

1200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

Rich Bauer

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UVIG Workshop - Nashville

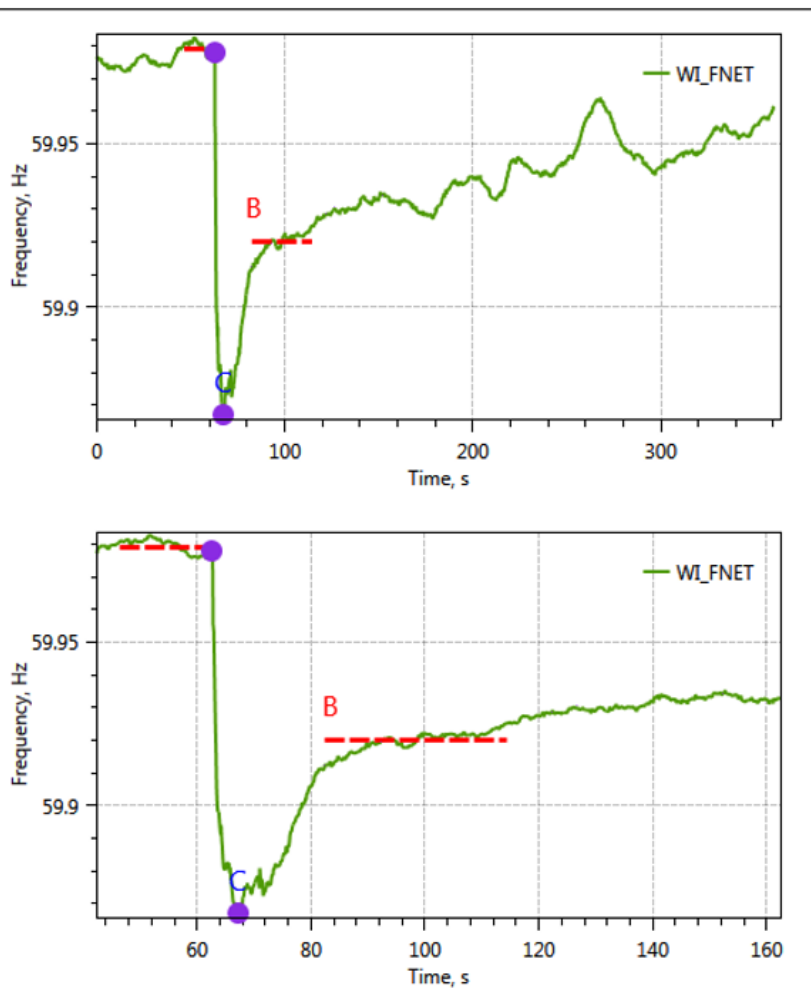
October 11, 2017

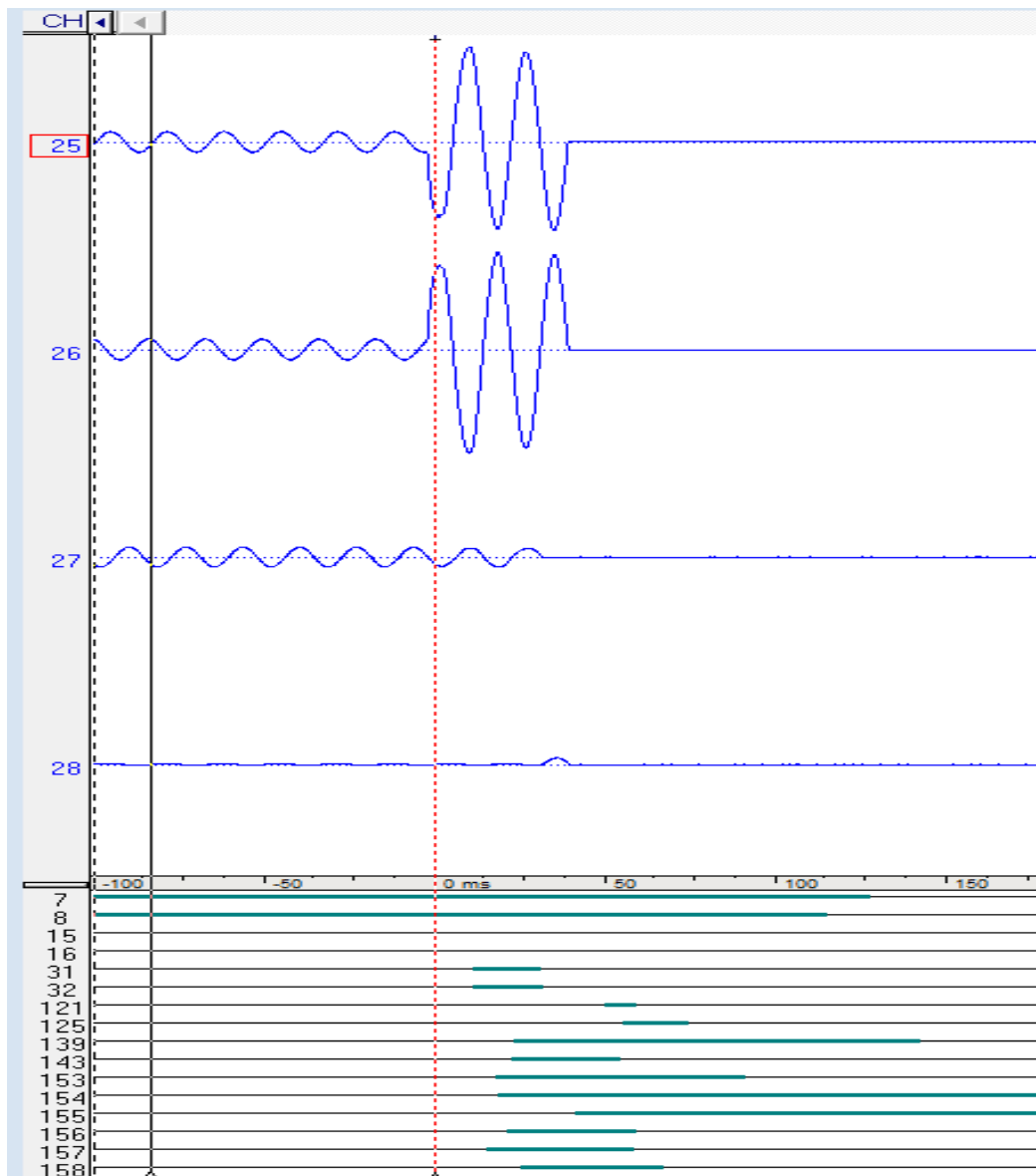
RELIABILITY | ACCOUNTABILITY



WI_20160816_184506

Event ID	WI_20160816_184506
Event Description	""
UTC Time	08/16/2016 18:45:06
Local Time	08/16/2016 11:45:06
Time Zone	PDT
M4 Flag	Yes
BAL003 Flag	Yes
MW Loss	0
Value A	59.979
Value B	59.92
Point C	59.8669
Time of C	4.7
Point C'	-
Time of C'	-
A-B [mHz]	59
A-C [mHz]	112
FRM_B [MW/0.1Hz]	0
FRM_C [MW/0.1Hz]	0



