RISKTOPICS

Photovoltaic systems

May 2014

INTRODUCTION

Photovoltaic systems installed on or integrated into buildings components introduce a variety of potential challenges and risks. The challenges and increased risks may include:

- Increased fire ignition sources introduced on exterior building surfaces that are beyond the reach of fixed or automatic fire protection and fire detection systems.
- Presence of solar power generation features that cannot be reasonably de-energized before fire suppression activities begin.
- Increased difficulty for fire department operations, with responding fire service making a reasonable decision to use defensive firefighting tactics to avoid placing personnel on roofs or within buildings equipped with solar panel systems.

- Increased flame spread or combustibility of roof coverings as the heat from a roof fire may be inhibited from dissipating upward away from the roof surface by the presence of rack-mounted photovoltaic modules.
- Unexpected structural loads not anticipated by codes and standards such as snow or ice loads that accumulate in shaded areas below panels, or deflection of structural members creating the potential for ponding of rainwater.

When photovoltaic panels are installed on the ground, designs should consider the guidance offered in this document.

DISCUSSION

The installation or integration of photovoltaic systems onto or into buildings can introduce challenges that are not considered to be adequately addressed within existing codes and standards.

Fire ignition sources

Most buildings possess some degree of electrical systems on their exterior surfaces that could fail and become a source of fire ignition. However, the installation or integration of a photovoltaic system onto or into buildings can significantly increase the number of potential ignition points, where conditions such as physical damage, thermal stress, or corrosion may lead to an electrical fault with ensuing fire.

Fires involving photovoltaic systems and exterior building surfaces can occur beyond the reach of automatic fire protection and fire detection systems that are present within buildings. Heat from a fire involving building roof and walls may activate interior fire protection systems; however, their operation may not have a beneficial impact upon the fire. If interior fire protection systems become overtaxed - for example, too many sprinklers activated by heat from a rooftop fire - the interior fire system may fail allowing the fire to spread into and throughout the building.

Interrupting power sources

Before initiating firefighting activities, the fire service will typically turn off all sources of electric power to the fire building, or at least the affected portion of the fire building. When photovoltaic systems are installed on or integrated into a building, a complete shutdown of electric power may not be possible, since the panels will generate current from any available light source. This life safety issue remains a paramount concern for the fire service community. As stated in the Fire Protection Research Foundation report Fire Fighter Safety and Emergency Response for Solar Power Systems, "Even with known shutdown steps taken to isolate electrical current, fire fighters should always treat all wiring and solar power components as if they are electrically energized."

Defensive fire service tactics

As the fire service is guided to assume photovoltaic systems installed on or integrated into a building cannot be fully de-energized, it is reasonable and realistic for the fire service to take measures to avoid exposing their personnel to uncertain electrical hazards. This may include avoiding aggressive fire attack in or on roof tops of buildings with photovoltaic panels. Instead, the fire service may transition to a defensive mode of operation including exterior fire attack efforts and the protection of surrounding exposures.

The presence of large rigid solar panel arrays create large areas of roof surface that are shielded from water of overhead fire streams or elevated firefighting platforms. These shielded areas can allow fires involving the roof assembly to involve a large portion of roof area, despite the presence of manual firefighting operations. Remote or defense firefighting operations can allow a major portion of a building roof, and perhaps a major portion of the building, to be consumed by fire.

Roof cover flame spread

Many roof covering systems include combustible materials such as asphalt, bitumen, rubber, and foamed plastics. These combustible materials are incorporated into roof cover assemblies evaluated by test agencies such as Underwriters Laboratories using tests such as UL 790, Tests for Fire Resistance of Roof Covering Materials.

Historically, roof cover assemblies have been evaluated for fire with no feature present above the roof covering. During this laboratory testing, heat from the fire and roof surface is allowed to freely dissipate upward and away from the roof surface under test.

Integrated fire testing of both the roof coverings with photovoltaic panels positioned above were conducted by UL in 2009. These tests demonstrated that the presence of photovoltaic panels above a roof cover can dramatically increase roof cover flame spread rates and combustibility of the roof system. This increased flame spread rate is undesirable.

