Solar Photovoltaic (PV) System Safety and Fire Ground Procedures

SAN FRANCISCO FIRE DEPARTMENT

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April 2012

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Published by:
Division of Training
2310 Folsom Street
San Francisco, CA
Phone: (415) 970-2000

April 2012

FOREWORD

The goal of this manual is to establish standard operating practices as authorized by the Chief of Department and implemented by the Division of Training.

The purpose of this manual is to provide all members with the essential information necessary to fulfill the duties of their positions, and to provide a standard text whereby company officers can:

- Enforce standard drill guidelines authorized as a basis of operation for all companies.
- Align company drills to standards as adopted by the Division of Training.
- Maintain a high degree of proficiency, both personally and among their subordinates.

All manuals shall be kept up to date so that all officers may use the material contained in the various manuals to meet the requirements of their responsibility.

Conditions will develop in fire fighting situations where standard methods of operation will not be applicable. Therefore, nothing contained in these manuals shall be interpreted as an obstacle to the experience, initiative, and ingenuity of officers in overcoming the complexities that exist under actual fire ground conditions.

To maintain the intent of standard guidelines and practices, no correction, modification, expansion, or other revision of this manual shall be made unless authorized by the Chief of Department. Suggestions for correction, modification or expansion of this manual shall be submitted to the Division of Training. Suggestions will be given due consideration, and if adopted, notice of their adoption and copies of the changes made will be made available to all members by the Division of Training.

Joanne Hayes-White
Chief of Department

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SECTION 1. SOLAR PV KEY SAFETY POINTS

Daytime, Daylight = Danger Shock Hazard!!

Nighttime, Darkness = Potential Shock Hazard!!

- During daylight hours the Solar PV modules (panels) are ENERGIZED and present a potential electrical shock hazard. This is also true during overcast days! Use extreme caution when working around a PV system to minimize any potential of electrical shock!

- During the nighttime/darkness, the Solar PV modules are generally not energized and present minimal hazard from electrical shock. However, scene lighting, low ambient light, or other artificial light sources **CAN** generate enough voltage-current to pose a shock hazard at night. The same safety precautions taken during the day should be taken in the darkness of night!

- **ALL** Firefighters working around PV systems MUST be in full PPE including SCBA.

- Never walk or climb on Solar PV modules. Although the modules will likely withstand some weight load, they still present a significant safety hazard from breaking glass, tripping and slipping. Exposure to the cells inside of the PV modules presents a potential electrical shock hazard.

- **Never** place roof or ridge ladders on or against the Solar PV modules/arrays.

- **Never** break a Solar PV module (panel) with an axe or other forcible entry tool.

- Do not attempt to remove a Solar PV module/array to perform firefighting duties. Leave the Solar modules/arrays in place and work around the system. If unable to work around the Solar PV *array*, notify the IC immediately. Alternative ventilation tactics should be considered.

- Do not cut metal conduit or wires strung between Solar PV modules or wires coming from a series of Solar PV modules to a combiner box. This could result in serious or fatal injury from electrical shock!

- Do not attempt to remove fuses from Solar PV fuse boxes. *(Not all PV systems have fuse boxes.)* Doing so will likely start a fire and presents a significant electrical shock hazard!

- Stay clear of the Solar PV modules and conduit. Utilize walkways and PV system clearances set by the installation requirements in San Francisco.

- Secure the Main Electric Service Panel *(Main Circuit Breaker Box)* for the building.

Securing the main electric power coming into the building from PG&E will only shut down power inside the building and does not stop the PV modules from producing DC power when sunlight or a light source is present. An electric shock hazard still exists from the array to the DC side of the solar inverter.

SECTION 2. BACKGROUND/PURPOSE

Solar Photovoltaic technology is a rapidly growing industry. Currently, San Francisco has approximately 2,657 PV systems, both residential and commercial. The number of PV installations is expected to continue to rise with the push to “Go Green.” SF Department of Environment has a goal of 10,000 rooftop solar PV.

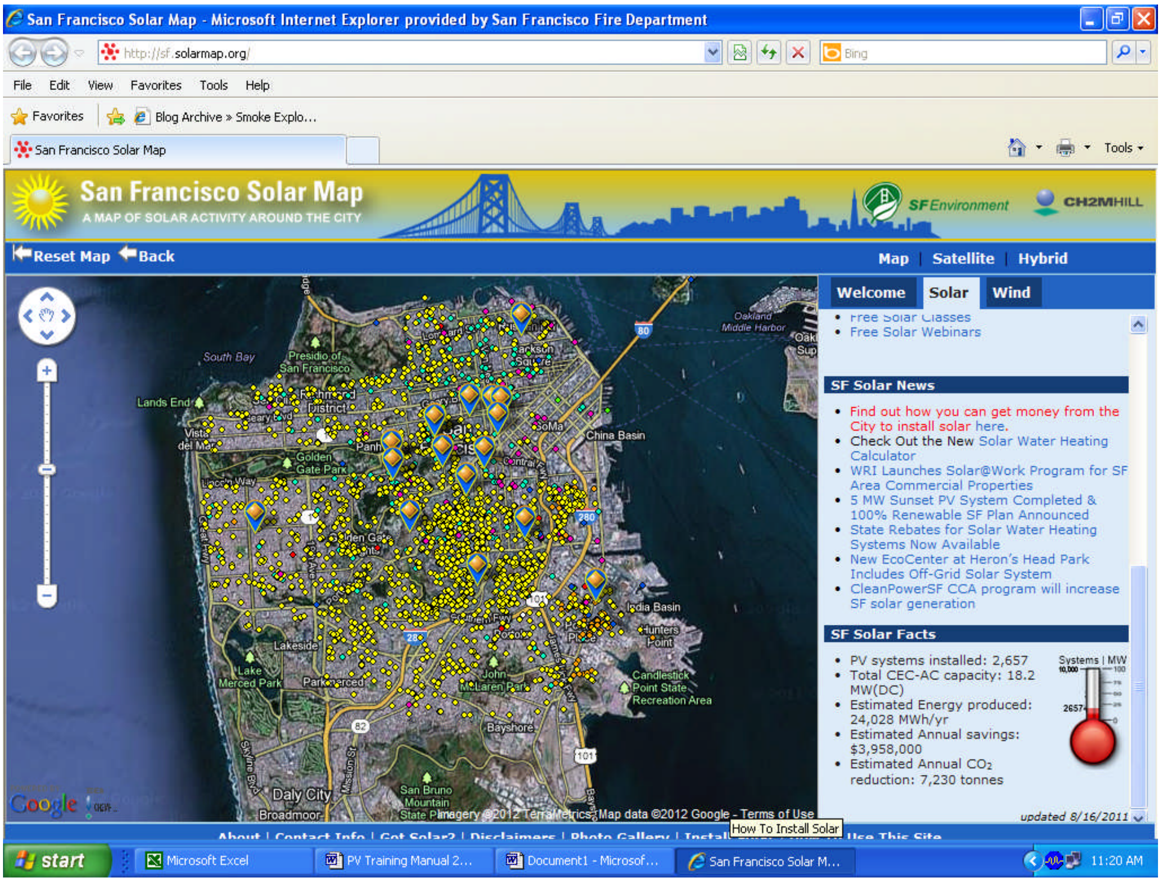


Figure 1 - SF Solar Map showing 2,657 solar installations throughout San Francisco. For more information regarding solar programs and installations please visit http://sf.solarmap.org

The purpose of this Manual is to establish standard operating procedures to enhance Firefighter awareness and safety related to identifying and mitigating potential hazards when working around Solar Photovoltaic systems (PV) at an emergency or fire scene. This manual will provide firefighters with a fundamental understanding of Solar Photovoltaic systems to improve confidence in identifying the presence of PV installations and to ensure safe and effective work habits when residential and commercial Solar PV systems are encountered.

A fundamental understanding of PV systems include, basic knowledge of PV components, how PV systems operate, how to safely secure a PV system, and how to safely perform firefighting operations, such as fire attack and ventilation at an emergency or fire scene with a PV system.

Learning and remembering the Solar PV Key Safety Points, frequently referred to throughout this training manual, will increase firefighter awareness and safety and lessen the potential for firefighter injuries or Line of Duty Death (LODD). Common Solar PV terminology and definitions are listed in Appendix A at the end of this manual.

SECTION 3. SOLAR SYSTEMS: "KNOWING THE DIFFERENCE"

While some people might think that all solar technology is the same, there are very distinct differences between the three common types of solar system technology on the market today. This section will identify the differences between Solar Photovoltaic, *(referred to as PV or Solar Electric)*, Solar Thermal *(Water-Heating)* and Solar PVT *(also known as cogeneration or combined systems)*. Firefighters will learn common terminology, general function, solar components and potential hazards for each system.

SOLAR PHOTOVOLTAIC

Solar Photovoltaic (PV) systems are used in both residential and commercial (Figure 2 & 3) applications and produce DC electricity that is converted, using an inverter, to AC electric power for use by the consumer. Roof mounted PV systems are the most common and are generally visible from the street. PV systems can also be integrated into building materials, such as roofing tiles, awnings or overhead covers for parking lots and other structures.

PV system components include cells, modules (aka panels), electrical conduit, and DC to AC inverter(s). The number of PV modules per system will vary according to the total kilowatt size design of the system. Potential hazards for PV systems include electric shock, limited or difficult roof access/egress, tripping, slipping, falling, increased roof loads, hazardous materials and battery hazards. Any of these hazards emphasize the need for constant awareness and adherence to safety procedures to prevent serious firefighter injury or death.

Solar PV Modules wired in series are referred to as Solar Arrays. The presence of a Solar PV system on this peaked roof may not be immediately noticeable from the street. Be prepared to change tactics if roof operations are hindered by the presence of a PV system. Access and egress become immediate concerns. Do not place ladders on, or break, PV modules!

Metal electrical conduit leaving Solar Modules and penetrating the roof can help identify Solar Electric versus Solar Thermal

Figure 2 - Residential Solar Photovoltaic (PV) roof system on a 2-Story Type V building; Noe Valley

The PV system on this roof is easily identified from the street. The awning is constructed of Solar PV Modules. Large commercial systems are engineered to maximize the amount of solar energy produced. Laddering access to the roof of this building may be challenging.

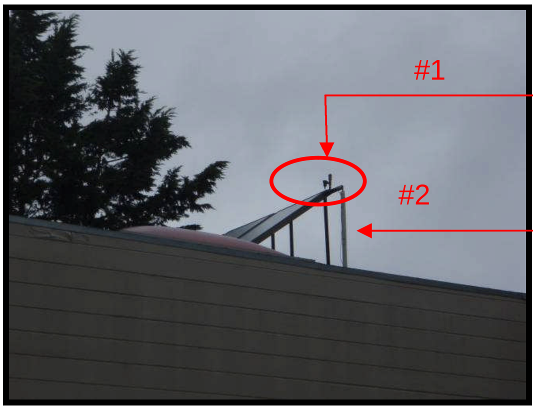
Figure 3 - Large Commercial Solar Photovoltaic (PV) system on a Type II Commercial Warehouse with a bowstring roof, Cesar Chavez and 3rd street

SOLAR THERMAL

Solar Thermal systems (Figure 4, 5) are used to harness the solar thermal properties of the sun to heat water and **DO NOT** produce electricity. Solar Thermal systems are generally roof mounted and, range between 4-6 collectors (panels), and cover a much smaller rooftop area than Solar PV.

Thermal system components consist of collectors with pipe to heat water, heat exchangers water pipes, usually copper, pressure relief vents, and storage tanks. The potential hazards related to thermal systems are increased dead load weight on the roof and thermal burns from hot water that can be as hot as 180 F if the panels or pipes are breeched.

