SOLAR PANEL INSTALLATIONS

INTRODUCTION

We have all seen them throughout our neighborhoods. Solar panel installations, formally referred to as solar photovoltaic (PV) systems, have become more and more common as an alternate power supply. They are located just about everywhere, including the roofs of residential, commercial and industrial buildings, open fields and parking lots, and our streets.

Why so popular? Compared to other energy sources, solar PV systems have many advantages: lower electricity costs, possible rebates and tax incentives to businesses and homeowners who install them; less pollution, cleaner environment than fossil fuel-powered electric generating stations and therefore a reduction in global warming.

According to the Solar Energy Industries Association, during the second quarter of 2013, the U.S. solar market had its second largest quarter in history. The industry installed 832 megawatts (MW) of PV capacity, up 15% over deployment levels in the first quarter of 2013. Some additional facts and figures include:

- Over 9,370 MW of cumulative solar electric capacity now operate in the U.S., enough to power more than 1.5 million average American homes.
- By the end of 2013, a solar project will likely have been installed an average of every four minutes in the U.S.
- Since the beginning of 2011, the average price of a PV panel has dropped by more than 60%.
- 4,400 MW of PV is forecast to come online throughout 2013, which represents 30% growth over 2012 installation totals.
- With new solar electric capacity added in 2013, the total clean energy generated will power more than 860,000 average American homes.

However, as with most electric power generating equipment, the potential exists for fires, electric shock and other hazards if these systems are not designed, installed and maintained correctly.

This paper will examine the potential hazards of solar PV systems and provide property risk control guidelines to reduce the probability of a fire or other catastrophic event.

RECENT INCIDENTS

The good news is that loss history associated with solar PV panel installations is limited. But will the frequency and severity of losses associated with these systems drastically increase as these systems age and installations become more prevalent? Only time will tell; however, two recent examples are worth mentioning.

An article in NFPA Journal reports the following solar panels malfunction: In Massachusetts, an electrical junction box for a solar panel array on the roof of an elementary school malfunctioned and ignited, starting a fire that spread to nearby roof materials over an area approximately 64 square feet (8 ft. by 8 ft.). A passerby spotted the fire and called the fire department at 12:30 on a weekend afternoon.

The two-story, steel-framed building had masonry walls and a metal deck roof covered with a rubber membrane. The school was protected by a full-coverage, wet-pipe sprinkler system and fire alarm system, but neither operated because the fire was on the exterior of the building. Investigators could not determine the cause of the malfunction in the junction box. Damage to the building was estimated at $30,000.

When a structure is on fire, proper ventilation is a critical fire ground operation. This is defined as the removal of heat, smoke and toxic gas from a building followed by the replacement of cooler air. Proper ventilation helps limit damage to a building by increasing firefighters’ visibility allowing quicker access to the seat of a fire, helps with search and rescue of victims and reduces...
the chance of back draft (an explosion due to the introduction of oxygen into an environment containing heat and flammable products of combustion). With this in mind, a September 2013, 11-alarm fire at a 300,000-square foot warehouse and distribution center in Delanco, NJ was much more difficult to extinguish because of more than 7,000 solar panels on the roof. “Volunteer fire crews rushed to the burning meat warehouse on Sunday and discovered the roof was covered in solar panels, forcing firefighters to change tactics. It took 29 hours to put out the flames at the Dietz & Watson warehouse, which was left gutted and smoldering in ruins.”

**HOW DO SOLAR PV SYSTEMS WORK?**

FM Global Data Sheet 7-106, “Ground-Mounted Solar Photovoltaic Power,” defines a Photovoltaic (PV) system as a system which uses an array of mechanically and electrically integrated solar panels to convert sunlight into electricity. It consists of PV panels, support framework and electrical connections and equipment to allow regulating and converting the electrical output from direct current (DC) to alternating current (AC). There are three main types of systems, which include grid-connected, grid-connected with battery backup and stand-alone systems.

Grid-connected photovoltaic power systems are power systems energized by photovoltaic panels that are connected to the utility grid.

These systems consist of photovoltaic panels, MPPT (a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels) solar inverters, power conditioning units and grid connection equipment. Unlike stand-alone photovoltaic power systems these systems seldom have batteries. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid.

PV systems with battery back-up capability use a battery bank to hold excess power during power outages or the lack of solar production. This is similar to having a generator attached to the solar array until the energy stored in the batteries is used up.

Below is a schematic of the typical components in grid-connected photovoltaic power systems with battery back-up and explanation of each component.

