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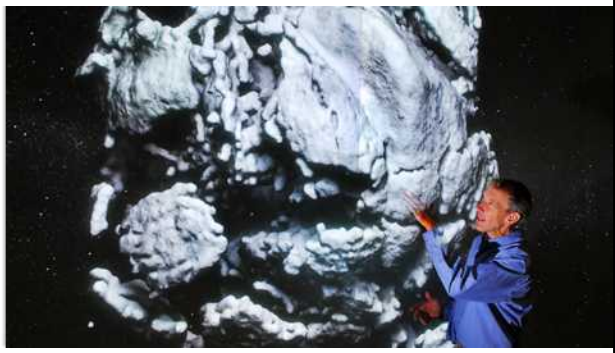

Sandia Recommendations for UL 1699B

10-11 Sept, 2013

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Goal and discussion topics

GOAL: Create repeatable tests that represent 'real world' arc-fault detection scenarios.

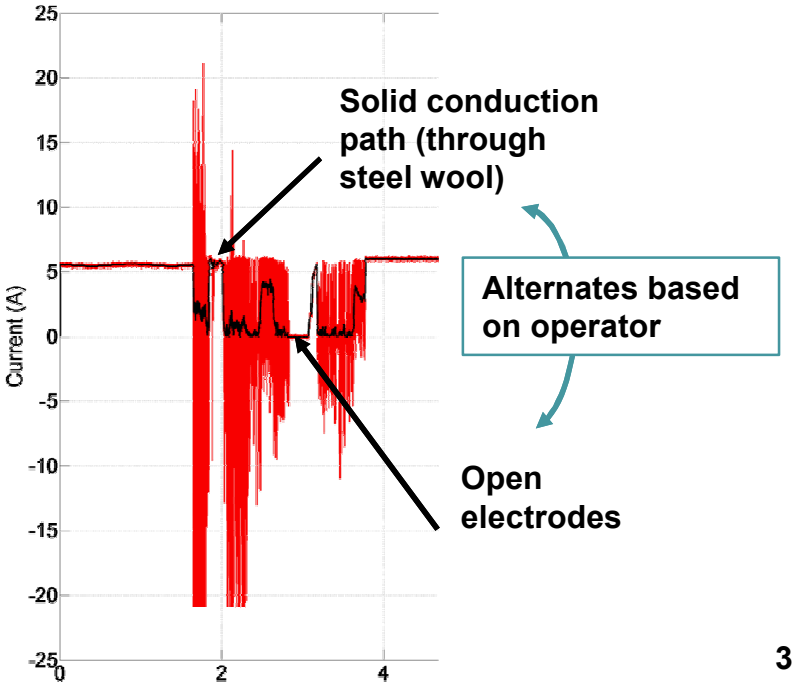
Topics:

- Arc-fault generation
- Ballast resistor testing
- Inclusion of low power arc-faults
- Nuisance tripping tests
- Parallel arc-fault generation
- PV simulators for AFCI testing

Arc-fault generation

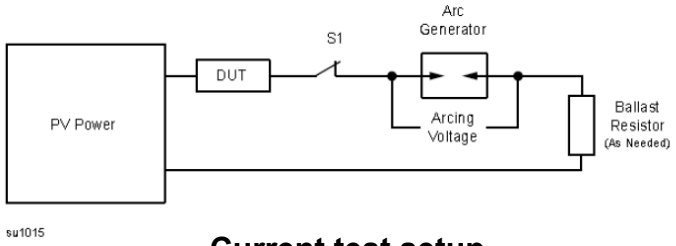
- Experience with steel wool and polycarbonate tubing demonstrate unrepeatable results and may create unrealistic arc-fault signatures.
- Current and voltage variability caused by 'micro arc flashes' when the steel wool burns. (See movie.)
- Polycarbonate can melt to electrodes and create sealed volume.
- Options:
  - Use motorized arc-fault generator.
  - Use hand operated arc-fault generator, but replace t_{trip}= min[2, 750/(I_{arc}*V_{arc})] with:

$$t_{trip} = \min\left[2, \frac{750 \cdot (t_{arc\_end} - t_{arc\_start})}{\int_{t_{arc\_start}}^{t_{arc\_end}} I_{arc}(t) V_{arc}(t) dt}\right]$$