A Solar Thermal system can be identified by noticeable air vents, and/or the copper pipes (Figure 4 & 5) running between the panels and down through the roof to the hot water storage tanks. Newer solar Thermal systems (Figure 4) can be difficult to identify from the street.



This Solar Thermal system can be identified from the street by the pressure relief vent (#1 arrow at left) sticking up above the array and the copper pipe wrapped with insulation (#2 arrow at left) leaving the array. Solar Thermal systems do not present an immediate risk to firefighters.

Figure 4 - Solar Thermal Heating system on a 2-story Type V building with a flat roof. The system is only visible from the street on the "D" side of the building, Eureka Valley

This Solar Thermal system may be difficult to identify from street level. The copper pipe wrapped in insulation (highlighted by the red circle at left) leaving the bottom of the Thermal panel is the main indicator to identify the system as solar Thermal versus Photovoltaic. Solar Thermal systems do not present an immediate risk to firefighters as there is no hazard of electrical shock.

Figure 5 - Large Solar Thermal system on a 3-story Type V Multi-Unit Apartment building; 22nd and Collingwood Street, Noe Valley

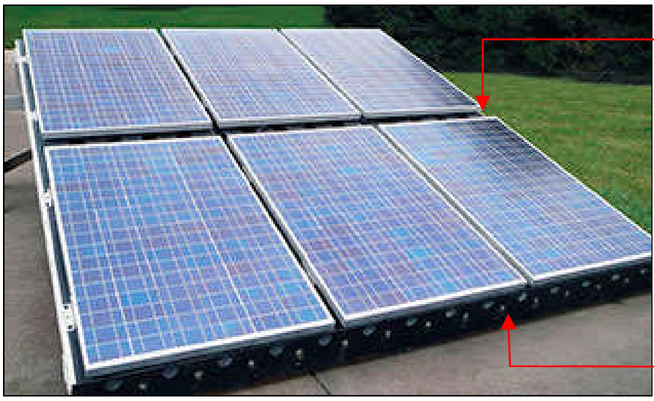
SOLAR CO-GENERATION

Solar PVT modules are designed to incorporate both Solar PV and Solar Thermal into the same system. This type of system is referred to as co-generation. Solar Photovoltaic/Thermal Co-generation (PVT) systems can generate DC electricity, solar thermal for heating water, or thermal heating of air used to heat a building.

A PVT system covers about the same amount of roof top area as a single PV system. The number of PV modules is dependent on the total kilowatt size of the system and are generally mounted on roof tops.

The potential hazards with Solar PVT are the same as thermal and single PV systems. The main hazard is electrical shock. These systems should be treated with the same caution as Solar PV.

Identifying PVT systems should not be difficult. At first glance the system will have the same appearance as PV. The only discernable difference will be the Solar Thermal panels or heat "tubes" for heating air incorporated into the system, which are generally positioned at the top of the array; however, other design configurations exist (Figure 6 & 7).



This Solar PVT Co-generation system may look like a Solar PV system from street level. A tip for identifying Solar PVT systems from the ground will be to look for electrical conduit and PVC piping leaving the same array. The immediate risk to firefighters from Solar PVT systems is electrical shock. Do not walk on, ladder, or break solar modules! Arrow #1 to the left is the PV module. Arrow #2 to the left is the Thermal component for heating water.

Figure 6 - Solar Co-generation PVT System; Solar PV module combined with Thermal components.

The Solar PVT Co-generation system at left has Solar PV (#1), Solar Thermal for heating water (#2) and harnesses heated air to heat the building (#3). This type of co-generation system will be easier to identify because of the apparent air duct (#3) used to carry the heat into the building. The PVC for water heating component is hidden by the sheet metal for the duct work. The PV electrical conduit is also obvious when looking at the system. Again, the immediate danger to firefighters for this Solar PVT system is electrical shock.

Figure 7 - Solar Co-generation system. Solar PV and Thermal combined. This particular system will generate DC electricity and harness thermal energy to heat water and to heat the building.

The integrated Solar PVT Co-generation system at left has a row of Solar Thermal, to heat water, on the top (#1) and three rows of Solar PV (#2) on the bottom. From street level, this Solar PVT installation may appear to be a Photovoltaic system only. There are no pipes or metal conduit visible from the street since the system is integrated into the roof system. Firefighters should notify the IC immediately and take the appropriate steps to make the system safe to work around. Do not ladder, walk on, or break solar PV modules.

Figure 8 - Residential Solar PVT Co-generation installation.

SECTION 4. SOLAR PV SYSTEM COMPONENTS

Solar Photovoltaic systems are designed to harness the maximum amount of solar energy possible. Installation guidelines have been established by the Bureau of Fire Prevention in coordination with the San Francisco Department of Building Inspection (DBI). A basic understanding of PV system components and installation requirements in San Francisco will assist firefighters in recognizing the presence of a PV system.

This section will briefly identify and discuss PV components such as a PV cell, PV module/array, inverters, AC and DC disconnects electrical conduit, system labeling, and solar battery storage. Firefighters with this basic knowledge will be able to quickly and confidently identify PV components and learn the appropriate steps to safely secure and work around a PV system.

PHOTOVOLTAIC CELL

A Photovoltaic cell is the smallest part of a PV system. However, the PV cell is the most important part in terms of gathering solar energy produced by the sun (photons). There are two basic types of Photovoltaic semi-conductor cells: silicon and amorphous silicon. In most cases, the semi-conductor silicon is approximately 1/100th of an inch in thickness.

The basic function of a PV cell is to collect photons from the sun to energize and force electrons from a negative layer to a positive layer in the PV cell. The process of harnessing photons and forcing electrons from the negative to positive layers generates around .5 volts of solar energy per PV cell. Generally, semi-conductor cells are cut and cast together into a thin multi-crystalline construction, then fused and sandwiched inside a PV module. A PV module has many cells that work together to generate solar energy.

MODULE/ARRAY

Solar PV modules (also known as panels) are designed to harness DC electricity from sunlight. A module has no moving parts and is weatherproof. Photovoltaic modules consist of numerous PV cells wired together, enclosed in an aluminum frame, and covered with tempered glass. Although the modules can range in size, typically each module is 30” wide X 50” long, weighs between 30 to 50 pounds, and consists of 50 to 72 semi-conductor cells. Solar PV modules are generally rated between 125 to 300 watts and can produce 20 to 50 volts of DC power. Solar PV modules are normally grouped and wired in series and parallel to increase voltage and amperage. When PV modules are grouped and wired together, the group of modules is referred to as a PV array.

Residential PV arrays can have a total number of modules ranging from15 to 40, depending on the electrical needs and design of the home. A typical residential PV system is 3 to 4 kilowatts and can produce between 120 to 600 volts DC at currents from 5 to 9 amps during daylight hours depending on the intensity of sunlight. With optimal sun exposure, a PV array can generate between 2,000 to 5,000 watts, or 2 to 5 kilowatt hours of DC power daily. Commercial PV systems are widely variable.

From a safety perspective, what does all this discussion of voltage and amperage mean? Simply stated, the current (amperage) is what causes damage/injury to a person's body; the voltage is what drives the current through the body. The voltage and amperage identified above is more than enough, if contact or exposure to the DC electrical source is made, to cause serious injury or death from electrical shock.

Figure 9 – Solar Photovoltaic Module

Figure 10 - Back of PV module showing the wire connectors

PHOTOVOLTAIC INVERTERS AND DISCONNECTS

Solar PV system inverters and disconnects are critical PV components. Understanding the function of these components will assist Firefighters to know where the potential dangers exist and how to isolate and shut down power to the inverter as well as to the building. Shutting down and securing electrical utilities for a building with a PV system is a top priority at an emergency or fire scene to maintain a safe working environment for Firefighters.

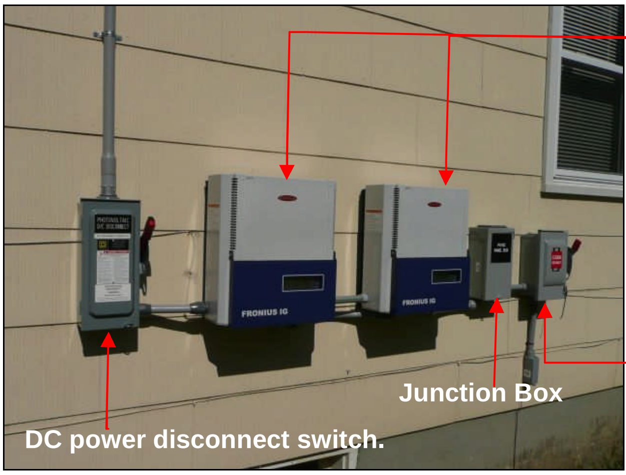
Inverters

Typical household fixtures and appliances utilize AC power to operate. Since PV arrays generate DC power, it must be converted to AC power before it can be used by the consumer. An inverter converts the DC electricity from the PV array to AC electricity which is fed into the Main Electrical Service Panel (Circuit Breakers) for the building. There are a variety of inverter styles and sizes. The two types of inverters used for PV installations are system inverters and micro-inverters.

System inverters (also referred to as String inverters) are the traditional and most common type of inverter used for solar PV systems to date. PV system inverters are rated and designed to receive a specific amount of DC voltage from multiple PV modules in the array, and toconvert that power to AC electricity. A Solar PV system may require one or more inverters depending on the total kilowatt per hour design of the system, which determines the potential amount of DC voltage generated by the array.

System inverters are generally large and can be located inside and/or outside of a building depending on available space. In order to operate and convert DC power to AC power, system inverters require a dedicated AC electrical circuit wired from the Main Electrical Service Panel. The dedicated AC circuit for the inverter(s) is a built-in safety design to prevent the potential of electrical power being back fed into the PG&E utility grid in the event of a power outage.

The dedicated circuit for the inverter(s) also provides Firefighters with the ability to quickly isolate converted AC electricity coming into the building from the inverter(s) by shutting down and securing all of the circuit breakers located at the Main Electrical Service Panel. However, this means that DC electricity is still present in the electrical lines and conduit from the PV modules/array down to the DC line side of the inverter(s).



Residentially installed system inverters. The inverters can be located inside or outside of the building. Inverters require a dedicated AC circuit to convert the DC electricity into usable AC power. Securing electrical power at the Main Electrical Service Panel will shut down the inverters. During daylight hours, DC power is still being generated from the Solar PV array to the DC disconnect or the DC side of the inverter

AC power disconnect switch.

Figure 11 - Residential System Inverters along with AC and DC disconnects.

Figure 12 – Multiple System Inverters for a large commercial PV system; Cesar Chavez and 3rd Street

Securing the Main Circuit Breaker at the Main Electrical Service Panel will shut down the inverters for residential and commercial PV systems.

To prevent equipment used during firefighting operations in commercial buildings with PV systems from being accidentally shut down, such as HVAC, consult with the IC or building engineers before securing the circuit breakers in the off position at the Main Electrical Service Panel.

Micro-inverters are single inverters built into and/or secured on, or adjacent to, each individual PV module. This type of inverter provides what is referred to as “Module Level Control”, which optimizes the DC voltage levels by converting DC electricity to AC electricity at each individual module in the array. After the individual Micro-inverters have converted DC voltage at each module, the converted AC electricity is fed through ordinary AC electrical circuit wiring to the Main Electrical Service Panel for use by the consumer. Micro-inverters can be used on residential and/or commercial solar PV installations and are becoming more prevalent as the solar industry grows.

