Issues with HPPV on Distribution Circuits

A Utility Perspective

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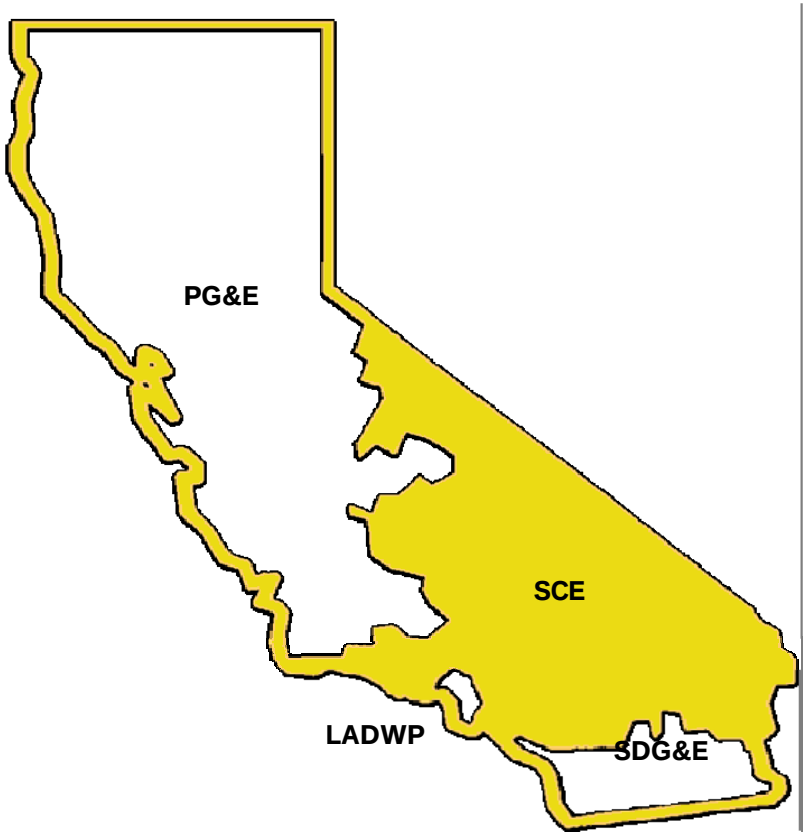


- Serves a population of about 14 million people in a 50,000-square-mile service area within central, coastal and Southern California
- 5 million electric meters
- 5,000 MW of generating capacity from interests in nuclear, hydroelectric, and fossil-fueled power plants
- Award-winning energy efficiency & DR customer programs
- Industry leader in renewable energy, electric transportation, Smart Grid and smart metering

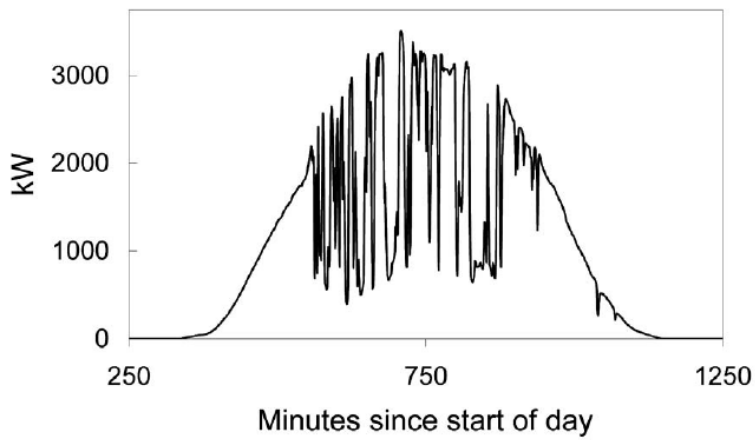
Drivers for HPPV on Distribution Circuits

- 33% Renewable Portfolio Standard
  - Barriers to new transmission
- Solar PV Program (SPVP)
  - 1-2 MW Solar WDAT on rented warehouse rooftop space
  - 250 MW Edison, 250 MW 3rd Party
  - Five year schedule

