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15 October 2024

9:00 am – 10:00 am | CST, Mexico City

11:00 am – 12:00 pm | EDT, New York City

5:00 pm - 6:00 pm | CEST, Berlin



**Marija Maisch**

Energy storage news director  
pv magazine

pv magazine  
**webinars**

# Understanding the dangers of arc flash in solar, battery storage systems




**Mark Pollock**

Application Engineering Manager, Codes & Standards  
Littelfuse

# Welcome!

Do you have any questions?  

Send them in via the Q&A tab.  We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 

We'll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience.  



# Understanding the dangers of arc flash in PV and BESS

October 15, 2024

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Littelfuse has over 60 million devices installed in power systems across the globe

# Agenda

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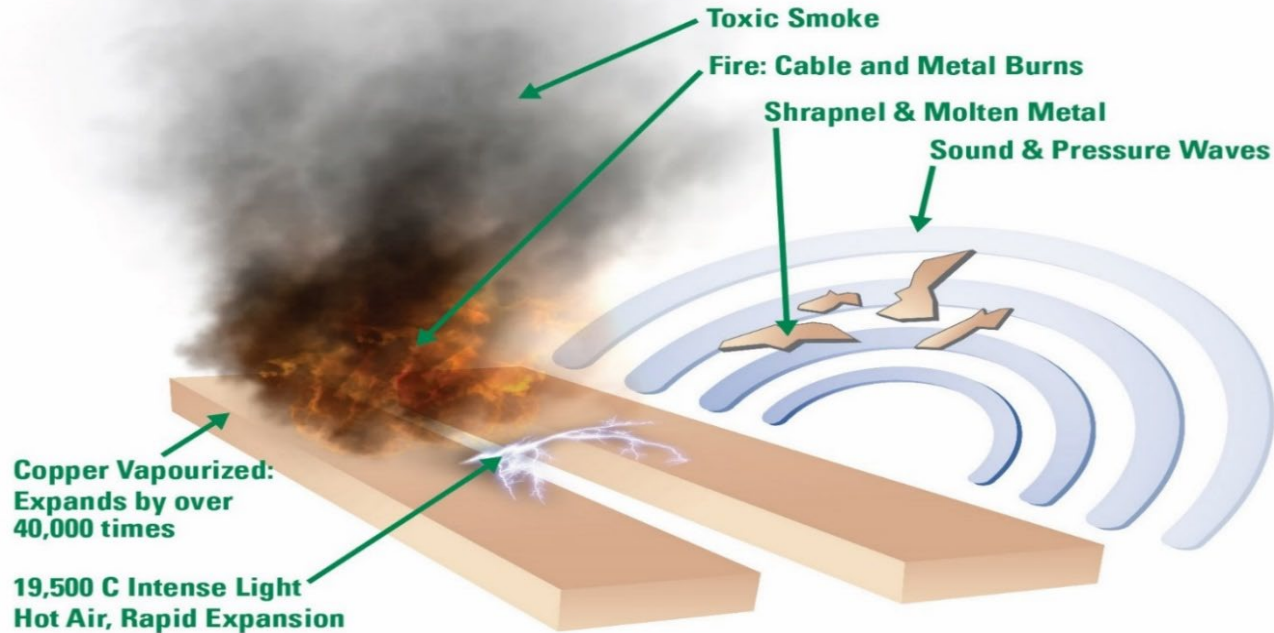
- Arc-flash events
- Relevance of arc flash for renewable systems
- Codes & standards
- Reducing risk
- Case study
- Q&A



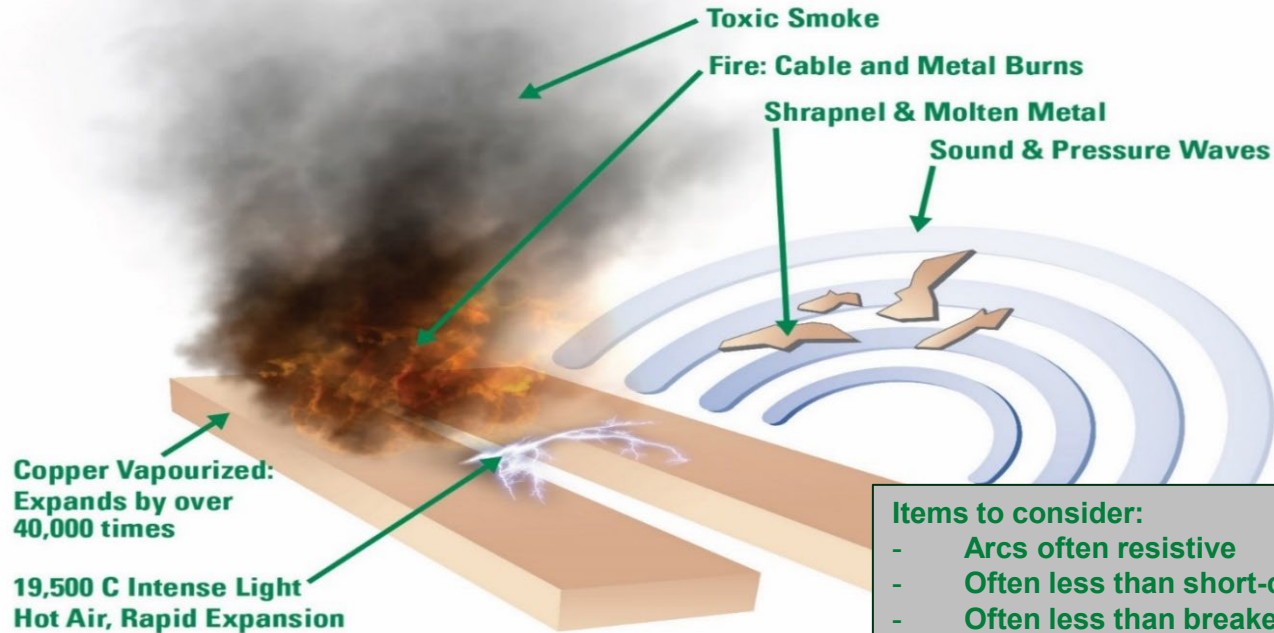
# Arc-Flash Events

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# The Breakdown of an Arc-Flash Event