PV systems that use Micro-inverters significantly improve system efficiency and provide a higher level of PV safety for Firefighters. This is due to the fact that, like string inverters, Micro-inverters require a dedicated AC circuit wired from the Main Electrical Service Panel in order to operate. When power to the building is shut down at the Main Electrical Service Panel, AC power wired to each Micro-inverter is also shut down. This isolates and contains DC power within each individual PV module in the array and prevents the Micro-inverters from converting DC power to AC power. Firefighters must still use extreme caution when working around the PV modules/arrays as they may still be energized and could pose an electrical shock hazard. Avoid breaking and/or exposing the internal construction of PV modules at all times to prevent serious injury or death.

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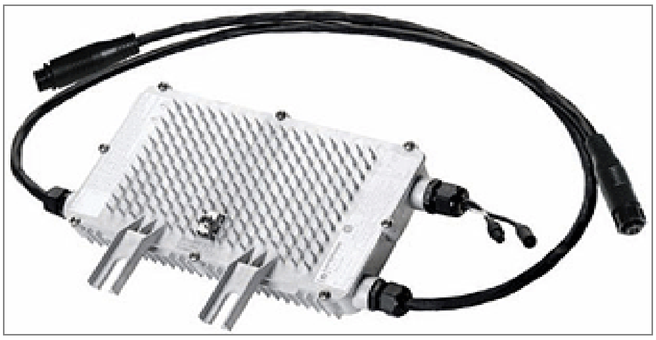


Figure 13 - Micro-inverter will be built into and/or mounted on or adjacent to PV modules.

Disconnects

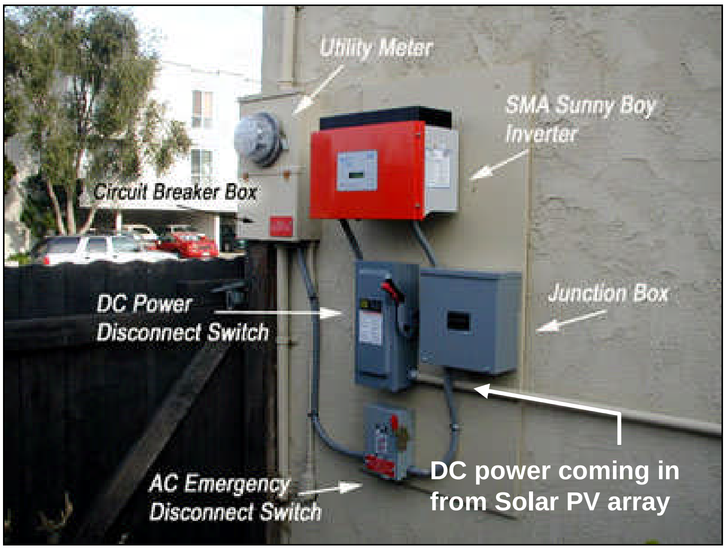
Disconnects are switchblade-type electrical components required for safety. Usually, disconnects are mounted and wired in-line on the DC line side (upstream) and the AC load side (downstream) of the system inverter(s) (Figure 12, 14).

When an electrical disconnect is located on the DC line side (upstream) of the inverter it is called the DC power disconnect. When an electrical disconnect is located on the AC load side (downstream) of the inverter it is called the AC power disconnect.

The primary function of the DC and AC disconnects is to allow solar technicians to perform routine maintenance on the inverters by isolating electrical power coming into and out of the inverters. Shutting down the DC disconnect only secures and prevents DC electricity produced by PV array from entering the inverter. The DC disconnect does not shut off DC electricity supplied from the PV array. The DC electricity coming from the array down to the DC disconnect is still energized during daylight.

Shutting down the AC disconnect only secures and stops converted AC electricity coming from the inverter(s). It does not shut off AC electricity supplied from the PG&E power grid, or any AC electrical circuits coming from the Main Electrical Service Panel for the building.

As a general safety rule for securing PV systems at an emergency or fire scene, Firefighters should shutoff and secure all switches/disconnects that are visible and accessible and all circuit breakers at the Main Electrical Service Panel. Communication with the IC is critically important before and after shutting off and securing electrical utilities.



When securing a Solar PV system, shutoff and secure all switches/disconnects that are visible and accessible. If the DC and/or AC disconnect switches are not found, securing ALL circuit breakers at the Main Electrical Service Panel will shut down the inverter and stop AC power from going into the building.

During daylight hours, DC power is still being generated and is present from the Solar PV array to the DC disconnect.

Figure 14 - Residential Solar PV inverter, DC and AC disconnect, junction box and Main Electrical circuit breaker panel.

ELECTRICAL CONDUIT

Electrical conduit used for PV systems is divided into two categories, interior and exterior. Firefighters must be able to identify electrical conduit in both interior and exterior applications to prevent accidental or purposeful damage to the electrical wires inside of the conduit and to mitigate other potential hazards. Failure to identify conduit presents a significant electrical shock hazard and could result in serious injury or death if the conduit is cut or damaged and the electrical wires inside are exposed.

Identifying and locating electrical conduit in, or on, a building with a PV system is a critical safety factor for Firefighters engaged in fire ground operations such as fire attack, ventilation, and during the overhaul phase of a fire.

Interior Conduit

Interior conduit applications require metallic electrical, thick or thin wall, tubing and/or galvanized metallic flex conduit. The type of interior metallic conduit used and the location where the conduit will be placed is variable and depends on the installer or can be specified on a case-by-case basis by the Department of Building Inspection (DBI). Generally, interior conduit is placed in areas with easy access and the most direct route to PV components, such as inverters and junction boxes.

Hazards related to interior electrical conduit include damage to conduit or wires from direct flame impingement. Any time Firefighters engaged in fire ground operations observe metallic electrical conduit, hard wall or flex, on the interior of a building, caution should be used and safety procedures followed to avoid serious injury or death from accidental electrical shock.

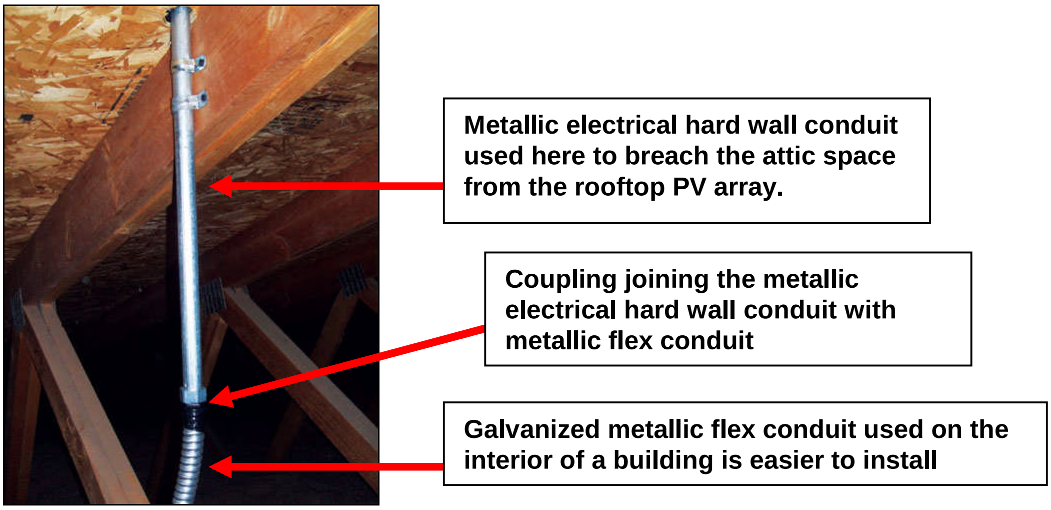
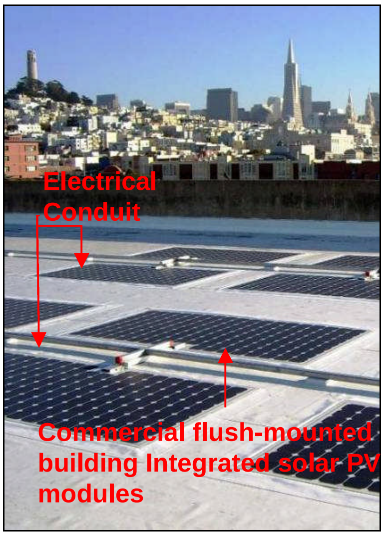


Figure 15 - Metal conduit penetrating the roof into the attic space. This conduit will continue to the location of the DC power disconnect.

Exterior Conduit

Exterior installation of electrical conduit must meet waterproof standard, but the type of conduit is variable. For external applications, metallic electrical hard wall conduit, thick or thin, metallic tubing with water tight couplings, water tight PVC coated galvanized metallic flex conduit, or gray electrical PVC conduit can be used. Generally, gray electrical PVC is used on ground mount PV systems when electrical conduit must be buried or where frequent exposure to rain and weather is anticipated. Identifying the location of exterior electrical conduit can be easier than interior electrical conduit; however, PV installers will sometimes hide exterior electrical conduit for aesthetic reasons.

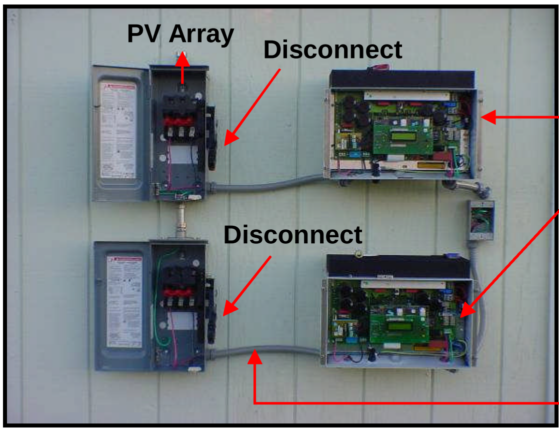
Firefighters should be aware of the potential for electrical conduit if a PV system and/or PV components are present, but no exterior conduit is seen. Hazards related to exterior conduit are electrical shock from accidentally cutting through the conduit or damaging the wires inside, as well as the hazard of tripping and falling when conduit is used on a rooftop.



These building-integrated solar modules are installed flush with the roofing system. This type of module installation can be extremely hazardous to Firefighters. The manner in which the electrical conduit is installed presents a significant tripping and falling hazard for Firefighters, especially during low light, darkness, or limited visibility conditions. This type of PV installation will not be easy to identify from the street level. A condition report from roof division must include information regarding the presence of a PV system.

KEY POINT: NEVER WALK ON OR BREAK PV MODULES.

Figure 16 - Metal conduit can also be installed on top of roof surfaces and can present a significant tripping hazard. This commercial system is located on top a SF Water Department building at Newcomb Avenue and Quint Street.



System Inverters

Exterior installed PVC coated Metal Flex conduit can be used in San Francisco. In this installation the Metal Flex is used between the inverters and the disconnects.

Figure 17 – PVC coated metal electrical flex conduit is legal in San Francisco.

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Solar PV System Labeling

Labeling of Solar PV systems, residential and commercial, can be a critical clue for overall Firefighter safety. This critical component can easily be overlooked if Firefighters are not performing thorough size-up and triage of an emergency or fire scene. The danger that exists with solar PV systems is having two electrical power sources for one building: the traditional AC electrical service provided by the PG&E power grid and the secondary electrical power source from the solar PV system.

Since solar PV systems are categorized as **“Customer Side Power Generation Equipment with BackFeed Potential,”** PG&E requires that labeling on the Main

Electrical Service Panel identify the presence of a secondary power source (Figure 19). Unfortunately, labeling for solar PV installations is not uniform or regulated. The type and amount of warning labels throughout the PV system will vary depending on who installed the system, where (what city or county) the system is installed, and how long ago the system was installed.

