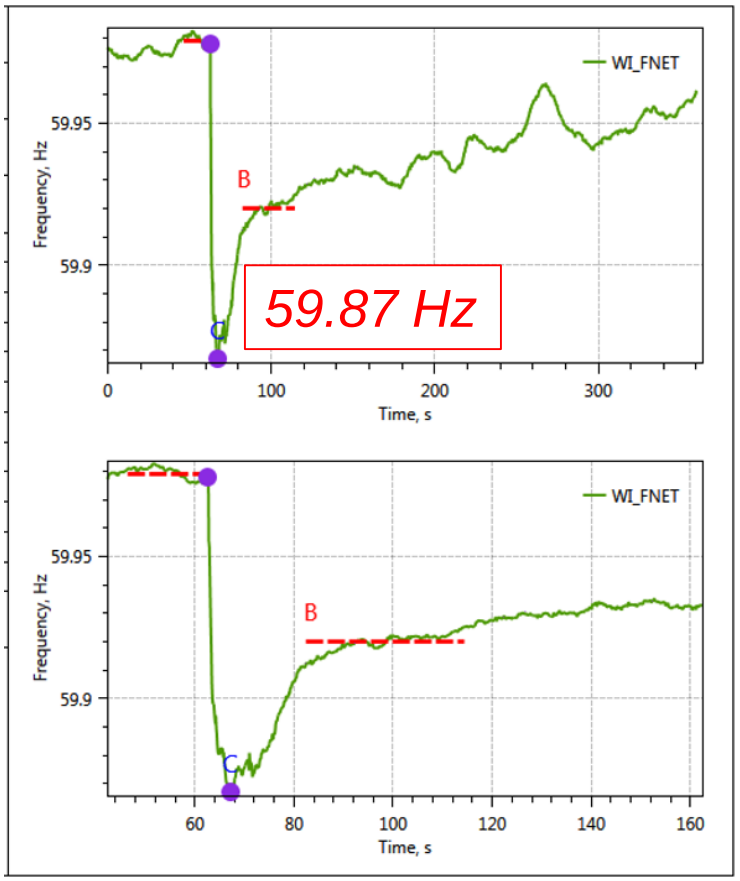
Solar Resource Loss

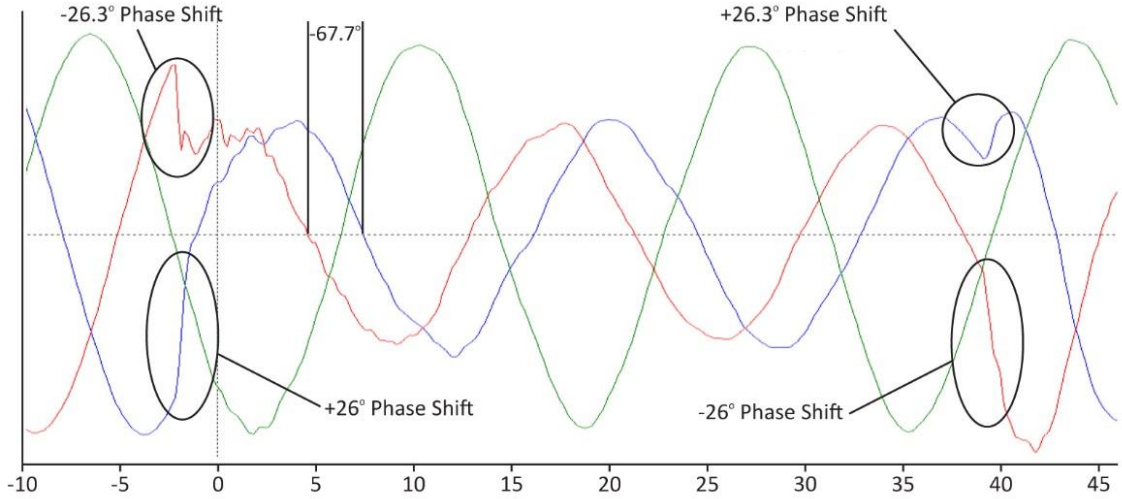


- 26 utility-scale (most at 500 kV and 230 kV) solar developments
- 10 different inverter manufacturers

Key Finding #1

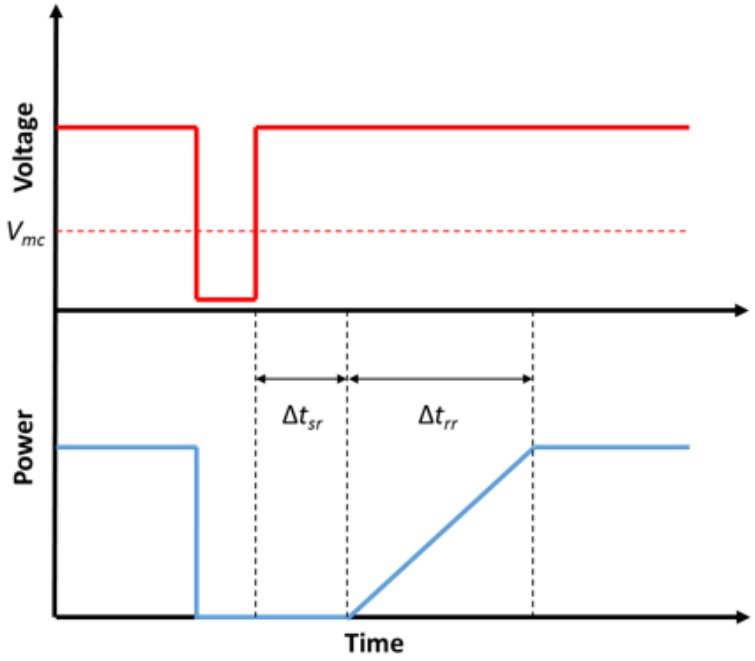
- Largest solar PV loss (~700 MW) due to underfrequency tripping
  - Inverter sensed near instantaneous frequency of < 57 Hz and tripped





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)



