Turn Down the Heat: Reducing Risk in Solar Panel Installations (EMR004)

Speakers:
Kurt Leisure, Vice President – Risk Services, The Cheesecake Factory Incorporated
Skip Donnell, Engineering Manager – Liberty Mutual Insurance
Learning Objectives

• At the end of this session, you will:
  • Identify the different types of PV arrays and how they work
  • Identify the building / structural hazards associated with PV arrays
  • Be able to describe the key areas of firefighter safety as it pertains to PV arrays
  • Be able to describe the key items of concern relative to PV arrays
Photovoltaics and
What is a Photovoltaic?

• Multiple PV modules that are interconnected and function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting, in smaller systems, an array can consist of a single module.
Growth of the Photovoltaic Industry

• Historically, photovoltaics has grown an average of 60.7% annually since 2007
• The market increased by 74.7% in 2011 (28% in 2014)
• Current photovoltaic production (2014) is 178 GW of power
• Projections show that will grow to between 288 and 423 GW by the end of 2017
Photovoltaic Trends

- The average cost of a PV system has dropped 11% since 2012
- The average cost of PV modules has decreased by 60% since the beginning of 2011
- Within the second quarter of 2013, the Solar Energy Industries Association (SEIA) measured a 15% increase of megawatts of photovoltaic capacity
- By the end of 2013, SEIA is expecting a solar project will be installed in the US on average of every 4 minutes
Number of Installations versus $/Watt
## Where is Photovoltaic Present

### Top 10 PV countries in 2014 (MW)

<table>
<thead>
<tr>
<th>Total capacity</th>
<th>Added capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Germany</td>
<td>1. China</td>
</tr>
<tr>
<td>2. China</td>
<td>2. Japan</td>
</tr>
<tr>
<td>3. Japan</td>
<td>3. United States</td>
</tr>
<tr>
<td>4. Italy</td>
<td>4. UK</td>
</tr>
<tr>
<td>5. United States</td>
<td>5. Germany</td>
</tr>
<tr>
<td>6. France</td>
<td>6. France</td>
</tr>
<tr>
<td>7. Spain</td>
<td>7. Australia</td>
</tr>
<tr>
<td>8. UK</td>
<td>8. South Korea</td>
</tr>
<tr>
<td>10. Belgium</td>
<td>10. India</td>
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</table>

<table>
<thead>
<tr>
<th>Total capacity</th>
<th>Added capacity</th>
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<tbody>
<tr>
<td>38,200</td>
<td>10,560</td>
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<tr>
<td>28,199</td>
<td>9,700</td>
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<td>23,300</td>
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<td>18,460</td>
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<td>5,104</td>
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<tr>
<td>4,136</td>
<td>800</td>
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<tr>
<td>3,074</td>
<td>616</td>
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</table>
Where is Photovoltaic Present

The top 10 solar states (2015):

<table>
<thead>
<tr>
<th>Rank</th>
<th>State</th>
<th>Capacity (MW)</th>
<th>Rank</th>
<th>State</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>California</td>
<td>9,976</td>
<td>6</td>
<td>Massachusetts</td>
<td>845</td>
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<td>2</td>
<td>Arizona</td>
<td>2,103</td>
<td>7</td>
<td>New York</td>
<td>456</td>
</tr>
<tr>
<td>3</td>
<td>New Jersey</td>
<td>1,235</td>
<td>8</td>
<td>Hawaii</td>
<td>414</td>
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<tr>
<td>4</td>
<td>North Carolina</td>
<td>1,070</td>
<td>9</td>
<td>Colorado</td>
<td>385</td>
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<tr>
<td>5</td>
<td>Nevada</td>
<td>1,010</td>
<td>10</td>
<td>New Mexico</td>
<td>341</td>
</tr>
</tbody>
</table>
PV Installations in the US