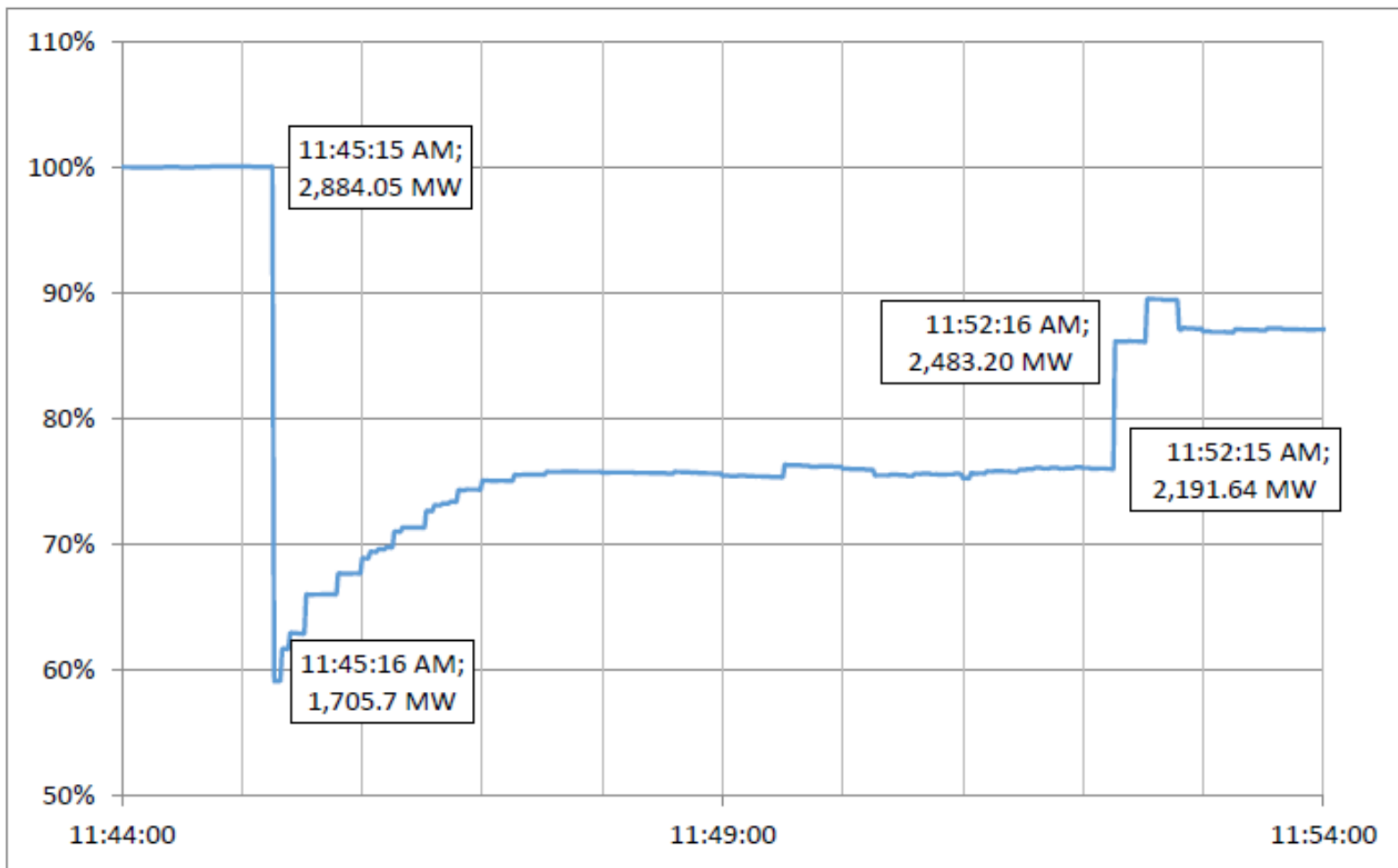


Phase A amps

Phase B amps

Phase C amps

Residual amps





- 26 different solar developments
- All utility scale
- Majority connected at 500kV or 230kV
- 10 different inverter manufacturers
- Reported causes of “trips”
 - Under frequency
 - Under voltage
 - Over voltage
 - DC overcurrent
 - 1 loss of synchronism

#	Date/Time	Fault Location	Fault Type	Clearing Time (cycles)	Lost Generation (MW)	Geographic Impact
1	08/16/2016 11:45	500 kV line	Line to Line (AB)	2.49	1,178	Widespread
2	08/16/2016 14:04	500 kV line	Line to Ground (AG)	2.93	234	Somewhat Localized
3	08/16/2016 15:13	500 kV line	Line to Ground (AG)	3.45	311	Widespread
4	08/16/2016 15:19	500 kV line	Line to Ground (AG)	3.05	30	Localized
5	09/06/2016 13:17	220 kV line	Line to Ground (AG)	2.5	490	Localized
6	09/12/2016 17:40	500 kV line	Line to Ground (BG)	3.04	62	Localized
7	11/12/2016 10:00	500 kV CB	Line to Ground (CG)	2.05	231	Widespread
8	02/06/2017 12:13	500 kV line	Line to Ground (BG)	2.97	319	Widespread
9	02/06/2017 12:31	500 kV line	Line to Ground (BG)	3.01	38	Localized
10	02/06/2017 13:03	500 kV line	Line to Ground (BG)	3.00	543	Widespread
11	05/10/2017 10:13	500 kV line	unknown	unknown	579	Somewhat Localized