Various labels can be found on PV components, such as Main Electrical Service Panels, PG&E utility meters, PV modules, electrical conduit, DC and AC disconnects, and other random locations. The purpose of PV labeling is to indicate the presence of a Solar PV system on or supplying the building with solar power.

A bi-directional PG&E meter (Figure 19), used only for grid-tied PV systems, will be identified with a label that states, **"Meter Runs in Both Directions."** This type of labeling is to prevent accidental back feed of electricity into the grid. The following photos are common solar PV labels for residential and commercial systems found in San Francisco.

Figure 18 – ***Warning label on the front of a Main Electrical Service Panel (circuit breakers). The label in this instance clearly identifies that the secondary power source is solar PV.***

Figure 19 - Bi-directional meter labeled to indicate the presence of an alternate power source (PV). Bi-directional meters will be present on all "grid-tied" Solar PV systems.

Key Point: This should be a Top Priority!
Securing both AC and DC electrical power sources to the building is critical to rendering the building as safe as possible for Firefighters. The electrical power to the building will not be completely shut down until the Main Circuit Breaker, located in or on the Main Electrical Service Panel for the building is secured (shut down). If any of system disconnects are visible, they should also be placed in the "OFF" position. Notify the IC when both AC and DC electrical power sources to the building have been properly secured. This should be a Top Priority!

Remember, during daylight, DC power is being generated from the PV modules down to the DC disconnect. DC power cannot be completely shut down unless all of the PV modules are completely covered with an opaque tarp or cover during daylight hours. During darkness, ambient light from fire or scene lighting may generate enough power to present an electrical shock hazard. Use extreme caution at all times.

Figure 20 - Label on the side of a Solar PV module installed on the roof of the Moscone Center, provides Firefighters with a reminder of potential hazards as well as the name of the electrical contractor who installed the system.

Figure 21- DC and AC power disconnect labels. Warning: "Line" and "Load" sides of any disconnect switch box could still be energized and present a shock hazard, even after the disconnect switch has been placed into the "OFF" position. This is generally the result of having dual power sources and the potential for backfeed of electrical power throughout the system

SECTION 5.   THE PHOTOVOLTAIC SYSTEM: HOW IT WORKS!

While every building is different, PV systems are functionally the same. The technology utilizes a basic process to produce and convert solar power for use by both residential and commercial consumers. Each of the PV components has a specific job; when combined with each other the PV system will harness the highest amount of solar power possible.

This section will bring all of the components together in one unit to provide a better understanding of the technology and operation of “grid-tied” and “off-grid” PV systems, battery back-up and storage, how daytime and nighttime light affects PV systems, and to improve recognition of different PV designs and installations. The differences in PV design and installation are based on individual consumer electrical needs, how the solar electricity will be used or stored, and whether the system will be residentially or commercially installed.

Knowing the difference between the system types determines what optional PV components might be installed and is an important safety factor for Firefighters. A basic knowledge of how solar PV systems work will help Firefighters understand where the potential hazards exist and how to reduce close-call injuries or Line of Duty Death (LODD).

BASIC PV SYSTEM OVERVIEW—“GRID-TIED” AND OFF-GRID”

The amount of DC electricity generated by a solar PV system is variable. Solar PV systems are dependent on the atmospheric conditions and the condition of interconnected PV components in order to operate correctly and at optimal efficiency. The time of day, the amount of direct and indirect sunlight on the array, cloud cover, shade, shadows, and the mechanical condition, location, and proper installation of PV components are examples of factors that directly affect the overall operation and performance of a solar PV system.

The basic function and operation of how Solar PV systems harness energy from sunlight to produce electricity is the same; Sunlight is converted to DC electricity by solar cells and DC electricity is converted to AC electricity using an inverter. The only difference from one PV system to the next is design. PV system design is divided into two categories, grid-tied and off-grid. In order to determine the most suitable PV system for a specific consumer, the design is based, in part, on individual consumer electrical needs and objectives and overall cost.

"Grid-Tied" PV Systems

The term "grid-tied" refers to alternative solar photovoltaic electrical power being used in combination with traditional electrical power supplied by the PG&E utility power grid. For most consumers, a grid-tied PV system is the ideal configuration. Consumers get all the benefits of using their own solar electricity as well as the benefits of being connected to the PG&E power grid. There are two design styles for grid-tied PV systems, direct and battery back-up.

A direct grid-tied system is the basic style design for grid-tied PV. Consumers do have the option to upgrade the system with battery back-up to mitigate power outages. The basic operation and design difference between direct grid-tied PV and a grid-tied battery back-up system is discussed below.

Direct Grid-Tied PV Systems

The most common PV system Firefighters will encounter in San Francisco is a direct grid-tied system. A grid-tied PV system is connected directly to the PG&E utility power grid. This allows AC power to flow both into and out of the building through a bi-directional meter on the Main Electrical Service Panel. The amount of AC power being supplied into or out the building depends on the electrical needs of building occupants and the amount of electrical power produced by the PV system at that exact time.

When the PV system is producing adequate solar electricity, the building only utilizes solar power. This is the PV system's first priority. During times when the PV system cannot produce enough solar electricity or is not producing solar electricity at all, such as at night, the building electrical service will utilize power from the PG&E grid.

When the PV system is producing more solar electricity than the building occupants can use, the excess is fed back through the bi-directional meter into the PG&E power grid. This is known as net-metering. With net-metering, when a consumer uses electricity from the PG&E grid, the bi-directional meter spins forward. When the consumer-based PV system is producing excess solar electricity and feeding power into the PG&E power grid, the bi-directional meter spins backwards. The offset means that consumers with PV systems are actually receiving market rates for the amount of electricity fed into the PG&E grid.

The downfall of direct grid-tied PV systems occurs during power outages. As discussed earlier, PV inverters require a dedicated AC circuit to convert DC voltage into usable AC voltage. When the PG&E grid has a power outage, the inverter also loses power and cannot convert DC electricity into AC electricity for the duration of the outage. This is a built-in safety design to prevent back feeding of DC electricity through the system and into the power grid. AC electrical power to the building will be restored after the PG&E grid power is restored. This will occur regardless of the time of day.

****Safety Point: If the power outage occurs during daylight, the solar PV array is still producing DC voltage. Therefore, DC electricity will be present at the arrays**

and in the electrical conduit from the array to the DC voltage side (input) of the system inverter(s). There will be no power beyond the inverter until grid power is restored. Light from fire or scene lighting during darkness may produce enough electricity to present a significant shock hazard. Use caution when working around the array and electrical conduit coming from the array to the inverter at all times, whether there is a power outage or not!

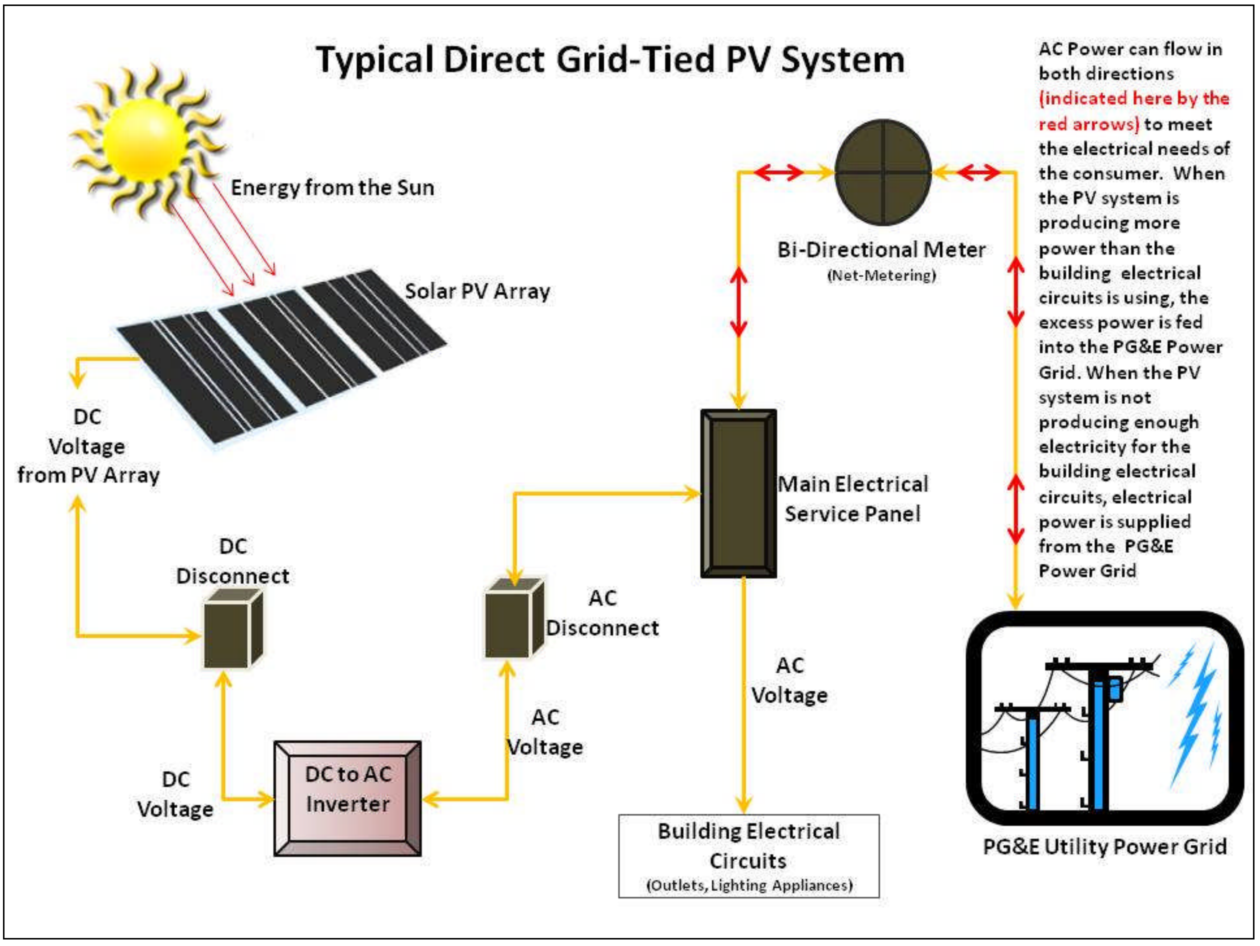

Figure 22-Typical Direct "Grid-Tied" Solar Photovoltaic System.   DC electricity is converted into AC electricity by the Inverter and then fed into the Main Electrical Service Panel.   The Main Electrical Service Panel supplies residential or commercial buildings with AC electricity. Excess AC power not being used in the building is fed into the PG&E power grid.

Grid-Tied PV with Battery Back-up Storage System

Grid-tied PV systems with battery backup storage offers the convenience of being connected to the grid with the security of having uninterrupted backup power during a PG&E grid power outage. This system design is commonly used for buildings that have critical electrical needs.

Grid-tied PV systems with battery back-up storage operate in the same basic manner as direct grid-tied PV systems and utilize Net Metering. The distinguishable difference between a direct grid-tied design and a battery backup storage design is that the battery backup system incorporates a bank of batteries to store DC electricity for use during power outages. The DC electrical storage is accomplished by adding components into the PV system designed to use excess DC electricity to charge the battery bank.

Safety precautions for working around an energized PV system must be followed. Identification of battery back-up storage systems must be reported immediately to IC to prevent accidental electrical shock. In order to isolate a battery back-up system, Firefighters should be familiar with the basic functions of the additional components, which include the following:

- Charge Controller - To prevent the batteries from overcharging.