Large Rooftop Solar (SPVP)

Issues at the Distribution Level

- Voltage
  - High voltage due to reverse power flow
  - Fluctuation due to variability
- Operations and Planning Impacts
- Protection
- Islanding



Actions to Support SPVP

- Industry standards not ready for ~2 years
- Near term requirements SCE may impose
  - Active Volt/VAr response
  - Curtail real power on over voltage
  - Real power ramp rate limits
  - Fault ride through (LVRT)
  - Remote disconnect
  - Short circuit and harmonics limits

NREL Project

- Study impacts and mitigations
- Combined DOE and CPUC/CSI funding
- Model three circuits with SPVP impacts
- Develop active inverter mitigations
- Field test and measurements
- Guidebook for deploying HPPV on distribution circuits

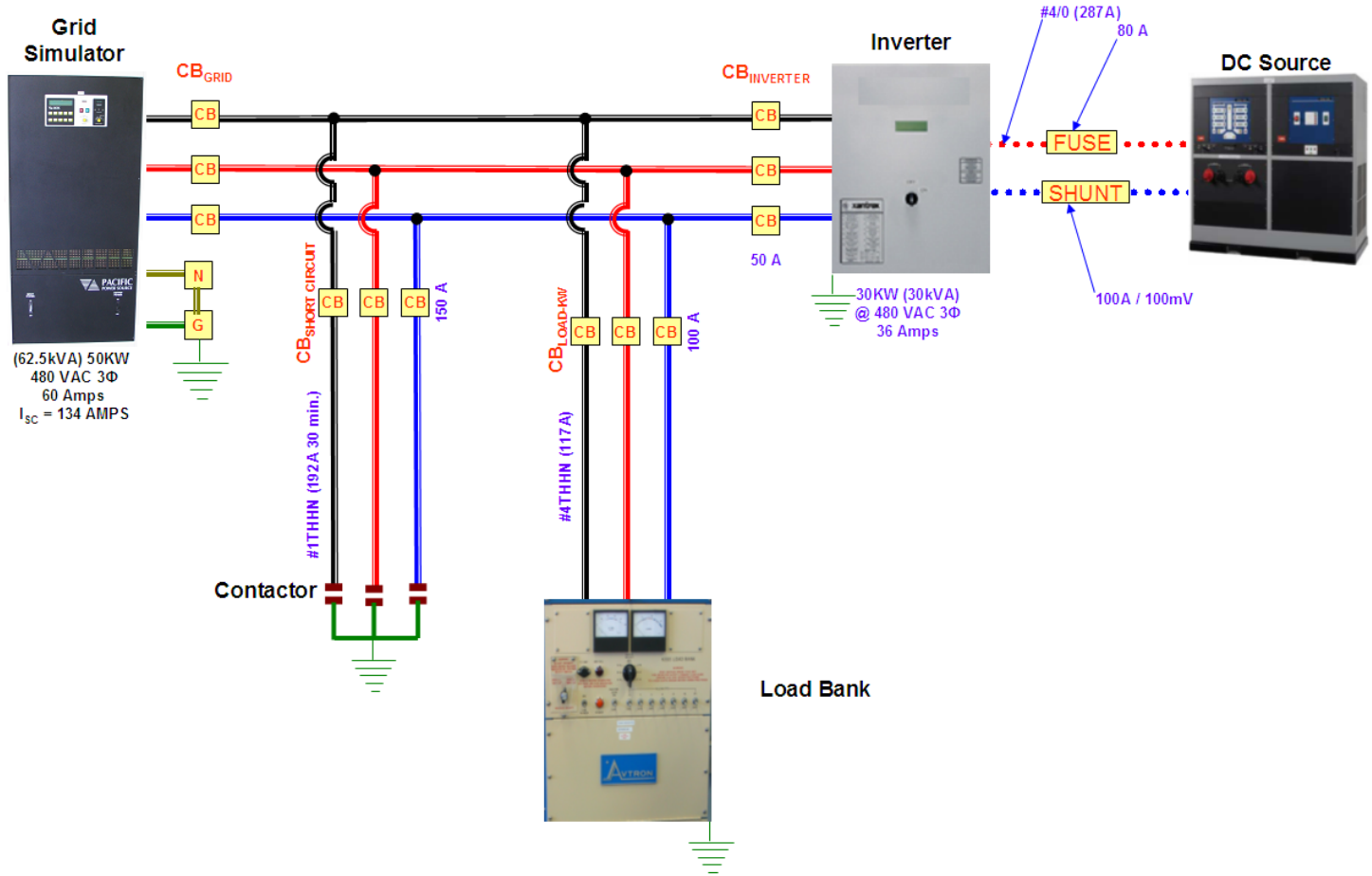
IEEE 1547.8

- Standard for DG interconnection is IEEE 1547
  - Assumed minimal penetration
- Recommended Practice 1547.8 initiative launched in August to address high penetration and other issues
- Two year timeline

