



# Arc Fault PV Industry Activities, and Testing and Modeling

**Jason Strauch**

**[jestrau@sandia.gov](mailto:jestrau@sandia.gov), 505-284-6114**

**Sandia National Laboratories**  
**Microsystems & Engineering Sciences Applications**  
**(MESA)**

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2009-2801P

# Current PV Industry Activities in Arc Fault

With the implementation of NEC 690.11, and UL1699B governing testing of Arc Fault Circuit Interrupters (AFCI), the PV Industry will be required to make hardware changes that adds to the \$/W costs.

- To reduce PV system costs, inexpensive arc fault detectors and circuit interrupters must be available to the market.


■ Sandia National Laboratories is actively working and partnering with Industry to reduce these cost by understanding arcs, signal propagation, and possible detection challenges.

- Inverter manufacturers
- Module manufacturers
- PV electrical component manufacturers
- AFCI manufacturers

Centre for Energy and Environmental Markets UNSW

## Other Measures

Testing / inspection




Visual inspection:

- Obvious failures
- Brown spots / scorching
- Inspection of rear & front

Arcing in PV DC-Arrays

IEC electrosuissse SWISSOLAR

## DC switching cabinet after the arcing event



Arcing in PV DC-Arrays



# Arc Fault Testing

## ■ Testing includes

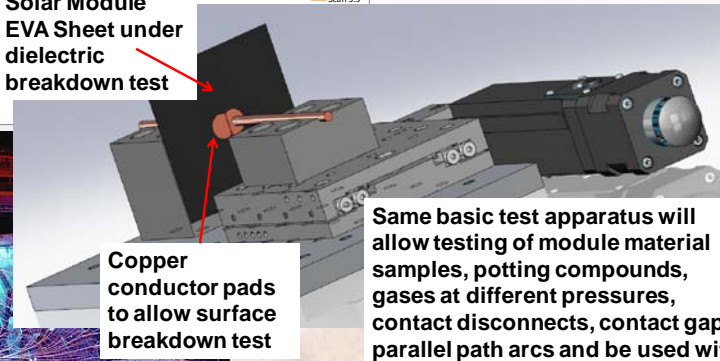
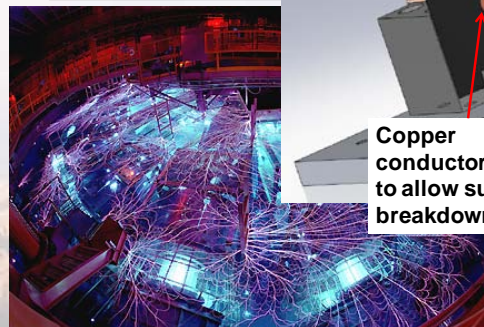
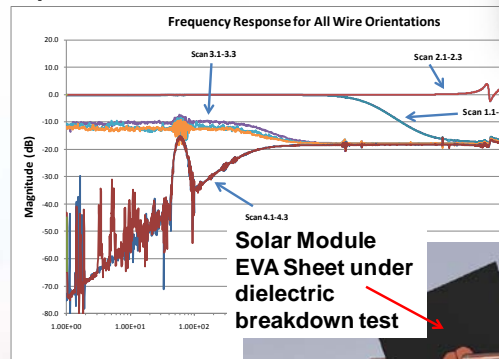
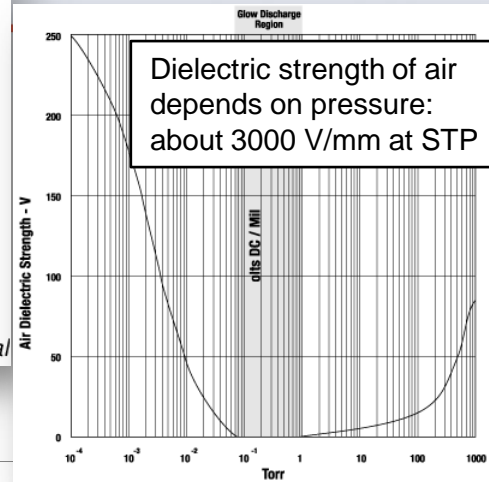
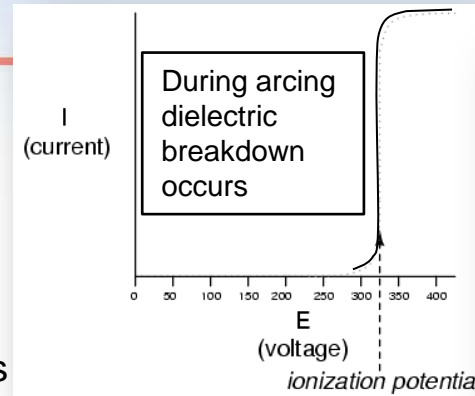
- Conditions that allow arcing
  - Materials for dielectric strength
  - Geometry
  - Voltages/potentials, boundary conditions
- Introduction of simulated arcs into PV systems
  - Measure electrical frequencies present during arcing events
- Filtering created by PV modules and other components