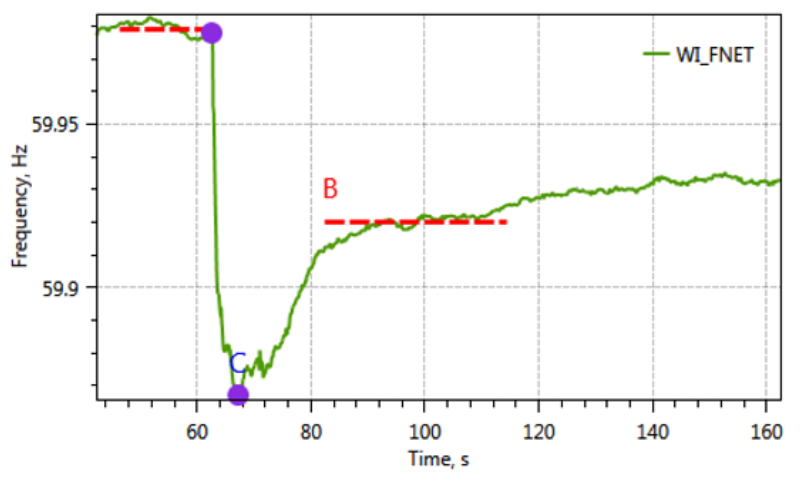
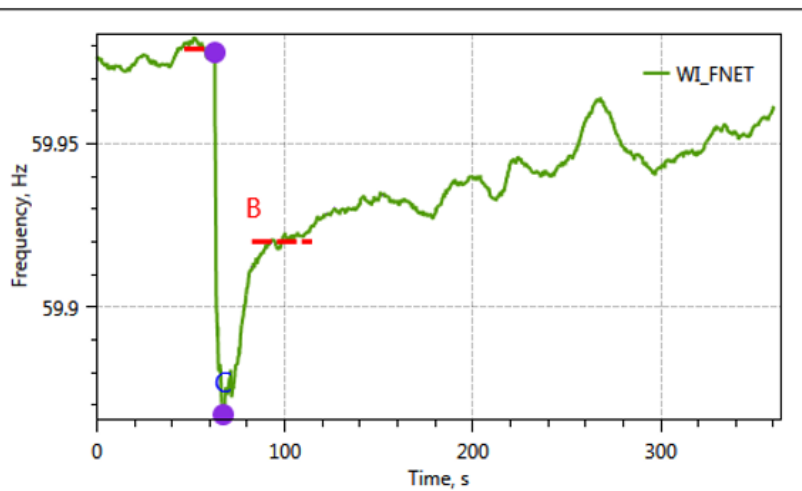
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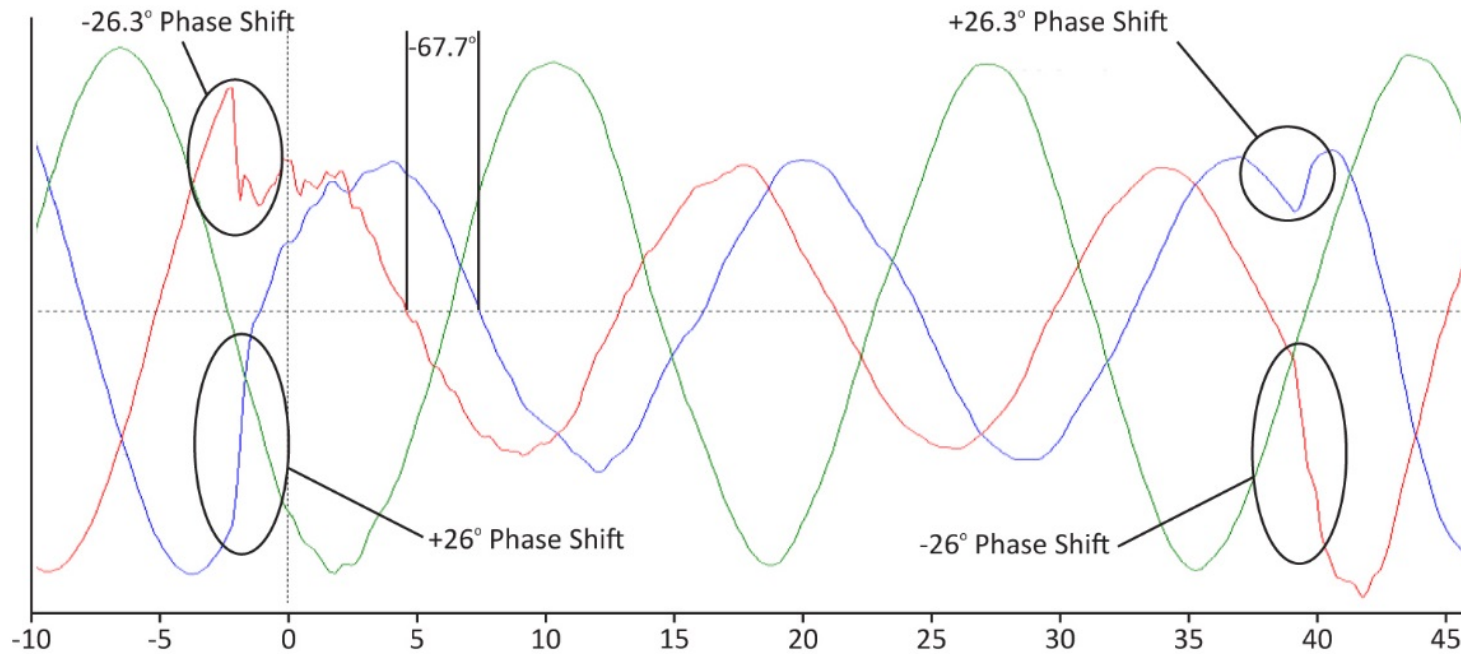