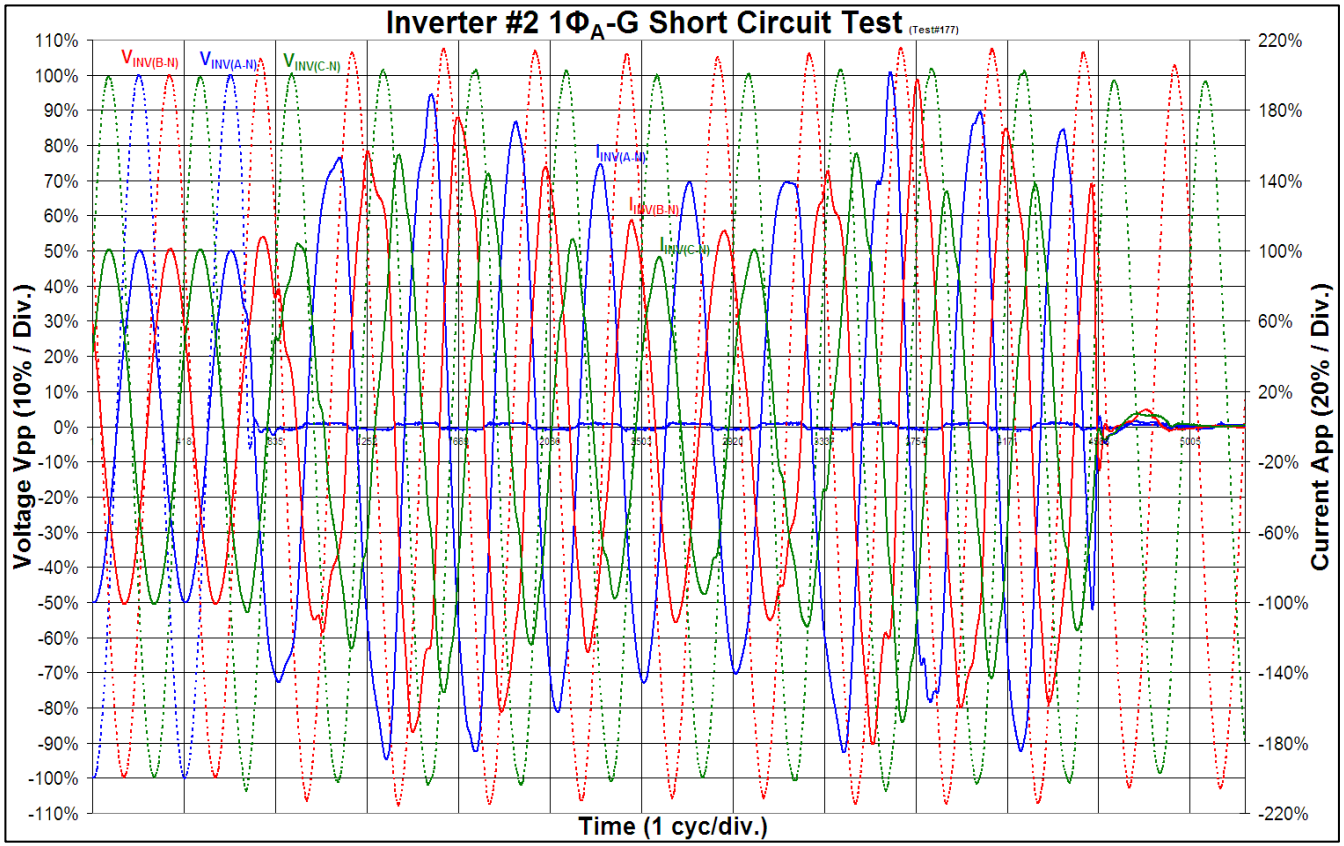
Inverter Testing at SCE

- Short Circuit Behavior
- Loss of Load Behavior
- Harmonics

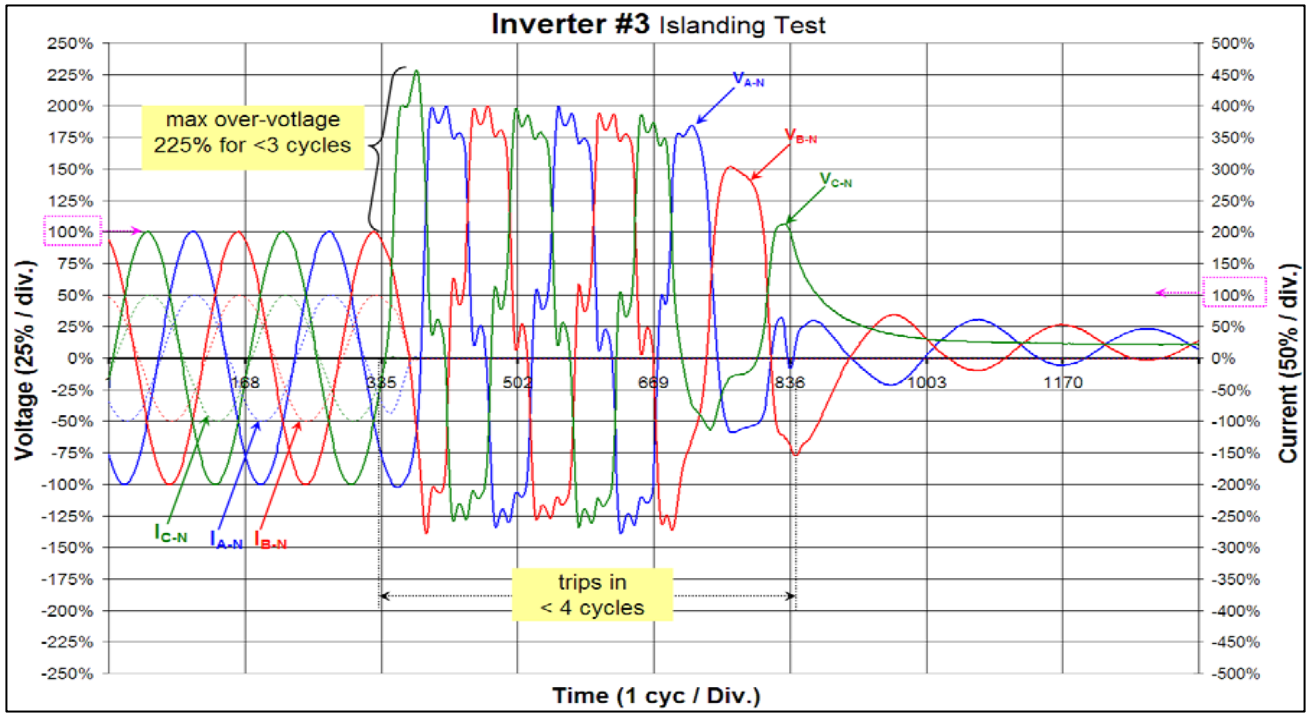
Short Circuit Test Diagram



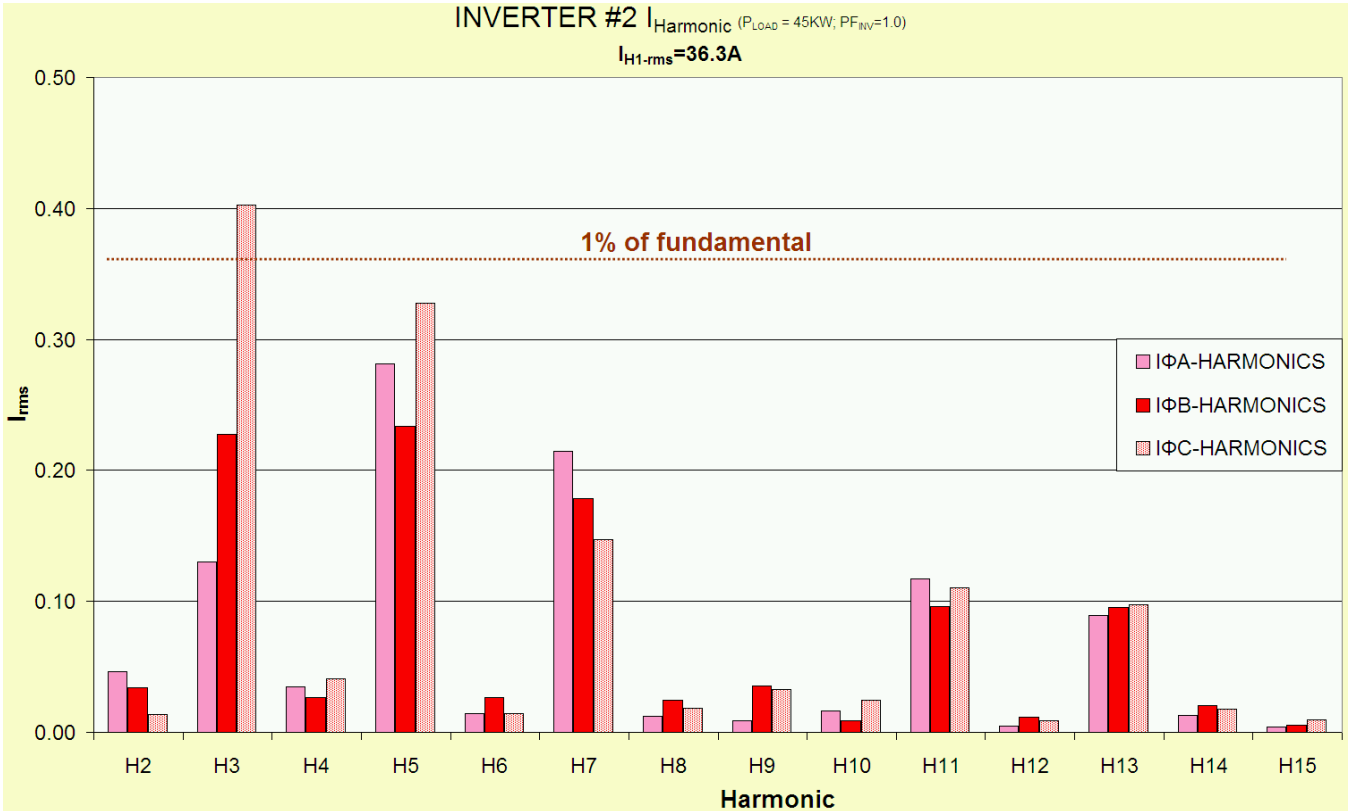
Short Circuit Contribution



Transient Over Voltage



Harmonics


INVERTER #2 I Harmonic (P LOAD = 45KW; PF INV=1.0)
I H1-rms=36.3A
0.50
0.40
0.30
0.20
0.10
0.00
I rms
1% of fundamental
IΦA-HARMONICS
IΦB-HARMONICS
IΦC-HARMONICS
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
H13
H14
H15
Harmonic

Conclusion

- High PV penetration introduces new issues to manage at distribution level
- Highly dependent on where PV is located on circuit
- Inverter capabilities to manage these impacts need to be exploited
- Standards process may lag our need
- Generators and utilities must work this out