There are 1,110 commercial systems across the United States with enough solar power to prevent 549,296 metric tons of damaging carbon emissions in the air. Find a system near you at seia.org/solarmeansbiz #solarmeansbiz
Classifications of PV Systems

- Ground Mounted
- Shade Structure
- Roof Mounted
- Building-integrated (BIPV) PV arrays
Photovoltaic Array Placement
Key Equipment in a Photovoltaic System

- Array or PV Power Source
- Panel
- Module
- Grid - Tied
- Combiner Box
- DC (PV) Disconnect
- DC Breaker Panel
- Inverter
- AC Breaker Panel
- AC Disconnect
- Kilowatt Hour Meter
- Utility
- to Household Loads
- to DC Loads
The Hot Spot

An undesirable phenomenon of PV device operation whereby one or more cells within a PV module or array acts as a resistive load, resulting in local overheating or melting of the cell(s).
The Blind Spot

- The Blind Spot is the main known issue plaguing PV system installations
- Problems arise when a ground occurs in the system, but it is too small to be identified by installed safety devices
- When a second ground event occurs, 100% of the energy output is allowed to flow through this short, resulting in arcing and fire
Initial Grounding Event

First Fault: Undetected Ground
Fault in grounded string feeder

A Ground fault in ungrounded string feeder (normally operating between 6 to 8 amps) can be too low to be detected by the GFP in the inverter when current is split between the feeder and ground (3 to 4 amps).
Secondary Grounding Event

Second Fault: Detected ground fault in ungrounded feeder

If second fault occurs in an grounded feeder, all current flowing to the inverters (1235 amps) from all of the combiner boxes can be re-routed to the ground and string conductors when GFP trips.
Micro Inverters vs. Central Inverters

- Central inverters receive their power from PV panels wired in series – in the range of 300-600 VDC
- Micro-inverters convert power from DC to AC at the panel – resulting in AC power being transferred to combiner boxes instead
Micro Inverters

- Systems easy to expand
- No single point of failure
- Improved safety
- Performance monitoring / reporting
- Longer warranty – 20-25 years versus 10-15 years for central inverters
Micro Inverters
Methods of Roof Mounting PV Panels

- Ballasted only
- Attached roof-bearing
- Structurally attached
Ballasted Only
Attached Roof-Bearing

- Bent Plate
- Attachment to Roof
- Bearing Support
Structurally Attached
Hazards Associated with PV Arrays

• Fire
• Wind
• Collapse
• Debris Accumulation
• Impairment for Fire Fighting

• Other Hazards
  • Snow Loading
  • Hail
Fire

- The fire resistance rating of roof coverings may be compromised with the introduction of PV systems
- Variations in mounting techniques can significantly impact flame spread
- Penetrations in the roof made to fasten PV systems can lead to failure of roof coverings
Flammability of Components

• Driven by two factors
  • The materials used
  • The arrangement of those materials
Fire Test Results

• The gap between PV panels and roofing materials will have a significant impact on heat and fire spread
  • When the gap between the PV panel and the roof is reduced from 10 inches to 5 inches, heat levels of the roofing material increases significantly
  • When the gap is further reduced to 2.5 inches, the heat levels of the roofing material actually decreases
Compromise of Roof Rating

- Testing of roofing materials completed by UL have initial indications that the installation of PV arrays can severely compromise roof ratings.
- There is a direct relationship between method of mounting and severity/involvement of roofing materials.
- Clear space between the PV panel and the roof deck has a significant impact on roofing material integrity/fire involvement.
Ignition Hazards

• Early component failure, especially electrical wiring – leading to an electrical fault, is often the source and the leading cause of PV system building fires

• Unsatisfactory grounding methods and adequate grounding devices are a significant concern

• Metal mounting systems for PV systems are also required to be grounded
Wind

- Each of the mounting systems act differently in wind situations
  - For ballasted systems, resistance to wind and seismic forces is provided by weight and friction
  - For attached roof-bearing systems, the load path for upward forces is different from that for downward forces
  - Structurally attached systems are the only type that the load path is the same for both upward and downward paths
Ballasting Issues