- Bank of batteries - To store accumulated DC voltage for use when there is a power outage or no electricity is being produced, such as at night.

- Stand-Alone Inverter - Inverters of this type use both AC power, on a dedicated circuit when the PG&E grid is operating, and DC power supplied from the battery bank during a power outage, to convert DC electricity into AC electricity. The inverter utilizes DC voltage from the batteries and capacitors that store energy to operate during an outage. Energy in the capacitors will discharge soon after the power to the inverters has been isolated. A significant electrical shock hazard could exist at all times.

- Backup Electrical Sub-Panel and Electrical Circuits – During a power outage the AC voltage being converted by the stand alone inverter is fed into a backup AC electrical circuit that energizes and feeds into a backup sub-panel before distributing power from the backup sub-panel into the building electrical circuits. The sub-panel is a safety feature designed to isolate electrical power during a power outage and any potential for electricity backfeeding into the PG&E grid. Backup electrical circuits are tied into the normal electrical circuits for the building such as outlets, lighting, and appliance circuits.

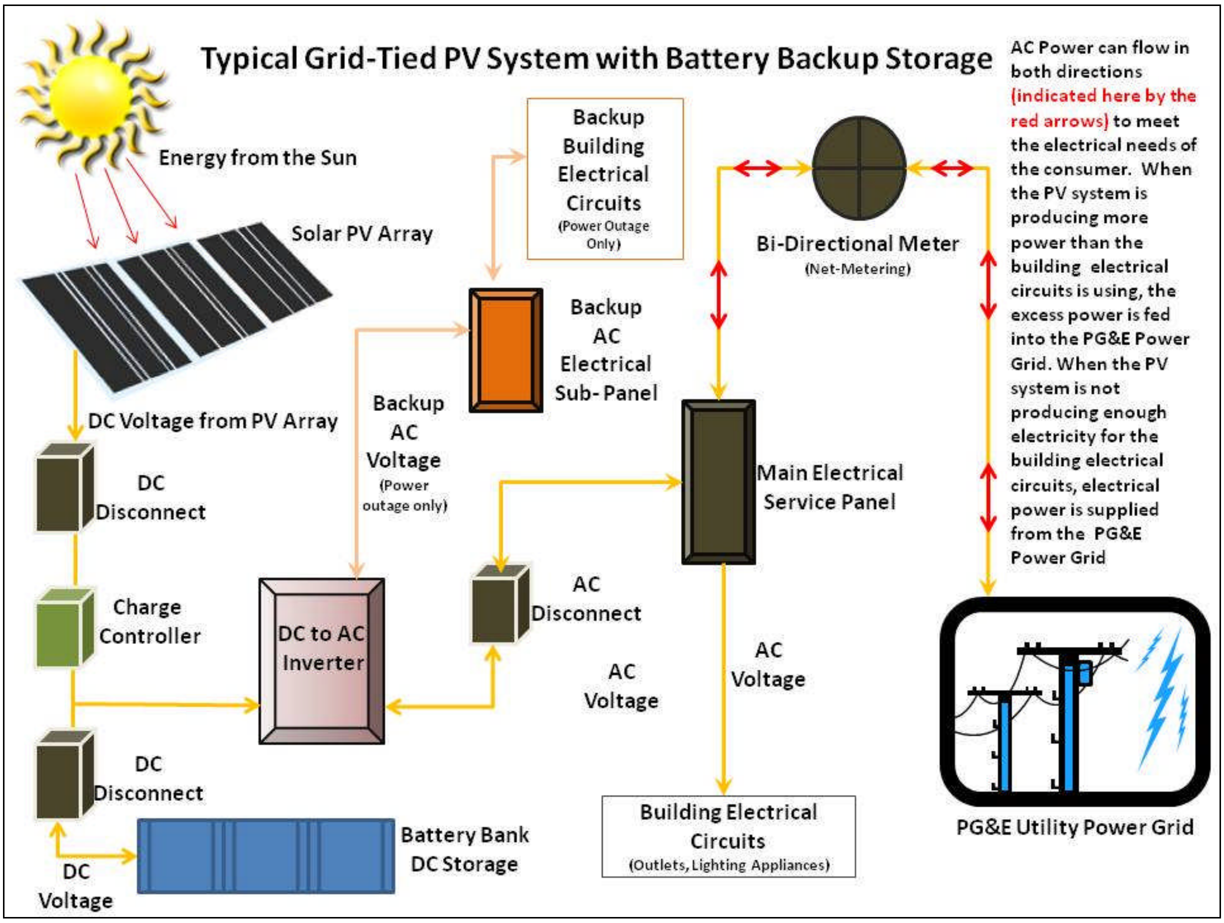

Figure 23 – Grid-tied PV system with Battery Backup Storage

"Off-Grid" PV System

A PV system that is "off-grid" or a true stand-alone PV system produces solar electric power independent of the PG&E utility power grid. This type of system is more commonly found in rural areas, in environmentally sensitive areas, or in illegal activity. Most off-grid PV systems rely on DC electricity produced during daylight to charge and store DC voltage using a large bank of batteries. The system components for an "off-grid" system are basically the same as a grid-tied system with battery backup storage.

Stand-alone inverters commonly utilize power from batteries and capacitors that store energy to convert the DC power into AC power. The capacitors hold an electrical charge capable of producing a significant electrical shock hazard for several minutes after power to the inverters has been disconnected. The basic operation of off-grid PV systems is essentially the same as a grid-tied PV system.

The most distinguishable difference is the use of a backup generator as a secondary source of electrical power when the battery bank is discharged or depleted of DC voltage. The backup generator produces DC voltage and is tied directly into the inverter. Backup power can be used during the night or when there is a problem with the bank of batteries. Off-grid PV systems reaffirm the need for Firefighters to have a standardized approach to working around solar PV for optimal safety.

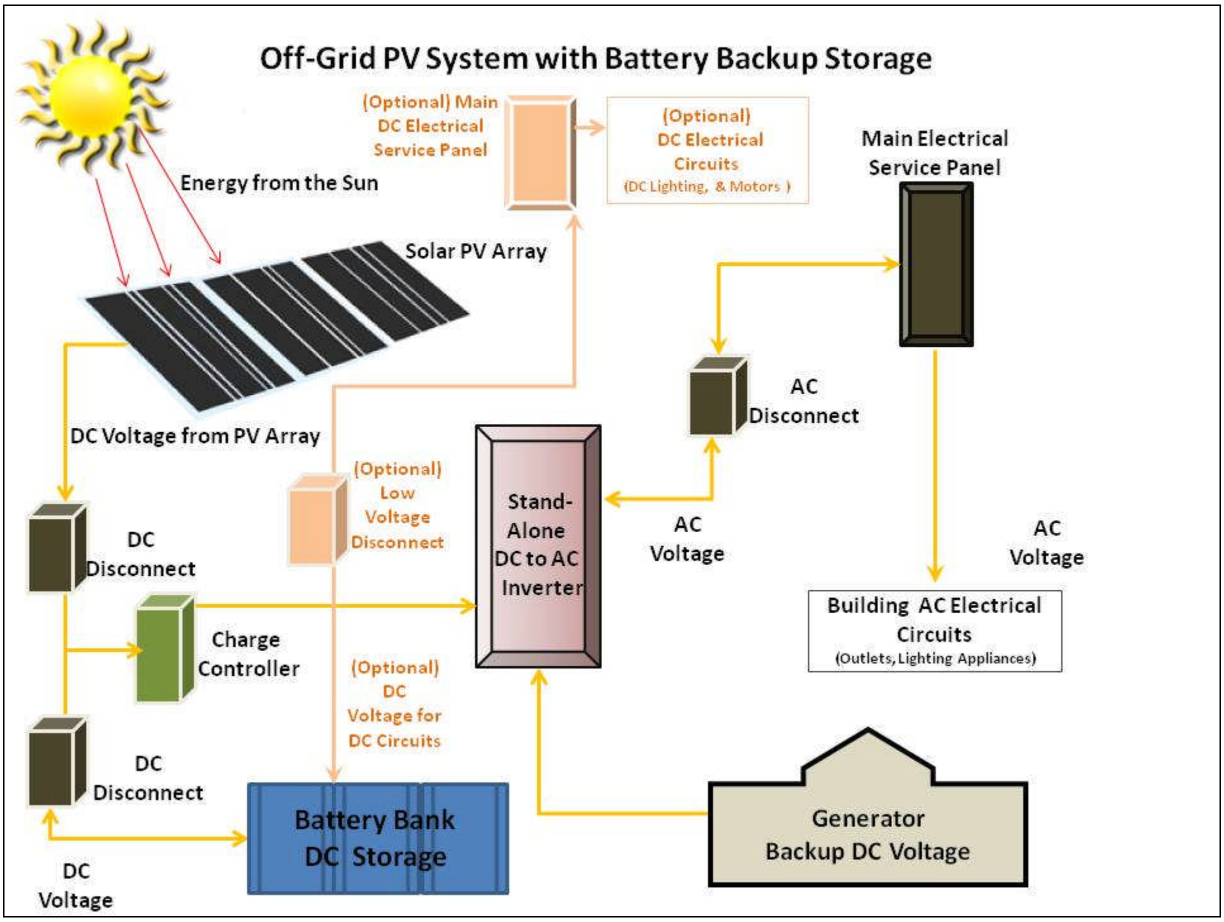

***Figure** 24 – Typical Off-Grid PV System with Battery Backup Storage and a backup generator as a backup/secondary power source.*

SOLAR PV SYSTEM RECOGNITION

<u>Roof-Mounted PV Systems</u>

Roof mounted systems are the most common installation design for residential and commercial solar PV Systems throughout the industry. Roof-mounted PV systems are a popular design because of the utilization of unused space on the roof and optimal southern exposure to the sun. Roof-mounted systems generally use metal racks or single anchors, specifically designed for PV modules, to secure the array over existing roof surfaces to the sub-structure (rafters) below the roof. In San Francisco, racks for PV modules can be elevated for flat roof installations, or may sit just a few inches over the existing roofing material on a peaked roof. Identification from the ground at street level can be difficult. Firefighters should be able to recognize PV components to assist in recognition of a PV system. Recognizable components from the street level include modules mounted on the roof, PV labels on electrical components, visible electrical conduit coming from the roof or entering the attic space, inverters, multiple disconnect switches, or a bi-directional meter at the Main Electrical Service Panel.

Street level recognition of roof-mounted systems is not always possible due to weather conditions, building height, flat roofs, parapet walls, and time of day. Firefighters working on a roof should immediately communicate the presence of a roof-mounted PV system and any hazards preventing normal operations to the IC.

Figure** 25– **Roof top Residential PV system on an apartment building near Stern Grove

Figure** 26 – **Residential PV system on a new home in West Portal

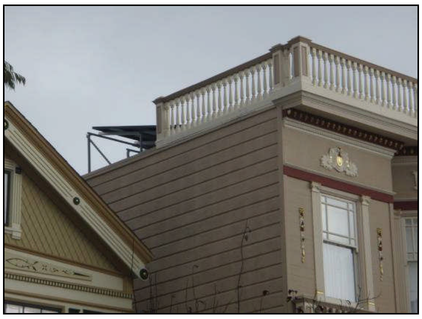

Figure 27- Elevated rack mount on flat roof in Noe Valley

Figure **28** ***– 600kW commercial rooftop PV system –San Francisco International Airport***

Figure 29 ***–Commercial system on the roof of REI: Brannan between 7th and 8th streets***

Building-Integrated PV Systems

Solar electric technology is rapidly evolving; as the industry grows the technology and components are being designed to be more efficient. These changes are occurring on both residential and commercial PV systems. Building-integrated design of PV components allows for better functionality, curb appeal and utilization of space, and for optimal exposure to the sun.