## ■ Testing facilities

- Manufacturers' laboratories
- Standard developers' labs
- National labs

## ■ Sandia National Laboratories facilities:

- PSEL: Photovoltaic Systems Evaluation Lab
  - Tests for module and cell manufacturers
- Pulsed Power, Z machine
  - The big 'daddy' of man made arc generators
  - Understanding of the physics of arcs
- DETL: Distributed Energy Testing Lab



Same basic test apparatus will allow testing of module material samples, potting compounds, gases at different pressures, contact disconnects, contact gaps, parallel path arcs and be used with the solar simulator and in the field hooked up to various locations.

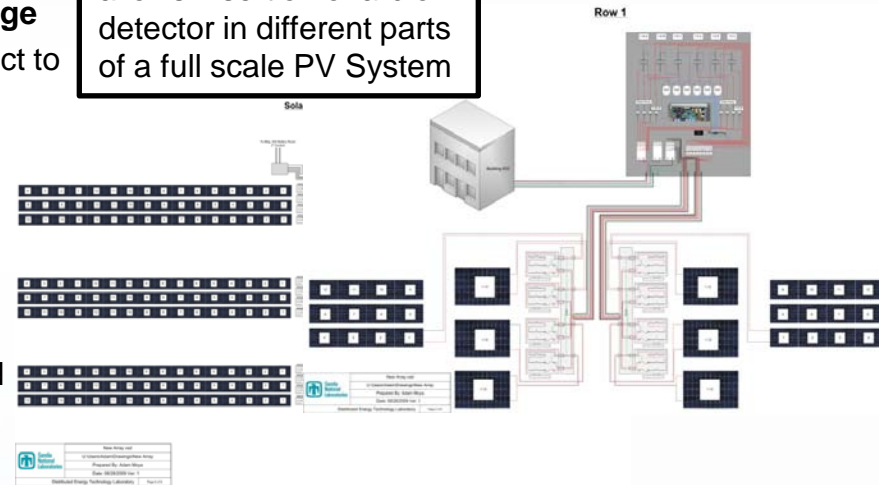


# Arc Fault Testing, Sandia DETL Facility

## Distributed Energy Testing Lab, DETL:

- **Many combinations of grid tied generation, loads and storage**
  - Inverter, AFCI and component manufacturers able to connect to PV arrays at any number of insertion points
- **Advanced R&D**
  - System level performance and reliability testing
  - Component interoperability testing
- **Advanced Power Electronics Components and Systems**
  - Solar Energy Grid Integration Systems (SEGIS)
  - Controllers for distributed grid equipment based on new and existing standards
  - Advances in inverter design, integration and manufacturing through partnerships with Industry
  - Long-term inverter performance characterizations
- **Technology Solutions for Communications and Security**
  - Secure Supervisory Control and Data Acquisition (SCADA) applications
  - Technology development and applications capable of supporting multiple communications protocols
- **Solar Standards and Codes**
  - Development of new procedures for performance and reliability testing
  - Assuring accountability, applicability and metrics of new standards development

Sandia DETL Facility allows insertion of arc or detector in different parts of a full scale PV System