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**

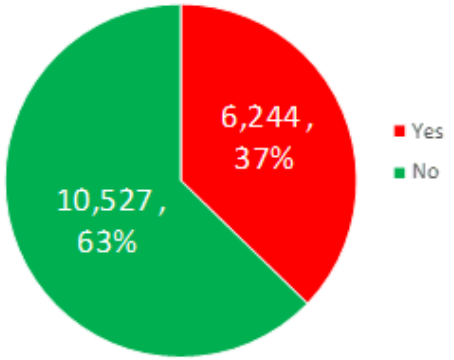


Figure 2: MW susceptible to Erroneous Frequency Calculations

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**

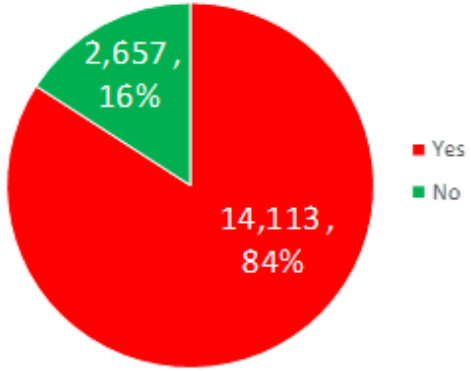


Figure 4: MW cease output during abnormal voltages

October 9, 2017
Canyon 2 Fire Disturbance

Key Findings and Recommendations

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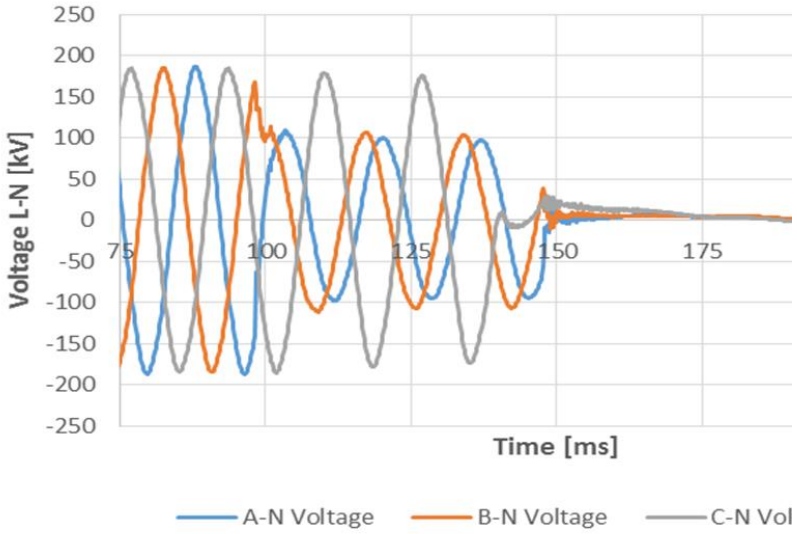
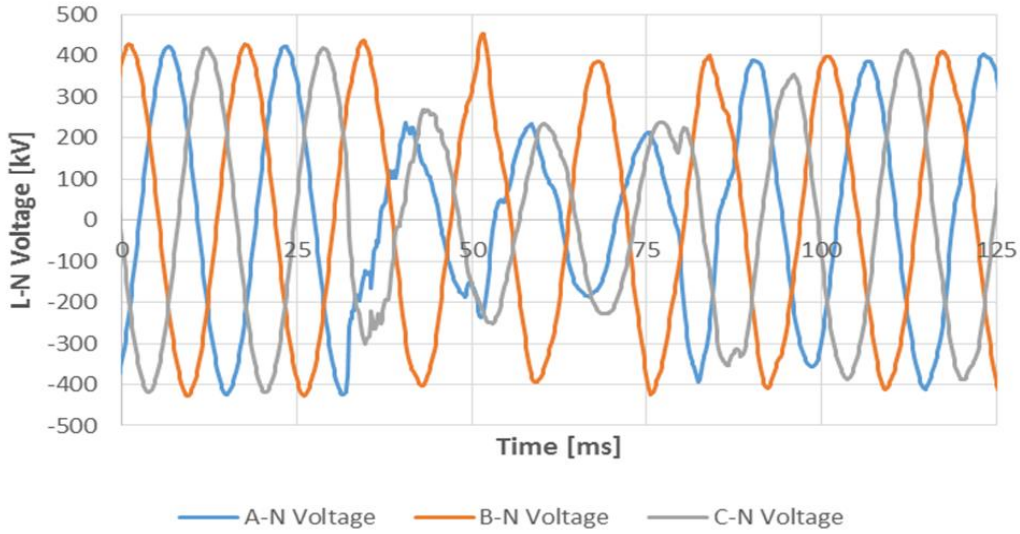
Map of Affected Area