# The Breakdown of an Arc-Flash Event



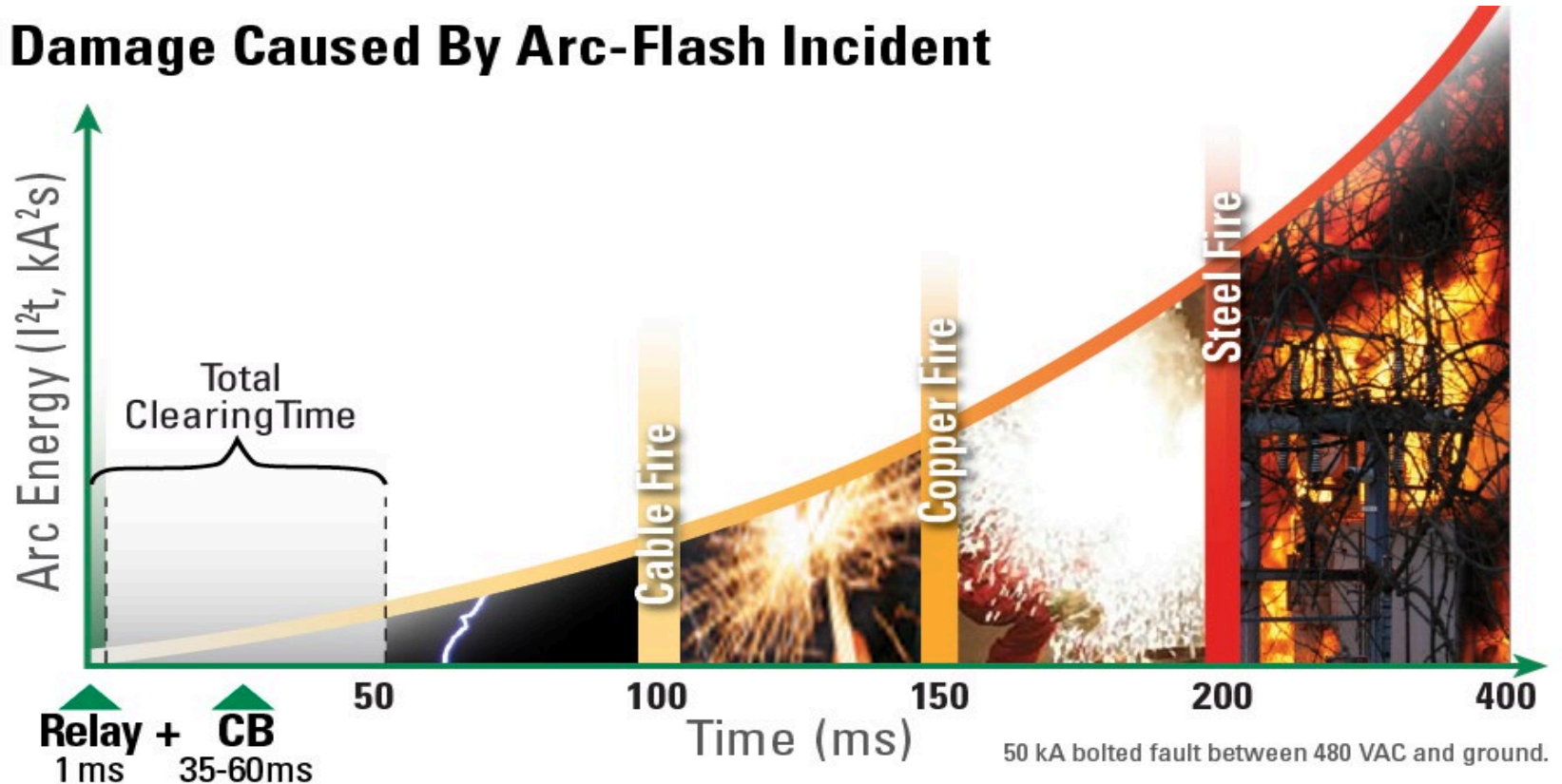
## Items to consider:

- Arcs often resistive
- Often less than short-circuit current
- Often less than breaker/fuse operating

