Australian PV Association

Solar Electric Systems – Safety for Firefighters

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Co-convener of the International Electrical Commission (IEC) working group on PV systems: TC82-WG3.

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Preface

Many Solar Electric (Photovoltaic or PV) Power systems have been and continue to be installed in Australia. Over recent years there has been a rapid expansion of the industry and this is expected to continue into the future. These systems are typically installed on roofs or may be installed on ground mounted racks. Although fires caused by the PV systems themselves are rare, it is important for firefighters to be aware of the safety issues that might be involved when fighting a fire on a structure that incorporates a Photovoltaic (PV) System.

The basic information provided here will help in identifying when a PV system is present, its basic operation, what hazards exist, what is safe and how to minimise risks. Much has been written lately on this topic. Some information, unfortunately, has been inaccurate, and it is hoped that this document will assist in clearing up some misconceptions. Short courses on PV systems and safety for fire fighters can also be arranged through the Australian PV Association on request.

This document discusses Grid-connected Systems which are the most prolific systems in Australia. It addresses the questions:

- What components comprise a system?
- What issues are important when you arrive at a fire location?
    - How can I identify if a PV system is present at an installation?
    - How do I shut down a System?
    - Once shut down, are there still hazards?
- Issues related to water on a PV array
- Safety issues when entering a fire compromised building.

Disclaimer

Contents

Grid Connected Systems

Introduction

Grid connected systems are at the present time the most predominant PV systems installed. They only exist where an installation is connected to the main electricity supply system ("The Grid"). Many of these systems have been installed on domestic roofs. An example of a domestic roof installation is shown in photo 1.

Photo 1. Example of Domestic roof PV System

Larger commercial installations can take many forms: either installed on a roof of a commercial building (see photo 2); or installed on a ground mounted frame (see photo 3).

Photo 2. Example of Commercial Roof Mounted PV System
(Photo courtesy of Sydney Solar Pty Ltd)

Note that in some installations PV arrays may be installed on more than one face of a roof.

Photo 3. Example of Commercial Ground Mounted PV System

System Components & Connection Diagram

Grid connected PV systems have three primary components: modules, inverters, and the wiring connections between the modules and inverter and between the inverter and the switchboard. A typical connection diagram is shown in Figure 1. In some cases of grid connected systems, batteries may be present to provide an uninterruptible power supply (UPS) function but this is unusual and from a safety perspective is no different to any other installation containing a UPS.

The PV modules generate DC electricity while they are exposed to light. The amount of electricity generated is dependent on the size of the modules or complete system and the amount of light falling on the modules.

The inverter converts the DC electricity into AC electricity that is compatible with the grid and injects this electricity into the grid. Unless the PV output is separately metered, grid connected PV systems will cause the electric meter to run backward on a sunny day when there is more power being generated than the house is using. At nighttime, the meter just spins forward again as house appliances are in use.

The inverters for grid connected systems cease operation and disconnect from the grid if the grid supply is disconnected or fails for any reason. This includes someone switching off the main electricity supply to an installation.

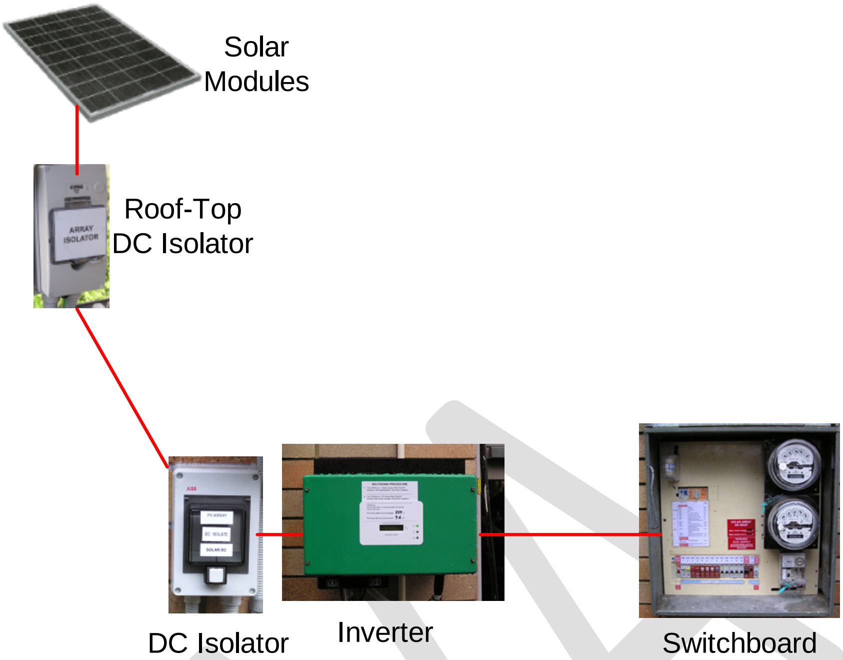


Figure 1. Typical domestic grid connected PV system diagram.