Unexpected structural loads

Where exposed to snow, building codes require the structural design of a building to include consideration of snow loads. Snow loads are typically based upon established ground snow loads for a geographic area. Many of these roof snow loading guidelines anticipate rooftop snow accumulations should melt or evaporate before an excessive amount of snow accumulates from one or more snow events.

When photovoltaic panel systems are installed on low-slope (flat) roofs, snow accumulations on panels will melt and drain onto the shaded roof below. The concern is that refreezing snow melt may develop into unexpected ice accumulations. The heavier ice accumulations may remain on the shaded roof for an extended period, allowing more time for the collection of an additional snow load that exceeds the structural design allowance, resulting in building collapse.

For areas where roof snow loads are lower, the weight of the new solar panels, racking, and other equipment can cause deflection of both the secondary and primary structural members supporting the roof. As these members deflect or sag, the slope of the roof is reduced and a basin is created that can catch and retain rainwater. As the rainwater is accumulated in this basin area, a rooftop pond develops. As the rainfall continues, the depth and weight of the ponded rainwater increases as the structural members continue to sag, creating the potential for a roof collapse.

GUIDANCE

Location

Locate photovoltaic systems:

- On the ground separated from important buildings and structures.
- At least 7.66 m (25 ft.) horizontally from combustible construction or yard storage.

- A suitable distance from outdoor flammable liquids storage or processing areas. Follow the directions of a recognized guideline such as NFPA 497.
- Beyond areas subject to inundation by flood, surface water runoff, or building roof drains.

Wind

Design photovoltaic panel systems to resist wind loads. Due to the potential for wind borne debris damage to the solar panels, rigid solar panels should not be located in areas of wind speeds greater than 160 kph (100 mph).

- Apply wind design guidance based upon wind tunnel tests
- Secure electrical conduit to the racks supporting the photovoltaic panels

Fire

Implement wiring practices including:

- Conduit expansion couplings to accommodate temperature heating and cooling cycles
- Flexible wiring loops at accumulation boxes to avoid transferring loads from conduits to wires

Manage exposures to undetected ground faults in grounded photovoltaic systems. Ground faults have been identified as a cause of fire. Implement actions including:

- Installation of ground-fault sensing devices to annunciate faults and cause maintenance actions
- Provide concrete or stone surfaces to control and limit vegetation growth
- Avoid the use of dissimilar metals where corrosion can potentially lead to electrical faults and sources of fire ignition.

Hail

In hail prone regions, select photovoltaic panels tested for hail impact resistance. Panels that have withstood the highest impact energy are more desirable. The most common hail impact test standards include:

- ASTM E1038, The Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls
- IEC 61215, Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval

Lightning

Provide surge protection for all cables associated with the photovoltaic panel system that enter important buildings or structures. Conduct and apply an engineering analysis performed in accordance with a standard such as NFPA 780.

Access control

Provide access controls to the photovoltaic panel system including:

- Fencing at least 2.4 m (8 ft.) high
- Gates normally locked
- Keys controlled by management
- Entry limited to authorized employees and contractors

Impact

Provide fencing, bollards, and similar features to control exposures to impact from lawn care equipment and motor vehicles.

Emergency planning

Support emergency plans for fire by providing:

- Photovoltaic system disconnects in accordance with standards such as NFPA 70, National Electrical Code®
- Fire service access to one-line electrical diagrams
- Clearly labeled photovoltaic system disconnects

  Note: Have signage clarify disconnects do not eliminate the presence of electrical power upstream of the disconnect
- Instructions for the operation of photovoltaic systems disconnects

Inspection, testing, and maintenance

Implement thorough inspection, testing, and maintenance procedures including:

- Weekly, inspect to identify and remove vegetation
- Annually, inspect to identify progressive system damage and cause maintenance actions
- Annually, conduct infrared thermographic studies to identify loose connections and failing components
- After severe wind storms, evaluate the condition of the system for deficiencies such as loose or rusted bolts securing the modules and frame

New or modified installations

Submit plans to Zurich for review and comment for all new or modified photovoltaic system installations. Plan submittal guidance is provided in Appendix A of this document.