Two Fault Events

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

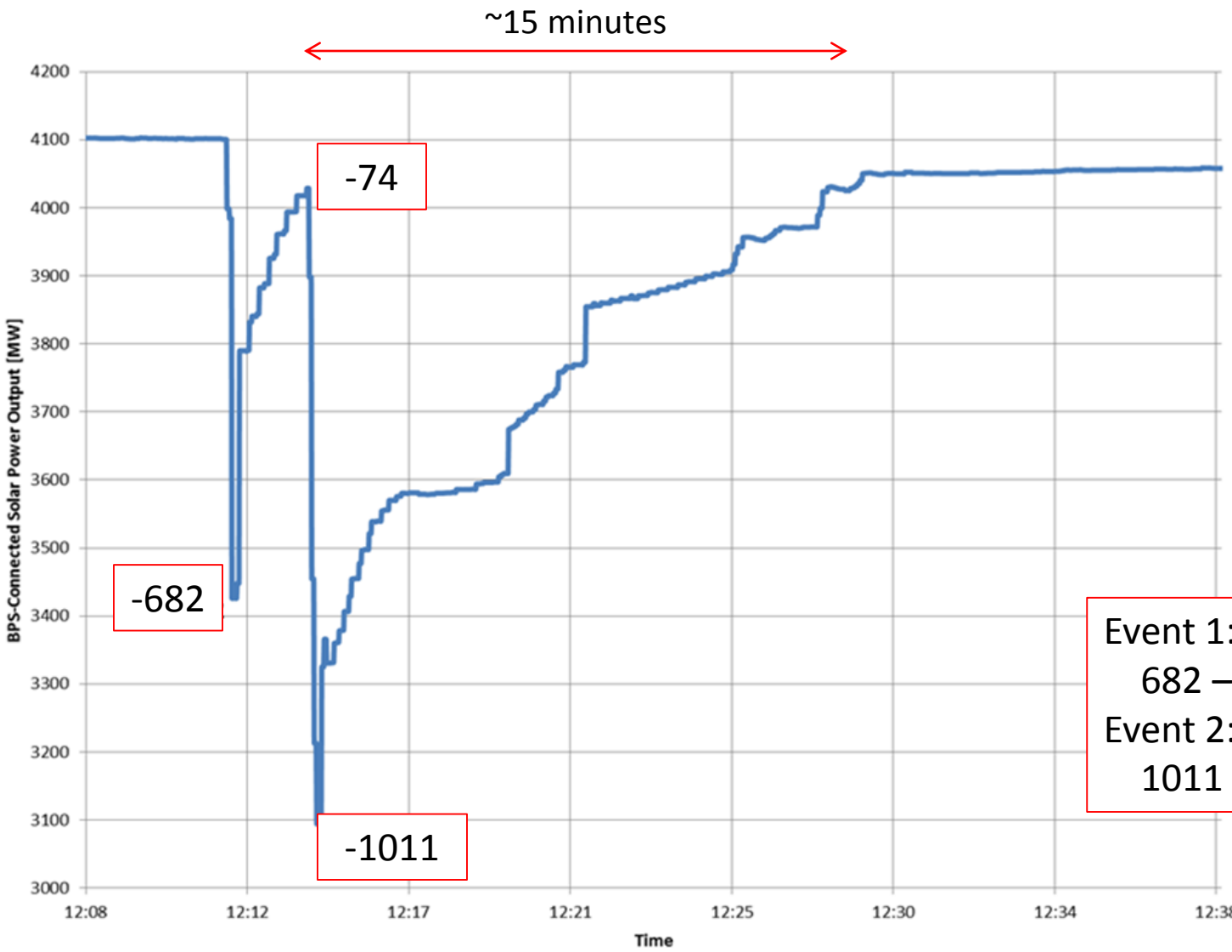




<u>Fault Event 1:</u>
220 kV
L-L Fault
< 3 cycle clearing

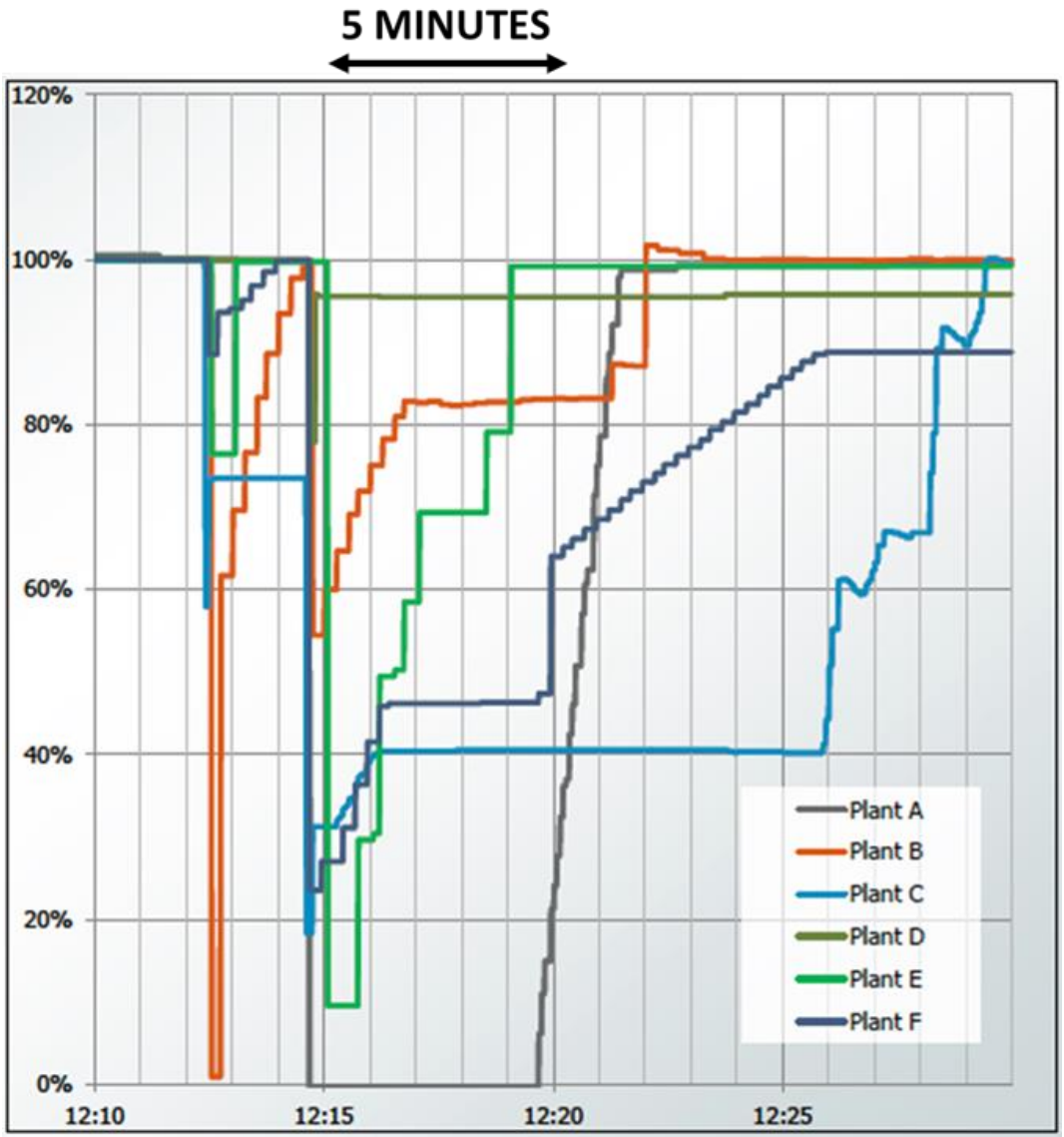
<u>Fault Event 2:</u>
500 kV
L-L Fault
< 3 cycle clearing