- Largest block of loss (~700 MW) was due to underfrequency tripping
- Inverter sensed a near instantaneous frequency of <57 Hz and tripped instantaneously

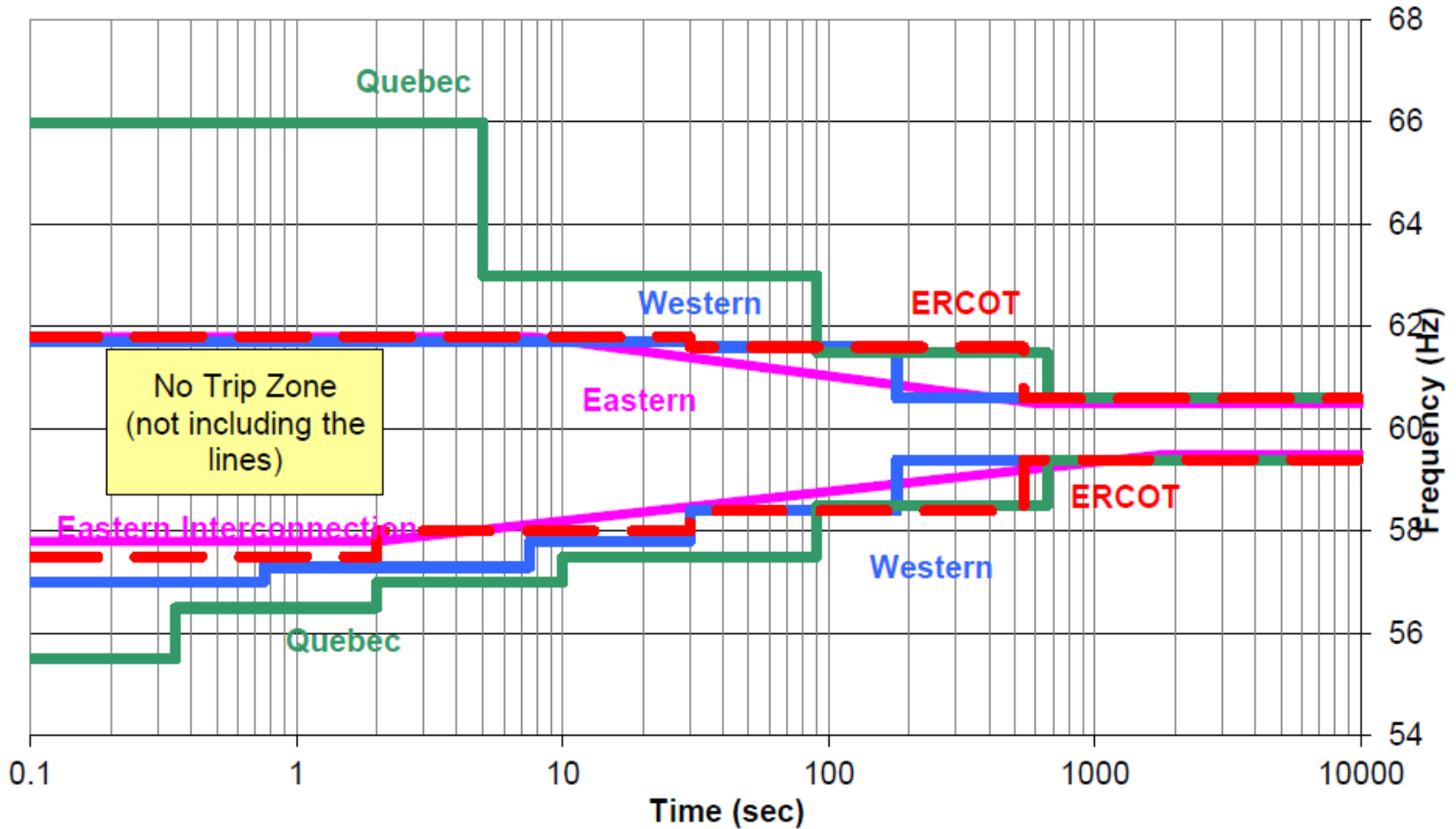
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OFF NOMINAL FREQUENCY CAPABILITY CURVE