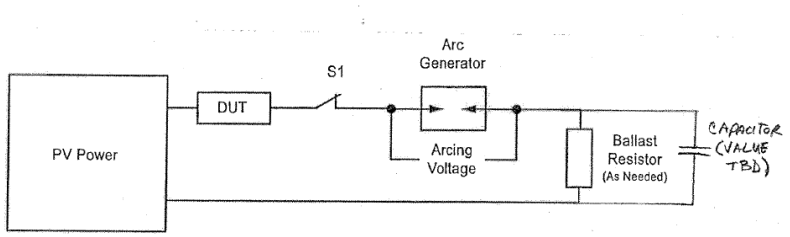


Ballast resistor testing

- Goal: Move toward realistic, repeatable arc-fault detection tests.
- Ballast resistor tests are unrepresentative of true PV systems.
  - Option 1: Only test using inverters.
  - Option 2: Add a capacitor in parallel to the resistor. [Lippert, PR19639]
    - Additional question: what capacitance should be selected? There's a large range of input capacitance values so should a reasonable mean be selected?
  - Option 3: Leave test the same.
- Experience: PV AFD prototypes have more difficulty detecting arc-faults with a resistive load bank than an inverter because there is no low AC impedance path without the inverter input bus capacitor.



Current test setup.



Lippert, PR19639

Low power arc-faults

- These are also dangerous!
- 100 W arc-faults can easily start polymers on fire.
- Would like to see another row in Table 27.2 for 100 W arc-faults. These should to be included in the testing too.

Table 27.2
Arcing tests and clearing times

Arcing current (amps)[a, d]	Arcing voltage[b] (volts)	Average Arcing Watts [a]	Approximate electrode, inches (mm) [b]	Max time (sec) [c]
7	43	300	1/16 (1.6)	2
7	71	500	3/16 (4.8)	1.5
14	46	650	1/8 (3.2)	1.2
14	64	900	1/4 (6.4)	0.8

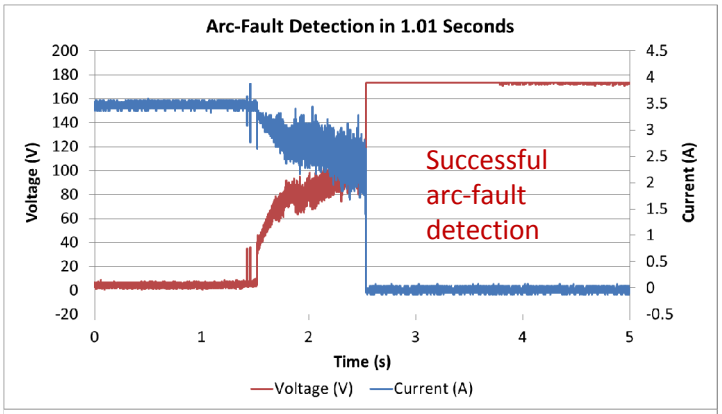
Note: Arcing current may be reduced, while still achieving average Watts, where arcing current exceeds rated current of the device.

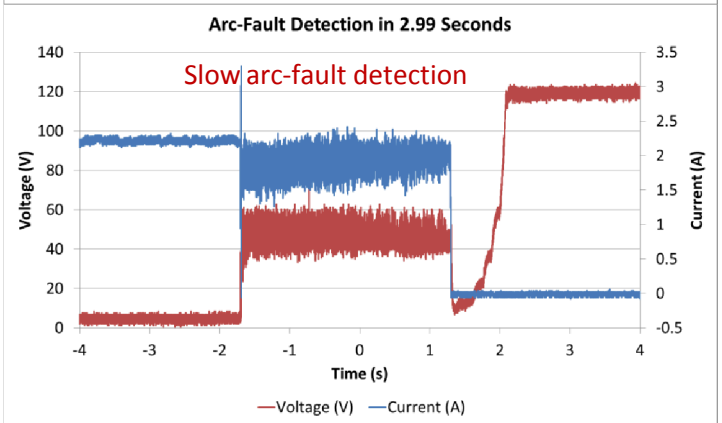
[a] ±20% for arcing current. ±10% for average arcing Watts.

