

# Troubleshooting photovoltaic systems: three typical problems

By Ron Auvil

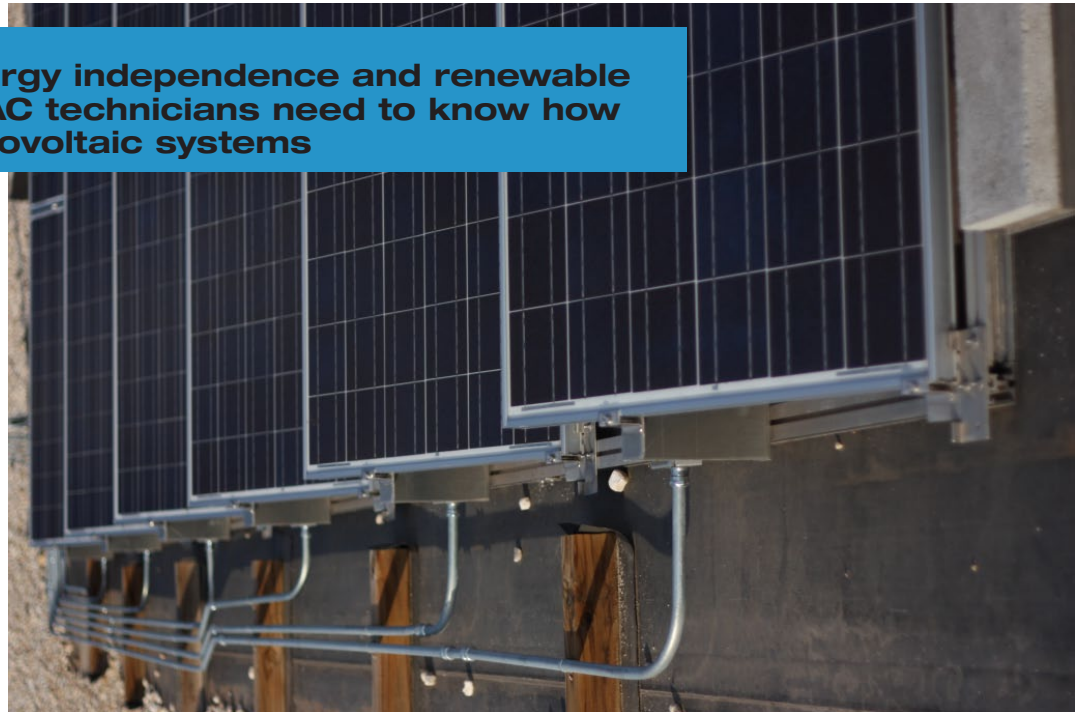
## Application Note

**With the push to energy independence and renewable energy sources, HVAC technicians need to know how to troubleshoot photovoltaic systems**

With the energy situation and problems in the last few years has come a major effort to increase the amount of energy from renewable resources. State and federal government policies in many areas mandate increased use of solar power. An HVAC technician who is servicing other equipment in the building might encounter solar power systems. Because the concepts and arrangements of these systems are new to HVAC technicians, a short overview of the systems and components is in order.

Photovoltaic systems convert sunlight (photo) into electrical power (voltaic). The sunlight that strikes the semiconductor material in the individual cells causes electrons to move through a wire. The electricity generated by photovoltaic systems can be used to run a range of equipment, from domestic appliances to commercial production equipment.

There are a number of variables in a PV system, but ordinarily the PV array is mounted on a roof that faces the south as much as possible. Obstructions are avoided. Note



This electrical conduit connects a series of solar cell arrays.

that less power will be generated in the winter than the summer due to the shorter days. Also, maximum power will be generated at midday rather than in the morning or evening.

As part of the PV installation, some facilities provide a real-time computer display that shows the amount of energy produced by the PV display, the dollars saved, and the amount of fossil fuel usage avoided. It is great to know that facilities are increasingly leading the way to energy independence and lowering the amount of pollutants released into the atmosphere!

The electricity generated by a PV system may be used immediately by that facility, stored, or

in some cases sold back to the local electric utility.