Curve Data Points:

Eastern Interconnection

High Frequency Duration		Low Frequency Duration	
Frequency (Hz)	Time (Sec)	Frequency (Hz)	Time (sec)
≥61.8	Instantaneous trip	≤57.8	Instantaneous trip
≥60.5	$10^{(90.935-1.45713*f)}$	≤59.5	$10^{(1.7373*f-100.116)}$
<60.5	Continuous operation	> 59.5	Continuous operation

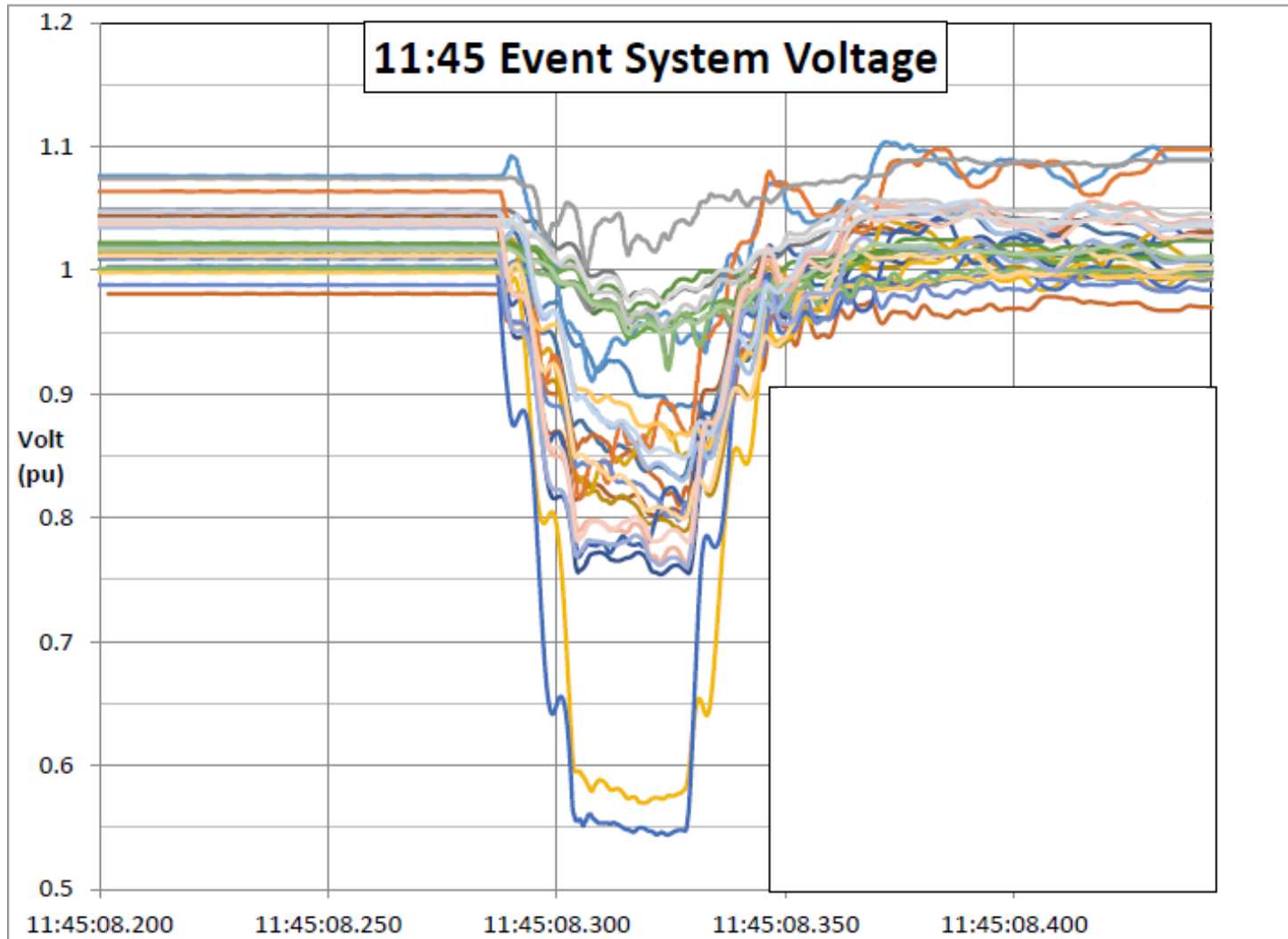
Western Interconnection

High Frequency Duration		Low Frequency Duration	
Frequency (Hz)	Time (Sec)	Frequency (Hz)	Time (sec)
≥61.7	Instantaneous trip	≤57.0	Instantaneous trip
≥61.6	30	≤57.3	0.75
≥60.6	180	≤57.8	7.5
<60.6	Continuous operation	≤58.4	30
		≤59.4	180
		>59.4	Continuous operation