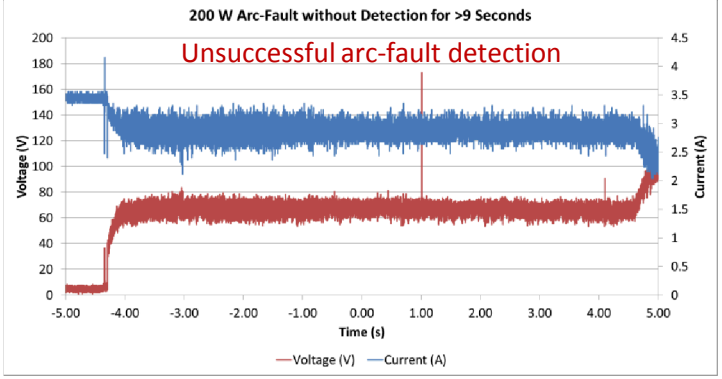
[b] Approximate, as needed to achieve arcing Watts. Electrode gap can be adjusted to achieve needed arcing voltage.

[c] Based on average Watts. See 27.3.1(e) for actual maximum detection or interruption times.

[d] For devices rated less than arcing current, test current may be reduced to rated current and arcing watts calculated accordingly.





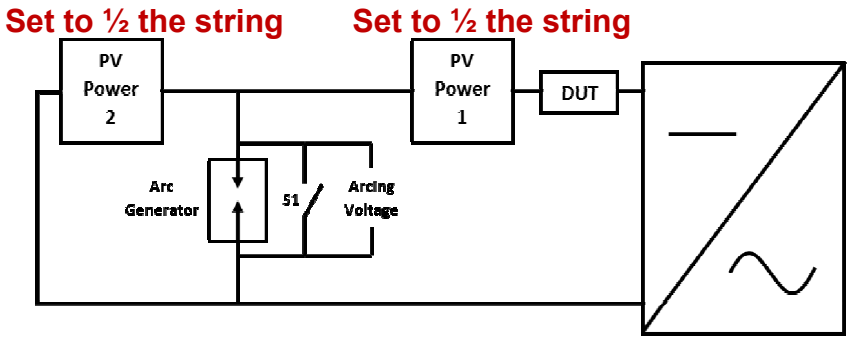


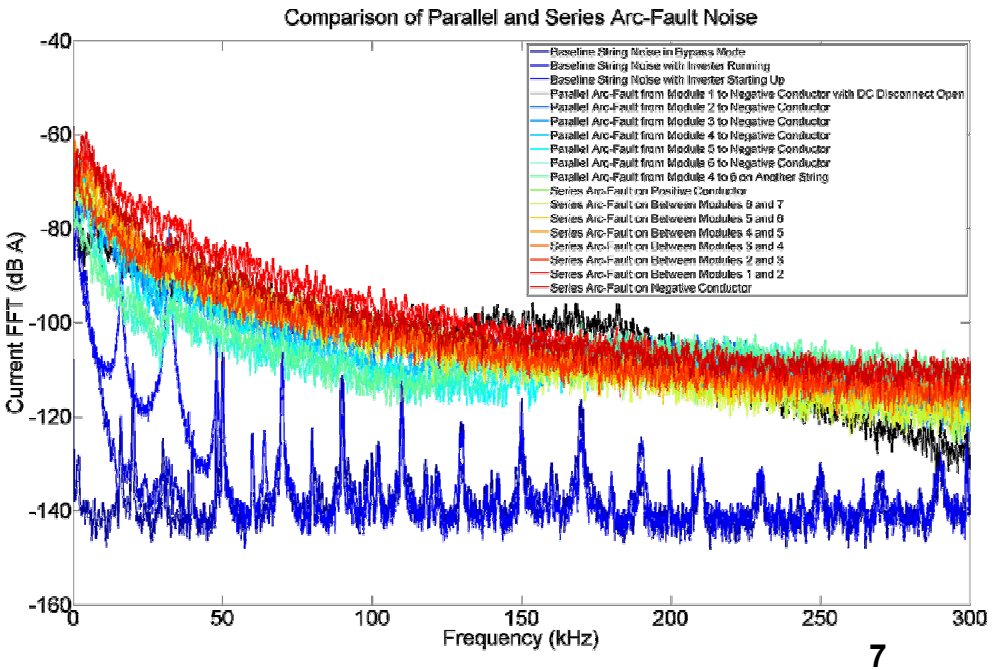
Nuisance tripping requirements

- Definitely a real problem. Question is where/how it should be addressed.
- STP can revise the standard in a couple different ways:
  - **More nuisance tripping requirements**—per my original recommendations, because it's VERY important that these devices don't give a bad name to PV.
    - Test multiple inverter/charge controller/converters for stand alone AFCIs (realistic but hard to perform the tests).
    - Test inverter AFCIs with multiple DC-DC converter noise signatures.
    - AC-DC coupling tests, etc. (See Haberlin for problems with elevator noise.)