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

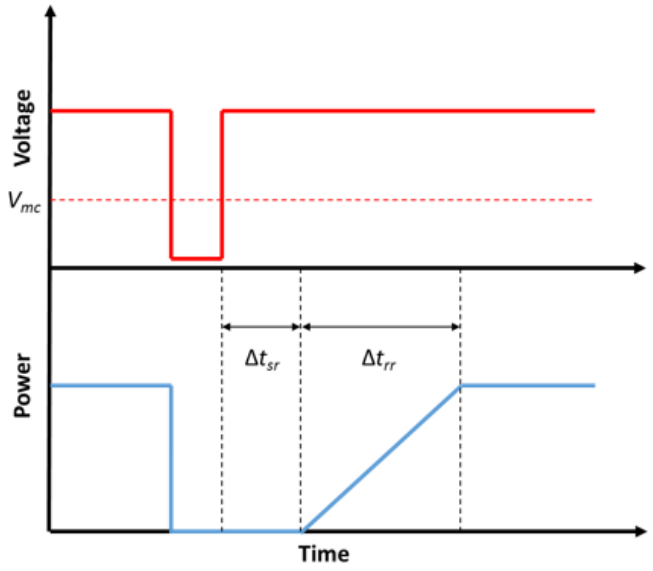
No erroneous frequency tripping

- 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

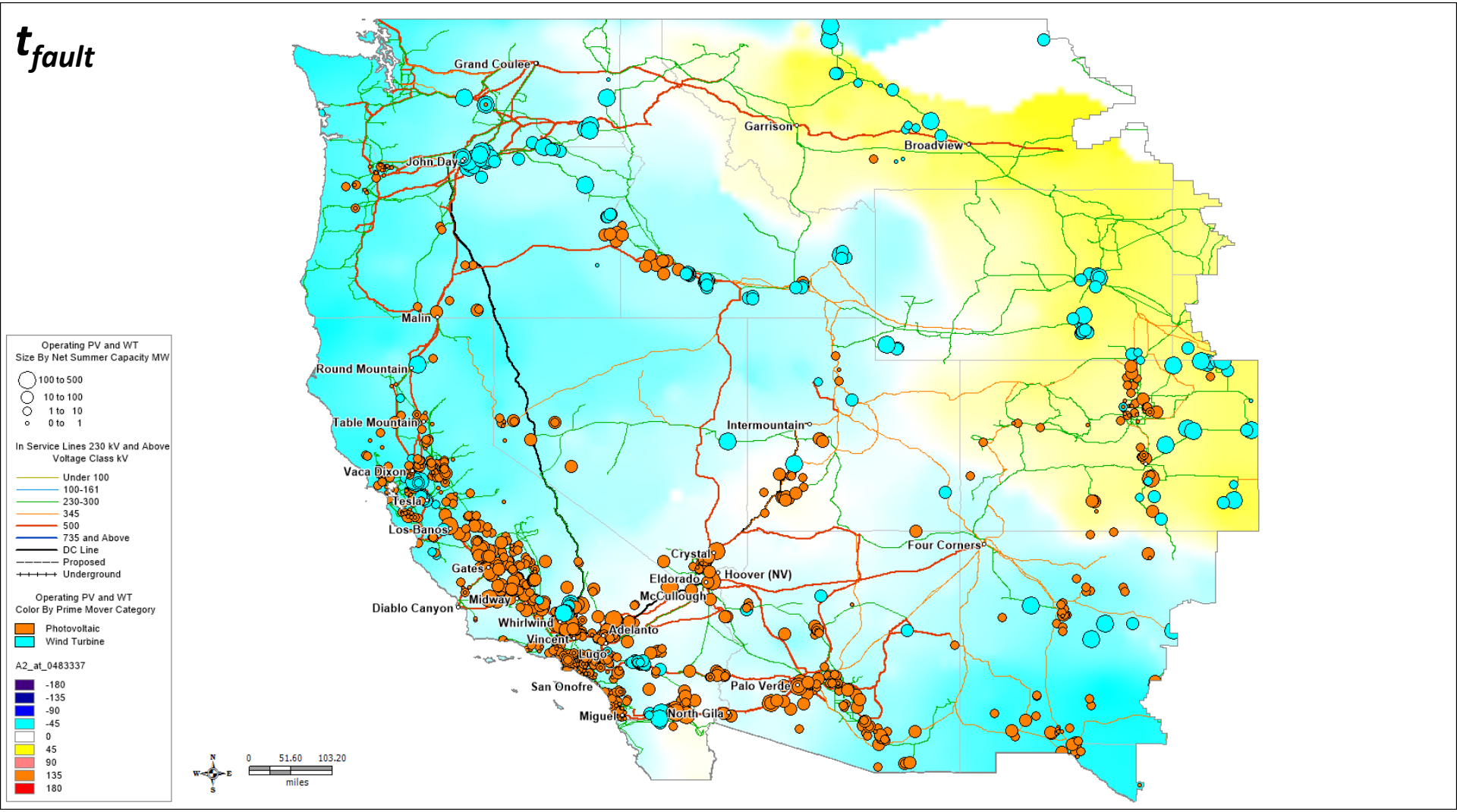
Key Findings #2

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

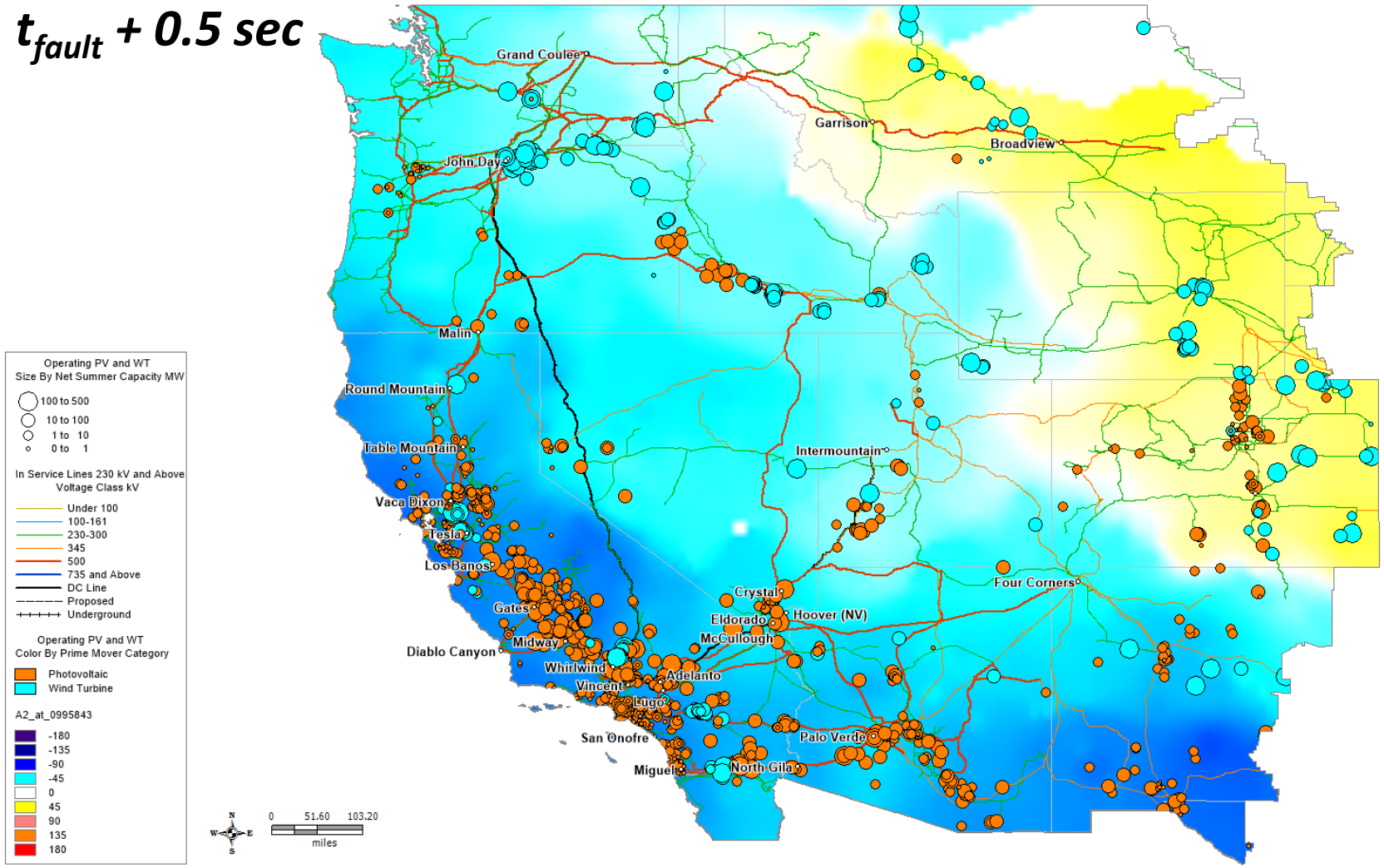


Clarification and Recommendation for Momentary Cessation



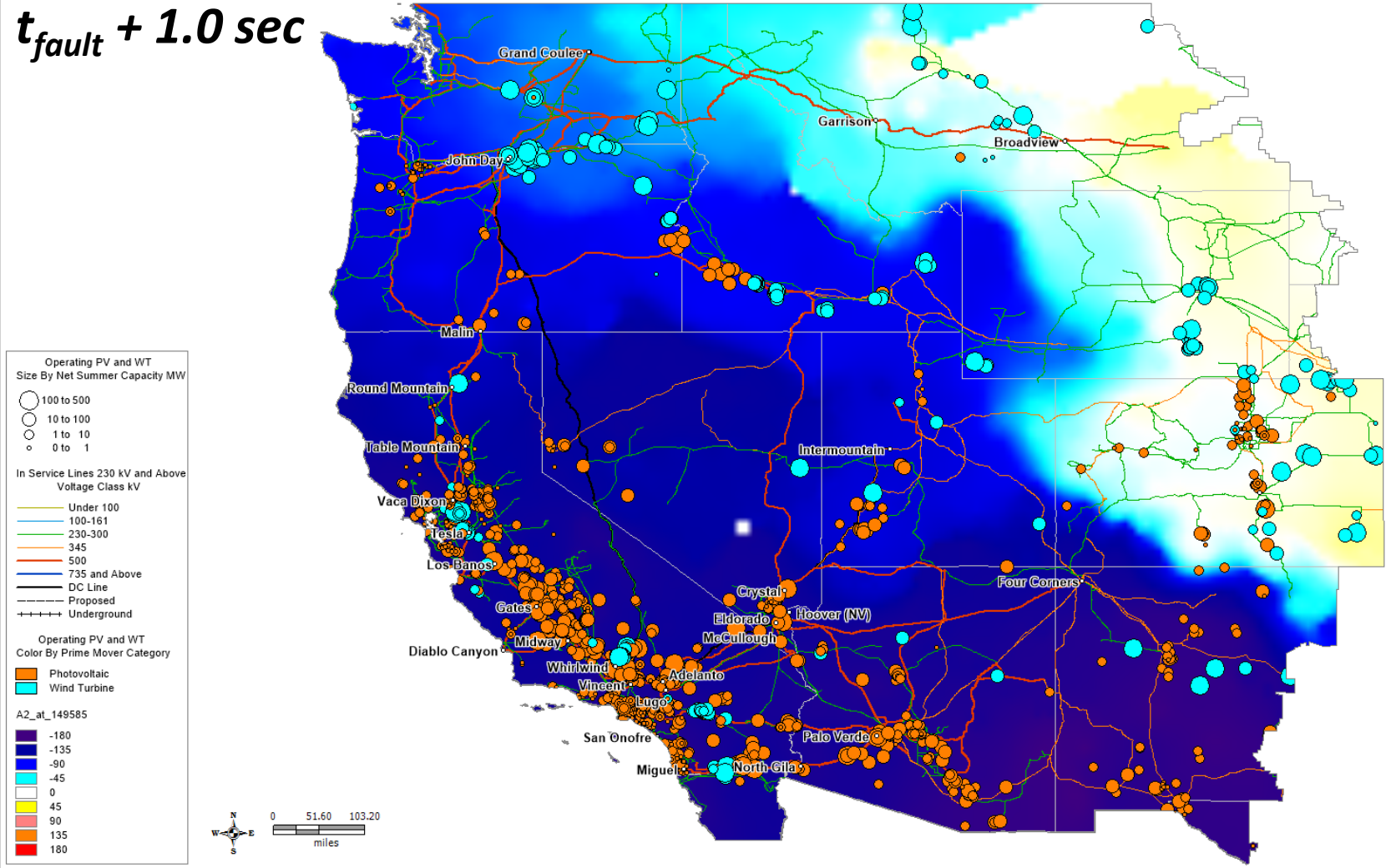
Clarification and Recommendation for Momentary Cessation