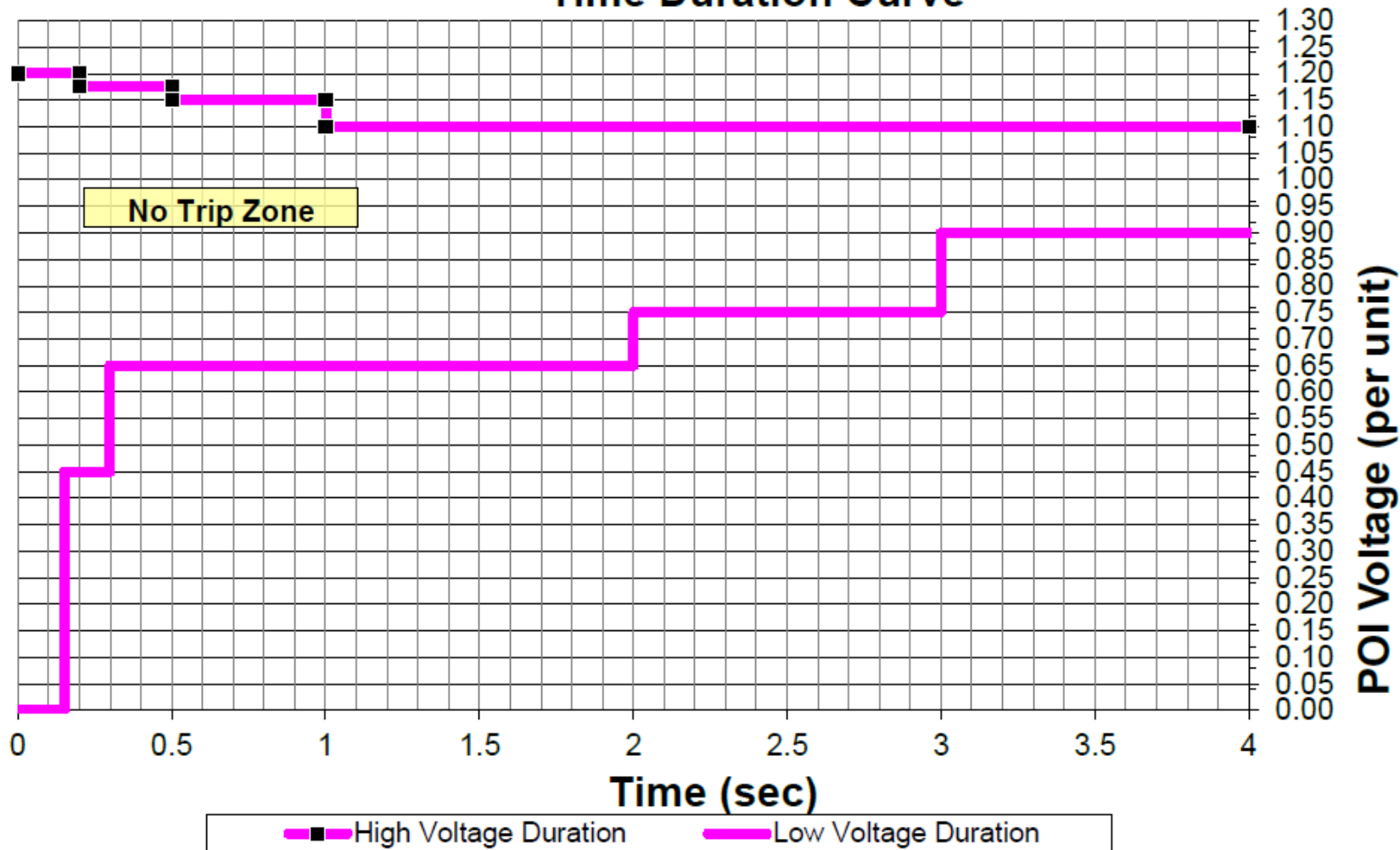


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- 2nd largest block of inverter loss (~450 MW) was attributed to low voltage



Voltage Ride-Through Time Duration Curve



- Inverters have three modes of operation
 - Operating (injecting active current into the system)
 - Momentary Cessation (momentarily cease to inject current during voltages outside continuous operating range - .9 to 1.0 per unit)
 - Trip (cease to inject current, disconnect from grid, wait ~ five minutes and return to service if grid voltage and frequency are within bounds)

- The inverters did not “Trip”, they went into Momentary Cessation
- Majority of installed inverters set to momentarily cease current injection for voltages $<.9$ p.u. or >1.1 p.u.
- In inverter language, Momentary Cessation does not equal trip

R1. Each Generator Owner that has generator frequency protective relaying activated to trip its applicable generating unit(s) shall set its protective relaying such that the generator frequency protective relaying does not trip the applicable generating unit(s) within the “no trip zone” of PRC-024 Attachment 1

R2. Each Generator Owner that has generator voltage protective relaying activated to trip its applicable generating unit(s) shall set its protective relaying such that the generator voltage protective relaying does not trip the applicable generating unit(s) as a result of a voltage excursion (at the point of interconnection) caused by an event on the transmission system external to the generating plant that remains within the “no trip zone” of PRC-024 Attachment 2

- Frequency tripping
 - Manufacturer is adding tripping delay
- Simulations to identify momentary cessation risk
 - ~7200 MW potential
 - Specify maximum delay and ramp rate for Restore Output

Actions

- Alert 6/20/2017
- IRPTF (guideline)
- Clarify that outside the PRC-024 “no trip” envelope is may trip, not must trip
- Reviewing PRC-024-2
- Socialize, socialize, socialize!



<http://www.nerc.com/pa/rrm/ea/Pages/1200-MW-Fault-Induced-Solar-Photovoltaic-Resource-Interruption-Disturbance-Report.aspx>

<http://www.nerc.com/pa/rrm/bpsa/Pages/Alerts.aspx>



Questions

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