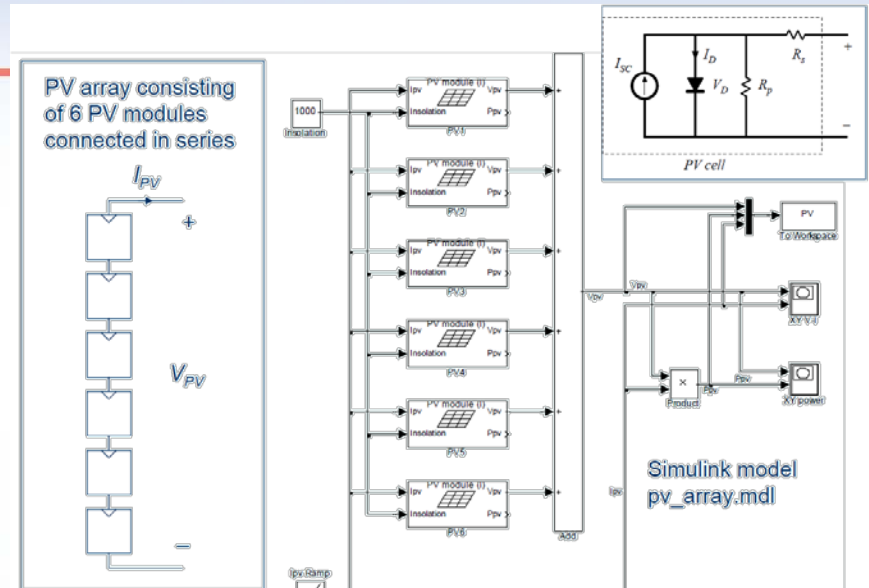
# Arc Fault Modeling

## Frequency modeling

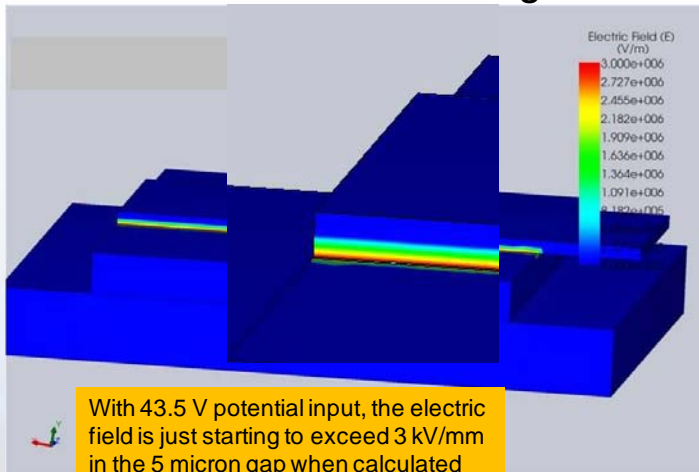
- Development of cell, module, and array models for AC studies
- Studies investigate attenuation effects of PV components

## Electrical modeling

- Simulation of current, voltage, and resistance changes preceding and for the duration of the arcing event

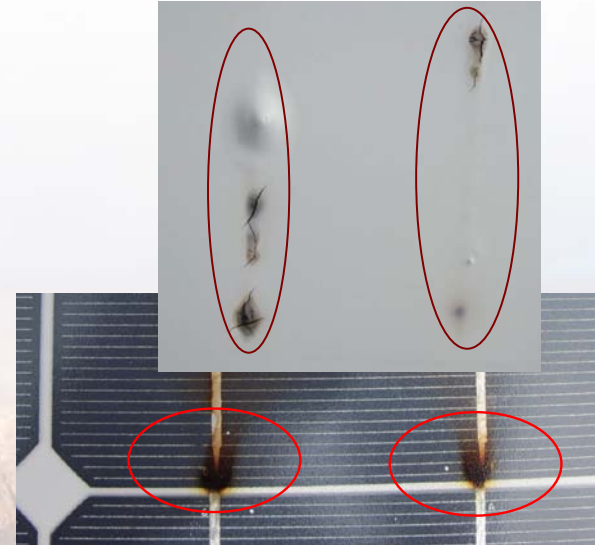
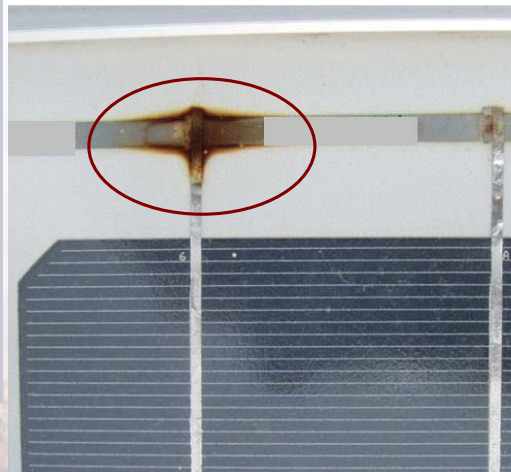


Source: [http://ecee.colorado.edu/~ecen2060/materials/simulink/PV/PV\\_module\\_model.pdf](http://ecee.colorado.edu/~ecen2060/materials/simulink/PV/PV_module_model.pdf)



