



# **Codes and Standards for Photovoltaic DC Arc-Fault Detection**

**Jay Johnson, [jjohns2@sandia.gov](mailto:jjohns2@sandia.gov)**

Ward Bower, [wibower@sandia.gov](mailto:wibower@sandia.gov)

Sandia National Laboratories  
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# Presentation Outline

- PV Arc-Fault Classifications
- Arc-Fault Codes and Standards
- Sandia National Labs Research
- Potential for Parallel Arc-Fault Protection
- Arc-Free Future

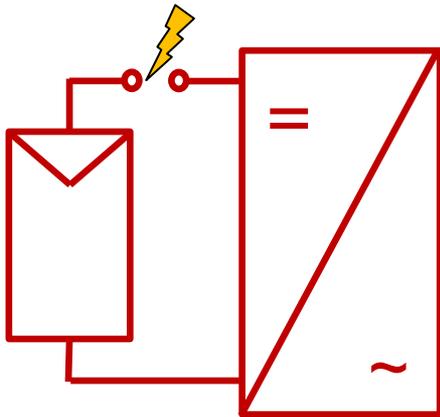


# PV Arc-Fault Detection Codes

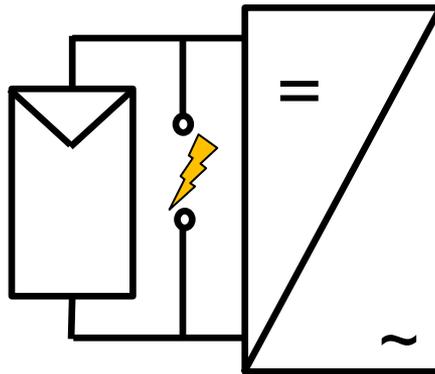
Arc-faults in PV systems cause fires.



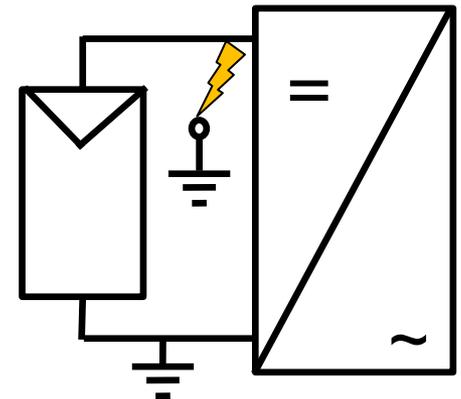
## 3 Types of Arc-Faults in PV Systems



Series Arc-Fault:  
NEC 690.11



Parallel Arc-Fault:  
Not in the NEC



Ground Arc-Fault:  
NEC 690.5



# PV Arc-Fault Detection Codes

Arc-faults in PV systems cause fires.



2011 *National Electrical Code*® requires PV arc-fault protection.



**690.11 Arc-Fault Circuit Protection (direct current):** Photovoltaic systems with dc source circuits, dc output circuits, or both, on or penetrating a building operating at a PV system maximum system voltage of **80 volts or greater**, shall be protected by a listed (dc) arc-fault circuit interrupter, PV type, or other system components listed to provide equivalent protection. The PV arc-fault protection means shall comply with the following requirements:

- (1) The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the dc PV source and output circuits.
- (2) The system shall disable or disconnect one of the following:
  - a. Inverters or charge controllers connected to the fault circuit when the fault is detected.
  - b. System components within the arcing circuit.
- (3) The system shall require that the disabled or disconnected equipment be **manually restarted**.
- (4) The system shall have an enunciator that provides a visual indication that the circuit interrupter has operated. This indication **shall not reset automatically**.

1. Arcing can occur at voltages well below 80 volts. Should this value be reduced to a level where there is certainty that an arc will not initiate?
2. Some members of the industry believe the manual restart is overly prescriptive. Are there situations where automated restarts could be permissible?

# PV Arc-Fault Detection Codes

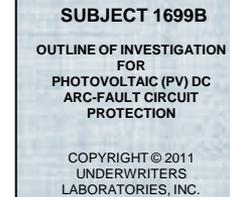
Arc-faults in PV systems cause fires.



2011 *National Electrical Code*® requires PV arc-fault protection.



UL 1699B is created to list arc-fault protection devices.