  - **No nuisance tripping tests [PR19857]**—acceptable as long as manufacturers develop quality products. This is a certification standard, not strictly a safety standard.
    - "The market will decide which products are good/bad."
    - Yes, but I don't want the market to have to through that process. Consumers are going to be very upset!

Parallel arc-fault generation

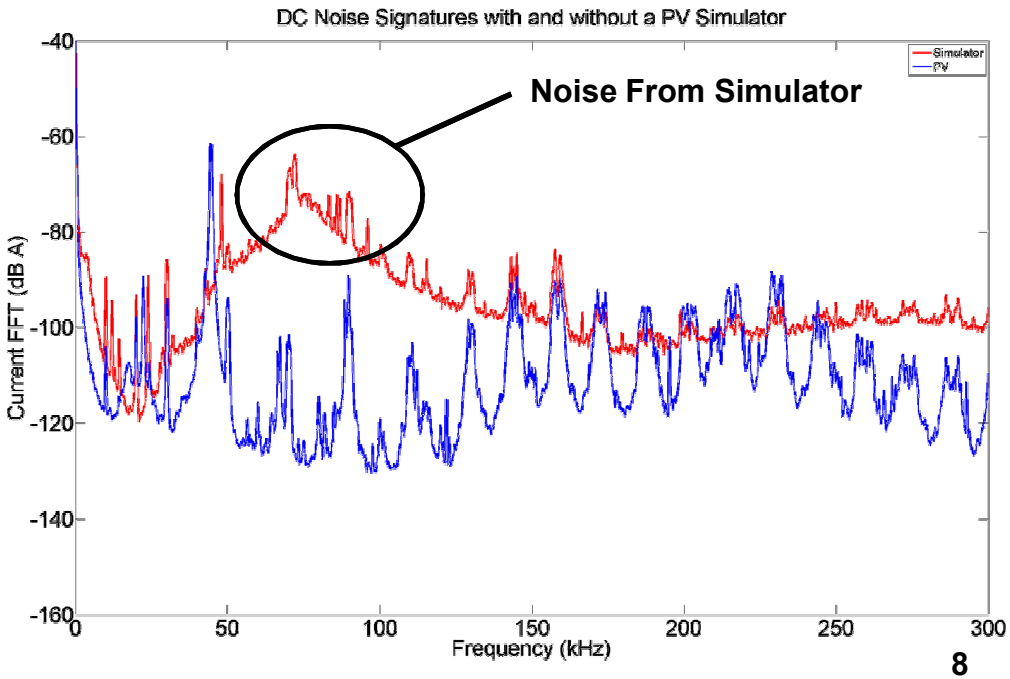
- Extensive testing at SNL shows that the arc-fault noise is very similar regardless of where the arc-fault is generated, so the parallel arc-fault should be created mid-string to prevent shorting the input bus capacitor of the inverter.
  - Realistic of true PV systems and repeatable.





A warning about PV simulators

- These are switching devices so they inject their own noise into the DC system.
- Not all simulators are the same.
  - Must require strict constraints on DC noise injection.
- Sandia recommends using physical PV systems.



Thank you.

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