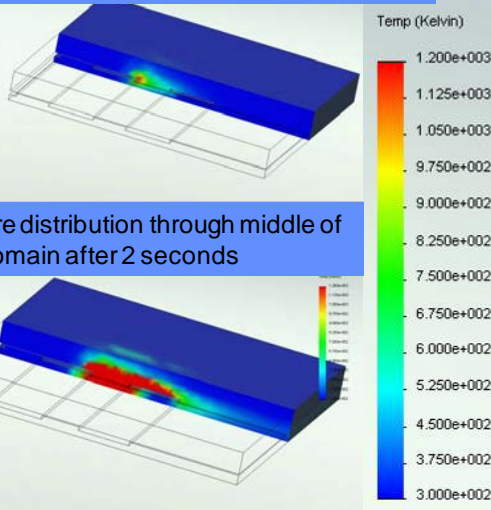
With 43.5 V potential input, the electric field is just starting to exceed 3 kV/mm in the 5 micron gap when calculated with the full integral solution, which is lower than the linear

$$\frac{43.5\text{V}}{5\text{micron}} = 8.7 \frac{\text{kV}}{\text{mm}}$$

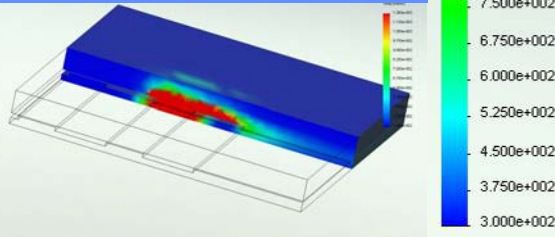


# Arc Fault Modeling, Thermal and Structural

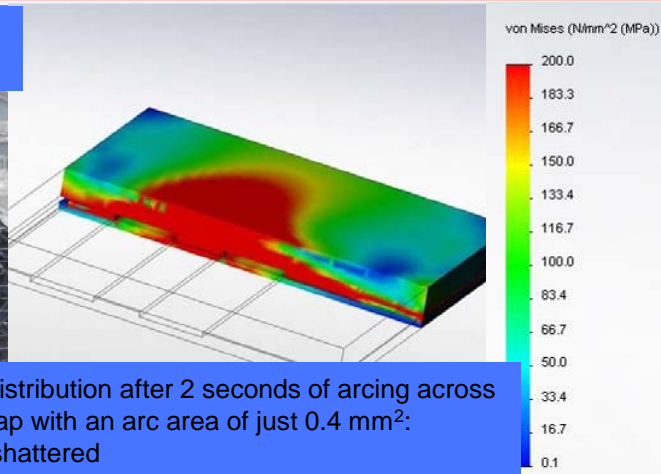
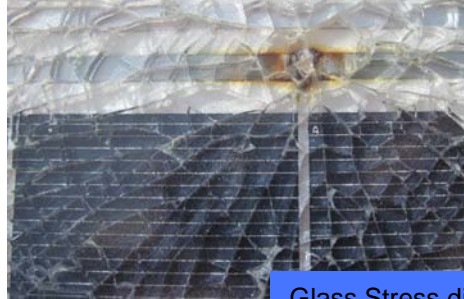
Temperature distribution through middle of domain after just 0.2 seconds



Temperature distribution through middle of domain after 2 seconds



Heat transfer physics leading to this shattered glass was simulated

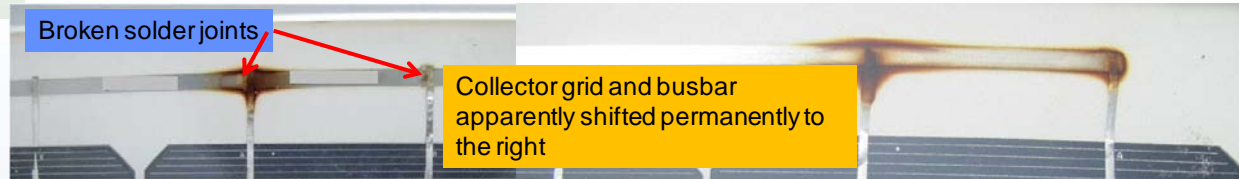


Glass Stress distribution after 2 seconds of arcing across the 5 micron gap with an arc area of just 0.4 mm<sup>2</sup>: the glass has shattered

## Thermo-mechanical modeling

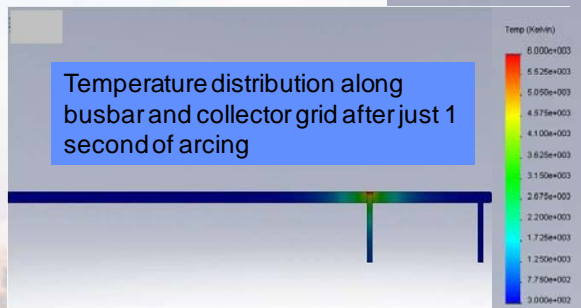
- Simulation and prediction of temperature and mechanical stress effects of arcing given boundary conditions, material properties and geometry
- Simulations provide insights into time scales for arc detection and material selection

Broken solder joints



Collector grid and busbar apparently shifted permanently to the right

Temperature distribution along busbar and collector grid after just 1 second of arcing



Simulation shows that the region near the arc and to the right is shifted 2-2.5 mm after 1 second, likely enough to break nearby solder joints