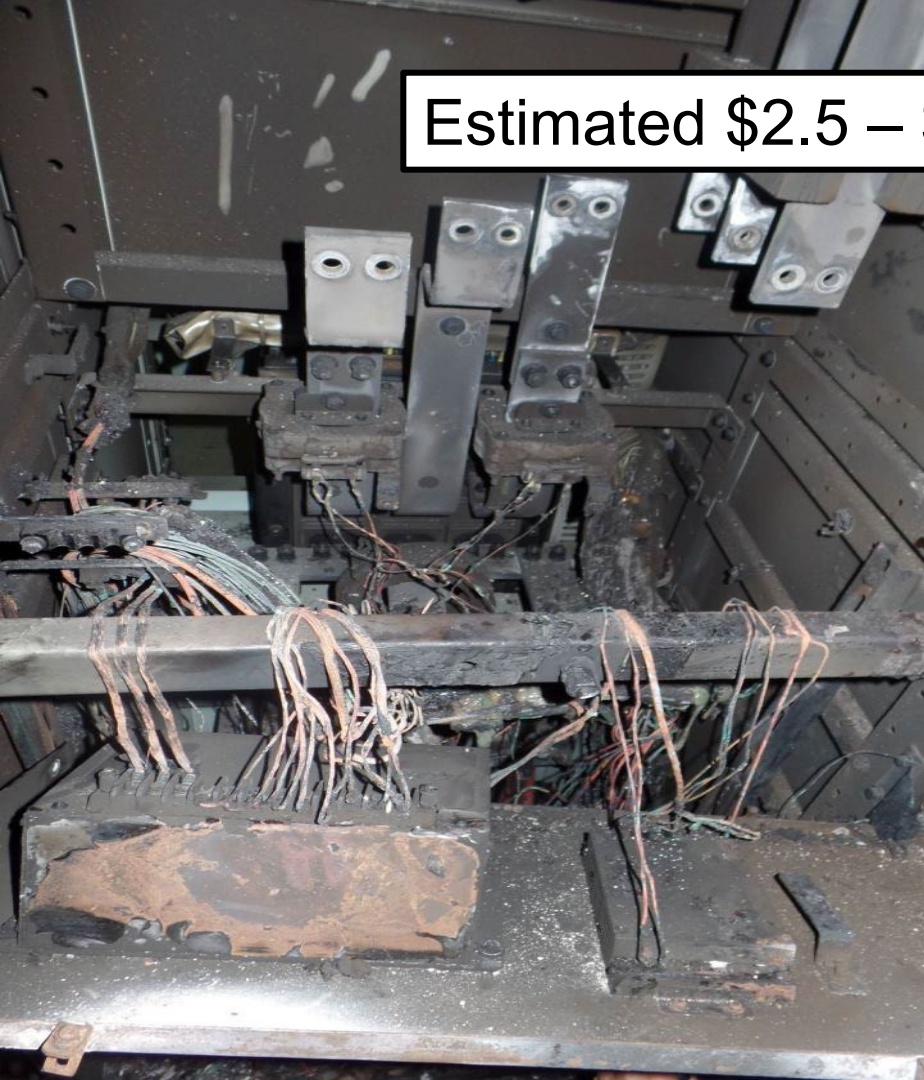


# Arc-Flash Energy vs Time

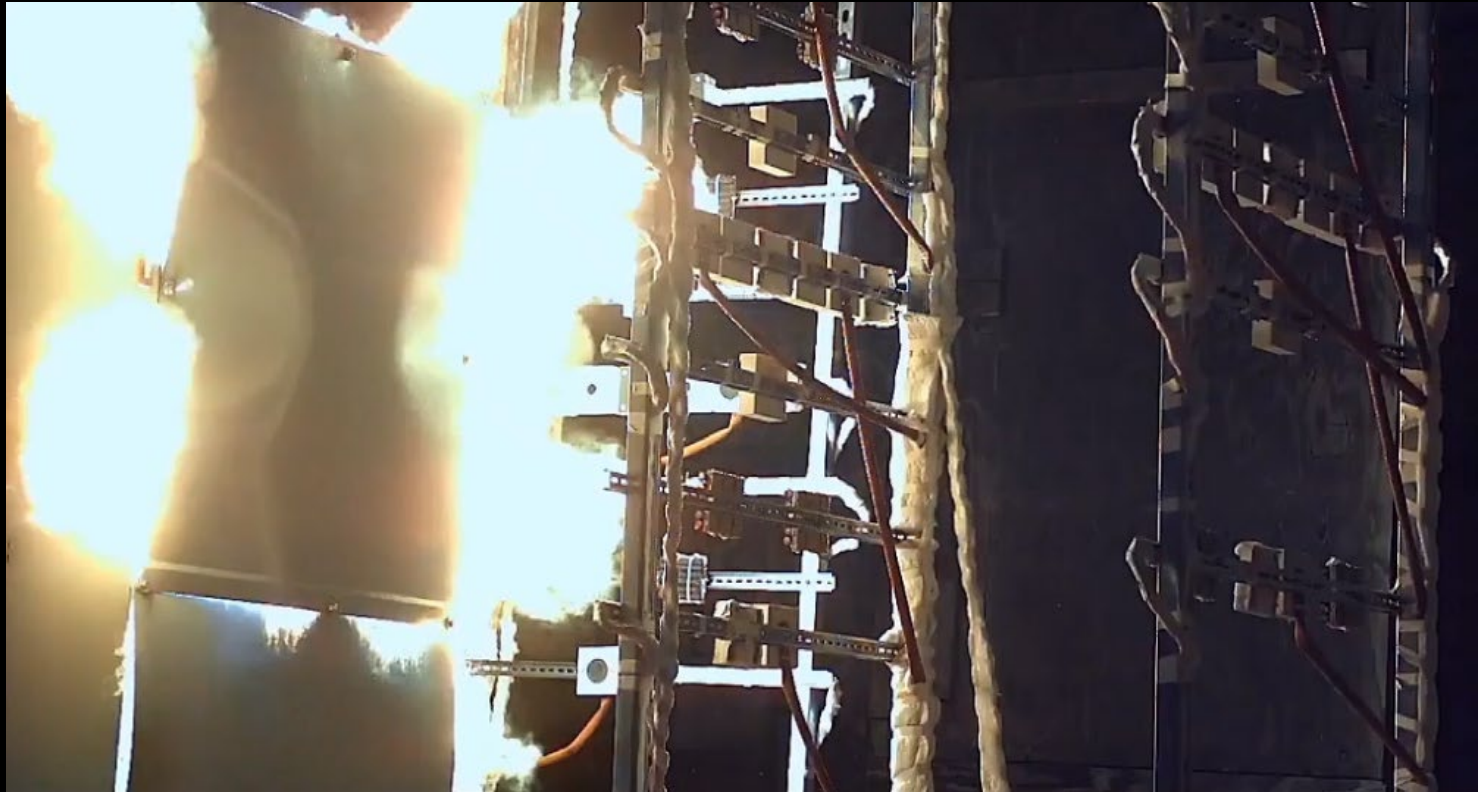
## Damage Caused By Arc-Flash Incident



Estimated \$2.5 – \$3.0 Million Damage



# Arc-Flash Event 1 – High-Speed Video



# Arc-Flash Event 2 – High-Speed Video

HIGH SPEED HIGH DYNAMIC RANGE IMAGING

NRC HEAF TESTS | T002\_hdr2.cine | 2018-09-11T17:14:09.768033028Z | photometrics@sandia.gov



[ 903] elapsed:+0.902 804 9 sec exp:0.000 005 0 sec 1,000 frames/sec

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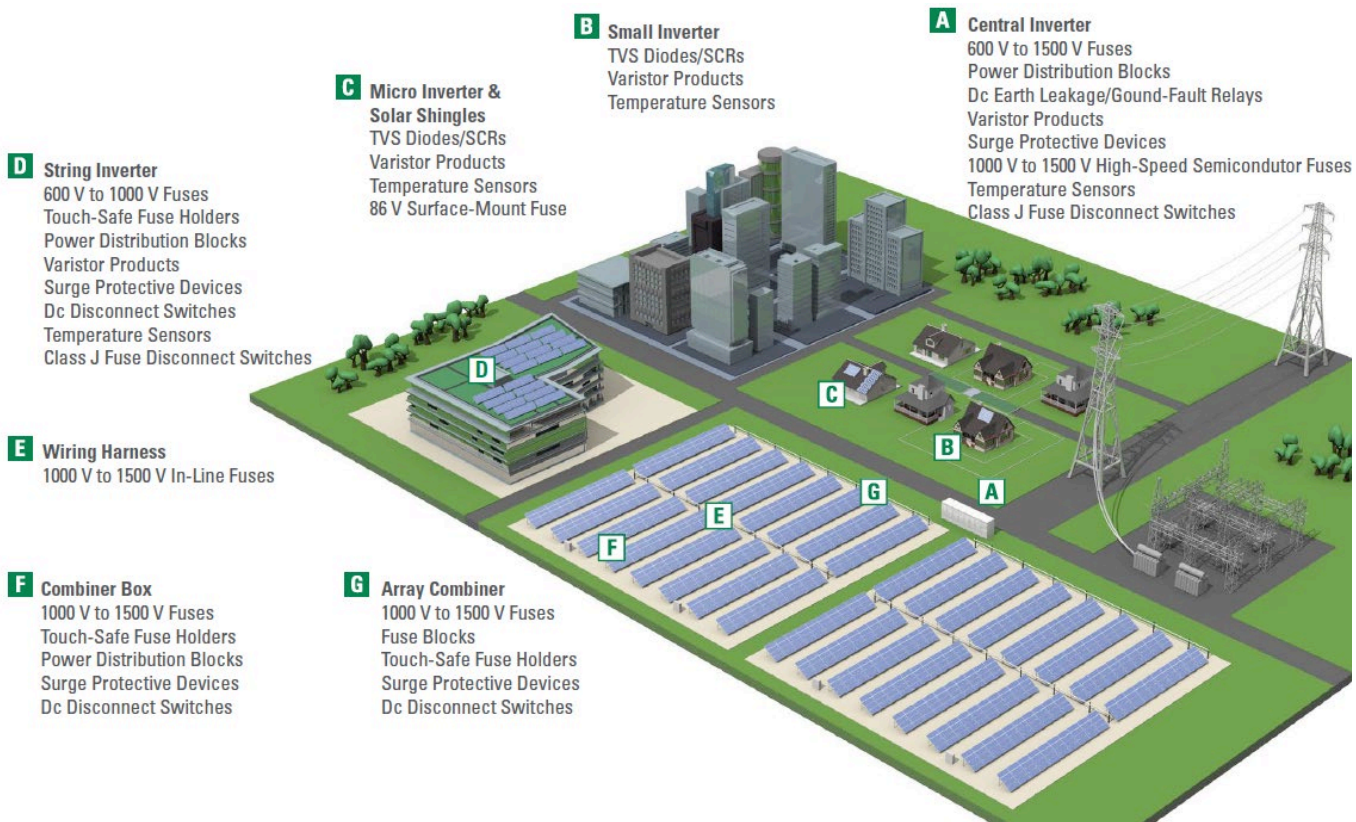
# Poll Question



