As photovoltaic systems become more commonplace, knowing how to troubleshoot one is a technician’s best bet for quality service during a call.

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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 many 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 PV 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 and obstructions are avoided. Note that less power will be generated in the winter than the summer due to the shorter days. Also, maximum power will be generated at mid-day 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. The electricity generated by a PV system...
A technician attaches a flexible current probe of a clamp meter as he prepares to troubleshoot a photovoltaic 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, technicians may be expected to perform some basic PV-system troubleshooting.

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 a 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 troubleshoot. 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, which means that HVAC technicians may need some basic troubleshooting skills.

Typical PV troubleshooting situations
Troubleshooting PV problems requires the use of a true-RMS ac/dc clamp meter with voltage capabilities for most of the work. Using a clamp meter with a flexible current probe capable of measuring the large number of wires connecting each module and array to the concentrator box—making the junction boxes stuffed with individual wires—makes the job easier. A flexible probe can help save time and increase accuracy.

Problem No. 1: Cell/Module/Array Problem—as with any troubleshooting call, try to get as much information from the customer as possible, such as prints, outputs and wiring diagrams. Try to find out when the problem occurred and when the last time the PV system operated normally.

Problem No. 2: Load Problem
Motor voltage can vary by ±10% without cause for concern. For example, a 230-Vac, 60-Hz motor can handle between 207 Vac and 253 Vac without causing damage. Voltage variations beyond 10% may indicate a problem with the motor or with wiring or connections.

Problem No. 3: Inverter Problem
With both single-phase and three-phase inverter models available, power output at the PV inverter can range from 5 kW to 17 kW and higher. Nominal dc voltage readings of 750 Vdc are common, with dc current readings of 12 A to 23 A, depending on the inverter rating. AC output voltages range from 380 V to 400 V line to line. From line to neutral, 220 Vac to 230 Vac is common.

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. Techs will have to trace out the individual branch wiring backward from the concentrator.

When on the roof, visually check the entire system for any obvious damage. Also, keep in mind that someone may have accidentally disconnected the wiring 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, a lightning 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 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 that should be checked with a 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 a meter at the junction boxes until the culprit is found.
If the inverter is not producing the correct output, first use a voltmeter and dc ammeter to check and record the inverter’s operating dc input voltage and current level.

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 a meter after any corrections are made.

Problem No. 2: Load Problem—Remember that the PV system is used to operate building electrical loads, so any problems with the loads will affect the system as well. The first step is to check the load switches, fuses and breakers. Using a voltmeter, check to see that the proper voltage is present at the load’s connection. Next, 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 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 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.

Problem No. 3: Inverter Problem—Many HVAC technicians work with variable-speed drives, so checking ac and dc power is an everyday task. 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 a voltmeter and dc ammeter to check and record the inverter’s operating dc input voltage and current level. On the ac side, use a 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. Using a true-RMS meter, the voltage and current can be used to measure and record the kilowatt output. If possible, use the inverter display to show the current total in kilowatt hours. 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, including a blown fuse, a tripped breaker or broken wires.

Also, use a clamp meter to measure the output ac side of the inverter, because the load on the inverter might have a current demand that is too high. The 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.

Keep in mind 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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