Examples of building-integrated PV components are integrated roofing shingles, awnings with integrated PV modules, and windows with solar cells sandwiched in between the glass. Street level recognition of building-integrated PV can be extremely difficult. While there are some recognizable components, Firefighters must have a slightly different approach and a higher level of awareness for identifying building-integrated PV components, and must notify the IC if solar PV components are found.

Figure 30 – Building Integrated PV system at AT&T Park. Promenade walkway cover with PV.

Figure *31 – Building Integrated Awnings with PV modules at AT&T Park*

Figure *32 – UCSF Mission Bay Parking Structure 23B with Solar PV integrated into the exterior construction*.

Ground Mounted PV Systems

Ground-mounted PV systems are not often found in urban areas, mostly because of the amount of space required to mount large solar arrays on the ground. Ground-mounted systems are very common in rural areas or regions where space is less of an issue. However, a PG&E-funded solar program has installed ground mounted PV systems in San Francisco. Ground-mounted PV systems generally allow the PV array to be installed in a proper location and angle for optimal exposure to the sun.

Ground-mounted PV systems are generally not difficult to recognize. The difficulties for Firefighters are the ability to identify the location of system disconnects, location of electrical conduit, and the ability to isolate and shutdown electrical power coming from the PV array.

Figure 33 – Ground Mounted PV system at Caesar Chavez Elementary between 22nd and 23rd Street, Folsom and Shotwell

***Figure 34 – Inverter installed under the PV array on Ground Mounted PV at Caesar Chavez Elementary*.**

Figure 35 – Disconnect located underneath the PV array at Caesar Chavez Elementary.

Other PV Systems

Other PV systems include atypical designs that are installed in locations to take advantage of solar electricity where space for a traditional PV installation is limited. Solar PV in San Francisco has utilized common structures such as parking structures, free-standing bus stops, water reservoirs, and overhead awnings, to accommodate the use of PV where there is a lack of adequate space to install more traditional systems. These atypical system designs operate and function in the same manner as otherl PV systems and possess the same safety concerns and hazards.

Most atypical mounted PV systems are commercial installations and present Firefighters with potential difficulty in identifying the location of electrical conduit, disconnects, and system components to isolate and shut-down the PV system. Other potential dangers also exist that are not directly related to the PV system, such as a car fire underneath a parking structure with PV.

Street level recognition can be difficult and Firefighters must have a higher level of awareness for identifying alternate PV system installations and designs located in their geographical response area.

***Figure 36 – Muni bus-stop shelter at Geary and Arguello with solar PV on top of the shelter*.**

Figure 37 – PG&E Parking Structure with PV tracking system between Shotwell and Folsom at 18th street

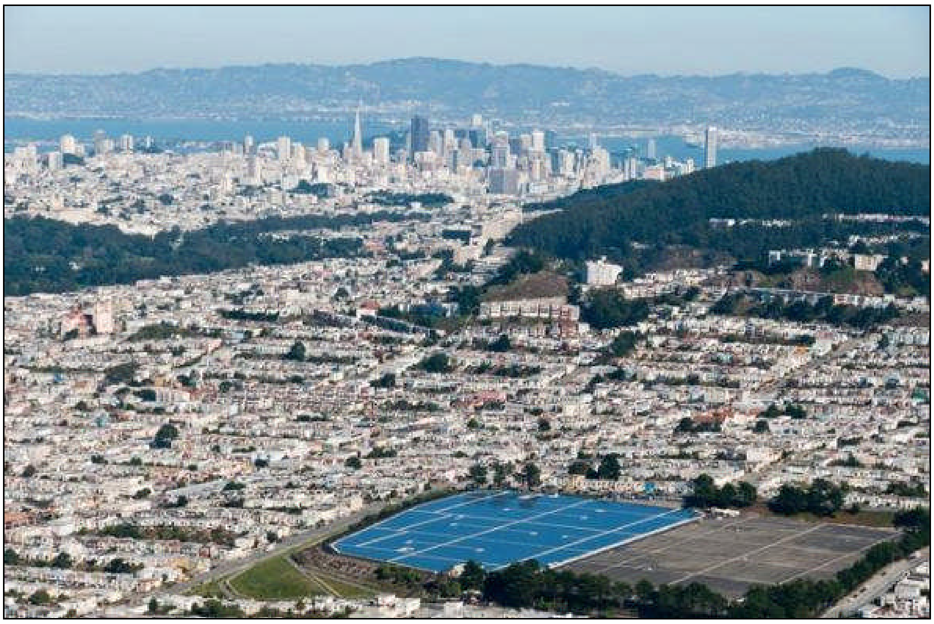

Figure 38 – 5 megawatt Sunset Reservoir PV system.

EFFECTS OF LIGHT ON PV SYSTEMS

Sunlight/Daylight

During daylight, a Solar PV system will provide some, or all, of the building's electrical needs, residential or commercial, depending on the amount of electricity that appliances or machinery inside the building require at the time. If the Solar PV system is not providing all the power needs, the balance of power needed is automatically provided directly from the PG&E power grid. On days when sunlight is intense, the PV system will generally produce more power than needed. The excess power is automatically fed into the PG&E power grid and a credit is recorded on the bi-directional meter (Net Metering).

During daytime hours, whether the sun is shining directly on the array or it is obscured by overcast or other objects casting a shadow or creating shade, a PV system will still generate DC power, at less than optimum levels. The intensity of sunlight or daylight on the solar array and the daily temperature will determine how much DC power is generated.

The PV system will produce less power on cloudy days and during winter months when sunlight is less intense due to clouds and overcast skies. The PV system will also produce less power if the modules are obscured by dirt and/or shade. Daily temperature affects optimum efficiency. Solar modules operate well during daylight; however, the modules are less efficient in higher temperatures. Moderate to mild temperatures and/or cold weather assist with better conductivity of the PV system.

The amount of power being generated at any time during the day will still present a significant electrical shock hazard that could result in permanent injury and/or death, regardless of the intensity of the light on the array. Firefighters should never assume that low levels of daylight or less intense sunlight due to clouds or shade will stop a PV system from producing electricity.

Nighttime

Generally, under the **absolute** darkness of night, solar PV systems will not produce electricity. However, low ambient lighting, artificial light from scene lighting, light from fire, or street lighting **may** be able to generate enough light for solar cells to produce DC electric power that could present an electrical shock hazard during hours of darkness. This has been documented by Underwriter Laboratories (UL) during recent experiments with solar PV and the effects of light from sources other than the sun.

The potential to create solar electricity from light sources other than the sun depends on several conditions; intensity, location, and distance of the light source from the PV modules.

In the recent past, the fire service considered a solar PV system safe to work around at night or during darkness because it was assumped that the systems do not generate enough DC electricity to be harmful. However, the potential for a PV system to generate enough DC electricity to present an electrical shock hazard, indicated by UL studies, has prompted a change for overall Firefighter safety related to solar PV during periods of darkness at a working fire or an emergency scene.

Even though it is nearly impossible to know if the PV system is producing enough DC electricity to present a hazard, Firefighters should consider the potential for electrical shock and take steps during hours of darkness to render the PV system as safe as possible. Remember, during the night, a “grid-tied” PV system is not producing enough DC power and electricity from the PG&E power grid is provided. Firefighters should also be aware of the potential for “grid-tied” systems to have battery back-up.

****Safety Point: For overall safety, ALL PV systems should be isolated at any time of day or night, before working around the system.**

SECTION 6. PV SYSTEM HAZARDS AND FIREFIGHTER SAFETY

The general hazards that exist for solar PV on residential or commercial structures are not strictly specific to PV technology. The same hazards exist with traditional electrical systems. However, when the integrity of a PV system component or protective covering is compromised or damaged due to fire or other destructive causes, the system presents significant hazards and unique safety concerns for Firefighters at all times of the day or night.

Determining the presence of a solar PV system is the key to understanding and preventing Firefighter injuries and/or Line of Duty Death (LODD).This section highlights hazards associated with overall Firefighter safety and PV technology.

ELECTRICAL SHOCK AND EFFECTS OF ELECTRICITY ON THE BODY

The primary danger for Firefighters working around any electrical system, including solar PV, is electrical shock. Electricity is dangerous because it is generally not seen or heard. Electricity can “grab” unsuspecting Firefighters without warning, which can lead to serious injury or death.

As discussed earlier, current flow (amperage) is what causes damage to human tissue. The amount of voltage (pressure) drives the current through the human body. Voltage is defined as the electrical potential of a circuit. It can be compared to the PSI of water in a hose stream, or how much force or power is available to push the current. Current (amperage) is a term used to describe the number of electrons moving past a fixed point in one second. Current is simply the rate of flow of electrical current. Compared to a hose stream, electrical current (amperage) can be thought of as the number of gallons per minute flowing through the hose line. The amount of damage to human tissue caused by current flow (amperage) and voltage (pressure) is affected by resistance. Resistance is a material’s opposition to the flow of current electrons. Resistance compared to a hose line is the amount of friction loss in the hose, valves, appliances, or nozzle. Resistance is measured in Ohms. With an understanding of current (amperage), voltage (pressure), and resistance on human tissue, Firefighters should recognize the serious potential for electrical shock related to exposure to energized PV components.

PV systems operate in a range between 120-600 volts DC. Typically, residential PV systems operate in a range between 5-9 amps, while a large commercial PV system can operate with currents between 200-1200 amps. DC voltage from a PV system is constant and current (amperage) levels pose a significant electrical shock hazard to any Firefighter that makes contact with exposed wires or PV system components. The severity of injury and damage to human tissue from electrical shock is variable and is determined by the following factors:

- The type of electrical current, alternating current (AC) or direct current (DC), flowing through the body. With both AC and DC there must be a completed path or circuit for current to flow. Injury from electricity can occur if a person's body becomes part of a circuit by completing a path for current to flow.

- The amount of current flow (amperage) through the body. Once resistance is overcome, amperage usually determines the degree of damage. At levels of current flow that exceed 1/10 of an amp (100 milliamps), the heart can stop beating and start fibrillating.

- The pathway of the current through the body. In order for electrical shock to occur, there must be two points of contact on the body for current to enter and exit. This can be as simple as touching a DC or AC high-voltage wire or component and being "electrically grounded" at the same time. Touching the high-voltage wire is one point of contact; being "electrically grounded" is the second point of contact, which completes the circuit and delivers the electrical shock.

- The duration of time the body is in contact with the current. As electrical current flows through the body it breaks down electrical resistance allowing the current to enter the underlying organs and structures. As current flows it also creates heat that will destroy and evaporate fluid in the tissue.

- Resistance of the body. The question is how much voltage is dangerous? The answer depends on how much total resistance of the body is in the circuit to oppose the flow of current. Voltage must be high enough to overcome the resistance before it can enter the body. The human body and dry PPE do provide some resistance to the flow of electricity. Conditions such as being wet greatly reduce resistance, which allows current to flow more easily. Resistance of living tissue changes as the current flows. Skin represents an initial barrier to the flow of current and insulates the deeper tissues, organs, and structures. Once an electrical current contacts skin, the amperage rises, followed by an abrupt and rapid climb. High voltage electrical energy greatly reduces body resistance by quickly breaking down human skin. After the skin is punctured, the lowered resistance results in massive current flow as electricity flows into the body. The change in current flow occurs at the same time the electrical current punctures the skin. Once the skin resistance is gone, electrical current enters the underlying tissue. Internal tissue, except for bone, does not have good electrical resistance to current flow. Electrical current will stop flowing when the heat from the current produces tissue charring and evaporates tissue fluid. Electrical resistance is different for all people and depends on body size and shape, area of body in contact with electrical source, how hard the body part is pressing against the electrical source at the point of contact, how moist the body part is at the time of contact with the electrical source, and the type of skin (callused or soft) at the point of contact with the electrical source.