**PV array** – Sunlight passes through the silicone wafers in the PV modules knocking loose electrons which flow into wires as direct current (DC) electricity.

**Charge controller** – Controls the voltage going into the batteries and maintains the battery bank charge at pre-programmed limits.

**Battery bank** – Stores the energy generated by the system during the day for use if the grid goes down.

**Main DC disconnect** – System shut-off with circuit breakers and ground fault protection. Required by code to ensure that all parts of the system can be disconnected from all sources of power.

**Inverter** – DC electricity from the PV array is converted to AC electricity to supply the loads and sell energy back to the grid.

**AC breaker panel and meter** – Grid power consumption and the power production from the PV array are metered. Net metering means you only pay the difference between what you use and what you produce.

Stand-alone PV systems are electrical power systems energized by photovoltaic panels which are independent of the utility grid.

**PROPERTY RISK CONTROL GUIDELINES**

There are many hazards inherent with the installation of solar photovoltaic (PV) systems that building owners need to be aware of before, during and after installation. The following are some property risk control guidelines to consider.
NATURAL HAZARDS
Locations susceptible to high winds, heavy snow, ice, and frequent hail may not be best suited for solar photovoltaic (PV) systems. Both ground-mounted and rooftop solar (PV) systems may be damaged by airborne missiles in the event of a hurricane or tropical cyclone. Some roof-mounted PV systems are adjusted for the angle of the sun for maximum power generation and do not lie completely flat against the roof. Wind driven snow can significantly accumulate below the panels creating an uneven weight distribution on the roof. For locations in areas susceptible to severe hailstorms, FM Global Data Sheet 7-106 recommends that FM Approved solar panels with a Class 4 hail rating (2-inch hail in diameter) be used.

STRUCTURAL INTEGRITY
In addition to the weight from natural hazards, such as ice and snow, you must consider the additional weight the solar photovoltaic (PV) systems place on a structure. A structural engineer should perform the required analysis to ensure that the building can withstand the additional weight of the panels, mounting structures and associated equipment. For example, one panel weighs approximately 35 pounds and a normal dwelling uses about 40 panels. This equates to an additional dead load of about 1,400 pounds added to the roof system.

Any roof penetrations that may have occurred during installation should be properly sealed. Water intrusion should be completely avoided. Also, if the roof is still under a manufacturer’s warranty you may want to ensure that any modifications will not void the warranty.

FIRE
For roof-mounted solar photovoltaic (PV) systems, only non-combustible support frames should be used. In addition, it is important to determine the type of roofing material that will be underneath the support frames and PV panels. Some roofing materials may be combustible and a fire originating under a solar panel array may quickly spread and penetrate the roofing materials and decking. This could allow smoke and fire to penetrate concealed space such as an attic or cockloft. In turn, automatic fire detection and/or suppression may not be installed in these areas or may be ineffective. Furthermore, you should avoid direct contact between solar photovoltaic (PV) system components and building components.

It is important to ensure that solar photovoltaic (PV) systems are properly grounded and adequate surge protection is provided to avoid electrical faults.

If existing lightning protection exists, you should integrate the solar photovoltaic (PV) components into this system. If none exists, you should consider performing a risk assessment to determine if lightning protection is warranted.

The area around ground mounted solar photovoltaic (PV) systems should be kept free of combustible material such as grass and vegetation. If a threat of vandalism, arson or other security issue exists the area should be enclosed with fencing.

MAINTENANCE OF PHOTOVOLTAIC (PV) SYSTEMS
FM Global Data Sheet 7-106 recommends that you maintain all solar photovoltaic (PV) systems and equipment in accordance with the manufacturer’s recommendations. Furthermore, you should check all equipment for damage or required maintenance after severe wind or snow storms.

Solar panel assemblies should be checked at least annually to ensure connections between panels and support systems have not become corroded or loose, that concrete pavers have not deteriorated, and temperature changes have not caused damage by expansion and contraction of components.

PRE-EMERGENCY PLANNING
The importance of rapid notification of first responders and written, pre-established procedures for when they arrive on scene cannot be overstated. Clear, concise and well-practiced emergency response plans have the following advantages:

- All personnel, both internal and external, respond quicker and more effectively than if no planning has occurred.
- Data, such as access routes, documents, schematics, important contacts and other technical material will play an important role when responding to an emergency involving solar photovoltaic (PV) systems. It may be a good idea for the first due apparatus to already have copies of this information on the vehicle.
- Equipment and supplies can be identified and obtained before the incident occurs.
- A clear assignment of tasks and responsibilities is understood.
- Training and additional resource needs can be identified.