t_{fault} + 0.5 sec

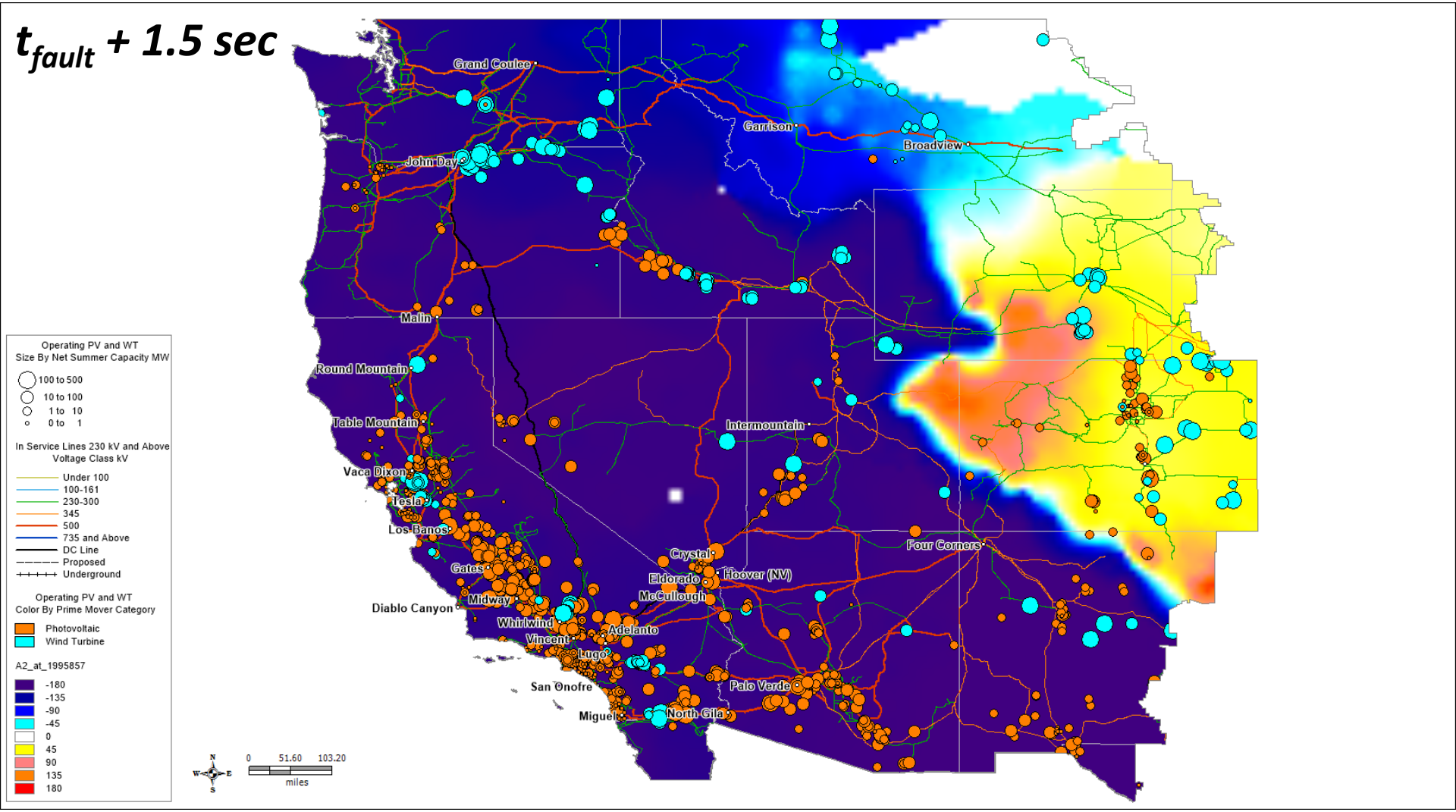


Clarification and Recommendation for Momentary Cessation

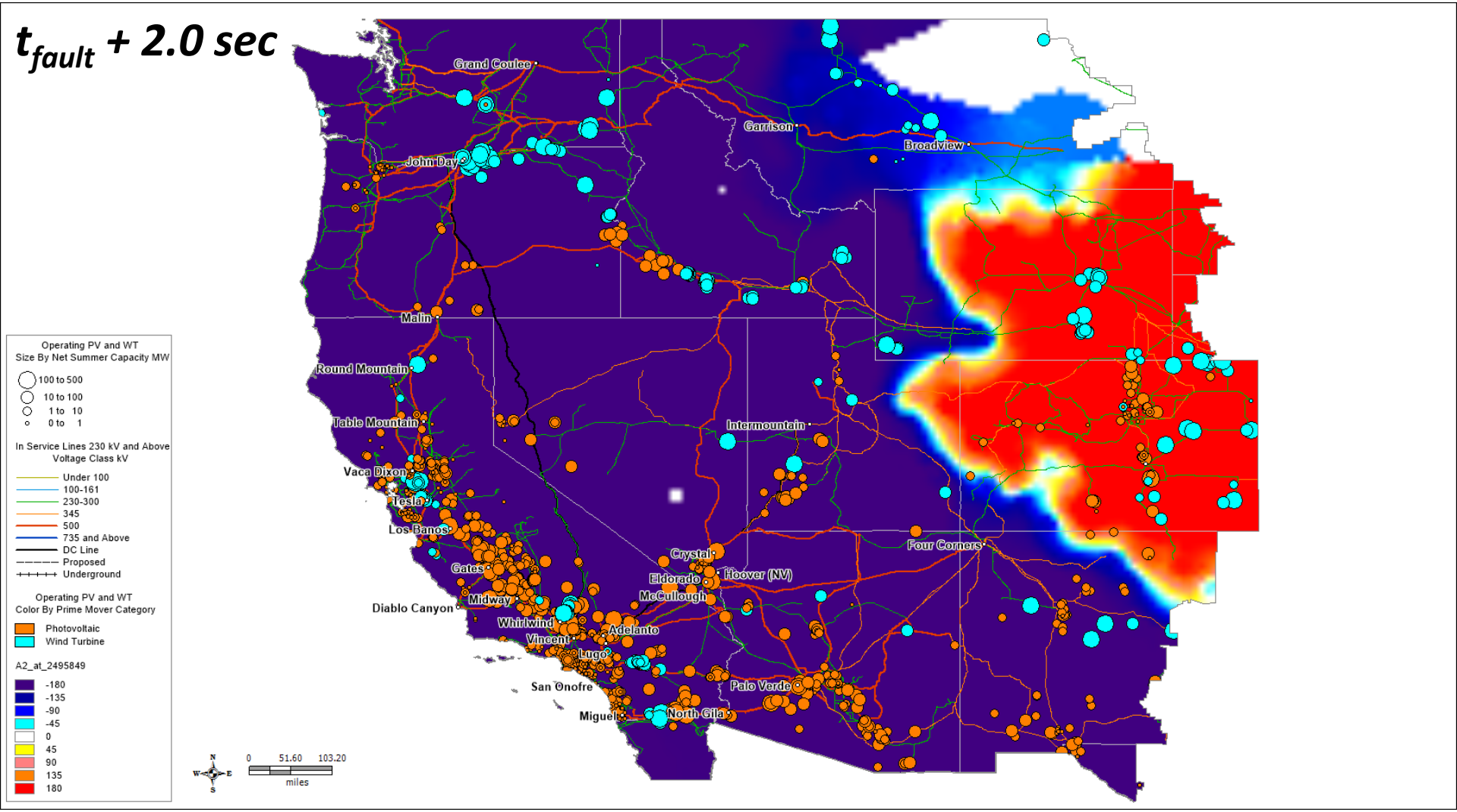
t_{fault} + 1.0 sec



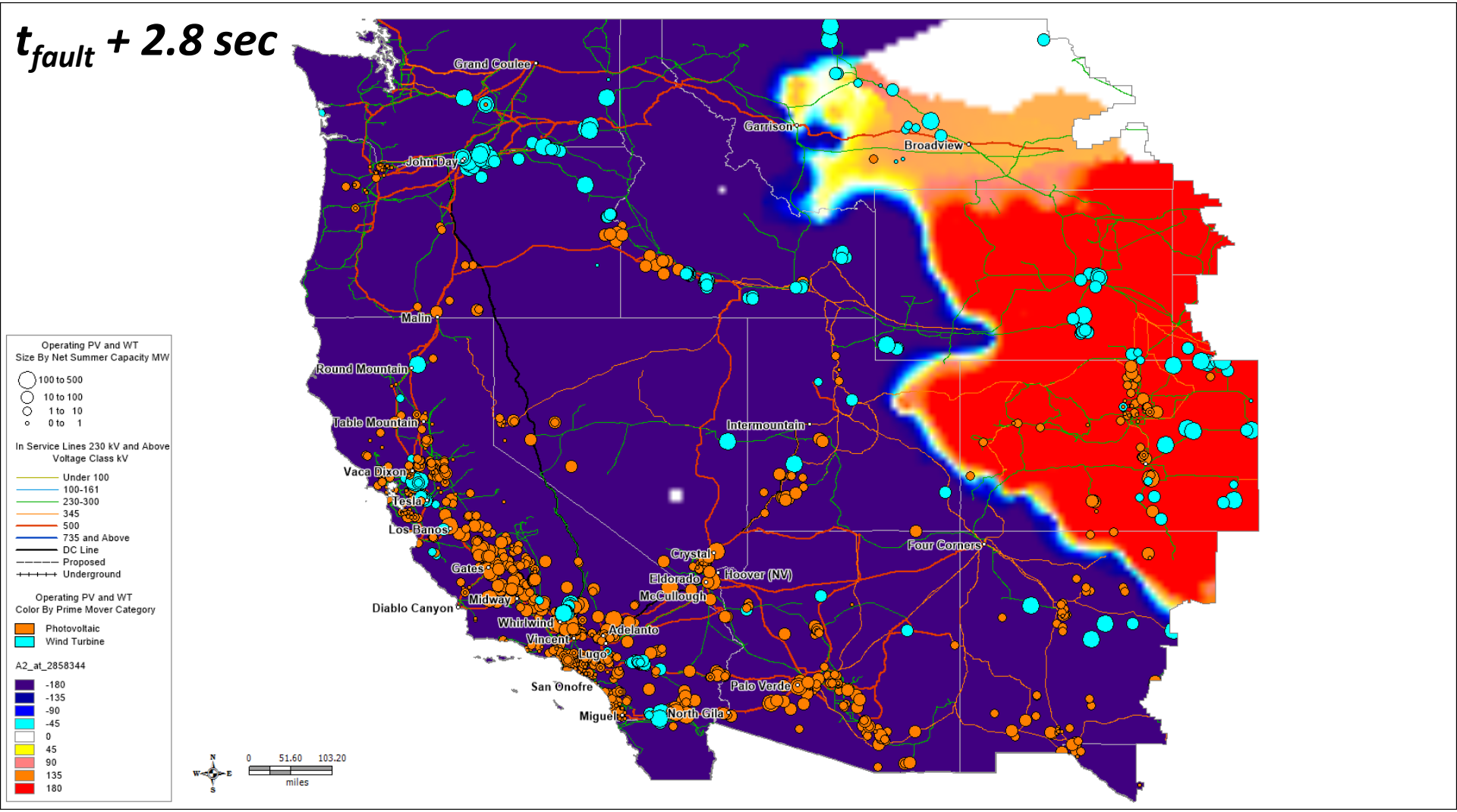
Clarification and Recommendation for Momentary Cessation