- Amount of voltage (pressure). The amount of voltage (pressure) drives the current through the human body. High-voltage quickly reduces body resistance because of the amount of "pressure" and allows the current (amperage) to flow more easily.

- Clothing and Jewelry. Rings, watchbands, necklaces, bracelets, and metal button, or rivets on clothing provide excellent electrical contact with your body, and can conduct electrical current.

The chart below illustrates potential physiological effects produced by the flow of DC and AC electricity through a full-grown adult. The chart does not account for serious secondary injuries that could occur with electrical shock resulting from collisions or falls when Firefighters are working at heights or in Immediate Danger to Life and Health (IDLH) environments. Secondary injuries caused by electrical shock can contribute to delayed line of duty fatalities.

Milli-Ampere (mA) (1000 mA = 1 Ampere)	**Adult Physiological Effect of Electrical Shock** (affects on smaller persons or children may occur at lower amperage)
DC 0.5- 2mA **AC** 0.5mA	**STARTLE REACTION** This is the body's reaction to electrical shock, which can be involuntary and involves muscle contractions resulting from direct or indirect passage of current throughout the body. At this level the shock is usually painful.
DC 30-40mA **AC** 6-20mA	**INABILITY TO LET GO** The body's inability to "let go" from the electricity. This is often referred to as "Lock-On." Extreme pain is present and can cause burns. Respiratory arrest from severe muscular contractions of the diaphragm is possible resulting in death by asphyxiation.
DC 70mA **AC** 70mA	**BURNS** Burns (internal and external) caused by thermal heating effect of electrical current through the body. There is extreme pain and an increased risk of death.
DC 80-240mA **AC** 20-105mA	**VENTRICULAR FIBRILLATION/CARDIAC ARREST** Ventricular fibrillation is a disorganized heart rhythm caused by electrical current passing through the heart and usually results in death. Early defibrillation of the victim may result in spontaneous return of an organized heart rhythm.

BURN HAZARDS

The most common electric shock-related injury is a burn. Victims of electrical shock accidents suffer from three types of burns: electrical burns, thermal burns and arc/flash burns.

Electrical burns occur from electrical current flowing through tissue and bones. A primary sign of electrical burns is the presences of an entry and exit wound. Damage from electrical burns can be external and internal.

Thermal burns are generally considered to be contact burns when electrical shock victims come in contact with hot surfaces of overheated electric conductors, electric conduit, or any other energized electrical equipment.

Electrical arc is the most common cause of high-voltage electrical burn injuries, which can occur while attempting to de-energize an electrical system. Arc/Flash burns are the direct result of contact or near contact with a high-voltage electrical source. PV systems are considered high-voltage electrical sources that operate between 120-600v DC. An arc can occur between the high-voltage power source and a grounded human body. The temperature of an electrical arc can be as high 4000°C and can melt bone.

Arc burns occur where the arc strikes the victim. Flash burns are caused by the “head” of the electrical arc when victims are in close proximity to the arc. The hot flash from an electrical arc generally passes over the surface of the skin and results in superficial partial-thickness burns. Flash burns do not cause internal electrical injury.

Firefighters should never attempt to cut or remove any PV system components or wires because of the potential for high-voltage electrical arcing. Firefighters should follow Lock-Out/Tag-Out procedures when shutting down the main power disconnects for a PV system, or any electrical system, to avoid someone accidentally re-energizing the system.

TRIP, SLIP, AND/OR FALL HAZARD

The California Department of Public Health has reported PV worker fatalities and serious injuries from tripping and/or slipping on PV components that have resulted in falls from roof-tops and through skylights. Fatal falls have been linked to accidental contact with high-voltage components, or tripping on wires, conduit, and mounting racks.

The most common residential or commercial PV installations are on roof-tops; working around roof-top PV systems can be very difficult. The PV system modules, mounting racks, conduit and wires pose a significant risk for accidental electrical shock, tripping, slipping and falling off of a roof. Factors for increased potential for electrical shock, tripping, slipping, and falling are highlighted below:

- A peaked or flat roof-top access and egress can be hindered and may not allow for safe walking areas.

- The surface of PV modules is normally slippery. When installed on a peaked roof or when the modules are wet, they become extremely slippery. DO NOT walk on modules.

- Accidental contact with high-voltage PV components could cause involuntary muscle reaction and could result in a fall from the roof.

- Firefighters should never attempt to place a ladder on PV modules. Never attempt to walk on or remove PV modules or components for access or ventilation.

- Do not attempt to break the glass covering PV modules, as this could expose high-voltage internal components within the module and increase the risk of electrical shock.

- Building-integrated PV roofing modules, such as tiles or shingles, are designed to look like traditional roofing materials and may not be immediately visible or identify at night. DO NOT attempt to walk across the roof or ventilate a roof with building-integrated PV modules.

- PV mounting racks, electrical conduit, and wires are generally installed slightly above the roof system and roof line, and cross between rows of modules.

- The mounting racks, electrical conduit, and wires are sometimes partially concealed and are not always visible during the day. They become even more difficult to identify in the dark or in the presence of smoke.

INCREASED ROOF LOAD HAZARD

When residential and commercial buildings are constructed, they are built to comply with the building codes. Residential compliance is generally not as stringent as commercial building construction. This is largely due to the differences in the building materials being used. Residential construction includes the use of building materials that meet code specifications for normal weight loads within a residential structure. The materials include dimensional lumber and manufactured light-weight trusses that meet specifications for structural integrity under normal building conditions.

Residential buildings are constructed to accommodate the dead loads of the roofing systems and walls with a margin for the occasional live loads that could exist under normal conditions. Examples of live loads include people walking on the roof, collection of water from rain on the roof, or a truck company working on a roof during a working fire.

Residential construction does not generally account for optional or increased dead loads from the installation of PV systems. This is especially true with light-weight constructed trusses. The structural integrity is engineered to carry the building's design load only under normal conditions. The addition of a PV system on a building with light-weight roof construction is not part of the normal building design load and ncreases the dead load for the roofing system.

For commercial structures, building materials will include cement and steel beams and girders that have been designed by structural engineers to meet specific weight loads.

In San Francisco, the total dead load weight of an array can be no more than eight pounds per square foot. Most systems weigh much less than the maximum dead load per square foot weight limit. For instances, the weight of a PV system consisting of 30 modules wired together and installed over a 420 square foot roof area would be around 2.5 pounds per square foot.

Most PV systems will range between 2.5 to 3.5 pounds per square foot. The assumption is that the design of the roofing system will be able to handle the increased weight capacity. Roof systems are normally engineered to carry a dead load of approximately 10 pounds per square foot and most composition roofing weighs about four pounds per square foot.

As a comparison, a truck company consisting of four firefighters weighing approximately 250 pounds each with gear and tools, standing in a 10'X10', 100 square foot area on a roof has a live load weight of around 10 pounds per square foot. Generally, the total weight of a truck company standing on a roof ventilating a building is not an immediate concern.

During, a working fire in a building with a PV system, there is a potential for the roof system to fail sooner, especially, light-weight construction, with active fire in the attic space. Increased dead load hazards, such as a PV system, could result in the roof being compromised to the point of imminent failure with direct flame impingement in the attic space. Increase the weight load further with the live load of a truck company attempting to vertically ventilate and the result could be serious injury and or death for Firefighters.

Additionally, it is not uncommon to find multiple roofing layers on an older building. Having more than one or two layers of roofing can dramatically change the integrity of the roof system under fire conditions.

Firefighters need to be vigilant when assessing a building with a PV system to identify a weak or compromised roof system. The presence of a PV system on the roof and the status of the integrity of the roof system should be immediately reported to the IC. Firefighters should maintain constant situational awareness for changing conditions. Considerations for implementing alternative firefighting tactics should be communicated with the IC.

HAZARDOUS MATERIALS INHALATION HAZARD

Hazardous materials used in the semi-conductor industry, such as silicon, boron, phosphorus, cadmium, tellurium, arsenic, and gallium, are used in the construction of PV modules and components. In PV modules these materials are sealed between the top layer of glass and the plastic backing of the module, and then are encased in an aluminum frame.

When the PV system is operating under normal conditions, these chemicals do not constitute a hazard. However, during a fire involving PV modules or components, or the adjacent areas around the modules or components, the aluminum frame can become deformed or melt, exposing the hazardous chemicals to direct flame and/or significant heat.

The exposure to flame and heat will cause the materials to dissipate in the smoke plume, constituting an inhalation hazard to Firefighters without breathing apparatus, as well as people standing near the fire building and in the path of the plume. The inhalation hazard from these chemicals can be mitigated for Firefighters by ensuring the constant use of breathing apparatus and all PPE during fire attack and overhaul operations. All chemicals listed above are considered toxic under fire conditions; some have a significant increased cancer risk with exposure.

PV SYSTEM BATTERY HAZARD

The bank of batteries used to store electricity are generally arranged in a line and are connected to each other with “jumper wires” to increase voltage or amperage. There are two types of batteries used as electrical storage for PV systems, lead acid and lithium ion. The most common type of battery used is lead acid.

Lead acid batteries contain sulfuric acid that can cause harmful and explosive fumes. During normal operation, the bank of batteries will emit both hydrogen and hydrogen sulfide gas, which are highly flammable. Hydrogen is lighter than air. Hydrogen sulfide is slightly heavier than air. For this reason, any equipment capable of producing a spark or open flames is not allowed near the battery back-up storage area. The area must be adequately ventilated to prevent a build up hydrogen and hydrogen sulfide.

Though lead acid batteries are more common, lithium ion batteries are more efficient and take up less space. Lithium ion batteries are more efficient than lead acid. However, they are hazardous. When lithium ion batteries are subjected to direct flame, high temperatures, or abuse, such as mechanical damage or overcharging, they may vent flammable liquid electrolyte, in liquid and gas form, which can explosively ignite and produce dangerous sparks. When lithium ion batteries burn, they produce a flare-like effect and can easily ignite other batteries or combustible materials in close proximity. Lithium ion batteries that are actively burning will produce irritating gases, such as hydrogen fluoride, that are corrosive and toxic. Firefighters that come in contact with the electrolyte inside of lithium ion batteries can complain of skin, eye, and mucous membrane irritation.

Firefighters working around battery banks must utilize proper PPE, including breathing apparatus, during fire attack and overhaul operations, should use caution in the battery storage area, and should continuously assess for the development of a hazardous materials situation.

Firefighters should be familiar with how to isolate the bank of batteries from the PV system, if needed. If the PV system is disconnected from the batteries, the bank of batteries themselves still has potential for electrical shock. Firefighter should never attempt to cut into or attempt to damage the batteries under any circumstance. If the batteries are punctured by a conductive object, such as halligan tool, the object may become energized. Firefighters working around or adjacent to the battery storage areas should only use flashlights and equipment approved for CLASS 1 atmospheres.

When Firefighters determine that a PV system is using a battery bank to store electricity, the IC should be notified about the hazard and the location of the batteries within the building.

