PV Safety & Firefighting

by Matthew Paiss

Courtesy Craig Allyn Rose

Fire safety is typically the last thing people think of when planning their rooftop solar-electric system, but it quickly becomes a hot topic when a blaze ignites. Here's a look into the potential hazards of PV systems when a fire breaks out—and how to minimize risks to firefighters.

Why do firefighters climb up on the roof of a burning building? In a house fire, superheated smoke and gases (which can exceed 1,200°F) rise to the ceiling and then bank down back to the floor. Just one lungful of this smoke can kill. Cutting a hole in the highest point of the room allows the superheated gases and fire to rise out of the building, rapidly improving visibility as well as the survivability of the structure and those trapped inside. This also allows firefighters on the hose line to advance inside to locate the seat of the fire and any victims. This "vertical ventilation" has saved many lives and valuable property—besides actual rescue, this is one of a firefighter's primary responsibilities.

But the presence of rooftop-mounted PV arrays has made cutting through a roof more challenging. In the past, the fire service had plenty of room to ventilate where it is most effective—directly above the fire. With PV arrays now covering large areas of roofs, firefighters are limited in where they can cut and where they can exit the roof. Since the PV modules cannot be cut through, and moving them is time-consuming and potentially dangerous, rooftop PV systems pose some risks—mainly shock and trip hazards.

Most firefighters have had some education in electrical theory but usually employ the tactic of avoidance when it comes to electrical equipment. However, there are still

those who believe that anything is manageable if you can swing an axe hard and fast enough—clearly not the best approach when dealing with electricity. Most firefighters will just ventilate as close as they can to the high point of a room. If an array is in the way, they will move to where they can cut safely and rapidly. One problem is that most roof systems employ lightweight trusses, held together by lightweight metal gusset plates. With small fastening points, they can warp and pull out in fire conditions. These roofs are known as "20-minute roofs," meaning that firefighters have 20 minutes or less to get up, make the necessary cuts, and get down before the roof gives out. So, time is of the essence when navigating a hot roof with a PV system.

Fire Safety Steps

Assessing the Situation. One of the first things firefighters do at the scene is to take a "hot lap"—a quick walk around the building to see all sides and to locate the utility shutoffs. It is usually at this point that a PV system is noted if the array was not visible upon arrival. An inverter—often outside near the meter and service panel—also serves as a signpost. Likewise, if metal conduit is present in an attic, that's a red flag that a PV system may be present.

But there are some cases where obvious indicators of a PV system are not evident—such as in cases where the modules are integrated into the roof or the inverter is located indoors. Besides visual identification, a common way to note a PV system is to look at the labels on the main service panel, typically located on an exterior wall. The labeling may be on the outside or inside of the main panel. There should be a dedicated breaker for the inverter, labeled "solar inverter" or some variation. This breaker also may be in a subpanel inside the structure, but a label on the main service panel should always state that there is a second generating source onsite as well as identify the dedicated breaker for the inverter. New guidelines from the California Office of the State Fire Marshal advocate labeling along the PV array's DC conduit run as well.

Shutting Down the System. With any structure fire, shutting off all the circuit breakers at the main distribution panel, closing any gas mains, and notifying all on the scene that the utilities are secure is standard operating procedure. Shutting down a PV system is not as simple or straightforward.

With grid-direct systems, the first step is to disconnect the inverter, which happens automatically when the utility

Taking Solar-Electric Systems Seriously

California's Office of the State Fire Marshal has put together a PV task force to respond to safety concerns of the fire services—as well as concerns from the solar industry over limits and inconsistent regulations being imposed on installations. Last year, a final draft of installation guidelines was created. These guidelines address:

Marking: High-contrast, reflective, and consistent wording must be used on conduit, electrical panels, and disconnects.

Access, pathways, and smoke-ventilation space: Providing a 3-foot setback from the edges of the roofline from gutter to ridge will ensure that firefighters can get onto and off the roof rapidly, if necessary. There is also a recommendation to provide a 3-foot setback along the ridgeline for ventilation. This is a highly contentious area, given the value of that space to both the fire service and solar installers. Alternative means of compliance are being considered.

Conduit runs: Considering the common use of chain saws for vertical ventilation, conduit runs should be kept 10 inches below roof decking (when run in attic spaces) to minimize the chance of being cut into.