It is only natural for facilities that have PV systems installed to expect HVAC technicians to at least know the basics. As these systems become more commonplace we may be expected to perform some basic troubleshooting of them.

### Components of a PV system

PV systems consist of the following general components:

**Individual cells.** An individual cell is a small part of a PV system. A cell consists of the semiconductor material, a support structure, and a transparent material that allows the

sunlight to strike the semiconductor material. The cell must be physically tough as it is exposed to the weather. The transparent material that covers the cell also must be stain and dirt resistant. Each individual cell produces only a few watts of electricity.

**Modules and arrays.** A module consists of a number of cells connected together side by side. Modules may be in either series or parallel, as needed to obtain the desired voltage and current. Since each individual cell only produces a small amount of electricity large numbers of them must be joined together to get significant amounts of electricity. As may be imagined, these modules can become quite large and limited by the size of the roof dedicated to their use. Modules joined together are then called arrays. Wiring connects the individual cells together to form these arrays. The arrays are then wired together to a central point.

**Concentrators and combiners.** A concentrator or combiner is a central wiring point for the cells and modules. It represents the aggregate power output of the entire solar array. Even though the output of each solar cell is small, at the point where multiple modules are connected many amps of current are present. Metering and conditioning of the power may also take place at the concentrator. The concentrator is then connected to either electrical storage or an inverter. Storage may consist of a large number of batteries.

**Inverters.** The power produced by a PV system is dc. The vast majority of loads in a building are ac. An inverter is used to convert the dc power created by the modules into usable ac power. The output of the inverter may also be connected to the local utility so that any excess unused power is put back into the grid and purchased by the local utility to be used by other customers. Metering and power monitoring equipment are installed here as well.

Since there are really few components in a PV system there are not many things to go wrong. As mentioned previously the major components are the cells, modules, arrays, concentrator/combiner and inverter. The PV system in the building may be providing power to HVAC equipment or affecting the power quality of the building. This means that HVAC technicians may need some basic troubleshooting skills. (After all, we are expected to know how to work on everything on the roof anyway, right?)

### Three typical PV troubleshooting situations

In the examples below, the person doing the troubleshooting is taking advantage of the features of the new Fluke 381 Remote Display True-rms Clamp Meter with iFlex™. While you can use a true-rms ac/dc clamp meter with voltage capabilities for most of the work, we used the Fluke 381 because of its wireless feature (remote readout and display), and the iFlex™ flexible current probe. The iFlex™ probe is absolutely vital for troubleshooting these photovoltaic problems. Since large numbers of wires connect each module and array to the

concentrator box, the junction boxes are stuffed with individual wires. The iFlex™ probe makes the measurement of the individual module wires MUCH easier, thus saving time and increased accuracy.

#### Troubleshooting Problem #1: Cell/Module/Array Problem

As with any troubleshooting call, try to get as much information from the customer as possible. Try to find out when the problem occurred and when the last time the PV system operated normally. Get as much information, such as prints, outputs, and wiring diagrams, as possible.

A good place to start is to check the output of the entire system at the metering system or at the inverter. Prior to getting on the roof, check and record the inverter's input voltage and current level from the array. If the entire PV system is down and not producing power it may be an inverter problem. If the PV system is operating at a reduced power output the problem may be one of the arrays or modules. You will have to trace out the individual branch wiring backward from the concentrator. Again, the iFlex™ makes this an easier job than it would be otherwise.



A technician attaches the iFlex™ flexible current probe of a 381 Clamp Meter as he prepares to troubleshoot a photovoltaic system.



To measure the current output of this photovoltaic cell, a technician wraps the 381 iFlex™ flexible current probe around the conductor.

When you get up on the roof, visually check the entire system for any obvious damage. Also, keep in mind that someone may have disconnected the wiring accidentally while servicing another device on the roof. Once the module or array that is not producing power is found, check all wiring, switches, fuses, and circuit breakers. Replace blown fuses and reset the breakers and switches. Keep in mind that since the PV system is on the roof that a lighting strike or power surge may have affected it. With the large amount of wiring present, check for broken wires and loose or dirty connections. Replace and clean as needed. Especially be on the lookout for wire nuts that are connecting modules together. They may have worked loose and caused lack of contact.