## UL Subject 1699B Test Sequence

- Humidity
- Leakage
- Voltage Surge
- Environmental Sequence
- Arc Fault Detection
- Unwanted Tripping
- Inhibition
- Temperature
- Overvoltage
- Overload
- Endurance
- Dielectric Voltage Withstand
- Abnormal
- Short Circuit
- Corrosion test
- Crushing
- Strain Relief
- Mechanical
- Resistance to Environmental Noise
- Electrostatic Discharge
- Radiated EMI
- Fast Transients
- Voltage Surge
- Induced RF Fields
- Voltage Dips
- Surge Current
- Abnormal Voltage

Listing standards must ensure quick detection without nuisance tripping in situations with:

- Noisy inverters
- Lightning, large radio signal amplitudes, and other RF noise
- Arcs from DC disconnects and other contactor open/closing operations



# PV Arc-Fault Detection Codes

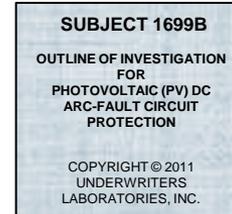
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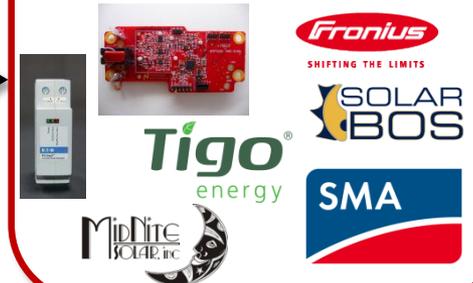
2011 *National Electrical Code*® requires PV arc-fault protection.



UL 1699B is created to list arc-fault protection devices.



Industry responds by creating PV AFCI devices.



# PV Arc-Fault Detection Codes

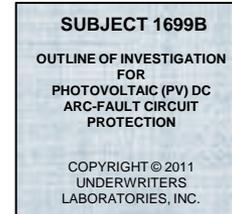
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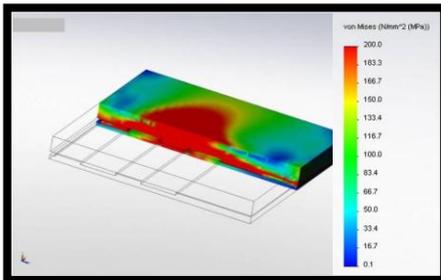


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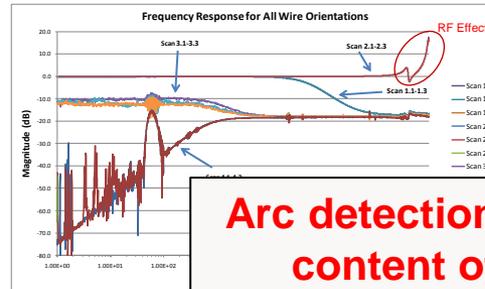
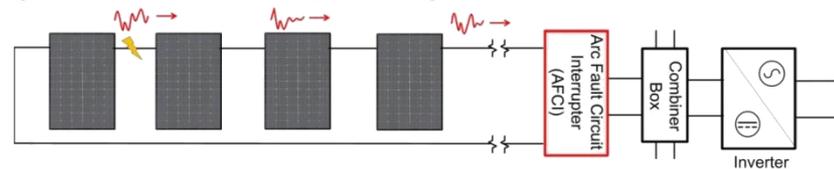
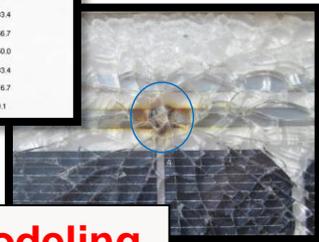


Sandia/Industry Collaborations

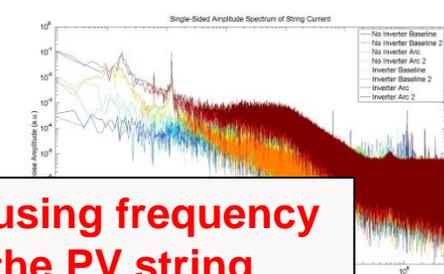
Sandia Research: Arc modeling and electrical propagation studies.