Clarification and Recommendation for Momentary Cessation



Clarification and Recommendation for Momentary Cessation

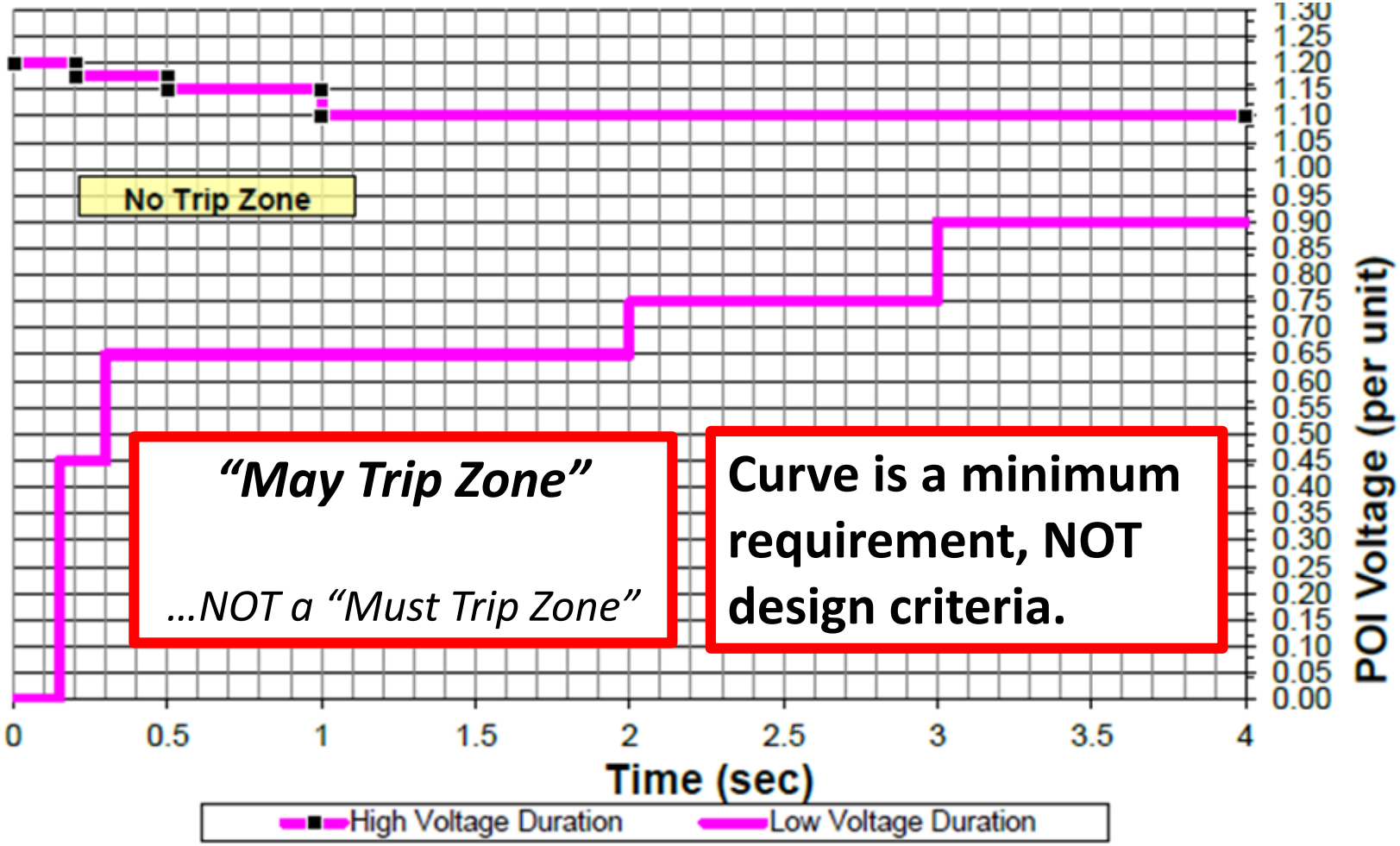


Momentary Cessation Recommendation Moving Forward

- 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.