# Renewable Systems

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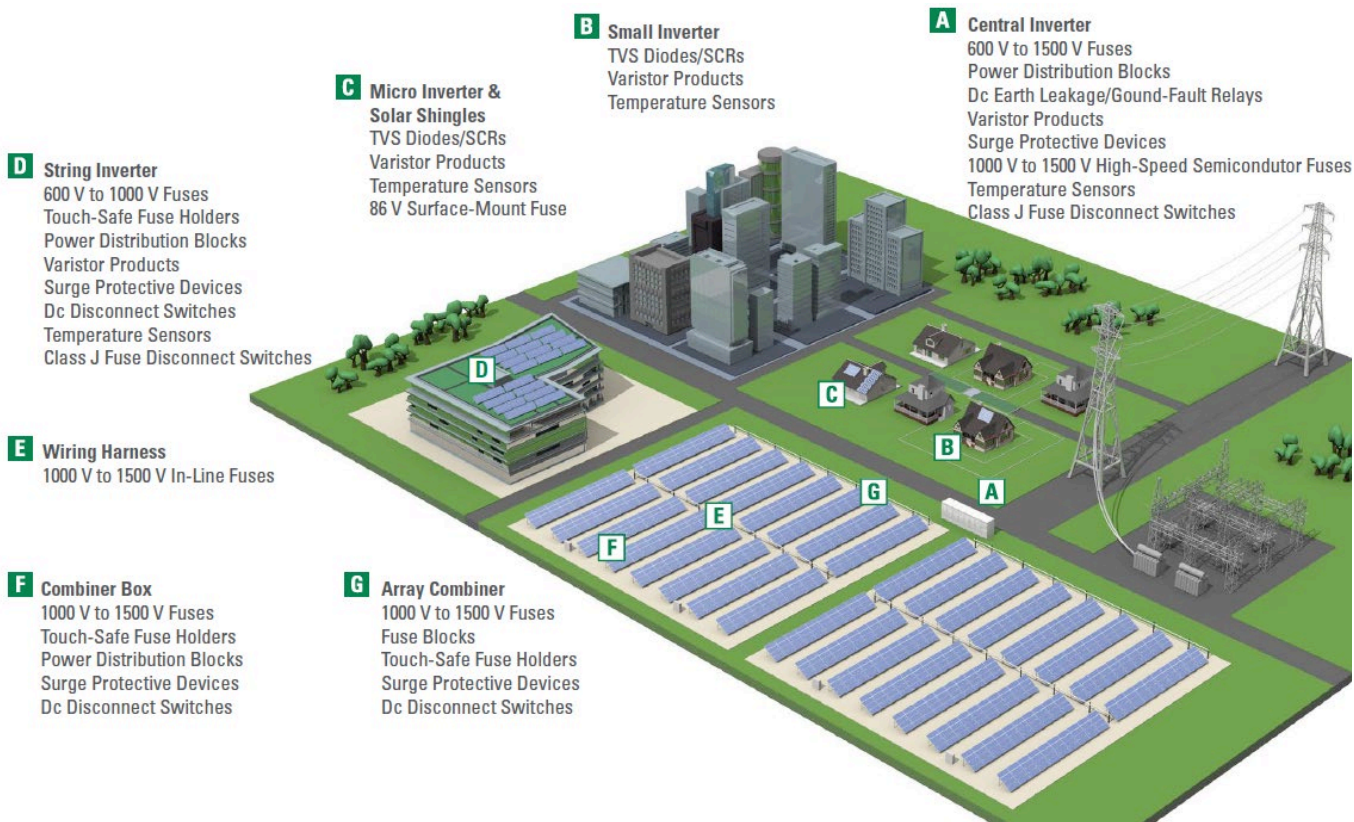
# Renewable Systems



# Renewable Systems

What devices are available to protect your system?

- **Overcurrent**
  - Equipment failure
- **Overvoltage**
  - Lightning strike
- **Ground fault**
  - Improper maintenance
  - Physical damage
- **Arc events**
  - Loose connection
  - Insulation fault
  - Seismic event

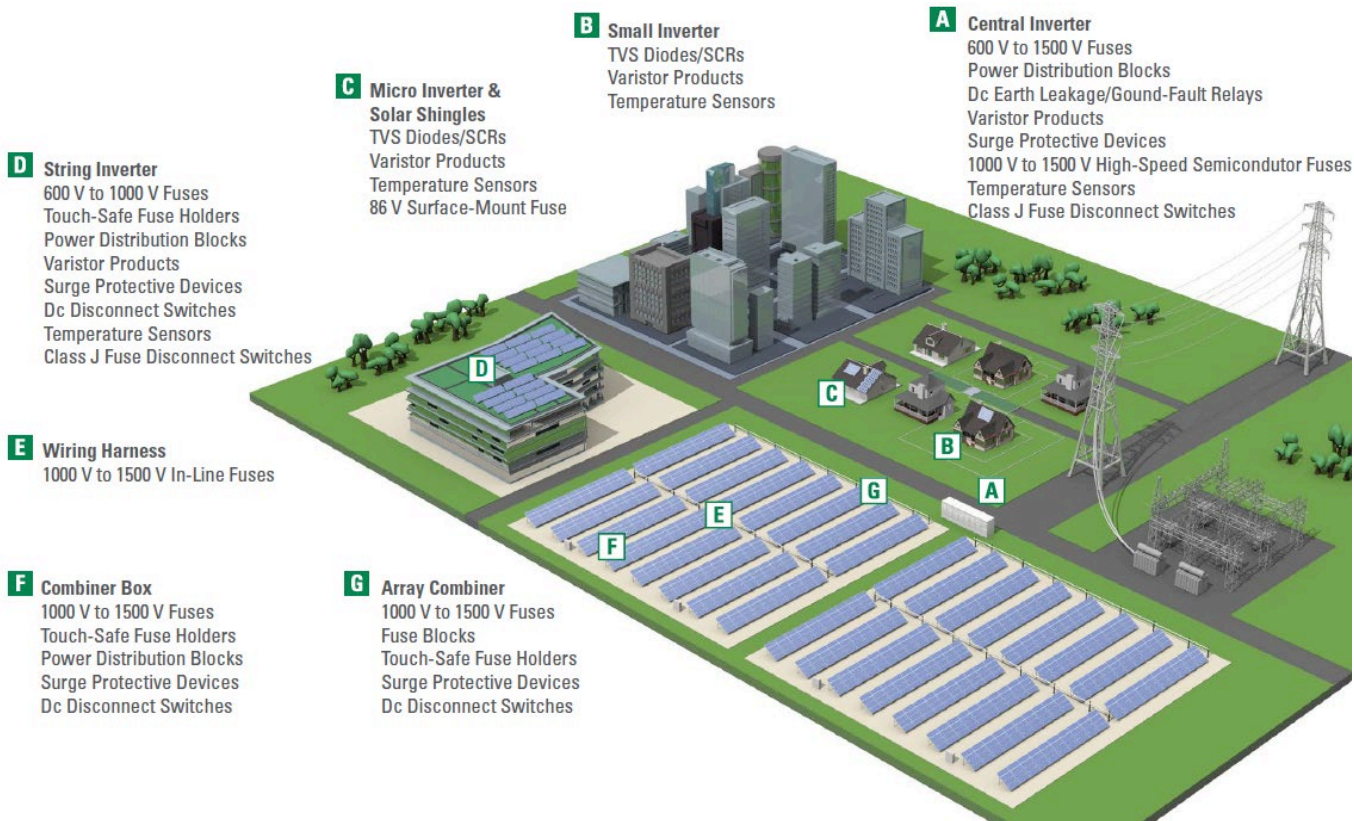




# Renewable Systems

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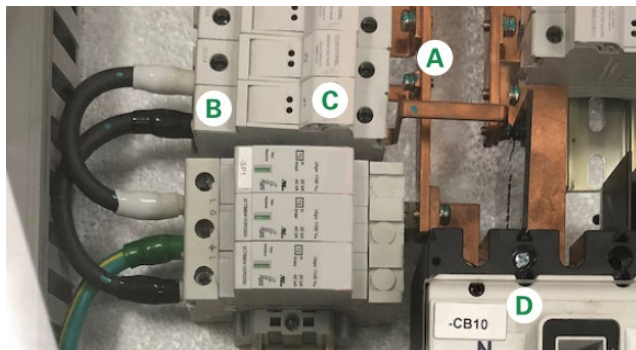


# Combiner Boxes

- 94 non-ground connections in combiner box
- Issues to consider
  - Connection not torqued properly on install or after maintenance
  - Damage during shipping
  - Vibration causing poor connection on solid bus
  - Tension on stranded wire causing breakage
  - Heating/cooling cycles in outdoor environment
  - Insulation failure/degradation
  - Condensation/corrosion
  - Debris inside panel shorting across connections

## Close contact points for 1000 Vdc

- A – bus crossover point
- B – between cable connections
- C – between bus connections
- D – between breaker terminals



