Overview of Arc-Faults and Detection Challenges

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Arcing in PV Systems

- How are PV fires created?
  - Discontinuities in the PV conduction path initiate electrical arcing
  - The arc creates a high temperature plasma which ignites surrounding materials

- What are the dangers?
  - Loss of property
  - Injury or death for building occupants, business owners, and firefighters
  - Reduced PV market penetration due to bad publicity for the PV industry

- How prevalent is the problem?
  - Difficult to quantify the number of PV-initiated fires
    - Solar companies do not publicize arcing events
    - No widespread reports on residential fires
    - Few documented fires - typically commercial installations
      - Buerstadt, Germany – Commercial building
      - Mont Soleil, Switzerland – 560 kW plant
      - Bakersfield, CA – Target store

- What is being done about it?
  - 2011 National Electrical Code Article 690.11: Arc-Fault Circuit Protection (Direct Current)
    - 80 V or greater PV systems on or penetrating a building must have a listed Arc-Fault Circuit Interrupter
  - UL 1699B: Photovoltaic (PV) DC Arc-Fault Circuit Protection
    - Provides the Arc-Fault Circuit Interrupter (AFCI) testing methodology

Arcing in PV Systems

Why are PV systems susceptible to arcing?
- PV systems have high DC voltages (600+ V)
- No zero-crossing like AC systems – PV arcs do not self-extinguish
- More systems are aging and exposed to wind, weather, rodents, trees, etc.

Where does arcing occur?
- Connections in the array
  - Fuses
  - Inter-module connectors
  - Inverters
- Connections in the module
  - Junction boxes
  - Bypass diodes
  - Cell-to-cell connections
  - Cell-to-busbar connections

Burned Busbar [3]
Failed Bond in Junction Box
Combiner box in Burgdorf [2]
Destroyed Junction Box from Arc [2]

What is the electrical behavior of an arc?
- In series arcs, voltage surges and current drops [4]
- The arcing frequency content is approximately 1/f (pink) noise.

May not be representative of PV Arcs

Detection Difficulties

- Some proposed AFCIs use frequency content of the string for detection
- Two challenges with remote arc detection
  1. Missed or delayed detection due to filtering in PV components (e.g., modules, connectors, bypass diodes)
  2. Nuisance tripping due to noise from electromagnetic coupling (crosstalk), inverter switching, and radio frequency (RF) effects

![Diagram showing detecting difficulties]

- “Pink” AC noise
- Modules/Connectors change frequency content
- RF phenomena, crosstalk noise
- Inverter switching noise