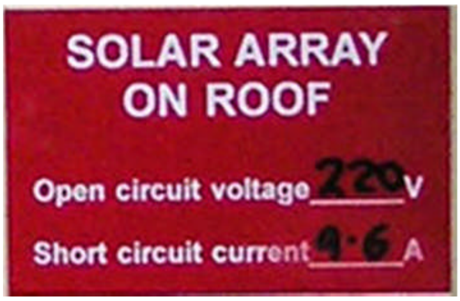
Note: Some older systems may not have roof-top DC isolators

What issues are important when you arrive at a fire location?

How can I identify if a PV system is present at an installation?

Determining the presence of a PV system is the first step in identifying potential risks. It is important for firefighters to be able to identify basic components of systems, such as the PV modules and the inverter. See appendix A for assistance with identifying these components. The existence of these components in an installation will alert firefighters to the existence of a PV system. Sometimes, because of the location of PV modules on a roof, it is difficult or impossible to see modules mounted on some parts of a roof. In all cases it is important if possible to go to the electric meter panel or switchboard where in both cases there is required to be a sign/s displayed indicating the presence of a system. See an example of this signage in photo 4.

Note: This documentation covers only measures associated with a PV system. Other sources of generation and devices, such as UPS systems, must be treated separately as per usual safety procedures for these devices.



OR

SOLAR ARRAY ON ROOF
HAZARDOUS D.C. VOLTAGE

Photo 4. Example of Signage in Switchboard

How do I shut down a PV System?

In the case of grid connected systems, the most important first step where possible is to switch off or disconnect the main electricity supply to the installation. If this is accomplished, all the AC wiring in the installation should shutdown including the inverter supply from the PV system.

If there is a shutdown procedure in the switchboard, those procedures where possible should be followed. See Example of Shutdown Procedure in Figure 2:

SHUTDOWN PROCEDURE

a) Turn off the MAIN SWITCH (Inverter Supply)

b) Turn off the inverter isolation device located near the inverter

c) Turn off the PV D.C. Isolator located next to the input terminals of the inverter

PV ARRAY D.C. ISOLATOR

Labels near associated switches

MAIN SWITCH (INVERTER SUPPLY)

Figure 2. Example of shutdown procedure and associated switch labels.

The most important second step in shutting down a system is to switch off the PV Array DC isolator adjacent to the inverter system (refer to Figure 1). The location of the inverter should also be signed in the switchboard, if it is not immediately adjacent to the switchboard. Operation of this DC isolator should disconnect the PV array from any permanent earth connection. This will make the array electrically more safe.

Some old and all new installations will also have a PV Array DC isolator adjacent to the PV array (typically on the roof) so for situations where access is possible this switch may also be opened to make sure that any wiring going away from the array to the inverter is also safe.

Once shut down are there still hazards?

Once the a.c. mains to the installation is switched off, all the AC wiring should be safe. The PV system will not feed AC wiring in the installation after the mains have been switched off.

After switching off or disconnecting the AC to an installation, the DC wiring coming from the PV modules to the inverter system may still have a dangerous DC voltage on it while there is any light falling on the array. This is certainly true in daylight conditions but may also be true under artificial lighting such as flood lights or with light associated with a fire. The electric current associated with PV arrays under artificial light is very significantly reduced compared to current under daylight, but still it must be treated as potentially hazardous to humans.

Issues Relating to Water on PV arrays and structures

Remember that while there is light the PV array will be generating electricity. Voltages on domestic systems may be up to 600V DC and on commercial installations up to 1000VDC.

It is important to operate fire hoses in a fog mode to break up the water path and ensure a non conducting water stream.

Note: Further research on the issue of water streams and current flow from PV arrays will be available before the end of 2011 from testing being undertaken by Underwriters Limited in the USA but until that time caution is important.

Note: Generally speaking the shock hazard from a PV array if the AC system is switched off and the PV Array DC Isolator is switched off is likely to be much less than any shock hazard associated with normal AC power supplies. This is particularly true in low light conditions.