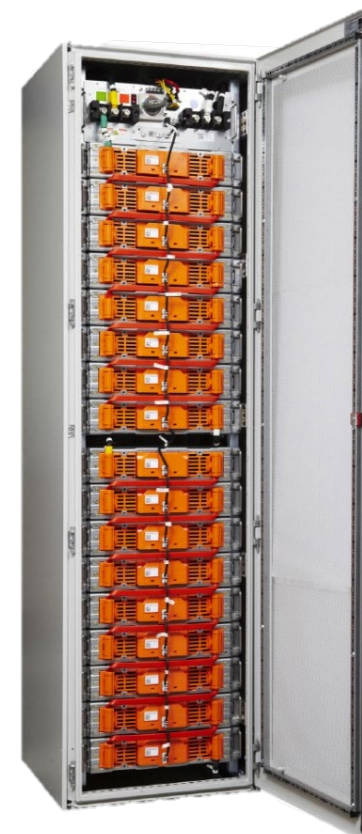
# Power Conversion and Inverters

- High power connections
- Possible initiators of arc event:
  - Component failure
  - Voltage/current fluctuations outside of equipment rating
  - Connection not torqued properly on install or after maintenance
  - Vibration/seismic events at site
  - Heating/cooling cycles
  - Insulation failure/degradation
  - Debris inside panel shorting across connections
  - Mistake during maintenance



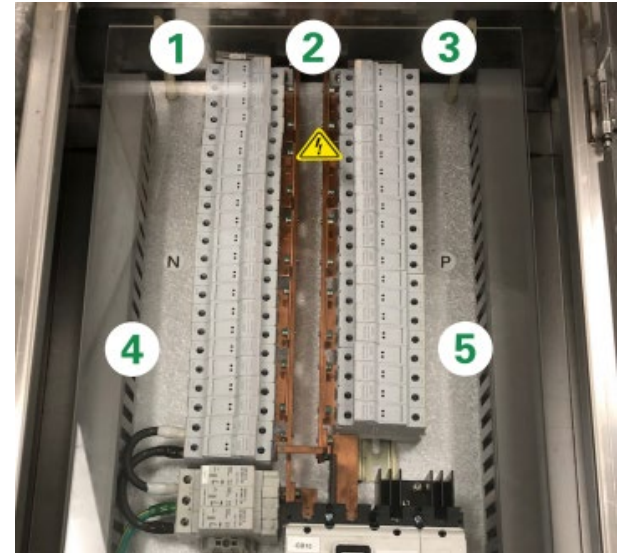
# Battery Energy Storage

- Tremendous amount of stored energy
- Extremely difficult to stop thermal runaway condition
- If an arc occurs within energy storage container (but not within battery), essential to detect and clear immediately
- Complement to BMS
- Similar arc initiators:
  - Cable connections coming loose, not torqued properly on install or maintenance
  - Mistake during maintenance
  - Vibrations, seismic events
  - Insulation defects

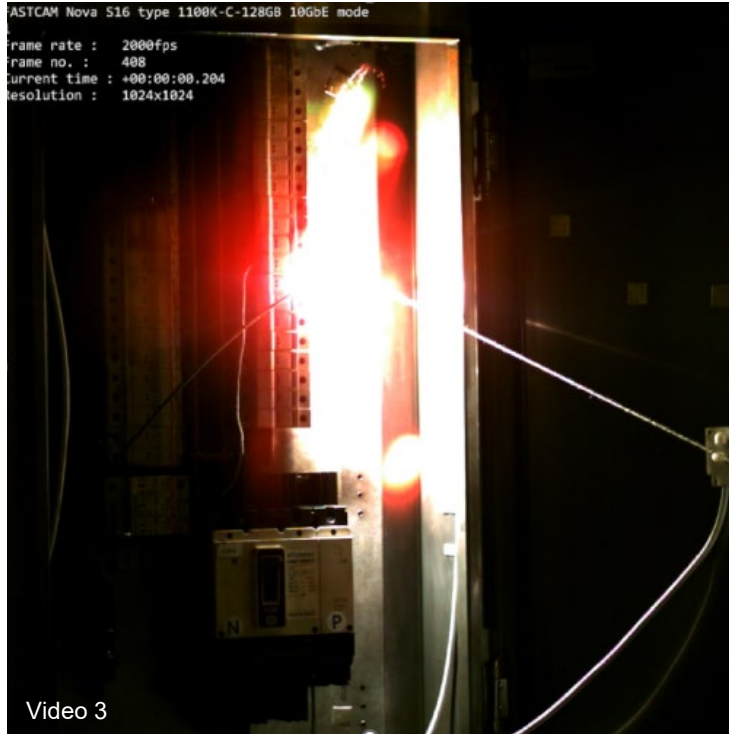


# Sustained Arc in a Combiner Box?

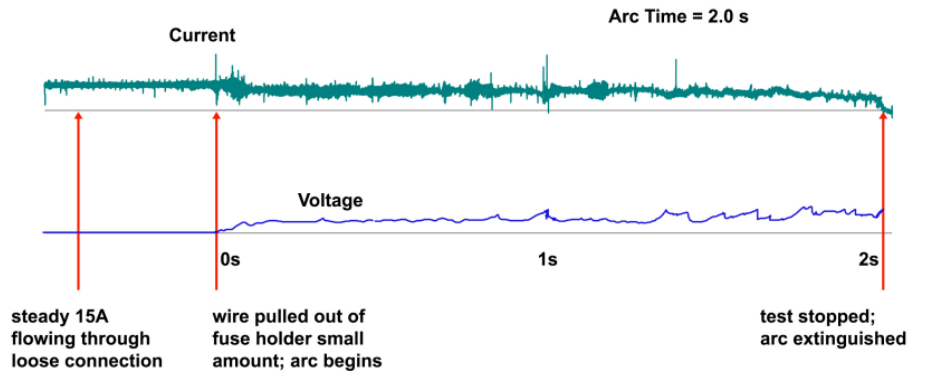
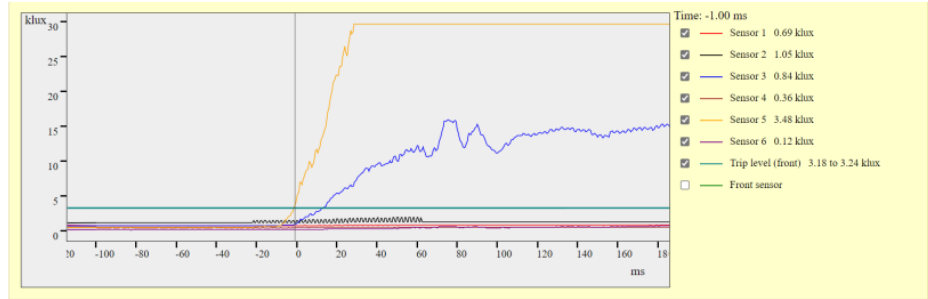
- What about other protection devices already installed? Would fusing clear the arc?
- What current magnitude needed to maintain an arc? Would 15A at 1000 Vdc sustain an arc?
- Some basic testing was performed
  - Dots indicate the position of light sensors added into the combiner box for basic arc tests