- Significant weight added to the roof
- Correct quantity and positioning of ballast is critical to system stability
Wind Driven Array Movement

- Recent testing has identified that systems can react to winds at low as 70% of their rated design
- Recommendation to inspect any ballasted PV system after a wind event that has 70 mph gusts
- Identification markers should be used to track cumulative system shifting
Wind Damage
Wind / Mechanical Damage
PV Setback

- PV setback is a critical design item
- PV must be positioned far enough away from the edge of the building to ensure the building is able to withstand uplift loads of the area
Collapse

- Addition of PV array(s) to the roof of a building can significantly impact the structural integrity of the building
- A comprehensive analysis of the building should be completed prior to any PV project is undertaken
Debris Accumulation

- Partial shading can compromise effectiveness of the PV system
- Debris accumulation around and beneath PV panels can quickly facilitate ignition and spread of fire
Rodent Damage
Hail Damage
Snow Accumulation
Firefighting Exposures

• Limited access to the roof
• Ventilation
• Electrocution Concerns
• Location and Identification of Disconnects

*NFPA 1 – Section 11.12.2 – Building-Mounted Photovoltaic Installations provides guidelines for access
***REMEMBER THIS***

• At this time PV panels cannot be fully de-energized. Electrical power to associated equipment (combiner boxes, inverters, DC systems) can be isolated. But, if there is a light source on the PV panel, then DC power **IS BEING GENERATED**

• Lighting from emergency vehicles is typically sufficient to activate PV panels

• **DO NOT** step on, cut, or try to remove panels
Significant PV Fire Losses
Bakersfield, CA – Target Store

April 5, 2009 at 4:15 pm

• Store manager was notified that smoke was coming from the roof of the building

• Fire department was notified and the store manager went to the roof to fight the fire with handheld extinguishers

• First arriving units found nine PV modules in Sub Array 1 and the roof under these modules completely engulfed in fire

• A second smaller fire was noted 200 feet away from the main fire
Bakersfield, CA – PV Fire
Mount Holly, NC – National Gypsum

April 16, 2011

- Minimal details are available for this event
- Duke Energy was aggressively “leasing” rooftop space for the construction of PV arrays
- Fire originated in combiner box 2A
- The fire was a multi-focal event
- Damage was limited to 20 PV panels being completely destroyed, with an additional 20 panels being heavily damaged
Mount Holly, NC – PV Fire

Combiner Box 2A; Heavy Arching

20 destroyed and 20 damaged panels

Combiner Box 2F; Origin of Fire
LaFarge, WI – Organic Valley

May 14, 2013

• Cause of the fire officially ruled as “undetermined”
• Firefighter efforts were hampered when the roof became energized because of the combination of fire, PV array, and metal roof
Delanco, NJ

September 1, 2013

• As this fire is still under investigation information is still limited as to the cause and origin of the event
• Building was in excess of 700,000 sf
• Roof was covered with over 7,000 solar modules
• Building and contents were a total loss
Before...
During...
After...
Critical Areas of Concern

- Expansion Joints on Conduit
- Disconnects
- Annual Preventative Maintenance
- Proper Installation Techniques
- Additional Ground-fault and PV array isolation sensing devices
- Adequate pathways
- Adequate Ability to Ventilate
- “Shift Training” for all Responding Fire Departments
- Upgrade Older Systems
System Inspection / Maintenance
Summary

• Photovoltaics is still in its infancy
• At this time, the industry as a whole has not adopted “uniform” standards
• Photovoltaic arrays pose a serious fire exposure when mounted on buildings
• Fire departments are reluctant to launch an offensive attack when photovoltaic arrays are present
• Proper evaluation of both existing and future installations is critical
• Maintenance of these systems is mandatory
Q&A