

## EXECUTIVE SUMMARY

Under the United States Department of Homeland Security (DHS) Assistance to Firefighter Grant Fire Prevention and Safety Research Program, Underwriters Laboratories examined fire service concerns of photovoltaic (PV) systems. These concerns include firefighter vulnerability to electrical and casualty hazards when mitigating a fire involving photovoltaic (PV) modules systems. The need for this project is significant acknowledging the increasing use of photovoltaic systems, growing at a rate of 30% annually. As a result of greater utilization, traditional firefighter tactics for suppression, ventilation and overhaul have been complicated, leaving firefighters vulnerable to potentially unrecognized exposure. Though the electrical and fire hazards associated with electrical generation and distribution systems is well known, PV systems present unique safety considerations. A very limited body of knowledge and insufficient data exists to understand the risks to the extent that the fire service has been unable to develop safety solutions and respond in a safe manner.

This fire research project developed the empirical data that is needed to quantify the hazards associated with PV installations. This data provides the foundation to modify current or develop new firefighting practices to reduce firefighter death and injury.

A functioning PV array was constructed at Underwriters Laboratories in Northbrook, IL to serve as a test fixture. The main test array consisted of 26 PV framed modules rated 230 W each (5980 W total rated power). Multiple experiments were conducted to investigate the efficacy of power isolation techniques and the potential hazard from contact of typical firefighter tools with live electrical PV components.

Existing fire test fixtures located at the Delaware County Emergency Services Training Center were modified to construct full scale representations of roof mounted PV systems. PV arrays were mounted above Class A roofs supported by wood trusses. Two series of experiments were conducted. The first series represented a room of content fire, extending into the attic space, breaching the roof and resulting in structural collapse. Three PV technologies were subjected to this fire condition – rack mounted metal framed, glass on polymer modules, building integrated PV shingles, and a flexible laminate attached to a standing metal seam roof. A second series of experiments was conducted on the metal frame technology. These experiments represented two fire scenarios, a room of content fire venting from a window and the ignition of debris accumulation under the array.

The results of these experiments provide a technical basis for the fire service to examine their equipment, tactics, standard operating procedures and training content. Several tactical considerations were developed utilizing the data from the experiments to provide specific examples of potential electrical shock hazard from PV installations during and after a fire event.

The tactical considerations addressed include:

- Shock hazard due to the presence of water and PV power during suppression activities
- Shock hazard due to the direct contact with energized components during firefighting operations
- Emergency disconnect and disruption techniques
- Severing of conductors
- Assessment of PV power during low ambient light, artificial light and light from a fire
- Assessment of potential shock hazard from damaged PV modules and systems.

The following summarizes the findings of this research project:

1. The electric shock hazard due to application of water is dependent on voltage, water conductivity, distance and spray pattern. A slight adjustment from a solid stream toward a fog pattern (a 10 degree cone angle) reduced measured current below perception level. Salt water should not be used on live electrical equipment. A distance of 20 feet had been determined to reduce potential shock hazard from a 1000 Vdc source to a level below 2 mA considered as safe. It should be noted that pooled water or foam may become energized due to damage in the PV system. A summary of the distances and spray patterns which measured safe (< 2 mA) and perception (< 40 mA) currents for various PV system voltages is shown in Appendix A.
2. Outdoor weather exposure rated electrical enclosures are not resistant to water penetration by fire hose streams. A typical enclosure will collect water and present an electrical hazard.
3. Firefighter's gloves and boots afford limited protection against electrical shock provided the insulating surface is intact and dry. They should not be considered equivalent to electrical PPE.
4. Turning off an array is not as simple as opening a disconnect switch. Depending on the individual system, there may be multiple circuits wired together to a common point such as a combiner box. All circuits supplying power to this point must be interrupted to partially de-energize the system. As long as the array is illuminated, parts of the system will remain energized. Unlike a typical electrical or gas utility, on a PV array, there is no single point of disconnect.
5. Tarps offer varying degrees of effectiveness to interrupt the generation of power from a PV array, independent of cost. Heavy, densely woven fabric and dark plastic films reduce the power from PV to near zero. As a general guide, if light can be seen through a tarp, it should not be used. Caution should be exercised

during the deployment of tarps on damaged equipment as a wet tarp may become energized and conduct hazardous current if it contacts live equipment. Also, firefighting foam should not be relied upon to block light.

6. When illuminated by artificial light sources such as fire department light trucks or an exposure fire, PV systems are capable of producing electrical power sufficient to cause a lock-on hazard.
7. Severely damaged PV arrays are capable of producing hazardous conditions ranging from perception to electrocution. Damage to the array may result in the creation of new and unexpected circuit paths. These paths may include both array components (module frame, mounting racks, conduits etc.) and building components (metal roofs, flashings and gutters). Care must be exercised during all operations, both interior and exterior. Contacting a local professional PV installation company should be considered to mitigate potential hazards.
8. Damage to modules from tools may result in both electrical and fire hazards. The hazard may occur at the point of damage or at other locations depending on the electrical path. Metal roofs present unique challenges in that the surface is conductive unlike other types such as shingle, ballasted or single ply.
9. Severing of conductors in both metal and plastic conduit results in electrical and fire hazards. Care must be exercised during ventilation and overhaul.
10. Responding personnel must stay away from the roofline in the event of modules or sections of an array sliding off the roof.
11. Fires under an array but above the roof may breach roofing materials and decking allowing fire to propagate into the attic space.