For additional information on the draft guidelines, visit www.osfm.fire.ca.gov/training/pdf/photovoltaics/solarphotovoltaicguideline.pdf

Key Safety Points for PV & Firefighting

- Daytime = Danger—the PV system will be energized whenever sunlight hits the modules.
- Nighttime = No hazard from the PV system, but be aware of potential battery bank dangers elsewhere on the premises.
- Ensure that all breakers at the main electrical service panel are shut off.
- When a PV system is identified, it is imperative that everyone on the fire ground be notified. Securing the main electrical panel does not shut down the PV modules. Voltage can continue in the wiring between the modules and the inverter in the daytime.
- Firefighter-supplied lighting, like high-lumen emergency lighting—called "scene lighting" in the fire service—will not produce enough light to generate dangerous voltage from the arrays.
- Sunlight can be blocked only by opaque material. Remember: All of the modules need to be covered for the array to be rendered inoperable.
- Stay away from the arrays and conduit. Don't break, remove, or walk on the modules.

power is shut off. Inverters also are designed with very good ground-fault interruption (GFI). If an inverter detects voltage between the ground and any of the metal conduit, the modules themselves, or the mounting racks, the inverter trips the GFI and opens the circuit. The circuit is also opened when the inverter is shut down manually by tripping the main circuit breakers either for just the inverter or for the whole house.

However, even with the inverter off, there's no easy way to shut off the high-voltage DC electricity flowing through the array and the DC wiring. In daylight when there is an open circuit, the modules are still putting out full voltage. There's no current flowing—that is, unless it finds a path to ground, like through a firefighter or an axe breaking through walls or ceilings.

The use of a rooftop disconnect at the array can lead to a false sense of security, since that merely opens one side of the circuit. Complicating matters is that many PV systems have more than one subarray—which can be located on another section of roof. These subarrays could backfeed power through the inverter or combiner into the conduit that was supposed to be de-energized by the rooftop disconnect. The concept of having both the line and load sides of a disconnect energized is a potentially dangerous situation in this application. For this reason, the California Office of the State Fire Marshal frowns upon the installation of rooftop disconnects.

Don't Forget!

Even though PV systems can produce high voltages, the AC line voltages that come into all structures can be much more dangerous. On a recent fire, I noticed that the utility service drop was within easy contact and the insulation on the wires was missing in some spots. Since this is on the utility side of the meter, the current would be unregulated up to the limits of the wire, which could be close to 1,000 amps—a serious electrocution hazard.

During daylight, there can be enough voltage and current to injure or even kill a firefighter who comes in contact with the energized conductors. A hanging conduit with wires sticking out of it is nothing out of the ordinary on the scene of a fire, so firefighters must exercise extreme caution when navigating a fire. It is best to always assume that a PV system is energized and steer clear of the modules and conduit. Here's an example: If a firefighter accidentally or deliberately axes through a string of twelve 44 VDC modules, he or she will experience a potentially deadly surge of 528 volts.

Off-grid and grid-connected systems with battery backup have a few more circuits to consider. First, PV array disconnects should be shut off. Second, the battery banks in these systems are another power source that need to be shut down via a main DC battery disconnect to fully de-energize the inverter and any AC circuit fed by the inverter, as well as any DC circuit that might be present. Like the PV array, battery banks are live even after they have been disconnected from the rest of the system. And even though most battery banks are wired to low DC voltages (commonly 24 V to 48 V), which pose less of a shock hazard than the high-voltage DC circuits discussed earlier, their low voltage and high current nature can cause fires from overheated connections. Batteries are also full of sulfuric acid and emit hydrogen gas that is highly flammable.

Battery banks are usually contained in a plastic, metal, or wooden storage box located near the system control panel—typically in the garage, basement, or shed. Battery banks also may be placed somewhere on the exterior of the house. If the heat and flames of the fire are near the battery bank, firefighters should use dry chemical or CO_2 extinguishers instead of water to avoid the potential for shock hazard of spraying a live inverter and to minimize damage to the batteries. That said, salvaging a battery pack is always secondary to firefighter safety and saving

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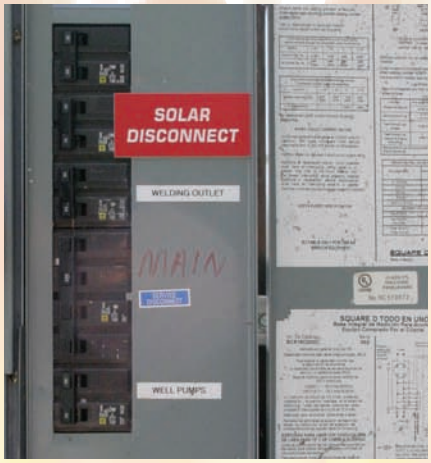

Courtesy Matthew Paiss (2)

Bright, clearly labeled disconnects are important to firefighters on the scene.

Courtesy Matthew Paiss

Firefighters cover a PV array with opaque tarps to cut off array power production.

Firefighting & Off-Grid PV Systems

Wildfire is a constant danger in many rural and remote areas, where off-grid PV systems are most common. Rural fire departments respond to both wildland and structure fires, ever mindful that each type of fire can quickly turn into the other. Federal, state, county, and other local wildland fire agencies often respond to all fires in their area as "mutual aid," depending on whose land is or might become involved. Unlike their counterparts in the suburbs and cities, wildland firefighters do not carry equipment to ventilate roofs or enter burning buildings, and usually do not have enough water or apparatus available to extinguish a burning building—their job is to prevent your home from igniting in the first place.