SECTION 7. INCIDENT PRIORITIES AND TACTICAL CONSIDERATIONS

Fire and emergency incidents for residential and commercial buildings have a basic and standardized approached. However, fire and/or emergency incidents involving solar PV systems require special considerations. The special considerations are a result of the inherent and associated hazards of PV systems and are necessary to ensure Firefighter health and safety and to accomplish fire control in a safe and efficient manner. Incident Priorities and Tactical Considerations for solar PV systems during fire and/or emergency operations are outlined below.

PRE-INCIDENT IDENTIFICATION

- Visual observations and inspections at the company level are critical steps to identification and pre-planning when dealing with PV systems.
- Companies should be aware of and should note any buildings or structures with PV systems in their first due areas when:
  - Responding to and returning from calls.
  - During area familiarization.
  - During routine company inspections (R1).
- When PV systems are encountered the officer should:
  - Enter a Premise Hazard into HRMS.
  - Make a note in the journal identifying the PV system and the location of any components such as disconnects or Main Electrical Service Panel.
  - Advise oncoming personnel so the information can be passed on

COMMUNICATIONS

- All findings during the initial and on-going size-up and any actions taken need to be communicated to the Incident Commander (IC).
- Incident size-up and identification of PV system and components
  - Questions to consider:
    - Is there a solar PV array visible from the street upon approach and/or arrival?
    - Is the system inverter(s) visible or evident anywhere on the building?
    - Is there PV labeling identifying the presence of a PV system?
    - Are there any DC or AC disconnects visible and/or accessible?
    - Is there visible electrical conduit penetrating the attic space or near the main panel?

        - Where is the PV array located?
- Controlling/Securing utilities and the PV system
    - Notify the IC when utilities have been secured and the PV system has been isolated.
- On-going size-up throughout the incident
    - If the PV system is not identified on initial size-up companies assigned to the roof or fire attack need to communicate the presence of a PV system or PV components immediately if encountered.
    - If the PV array or components will impact or delay ventilation or fire attack the IC must be notified.
    - Notify the IC if another form of ventilation is indicated due to limited or no access for ventilation.
    - Accountability of crews.

SECURING UTILITIES

- Securing Utilities is the **TOP PRIORITY** for incidents involving a PV system to maintain a safe work environment for Firefighters.
- Objective
    - De-energize PG&E power coming into the building.
    - De-energize electrical circuits leading from the PV system.
    - Isolate the DC power for the PV system and confine the power to the array.
- **Specifically assign a company to secure building utilities and the PV system.**
- Locate Main Electrical Service Panel.
    - Shut off Main Breaker inside the Main Electrical Service Panel.
        - This will shut down the AC power at the Main Electrical Service Panel and AC power going into the building.
        - Shutting off the Main Breaker will also de-energize the AC power used by the inverter to convert DC into AC power.
    - If in doubt which is the Main Breaker, shut-off all circuit breakers inside the Main Electrical Service Panel.
        - Use caution for large commercial and high rise buildings.
            - Electrical power might still be needed to power HVAC systems and elevators.
            - Consult with building engineers (if applicable) to isolate the PV system ONLY!
- Consider using Lock-out/Tag-out system to secure PV system.
- Locate and isolate the PV system and battery bank (if applicable).
    - Locate PV Inverter(s) and disconnects.
        - Shut disconnects into the “OFF” position.
    - Locate PV system batteries (if applicable).
        - Shut disconnects for battery bank into the “OFF” position.

  - Locate and shut off any and all visible disconnects or switches for the PV system.
    - Near Bi-directional Electric Meter.
    - Near the inverters.
    - Switch-gear on the roof.
    - Roof top disconnects.
- Notify the IC when the utilities and PV system have been secured.
- **REMINDER:**
  - **During hours of daylight, the Solar PV modules are ENERGIZED and are still generating DC electricity from the modules to the DC side of the inverter, even after the Main Electrical Service Panel has been secured.**
  - **At night scene lighting or other artificial light on the PV array can produce DC electricity with the potential for electrical shock.**

FIRE ATTACK CONSIDERATIONS

- Coordination of fire attack and ventilation
  - Fire attack could be delayed or hindered due to difficulties with completing ventilation.
  - Advancing hose lines could be delayed due to securing PV and building utilities.
- Be aware of energized PV system components inside the building.
- Notify the IC if wires and conduit inside the building is located.
  - Avoid contact with conduit or wires if possible.
- Attempt to avoid directing hose streams directly onto energized PV system components.
- If possible and indicated, use Dry Chemical Extinguishers or CO2 Extinguishers around PV components.
- If water is used PG&E recommends Fog Nozzle at a 30 degree pattern at 100 psi minimum at the tip and at least 33 feet from the energized source.
- UL experiments indicate that using a solid stream, smooth bore nozzle at 50 psi at the tip and at least 20 feet from the energized source is considered safe up to 1000 volts. PV systems have a maximum allowable voltage of 600 volts.
- Difficulties with fire attack must be communicated to the IC.

VENTILATION CONSIDERATIONS

- Early recognition of the PV modules and identification of difficulties with completing ventilation objective is key for Firefighter safety.
- Identify safe access and egress to the roof if possible.
- PV modules/array on the roof may affect ground or aerial ladder placement.

- Consider using Breathing Apparatus while working on the roof due to inhalation hazards.
- Do not cut through any conduit or wires to complete ventilation due to the potential for electrical shock.
- Do not break PV modules with an axe or attempt to remove PV modules to ventilate due to electrical shock hazard.
- On a flat roof, try to cut a ventilation hole according to Department SOP's.
    - Avoid standing underneath the elevated rack mount for PV installations on a flat roof.
- On a peaked roof, consider utilizing another area of the roof that is not covered with PV modules and notify the IC.
- If a ventilation hole cannot be cut directly over the fire, identify an alternate location and notify the IC that an alternate location for the ventilation hole has been selected so fire attack crews inside the building are aware of a potential change in fire behavior. If the modules limit roof area, consider altering the dimensions of the ventilation hole. For example, instead of a 4x4 hole a 2x4 or 2x8 hole can be cut given the limited access.
- If vertical ventilation cannot be accomplished because the PV system does not provide firefighters with clearance, consider changing ventilation tactics and notify the IC immediately.
- If a PV module is involved in fire, it does not present a hazard to utilize a hose line to extinguish the fire as long as all recommendations for PPE, SCBA, and use of water streams are followed.

SALVAGE/OVERHAUL CONSIDERATIONS

- Make certain that the building utilities have be de-energized before initiating overhaul.
    - Priority is to confirm that the PV system is shut down (De-Energized) and the DC power coming from the PV array is isolated at the array and is not coming into the building to prevent accidental electrical shock.
- BE AWARE of electrical conduit when "pulling ceilings or "opening up" walls during salvage/overhaul operations. Electrical conduit could be ENERGIZED!
- Use extreme caution when performing salvage/overhaul during daylight hours.
- Visually assess the PV system for overall damage and obvious hazards, such as broken modules, loose or hanging wires, and spot fires in or around the PV system.
- Visually assess the type of roofing material to determine if the roofing material is flammable and if any actions need to taken to prevent flare up or rekindle.
- If possible, visually assess the integrity of the roof system for stability.

- Smaller PV systems with safe access and egress should be covered with an opaque tarp (a tarp that does not allow light through) to prevent the modules from producing DC power.
    - Consider using canvas salvage covers on small PV systems to prevent sunlight striking the modules. This will secure the PV system and render it safe during daylight, or low/artificial light conditions, and prevent accidental electrical shock.
- During daylight hours, PV systems (residential or commercial) that are too large to cover with an opaque tarp should be left alone and all personnel on scene should be aware that a PV system is present has not been isolated or shut down and is not safe.
    - Consider special calling PV technician to secure the systems to render the PV systems safe
- DO NOT remove or otherwise dismantle PV modules during salvage and overhaul.
- DO NOT cut any electrical wires or conduit during salvage and overhaul.
- DO NOT break PV modules during salvage and overhaul.
- DO NOT attempt to shut down or disable inverters other than using the DC and AC disconnects during overhaul.

SECTION 8. SOLAR PHOTOVOLTAIC TERMINOLOGY/DEFINITIONS

AC Disconnect
The AC disconnect is the AC power shutoff. The AC disconnect is located inline between the inverter and the Main Electrical Distribution Panel for the building.

AC Voltage
AC stands for "Alternating Current." This means that the voltage is not constant and changes polarity (reversing positive and negative) or direction over time. AC is the type of electricity that is found in your home and delivered by PG&E. AC voltage in the home is commonly 110 volts for most ordinary electronics. Larger appliances, such as a clothes dryer, are usually 220 volts.

Array
A group of modules wired together in series to generate a greater amount of DC voltage. Arrays can be mounted in various locations on a building or adjacent to a building. Arrays will vary total size.

Combiner Box
The combiner box is used as a collection point for the many wires from the modules that are wired together (combined). The wires coming into the combiner box will vary in number depending on the number of PV modules in the array. Wires leaving the combiner box will generally be encased in electrical conduit on the way to the DC disconnect before the inverter(s).

DC Disconnect
The DC disconnect is the DC power shutoff. The DC disconnect is located inline between the solar arrays and the inverter

DC voltage
DC stands for "Direct Current." This means that the voltage or current maintains constant polarity or direction over time. DC is the kind of electricity made by a battery (with definite positive and negative terminals), or the kind of charge generated by rubbing certain types of materials against each other. DC electricity must be converted to AC electricity in order to be used for household appliances and electrical circuits.

Dead Load
Dead load refers to a constant load in a structure (such as a bridge, building, or machine) that is due to the weight of the members, the supported structure, and permanent attachments or accessories.

Grid Tied
A solar PV system that is capable of feeding electrical power into the PG&E utility power grid.

Inverter
The inverter converts incoming solar DC voltage from the modules to AC voltage before going to the building circuit breaker panel.

Line
In relation to a given switch or device, line refers to wires or voltage being "supplied" to it from "upstream" or from the direction of the Main Electrical Service Panel or power source.

Live Load
The term live load refers to the weight or forces applied to a structure, excluding actual construction materials, from a variety of sources that are not permanently secured to a structure. Snow, wind, water accumulation, people, and equipment are examples of live loads. Live Loads are variable and are generally thought of as temporary, movable, or there for a short duration. When buildings are constructed, reasonable Live Loads are factored into the construction and are based on allowable parameters within the building code. These simple calculations do not account for structural compromise, such as charring from a fire or an added Load, dead or live, which was not factored into the structural integrity of a building.

Load
In relation to a given switch or device, load refers to wires (or terminals) that are "downstream" from or controlled by the switch or device. Another use of the term "load" is to refer to the energy "user(s)" along the circuit's path, such as a light or appliance. By providing resistance, these items limit current and, in the process, do useful things with that current.

Module
A single aluminum-framed solar panel covered with tempered glass. Modules are sometimes referred to as panels.

Module Level Control
Solar PV components designed to improve overall PV system efficiency and safety. Increased safety is achieved by improving the ability to isolate a PV system to prevent accidental electrical shock.

Net Metering
Agreement between the utility company and the PV system owner to "bank" excess power produced by the PV system and to feed it into the utility power grid. The excess power used by the utility company is offset when the PV system owner needs to use power from the utility power grid when the PV system is not producing power.

Off Grid
A PV system that is not connected to the utility power grid. This type of system is otherwise known as a "stand-alone" system.

Photovoltaic Cell
A semi-conductor device designed to convert solar energy, produce by the sun, into DC electric power.

PV
PV stands for Photovoltaic. Solar Photovoltaic Systems generate DC electricity from sunlight (photons).

PVT
Solar Photovoltaic and Thermal Systems generate DC electricity and solar thermal heating for water co-generated from sunlight.

SECTION 9. MANUAL REFERENCES

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