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Solar PV Inverter Behavior During the Clearing of System Faults

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Issue - Solar PV generation lost during the routine clearing of high voltage transmission line faults

- August 2016 - April 2018: Experienced 13 transmission system faults that resulted in the unanticipated loss of inverter based generation.
  - All transmission line faults cleared in four cycles or less (normal high speed tripping)
  - Inverters should not have tripped nor ceased to operate for any of these events
  - In January 2017 CAISO and SCE brought this to WECC and NERC. NERC formed the Inverter based Resource Task Force (IRPTF) to investigate

Summary of Transmission System Events

Date	Transmission Line	Solar PV Lost
8/16/2016 1145	Lugo – Mira Loma No.3 (500 kV)	1178 MW
8/16/2016 1404	Lugo – Mira Loma No.3 (500 kV)	234 MW
8/16/2016 1513	Lugo – Mira Loma No.2 (500 kV)	311 MW
8/16/2016 1519	Lugo – Mira Loma No.2 (500 kV)	30 MW
9/06/2016 1317	Kingbird – Whirlwind (220 kV)	755 MW
9/12/2016 1740	Antelope – Whirlwind (500 kV)	62 MW
11/12/2016 1000	Victorville Sub (LADWP) (220 kV)	231 MW
2/06/2017 1213	Antelope – Vincent No.2 (500 kV)	740 MW
5/10/2017	Hasayampa – Hoodoo Wash (500 kV)	543 MW
6/15/2017 1300	Victorville – McCullough (500 kV)	813 MW
10/09/2017 1212	Serrano – Chino (220 kV)	682 MW
10/09/2017 1214	Serrano – Valley (500 kV)	937 MW
4/20/2018 1711	Mira Loma – Vincent (500 kV)	694 MW

NERC IRPTF – Issue Identification

Problem 1: system frequency calculation - resolved

- The NERC IRPTF studied the August 2016 events (Blue Cut Fire) and issued a report (6/2017) and its first Alert (6/20/2017)
- The task force identified that most of the inverters tripped due to erroneous calculation of system frequency. Report also identifies momentary cessation as an item for study.
- CAISO worked with inverter manufacturers to develop new frequency control settings and impacted inverters were updated

Problem 2: momentary cessation - ongoing

- NERC IRPTF issued second report 2/2018 for Canyon 2 fire, which occurred in southern California on 10/02/2017. Momentary cessation and transient over voltage tripping identified as main issues. Second NERC Alert issued 5/01/2018.

CAISO and the NERC task force continue to investigate and identified other issues

Problem 3: voltage issues - ongoing

- Solar PV can still be lost due to:
  - Inverters momentarily ceasing operation during transient voltages (low and high) – Momentary Cessation
  - Tripping during transient high voltage levels (typically >120%) - NERC task force identified that manufacturers may not be using filters to accurately measure voltage – High Voltage or DC overcurrent trip
  - Both of the above items are addressed in NERC's second Alert
- NERC IRPTF issued draft Guidelines for inverter based generation for public comment, comments due June 29, 2018

Lack of National Standards

- There are no national standards that govern the performance and response for inverters connected to the high voltage transmission system
- There are national standards for inverters connected to the distribution system
  - IEEE 1547 and UL 1741
  - California has Rule 21 in place
- Generator owners typically specify inverters to be in compliance with distribution standards.
- These distribution standards are not compatible for interconnections to the high voltage electric system

Additional CAISO Actions

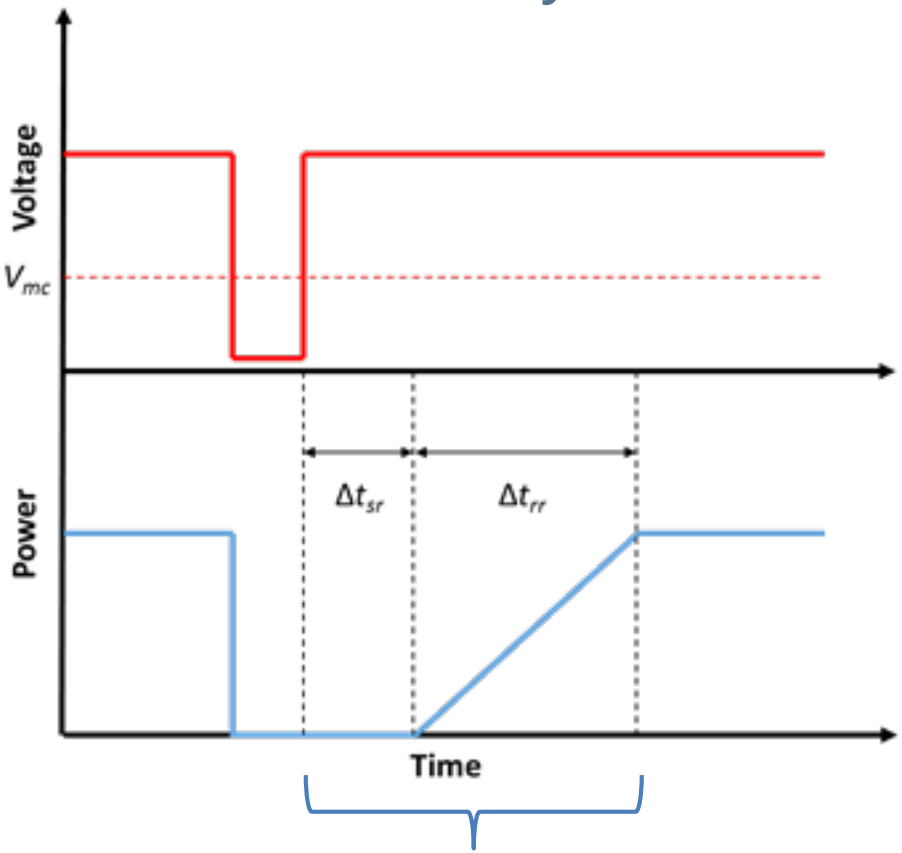
- Updating Generator Interconnection Agreements to include as requirements the recommendations in the second NERC Alert.
- Developing a solar PV database to include data on installed inverters and associated control settings
- Continuing to adjust contingency reserves
- Working with inverter manufacturers and generator owners to get accurate inverter models and conduct system studies to assess risk
- In May 2018, the CAISO filed a Standard Authorization Request (SAR) at NERC requesting the development of a new standard for inverter based generation

Appendix

- NERC Blue Cut Fire Report
- https://www.nerc.com/pa/rrm/ea/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_Interruption_Final.pdf

- NERC Canyon 2 Report
- https://www.nerc.com/pa/rrm/ea/October%209%202017%20Canyon%202%20Fire%20Disturbance%20Report/900%20MW%20Solar%20Photovoltaic%20Resource%20Interruption%20Disturbance%20Report.pdf

Momentary Cessation Example



V_{mc}: voltage threshold where momentary cessation occurs

Δt_{sr} : delay of current injection after voltage recovers

Δt_{rr} : ramp duration of recovery in current injection

Inverters often return within tens of seconds when voltage conditions stabilize.

NERC Alert recommends that delay time be no longer than 0.1 sec, and the total time to return upon voltage stabilization no longer than one sec