**ADDITIONAL CONSIDERATIONS**

In 2011, Underwriter’s Laboratories released a report regarding firefighter safety and photovoltaic systems. Specifically, “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.” While the scope of the report was to identify and/or develop fire fighting practices to reduce death or injury, the following is some specific data that *anyone* involved with solar photovoltaic (PV) systems should be aware of:

- 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.
- 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.
- 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 it, the tarp should not be used. Exercise caution during the deployment of tarps on damaged equipment, as a wet tarp may become energized and conduct hazardous current if it contacts live equipment.
- 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.
- 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). You should consider contacting a local professional PV installation company to mitigate potential hazards.
- 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.
- Severing of conductors in both metal and plastic conduit results in electrical and fire hazards.
- Personnel must stay away from the roof line in the event of modules or sections of an array sliding off the roof.

**CODES AND STANDARDS**

“The Solar America Board for Codes and Standards (Solar ABCs) is a collaborative effort funded by the U.S. Department of Energy that dedicates experts to transforming solar markets by improving building codes, utility interconnection procedures, and product standards, reliability, and safety, and is part of its overall strategy to reduce barriers to the adoption of solar technologies and to stimulate market growth.

The Solar ABCs was formed to identify current issues, establish a dialogue among key stakeholders, and catalyze appropriate activities to support the centralized development of codes and standards that facilitate and accelerate the installation of high quality, safe photovoltaic (PV) systems. The Solar ABCs also provides access for PV manufacturers, sellers, buyers, users and regulators of a particular PV, material, product, process or service to sponsor PV codes and standards research studies to help foster the acceleration of the PV market.”

Below is a list of organizations that all publish codes and standards for PV products and each organization has its own process to develop and publish standards:

- **ASTM** (American Society for Testing and Materials) – Develops and delivers international standards. The ASTM technical committee dedicated to PV standard development is the **E44.09 Photovoltaic Electric Power Conversion**.
- **IAPMO Standards** – The International Association of Plumbing and Mechanical Officials works with government and industry to implement comprehensive plumbing and mechanical systems around the world.

- **ICC** – The International Code Council is an organization that develops a single set of comprehensive international model construction codes focused on building safety and fire prevention. Many ICC Codes (also known as I-Codes) have sections relevant to PV installations, including the International Building Code (IBC), International Fire Code (IFC), International Green Construction Code (IGCC) and International Code Council Evaluation Services (ICC-ES).


- **IEEE** – The Institute of Electrical and Electronics Engineers standards portfolio includes hundreds of industry-driven consensus standards in a broad range of technologies and applications, including photovoltaic (PV) systems and integration with the utility grid.

- **NFPA** – The National Fire Protection Association issues the *National Electrical Code®* (NEC), the Uniform Fire Code and other codes. The NEC has two articles that address photovoltaic (PV) systems:
  - Article 690, Solar Electric Systems
  - Article 705, Interconnected Electrical Power Production Sources

- **SEMI** – An organization that represents the worldwide semiconductor, PV and flat panel display (FPD) industries.

- **UL** – Underwriters Laboratories Inc. has more than 1,000 safety standards including standards for PV related products.

**CONCLUSION**

Without a doubt, the use of solar photovoltaic (PV) systems will be ever increasing. As with any emerging technology, we can look forward to lower and lower prices, improvements in efficiency and faster returns on investment, as well as systems that are engineered to lessen the fire hazard and improve safety. Keep in mind that extensive consultation and plan review is needed before any work commences, whether it appears to be a simple change in configuration or an entire new installation project. Willis Property Risk Control Engineering is able to assist in the reduction of loss potential for these systems.

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We encourage you to visit our [website](#) to access prior publications on topics that may be of interest.
1. http://www.seia.org/research-resources/solar-industry-data

2. NFPA Journal, (September/October 2013), p.27.


4. (FM Global Property Loss Prevention Data Sheets are engineering guidelines written to help reduce the chance of property loss due to fire, weather conditions and failure of electrical or mechanical equipment, and incorporate loss experience, research results, input from consensus standards committees, equipment manufacturers and others. FM Global data sheets are available via download at http://www.fmglobal.com/page.aspx?id=04010200)


8. http://www.state.nj.us/dca/divisions/dfs/pdf/trgmaterial/solar_energy_and_the_fire_service.ppt


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