Prevention & Preparation

The more remote your area, the more responsibility you must take for fire prevention and preparation at your home. The time to prepare, though, is well before fire season—not when the sheriff drops by and tells you to leave within 15 minutes.

Keep your system clean and clear of flammable debris. Regularly remove any leaves, pine needles, or twigs caught between your PV modules and the roof. Firebrands can be carried by wind for long distances and can easily ignite such litter. If your PV array is on a ground-mounted rack, keep grass and brush trimmed underneath and around it.

Label all racks, combiner boxes, and conduit. Should burning debris land on your roof, firefighters may need to climb up there to extinguish it, and may not understand the electrical hazards from PV modules. Simple warning labels—such as "Caution: High-Voltage Solar-Electric System"—could help prevent personal injury as well as avoid damage to your system and home.

In an Emergency

Your ever-reliable off-grid system can help keep firefighters safer while they are protecting your off-grid home and give them a critical edge in saving your home from an approaching wildfire. The key: Leave your PV system on when you evacuate!

In remote areas with no fire hydrants, shuttling water in fire engines is a difficult problem. Prepare a sign in advance with details about your water—where it is, how much there is, and how to access it. Post the sign on your front door before you evacuate, and leave the porch light on to illuminate the sign and make your home visible to firefighters at night. Make sure all of your doors are unlocked—to your home, outbuildings, and water pumping control point.

Since your PV system has been left on, your domestic water pressure pump will be working. Connect garden hoses to outdoor faucets before you leave. If your well pump requires a generator to fill the cistern, then keep the generator gassed up, with instructions posted on how to pump from your well.

Also, keep in mind that "scene lighting" for a typical wildland fire crew consists of helmet headlamps and fire engine headlights. Your outdoor lighting could be very helpful for defending your home.

—Dan Fink

Courtesy Matthew Paiss

The author and his ground-mounted PV array.

the structure. However, when dealing with a minor fire or an overheated battery connection, firefighters should act prudently and do their best to avoid damaging thousands of dollars' worth of equipment.

Eliminating the Source. One option for shutting down a PV system is to cover the arrays with opaque material, such as heavy canvas tarps or black plastic. Most fire response vehicles carry some type of salvage covers or tarps that are commonly used to protect belongings from water damage during firefighting. These same tarps can also be used to prevent light from reaching the PV cells, shutting off the flow of electricity to the inverter. However, high winds, tarp sizes, structural conditions, and the size and shape of the array may prevent using this option. Some departments do not carry suitable tarps, and common blue poly tarps will not work because they let too much light through.

Dealing with Conduit. If the array cannot be tarped, it is important for the crews inside to be careful when opening holes in the ceiling, as they may contact the conduit from the array with their tools. Since plastic insulated wire (Romex) is all that's typically required for home wiring, metal conduit is rarely used in an attic spaces.

Firefighters must verify whether a metal conduit run is intact. If so, it is grounded from the array to the inverter, so any wires that may be shorted to it from the high heat of a fire will carry any voltage/current to ground rather than to the firefighter who contacts it. In other words, it is safe to touch. But if portions of the roof have collapsed, it should be assumed that the conduit is no longer grounded and therefore dangerous to touch. Most fire departments carry noncontact voltage detectors that can be used to find hot AC lines. Unfortunately, DC noncontact voltage detectors, which would alert firefighters to the presence of PV-generated electricity, are unavailable.

In a nighttime fire where the attic space was exposed to severe heat damage, the conduit and wires inside may have become compromised. Some arcing could begin as the rising sun energizes the modules the following morning—a potential for starting a new fire. A qualified solar contractor should be called in to disconnect the arrays. Unfortunately, most PV companies do not have an on-call technician available, so the disconnect usually must wait until the next day—not always the safest measure. In this case, most fire departments will post a "fire watch" until a qualified contractor can ensure the array is disconnected. Local utility companies are not responsible for the customer side (the house side of the meter) appliances and will not respond just to secure PV systems. This is where cooperation with the solar industry comes into play. The fire service recommends that all PV installers have an after-hours response contact for such emergency situations.

Keeping Safety in Mind

Identification is the key to understanding these systems and avoiding injury. Taking precautions with a PV array is one way to ensure the safety of firefighters and reduce the risks to your system. Beyond siting your system for optimal safety in the event of a fire, homeowners should consider installing interior fire sprinklers, which could be the critical difference between saving or salvaging your home and system. Invite your local fire department to tour your PV system if it's a rarity in your locale and provide them with a schematic of the system for their records. Further information about installing safe PV systems can be found in the California Office of the State Fire Marshal's draft guidelines.

Access

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