Arc-fault modeling

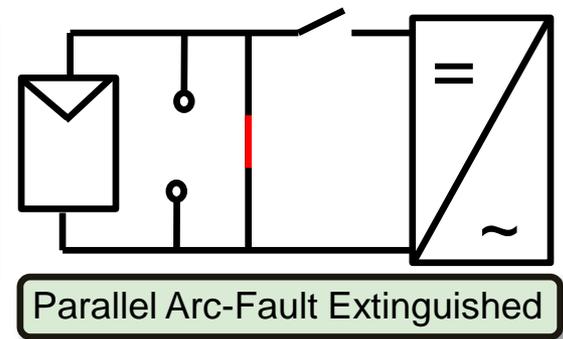
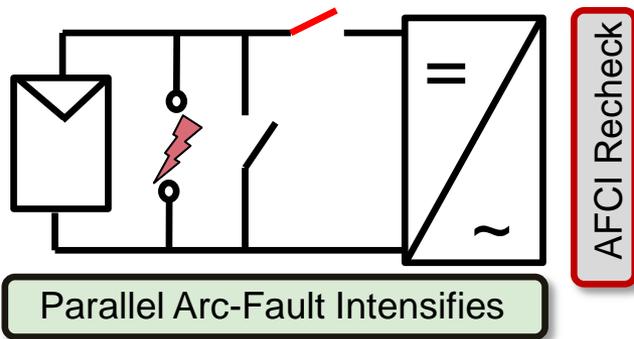
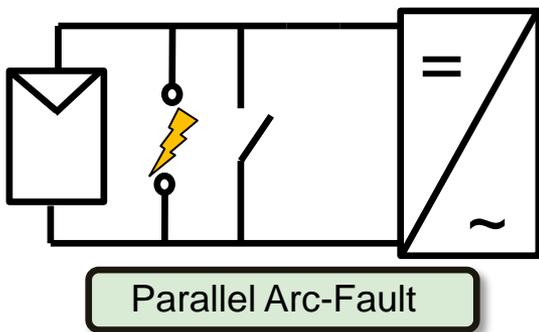
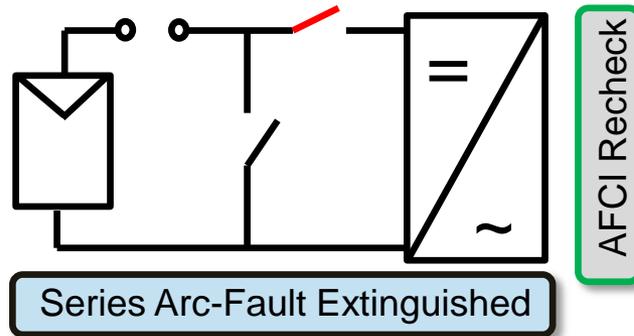
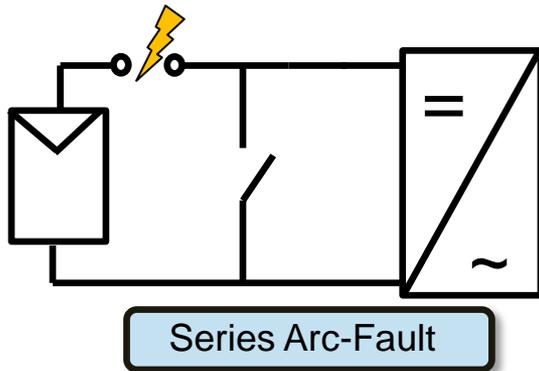


Arc detection using frequency content of the PV string



# Parallel Arc-Fault Detection

- Often AFCIs use the AC frequency content of the string for detection
  - Parallel and series arcing frequency are (supposedly) not differentiable
  - Opening the circuit makes parallel arcs worse
- One solution: guess-and-check
  - If there's an arc, assume it's a series arc and open the circuit. If arcing frequencies still exist, short the PV.



How fast can this be done? Will series+parallel AFCIs meet the current 1699B requirements?



# Moving Toward an Arc-Free/Fire-Free Future for PV

- Need Codes and Standards for Series, Parallel, and Ground Faults
  - Parallel arc-fault detection must be addressed to prevent all PV-initiated fires
- Tools to Determine Arc-Fault Location
  - Once the AFCI is tripped how can the faulty component be located?
- PV DC Arc Mitigation
  - Design smart PV systems and materials that mitigate arcing
- PV System Prognostics
  - Develop tools or passive indicators to report the health of PV systems



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