When Entering a Building

When entering a building that has been compromised by fire, firefighters should avoid contact with any wiring hanging down from ceilings or roof structures under PV arrays or in the path between the PV array and the inverter equipment. Again, if there is light on the PV array, some of these wires may be live unless all roof top isolator/s have been opened.

Other Issues

- PV modules are not meant to be walked on - doing so could lead to a collapse.
- If your department carries noncontact voltage detectors, remember that they detect only the presence of AC voltage, not DC voltage. There is no noncontact detector on the market for detecting DC voltage.
- It is possible to make the PV array electrically safe using tarps to cover the array. Semitransparent tarps such as blue tarps are not suitable as they let too much light through. Silver, black or heavy canvas tarps are suitable and will reduce the available current from the array to a level that is safe. It must be emphasized that the whole array has to be covered to make this technique effective. On roofs with multiple sections of arrays, all sections of all arrays must be covered.

Photo 5. Tarping an array to make it electrically safe.

- Finally, remember that in a nighttime fire in which the ceiling/roof space has been exposed to severe heat damage, the conduit and wires inside may have become compromised. It is possible that when the sunlight contacts the array the next day, it could result in some arcing. It is a good idea to recheck a structure in the morning for arcing or rekindling from arcing until a qualified solar contractor can respond to disconnect the array connections.

SUMMARY

1. On arrival, look for indications and signs associated with PV systems.
2. Turn off the AC supply. This will shutdown and disconnect the inverter.
    - ➔ AC house wiring safe.
3. Shutting down the DC isolator near the inverter will separate the array from earth.
    - ➔ Safer option.
4. Shutting down the rooftop isolator will make safe wiring coming down from the roof.
5. Use FOG spray when putting water on a fire.
6. When entering a building be aware of wires hanging down from the ceiling or roof structures in areas under PV arrays.

APPENDIX A: Identification of System Components

Solar Panels or Modules

There are two main categories of **solar panels (modules)** used in residences:

- ***Solar Thermal panels*** (photo A1 & A2), that are used for hot water systems and
- ***Photovoltaic (PV) modules*** which generate electricity (photos A4 to A8).

This article deals only in detail with PV panels, also known as PV modules in the industry. It is important that fire-fighters are able to quickly distinguish the two different types.

Solar Thermal panels

Thermal panel systems may represent a physical load on the roof and may contain hot water. They sometimes have water tanks with electric or gas boost on the tank but the issues associated with these appliances are not covered in this document, other than to say that they need to be identified and do not represent the same risks as PV systems because they do not generate electricity.

Photo A1.   Solar thermal panels used for hot water

Note: joined at top and bottom with water pipes

Photo A2.   Solar thermal panels with storage tank.

Photo A3. House in Sydney Olympic Village Sydney with both solar thermal and solar PV electric panels

Photovoltaic (PV) modules:

Most of the PV electric modules installed today are comprised of many silicon cells wired together and enclosed in an aluminium frame with a glass cover. See photos A4 to A6. Crystalline and multicrystalline modules have individual cells that are easily seen under the glass in Photos A4-A6. Some modules are a double layer of glass with the cells sandwiched between to form a semitransparent module used often as atrium roofs or for shade elements in a building (photo A6). Amorphous cells are deposited as a thin uniform layer under the glass. See Photos A7-A8. Some amorphous modules come in the form of a thin plastic film that is bonded to metal deck roofing. See photo A8.

Photo A4. Mono-crystalline PV modules

Individual cells visible – uniform colour generally dark grey.

Photo A5. Multi-crystalline PV modules.

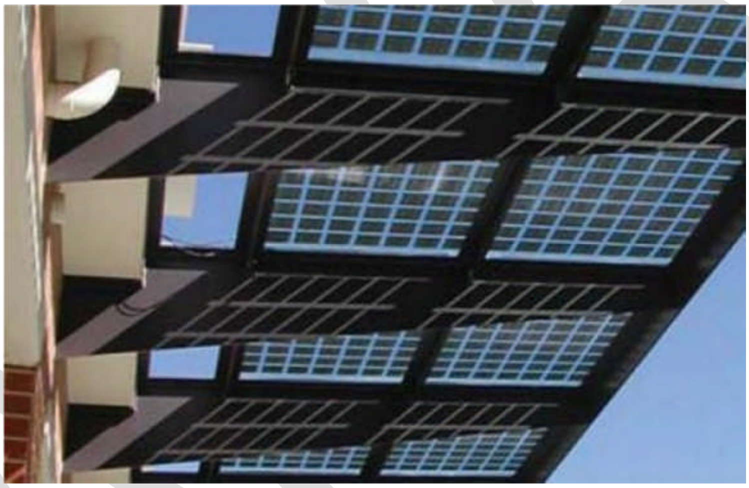


Photo A6. Example of Double Glass PV Module used as a shade element in a building.