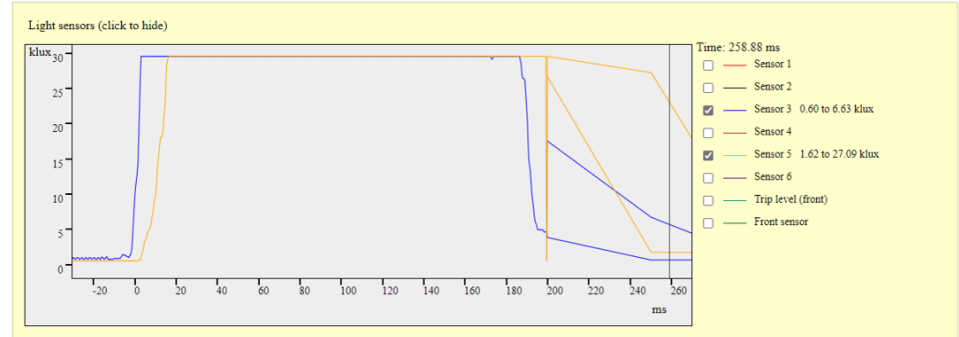
# DC arc testing 1 – 15 A 1000Vdc (2s)



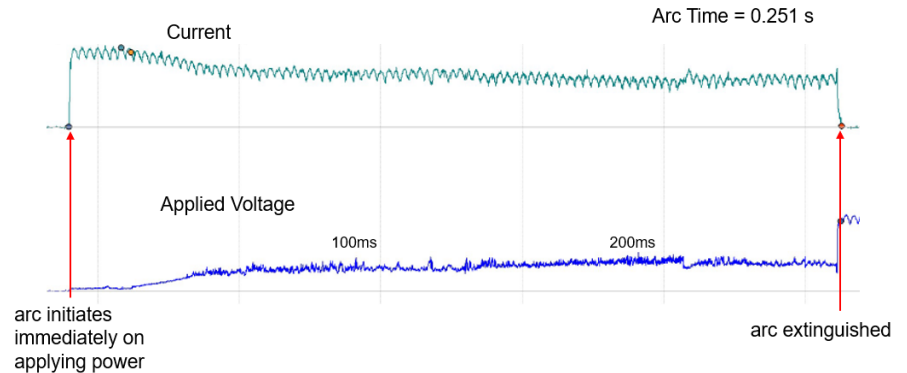
SENSOR 1 = TOP LEFT      SENSOR 2 = TOP MIDDLE      SENSOR 3 = TOP RIGHT  
 SENSOR 4 = LEFT SIDE      SENSOR 5 = RIGHT SIDE      SENSOR 6 = DOOR



# DC arc testing 2 – 1000 A 1000Vdc (0.25s)



**SENSOR 3 = TOP LEFT**  
**SENSOR 5 = TOP RIGHT**





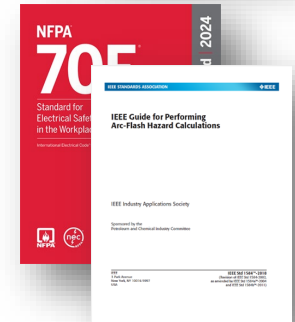
# Codes & Standards

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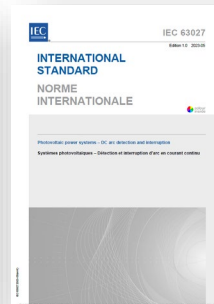
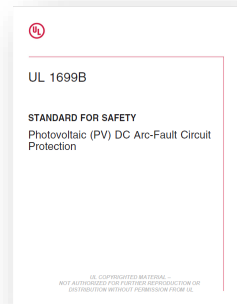
# Protection Requirements

- Requirements embedded for many years in electrical codes:
  - NEC 690.9 Overcurrent Protection
  - NEC 690.41 Ground-Fault Protection
  - NFPA 780 Surge Protection
- Arcing “new kid on the block” to reduce fire loss/risk
  - Household adoption of arc-fault circuit-interrupters (AFCIs) (global)
  - Industrial circuits 1200A+ (North America)
  - Limited renewable arc-fault detection (North America)
- Arc testing and safety
  - IEEE 1584 standard focused on ac calculations; dc potentially next version
  - NFPA 70E added battery safety content in 2024



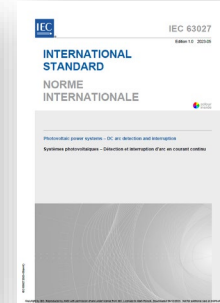
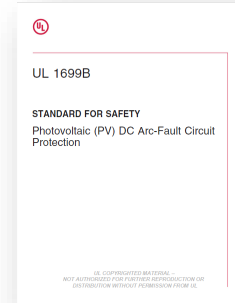
# Arc Fault and Arc Flash

- NEC 690.11 – requirement for building-mounted PPV systems 80 Vdc+ to use arc-fault protection
- UL 1699B PV DC Arc-Fault Circuit Protection
  - PV AFCI arc-fault circuit-interrupter
  - PV AFD arc-fault detector
  - PV ID interrupting device
- IEC 63027 DC arc detection and interruption
  - AFD arc-fault detector
  - AFI arc-fault interrupter
  - AFPE arc-fault protection equipment
- **Arc fault** protection
  - Referring to **current-based** detection
  - Can be installed in inverter / branch location
  - Similar terminology used in ac world for arc-fault circuit-interrupters in home
- **Arc flash** protection
  - Referring to other forms (**typically light**) of detection
  - Installed at location where fault detection is desired
  - Separate set of standards



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## IEC 60947-9-2

Active arc-fault mitigation systems – Optical-based internal arc-detection and mitigation devices

## IEC TR 61641

Specifies tests requirements for assemblies under internal arc-fault

## IEC TS 63107

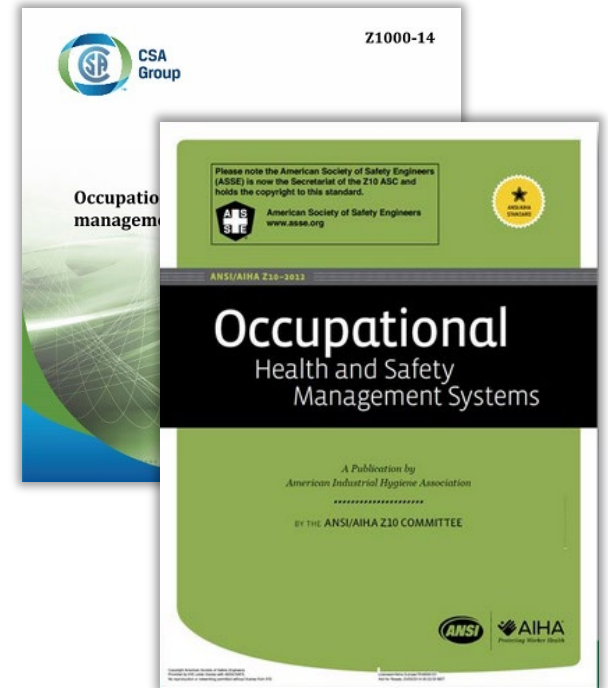
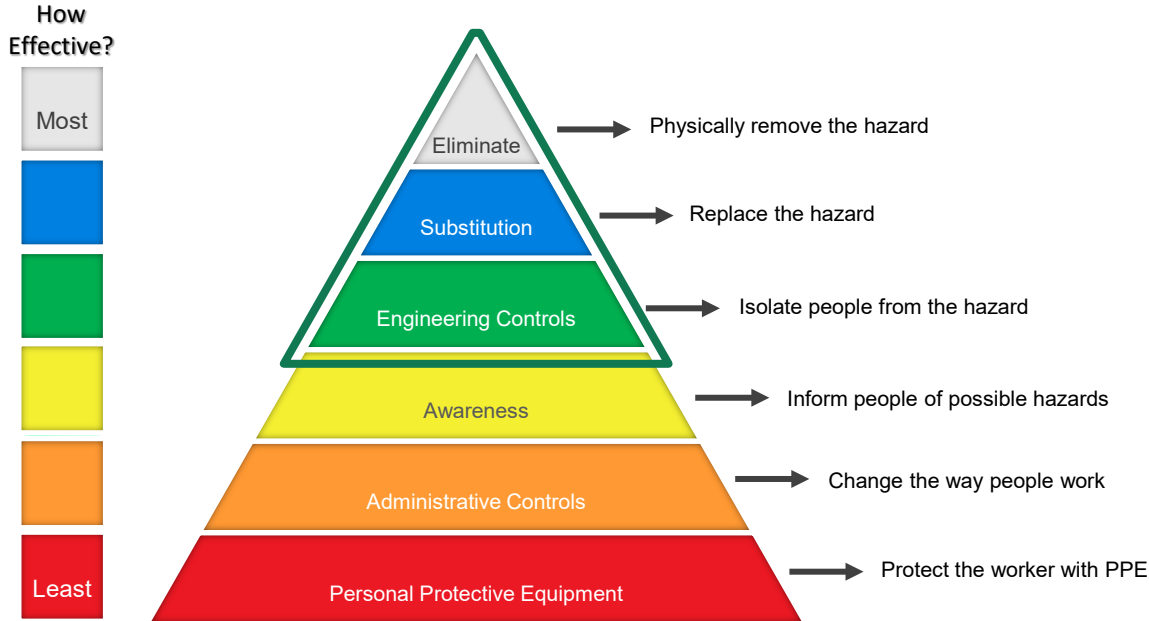
Integration of internal arc-fault mitigation systems in power switchgear and controlgear assemblies (PSC assemblies) according to IEC 61439-2