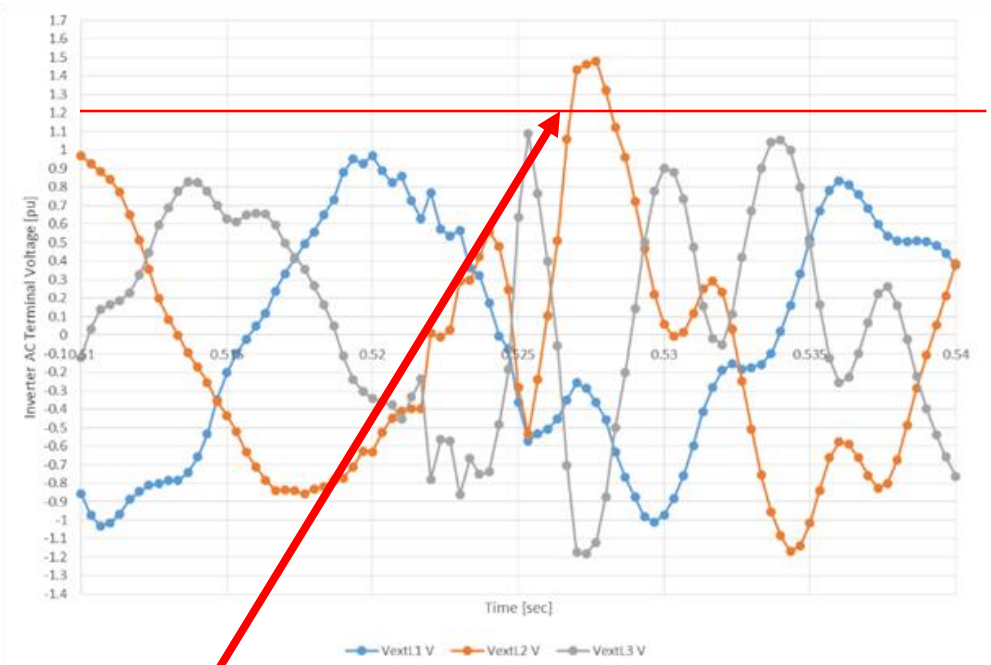
Key Findings #4

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



Key Findings #5

Instantaneous voltage tripping and measurement filtering

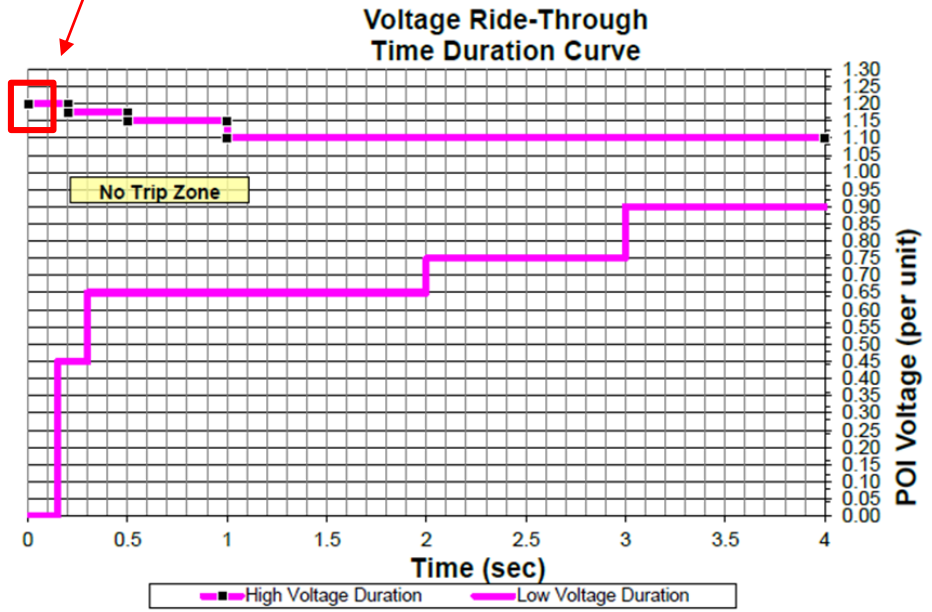


Inst. Voltage [pu nominal peak]	Samples	Time [sec]	Cycles
> 1.1	5	0.00167	0.1
> 1.2	4	0.00133	0.08
> 1.3	4	0.00133	0.08
> 1.4	3	0.00100	0.06

Key Findings #5

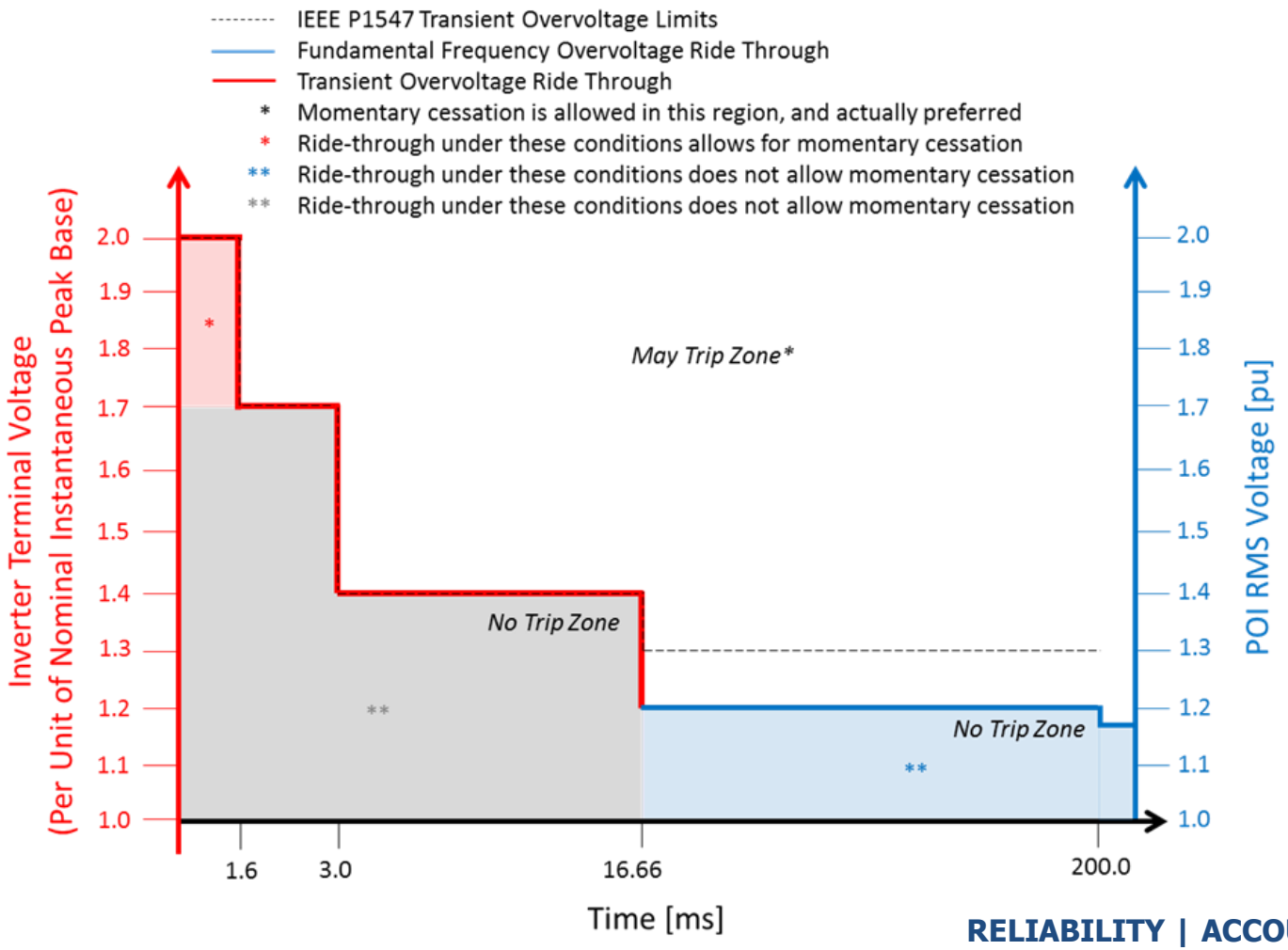
Instantaneous voltage tripping and measurement filtering

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
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 – coming likely in March 2018
- Reliability Guideline on Inverter-Based Resources Performance – Q3 or Q4 2018
- 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