CONCLUSION

Avoid the installation or integration of photovoltaic systems onto or into buildings until the challenges and increased risks associated with these systems are fully understood and addressed in applicable codes and standards.

As an alternative, locate photovoltaic systems at ground level separated from important buildings and structures.

Submit plans for new or modified photovoltaic system installations to Zurich for review and comment.

REFERENCES

Grant, Casey C. Fire Fighter Safety and Emergency Response for Solar Power Systems. Quincy, MA: Fire Protection Research Foundation, 2010. Web. Web accessed 20131008. http://www.nfpa.org/~/media/Files/Research/fftacticssolarpower.pdf

Rosalie Wills, James Milke, Sara Royle and Kristin Steranka, Department of Fire Protection Engineering, University of Maryland, Commercial Roof-Mounted Photovoltaic System Installation Best Practices Review and All Hazard Assessment. Quincy, MA: Fire Protection Research Foundation, 2014. Web. Web accessed 20140128. http://www.nfpa.org/~/media/Files/Research/Research%20Foundation/Research%20Foundation%20reports/Building%20and%20life%20safety/RFCommercialRoofMountedPhotovoltaicSystemInstallation.pdf

NFPA 70, National Electrical Code®. Quincy, MA; NFPA, 2014. Online.

NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas. Quincy, MA; NFPA, 2012. Online.

NFPA 780. Standard for the Installation of Lightning Protection Systems. Quincy, MA; NFPA, 2011. Online.

Brooks, Bill. The Ground-Fault Protection BLIND SPOT: A Safety Concern for Larger Photovoltaic Systems in the United States, A Solar ABCs White Paper, Solar America Board for Codes and Standards , 2012. Web. Web accessed 20131008. http://www.solarabcs.org/about/publications/reports/blindspot/pdfs/BlindSpot.pdf

Rosenthal, Andrew, Larry Sherwood, Bill Brooks, Pravinray Ghandi, and Bob Backstrom. Flammability Testing of Standard Roofing Products In the Presence of Standoff-mounted Photovoltaic Modules. Solar America Board for Codes and Standards , 2012. Web. Web accessed 20131008.

APPENDIX A - Photovoltaic plan submittals

For new or modified photovoltaic systems, submit the following information to Zurich for review and comment.

1. Name of photovoltaic system manufacturer
2. Name of photovoltaic system installer
3. Photovoltaic system design data
   a. Wind design rating (provide wind tunnel or other substantiation of design coefficients)
   b. Snow and ice load design
   c. Hail resistance
   d. Fire rating (photovoltaic panels should be UL Class A or equivalent)
4. Photovoltaic systems securement methods and descriptions
   a. Panel or module securement
   b. Electrical conduit securement
5. Photovoltaic system physical drawings
   a. Array configuration (plan and elevation drawings)
   b. Disconnecting means location and signage
   c. Inverter location
   d. Conduit/wiring routes
6. Photovoltaic system electrical drawings (single line)
   a. Array wiring
      1) Modules in series
      2) Parallel source circuits
      3) Combiner/junction box
      4) Conduit/wiring from array to inverter
      5) Disconnects
      6) Overcurrent Protection
      7) Operating voltage
      8) Operating current
      9) Maximum system voltage
      10) Short-circuit current
7. Grounding systems
   a. DC grounding system
   b. AC grounding system
8. Manufacturer's literature
   a. Photovoltaic modules
   b. Inverter
9. Bill of materials
10. Commissioning plan. Plan should include:
    a. Insulation resistance tests on all field-installed conductors including modules and module wiring
    b. Open-circuit voltage and polarity tests on all string and feeder circuits
    c. Operational current readings on all series strings and feeders; and
    d. Thermographic scans
       a. All inverters, disconnects, and combiner boxes at 50% load or higher
       b. Overall array to identify hot spots not caused by shading or other temporary conditions

The Zurich Services Corporation
Risk Engineering
1400 American Lane, Schaumburg, Illinois 60196-1056
800 982 5964 www.zurichna.com

ZURICH