# Reducing Risk

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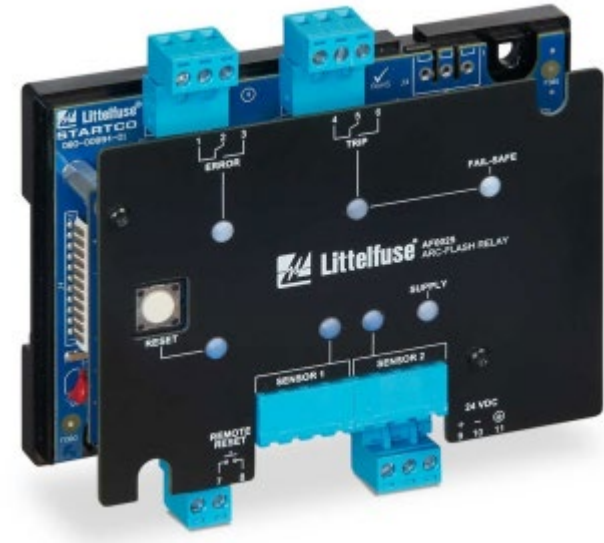
# Hierarchy of Risk Controls



**ANSI Z10-2012 and CSA Z1000-14 – Occupational Health and Safety Management Systems Standards**

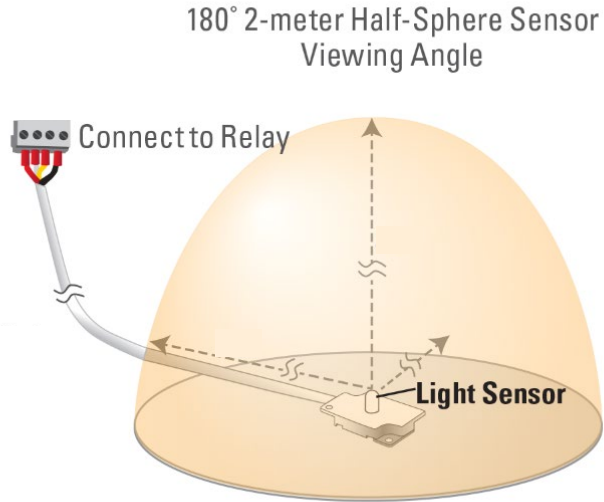
# Arc-Flash Relay

- Light sensors are installed within the cabinet where protection is desired
- Provide very fast response times to arc-flash events (as fast as 1 ms)
- Products range from basic to advanced with many capabilities such as multiple protection zones
- Very low probability of nuisance events—responding to light intensity
- Devices can be installed on ac or dc equipment



Example of an arc-flash relay

# Point Light Sensors



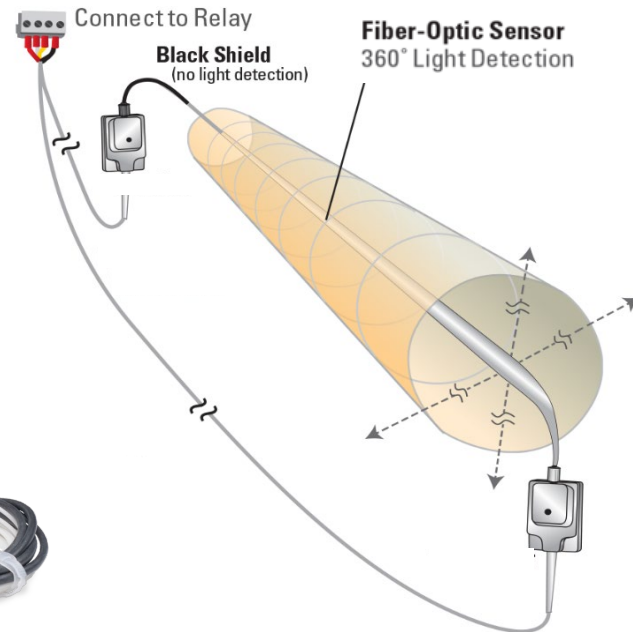
- Point light sensors detect light in one fixed location
- May have copper or fiber connections to arc-flash relay depending on manufacturer
- Allow the location of the arc event to be quickly and easily pinpointed
- Typically have some form of self-check capability



Example of a point light sensor

# Fiber-optic Light Sensors

- Fiber light sensors detect light down entire exposed length
- Adds significant flexibility for large equipment or densely packed cabinets
- Some fibers may have portion of fiber covered to balance light intensity response
- Typically have some form of self-check capability