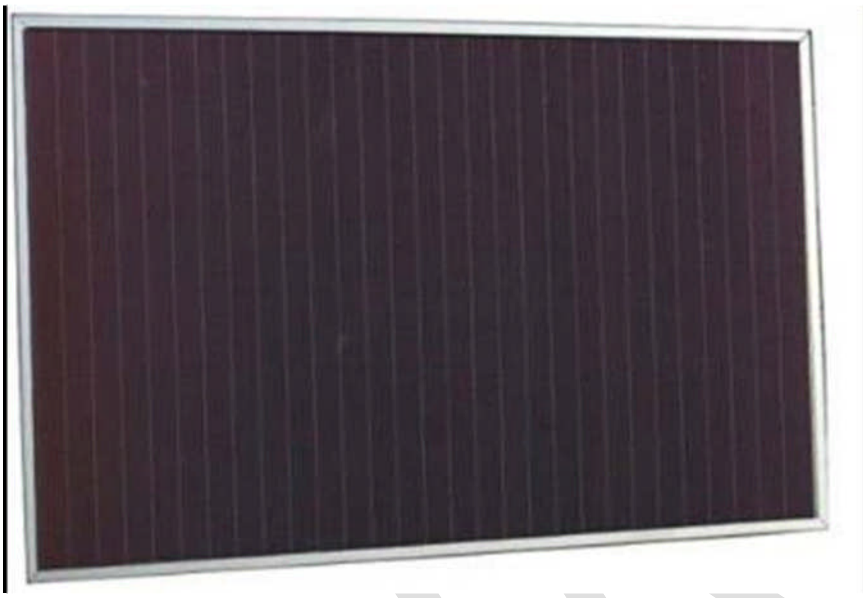


Photo A7. Amorphous PV module

Note: The individual cells are not apparent – generally a uniform dark grey or bluish colour with fine lines on surface.

Photo A8. Amorphous modules bonded to metal roofing.

A group of modules mounted on a structure is called an array (photos 1-3). An array's weight load on a roof is usually less than 25kg/sq meter. The modules generate electricity from sunlight and have no moving parts. When modules are electrically connected to each other in series, the voltage increases. Most domestic residences will have from 1000 to 5000 watts (one to five kilowatts) of power in optimal sunlight conditions, at between 120 and 600 volts DC. The current typically ranges between five and ten amps. Of course there are both smaller and larger systems and Commercial PV systems can range up to 100s of kW through to megawatts. The larger systems typically being on open racks in fields (photo 3).

Inverters and Disconnects

Since the modules produce DC power, they are wired to an inverter, which converts the voltage to alternating current (AC) and then feeds the electricity directly back into the main power distribution panel. Photo A9 shows, from left to right, the main electrical meter and circuit breakers which includes the AC disconnect, the inverter, and the DC disconnect underneath the inverter.

Photo A9. Example of Inverter installation adjacent to switchboard.

Note: The inverter may not always be mounted adjacent to the switchboard.

Since the inverter requires AC from the power company to do its job, shutting off the residence's main circuit breakers also shuts down the inverter. This means that no AC power is being sent into the house. Similarly, if there is a local power outage on a bright sunny day, the system cannot feed power back into the power company grid because the inverter is shut down.

Switches for a.c and d.c disconnects should be close to the inverter to shut off the DC power entering the inverter (the DC isolator/disconnect) and the AC power leaving it (AC isolator/disconnect). If the inverter is adjacent to the switchboard, as in the photo A9, the AC disconnect will generally be on the switchboard.

Caution: The wires from the array to the inverter are live in the daytime hours, even when it is overcast. The DC disconnect does not shut off the power in the DC conduit coming from the array; it just keeps it from entering the inverter. The DC wiring is still live between the array and the inverter DC disconnect. As you can see in photo A9, this inverter is mounted close to the main switchboard. Inverters may also be installed in other locations. Instructions as to the location of the inverter should be located in the switchboard.