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

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Questions and Answers

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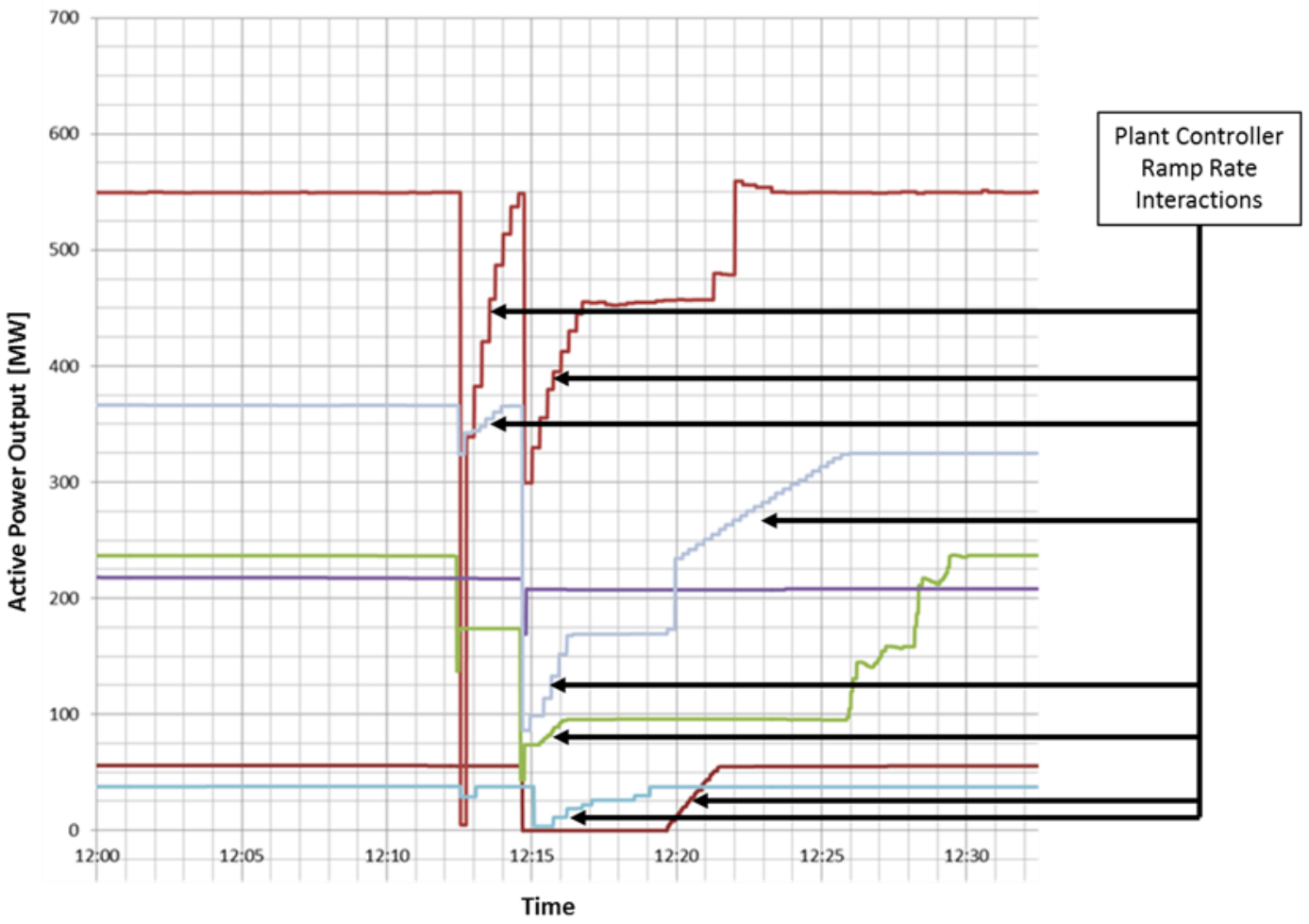
Key Findings #3

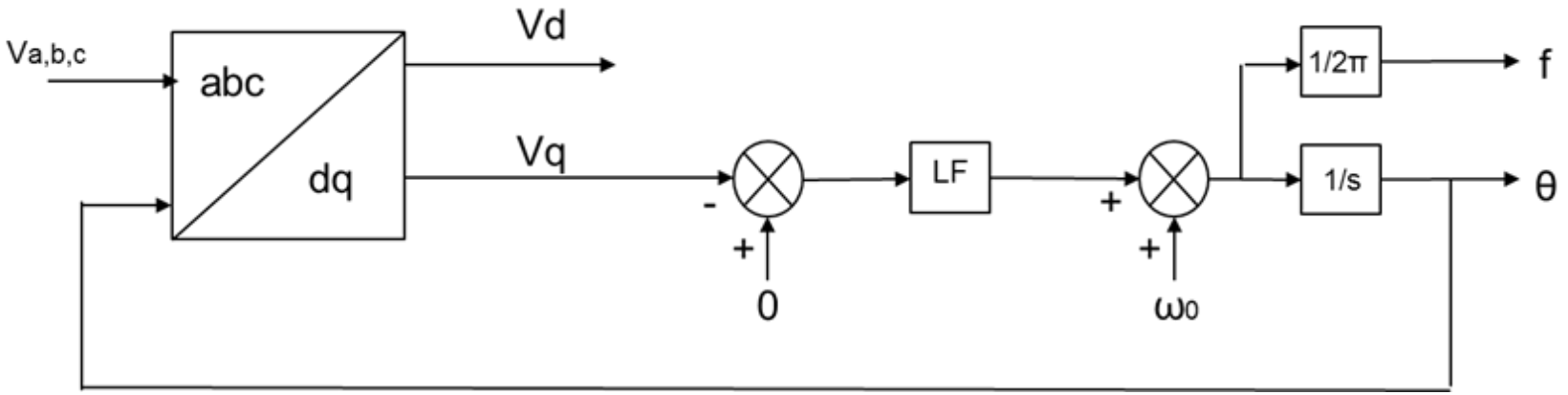
Ramp rate interactions with return from momentary cessation



Key Findings #6

Phase lock loop synchronization issues

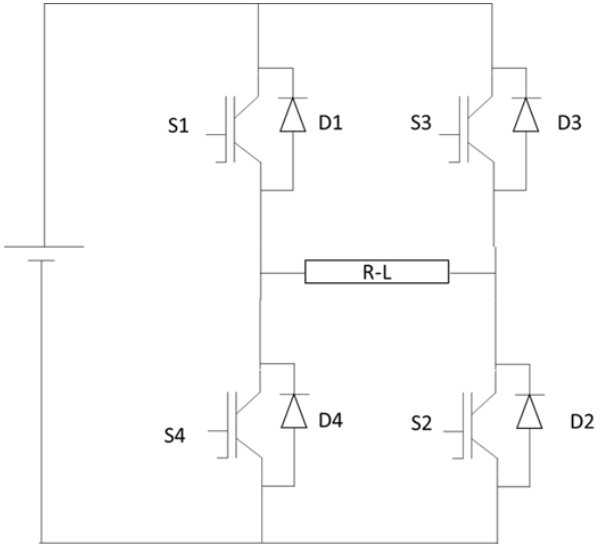
- Grid voltage phase jumps occur (e.g., during faults)
- Inverter PLLs should be robust to withstand BPS phase jumps
- Should not result in inverter tripping or momentary cessation
- Advanced controls should enable “PLL ride-through” rather than tripping

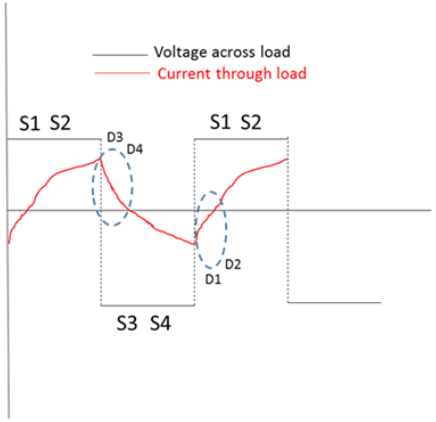


Key Findings #7

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