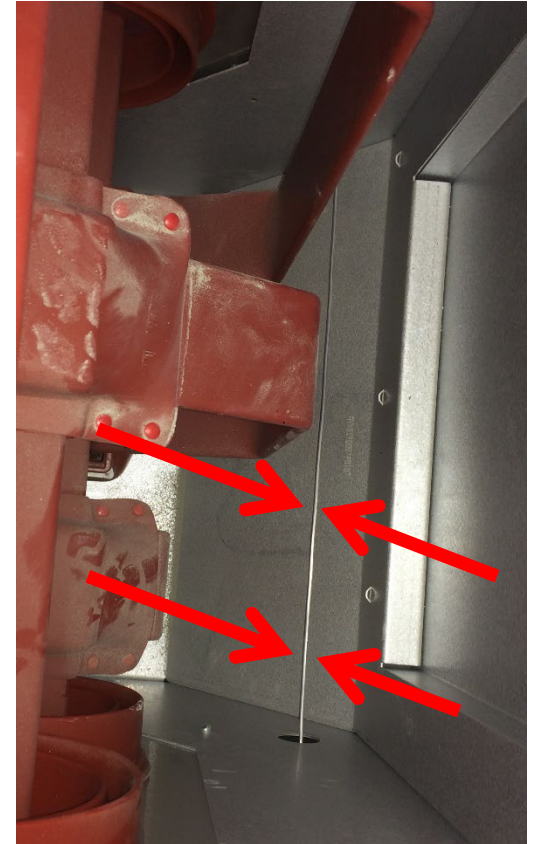
Example of a fiber light sensor



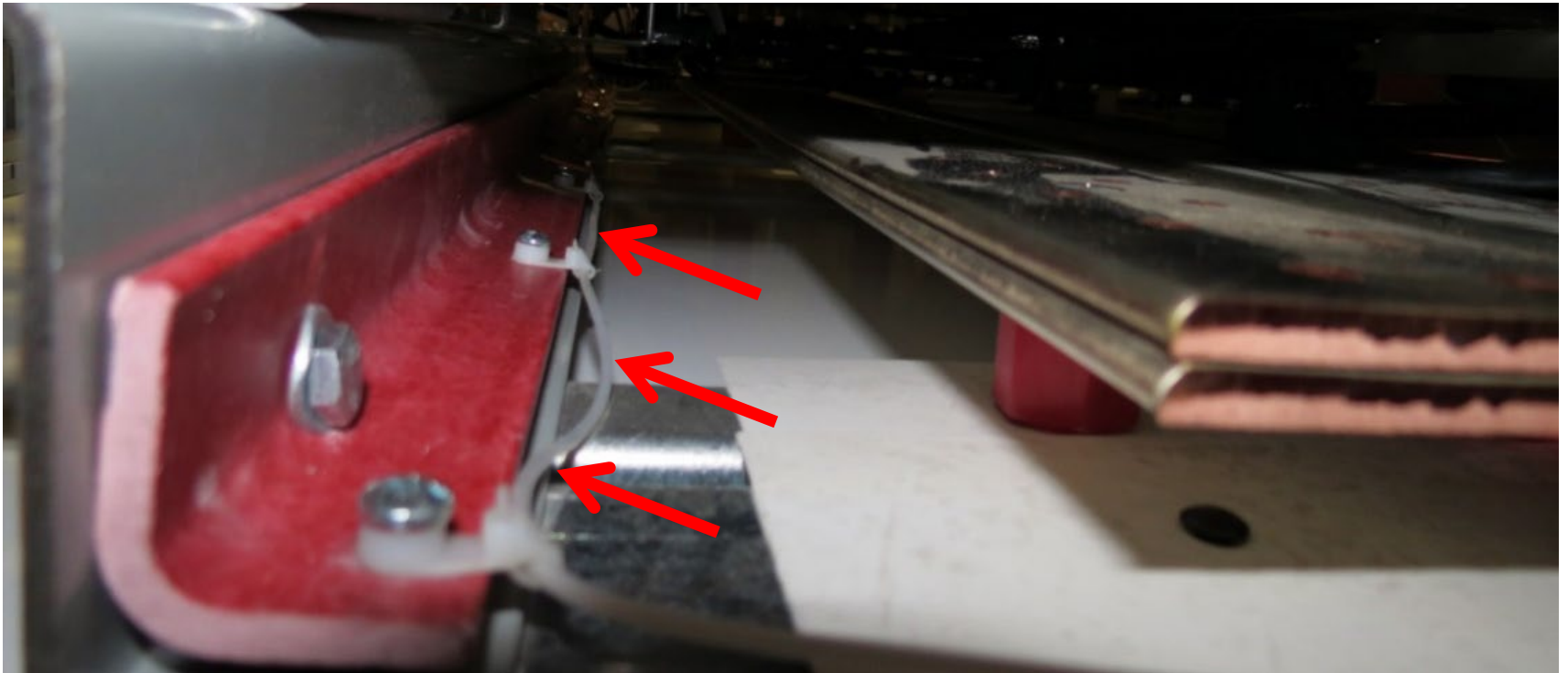
## Point Sensor Installation Examples



# Fiber Sensor Installation Examples



# Fiber Sensor Installation Along Bus



# Methods to Addressing Arcing Risks

	PRO	CON
<b>Arc-Fault Detector (current based)</b>	<ul style="list-style-type: none"> <li>- Can cover wide area with single device</li> <li>- May already be included with inverter functionality</li> </ul>	<ul style="list-style-type: none"> <li>- Nuisance operations cause significant headaches; reduce confidence</li> <li>- May require software updates</li> <li>- May de-energize large segments</li> <li>- Separate equipment for ac and dc sides</li> </ul>
<b>Arc-Flash Relay (light based)</b>	<ul style="list-style-type: none"> <li>- Extremely fast acting</li> <li>- Low probability of nuisance operation</li> <li>- Localized fault, can shut down minimal equipment</li> </ul>	<ul style="list-style-type: none"> <li>- Requires device to be installed in each cabinet to be monitored</li> </ul>
<b>Smoke Detectors</b>	<ul style="list-style-type: none"> <li>- Detect smoldering events prior to larger fault occurs</li> </ul>	<ul style="list-style-type: none"> <li>- Slower to react</li> <li>- Nuisance alarms can occur due to environmental conditions</li> </ul>
<b>Thermal Imaging</b>	<ul style="list-style-type: none"> <li>- Detect heating caused by poor connections and other damaging items before they lead to an arc</li> <li>- Proactive protection</li> </ul>	<ul style="list-style-type: none"> <li>- Manual process subject to error</li> <li>- May not be suitable for use on larger scales due to time and cost</li> </ul>



# Case Study

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## Case Study

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- Utility-scale BESS installation experienced major fire and total loss of central inverter
- Failure in power conversion equipment caused an arc that quickly destroyed the enclosure
- OEM decided to fit arc-flash relays into replacement power conversion unit, and open program to retrofit existing installations
- Extremely fast detection allows damage to be minimized in case of a future arc

# Headlines

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- **“Amazon took all U.S. solar rooftops offline last year after flurry of fires, electrical explosions”**

<https://www.cnbc.com/2022/09/01/amazon-took-solar-rooftops-offline-last-year-after-fires-explosions.html>

- **Fire accident at Argentinian solar park’s central inverters**

<https://www.pv-magazine.com/2020/10/21/fire-accident-at-argentinian-solar-parks-central-inverters/>

- **Evacuation orders lifted in Escondido after lithium-ion battery fire at SDG&E facility that also prompted school closures**

<https://www.nbcsandiego.com/news/local/lithium-ion-battery-fire-in-escondido-prompts-large-response/3615328/>

- **Rooftop Solar’s Unspoken Truth: Fires and Safety Risks are Uncomfortably Common**

<https://www.altenergymag.com/article/2022/05/rooftop-solars-unspoken-truth-fires-and-safety-risks-are-uncomfortably-common/37351>

- **Solar system fires are on the rise**

<https://pv-magazine-usa.com/2020/04/22/solar-system-fires-are-on-the-rise/>

- **Battery storage is a key piece of California’s clean energy transition. But there’s a problem with fires**

<https://www.latimes.com/business/story/2023-10-12/battery-storage-is-a-key-piece-of-californias-clean-energy-transition-but-theres-a-problem-with-fires>

- **Worker injured in fire at South Australian solar farm**

<https://www.pv-magazine.com/2024/01/15/worker-injured-in-fire-at-south-australian-solar-farm/>

# Summary

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- Arc-flash events are not everyday occurrences, but must be considered as they are very destructive
- Differences in arc fault and arc flash terminology
- Arc-flash relays are an effective way of reducing risk



# Thank You



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## Q&A



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by Gwénaëlle Deboutte



**Reliance introduces bifacial heterojunction solar modules**  
by Uma Gupta



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## Tuesday, 29 October 2024

12:00 pm – 1:00 pm EDT, New York City  
5:00 pm – 6:00 pm CET, Berlin

## Wednesday, 30 October 2024

11:00 am – 12:00 pm EDT, New York City  
4:00 pm - 5:00 pm CET, Berlin

Many more to come!

**Stow the right way for  
your solar installation:  
minimize yield losses  
and increase energy  
production**

**Scaling renewables  
operations: Using  
digital tools for  
efficient asset  
management at the  
utility scale**

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