The concentrators can be a great place to troubleshoot the system because the individual wires from the modules are brought back there. Each module may have a fuse which should be checked with the 381 meter.

Wiring problems and loose connections may also cause a particular module to produce too low a voltage. Again, all wiring connections should be checked. If a particular module output is low, it may mean that an individual section of cells is bad.

These may be traced out using the 381 meter at the junction boxes until the culprit is found.

Any dirt on the modules, or modules in the shade, can cause a reduced output. Although the modules are usually designed to be maintenance free for years, they may need to be cleaned. Pollen can be a problem in some areas of the country. Check the system with the 381 meter after any corrections are made.

### **Troubleshooting Problem #2: Load Problem**

Remember that the PV system is used to operate building electrical loads. Any problems with the loads will affect the system as well. The first step is to check the load switches, fuses, and breakers. With the 381's voltmeter, check to see that the proper voltage is present at the load's connection. Next use the 381 to check the fuses and circuit breakers. If there are blown fuses or tripped breakers, locate the cause and fix or replace the faulty component. If the load is a motor, an internal thermal breaker might be tripped or there might be an open winding in the motor. For testing purposes plug in another load and see if it operates properly.

As with any electrical system, check for broken wires and any loose connections. Clean all

dirty connections and replace all bad wiring. With the power off, check for and repair any ground faults. If any fuses and breakers blow or trip again, there is a problem short that must be located and repaired.

If the load still does not operate properly, use the 381 meter to check the system's voltage at the load's connection. The wire size may be too small and need to be increased. It may also be possible that the wire runs to the load are too long. This will show up as a low voltage at the load. In this case you can reduce the load on the circuit or run a larger wire.

### **Troubleshooting Problem #3: Inverter Problem**

Many HVAC technicians work with variable speed drives every day, so we are used to checking ac and dc power. The inverter in a PV system can also fail and cause problems. The inverter converts dc from the PV system into ac power for building use. If the inverter is not producing the correct output first use the 381's voltmeter and dc ammeter to check and record the inverter's operating dc input voltage and current level. On the ac side, use the 381 clamp meter to check the inverter's output voltage and current levels. As mentioned previously, many of these systems have a display that

indicates current inverter and system performance. Remember that the 381 clamp meter produces a true-rms reading; you can use the voltage and current to measure and record the kilowatt (kW) output. If possible use the inverter display to show the current total kilowatt hours (kWh). You can then write down this value and compare it to the one recorded during the last inspection.

If the inverter is not producing the right amount of power there

may be a number of problems, all of which can be easily checked with the 381 meter:

- blown fuse
- tripped breaker
- broken wires

Also, use the 381 clamp meter to measure the output ac side of the inverter, because the load on the inverter might have a current demand that's too high. Your choice then is to reduce the loads or install a larger converter.

With the power off, check for and repair any ground faults before starting the inverter again.

Remember that the inverter may be tied into the local utility. The ac current output from the inverter fluctuates with the level of solar input on the array. The inverter maintains the correct output voltage and phase to the utility. Any voltage problems from the utility may cause the inverter to shut down. In this event contact the utility for repairs.

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**Fluke Corporation**  
PO Box 9090, Everett, WA 98206 U.S.A.

**Fluke Europe B.V.**  
PO Box 1186, 5602 BD  
Eindhoven, The Netherlands

**For more information call:**  
In the U.S.A. (800) 443-5853 or  
Fax (425) 446-5116  
In Europe/M-East/Africa +31 (0) 40 2675 200 or  
Fax +31 (0) 40 2675 222  
In Canada (800)-36-FLUKE or  
Fax (905) 890-6866  
From other countries +1 (425) 446-5500 or  
Fax +1 (425) 446-5116  
Web access: <http://www.fluke.com>

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