Green Inspections: SOLAR PHOTOVOLTAIC SYSTEMS

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GREEN. It's difficult to get through a day without hearing or seeing the word. Whether it's green jobs, green buildings or green energy, green seems to have gone beyond the mainstream and is approaching a mania. Not that there's anything wrong with that. After not being green for so long, we have some catching up to do.

One of the more established forms of green energy is a solar photovoltaic (PV) system. While rare on most homes we inspect today, we will see more of these systems in the near future as PV system costs decrease, installation incentives increase and utility rates maintain their inexorable march upward. This article presents basic information about PV systems including common types, components, inspection issues and installation considerations.

NOT MY JOB

PV systems are and probably will remain out of scope for home inspections. Nevertheless, while you disclaim PV systems, you can look for certain basic issues during your inspection that can benefit your client and can differentiate your inspection services from others. A basic understanding of PV systems also will help if you decide, as I did, to install a PV system on your home.

PHOTOVOLTAIC SYSTEM TYPES

A basic PV system is a collection of individual silicon-based solar cells assembled into modules that are, in turn, assembled into one or more arrays that produce direct current (DC) voltage when exposed to light. The PV system may use new thin film technology that is integrated into building materials, such as shingles, to produce voltage. Such systems are not yet common. Using few other components, the array provides DC voltage to run DC-compatible lights and equipment during the day and to charge batteries for use at night and on cloudy days. Obviously, this basic system is practical only for survivalists or for remote, rustic buildings. Most PV systems are more complex.

The next level of complexity is a stand-alone PV system. In this system, most of the DC voltage from the array is passed through a device called an inverter, which changes the DC voltage into alternating current (AC) voltage. The remaining DC voltage charges the batteries. A large enough system can power an average home that does not have high-demand appliances such as air conditioning and electric cooking. These PV systems are financially attractive when the building is located far from the electric grid.

The most common PV system is a grid tie system; also known as a utility-interactive system. Grid tie PV systems come in two forms. In one form, the PV system supplements power from the grid. If power from the PV system is greater than the power the building is using, the PV system may feed the power into the utility's grid. Utilities will usually offset the power supplied to the grid against the customer's electric bill, but the amount of the offset varies by utility.

It is important to note that a grid tie PV system automatically shuts down (in most configurations) when grid power is interrupted. This prevents a potentially dangerous power back feed condition that could injure workers who are trying to restore grid power. Thus, this form of grid tie PV system usually provides no power when grid power is down *(see illustration at right).*

The National Electrical Code (NEC) allows a grid tie PV system to operate in stand-alone mode if it supplies circuits that are disconnected from the grid. A grid tie/stand-alone configuration requires sophisticated (read expensive) automatic relays and different building wiring and, as such, is not common in residential applications.

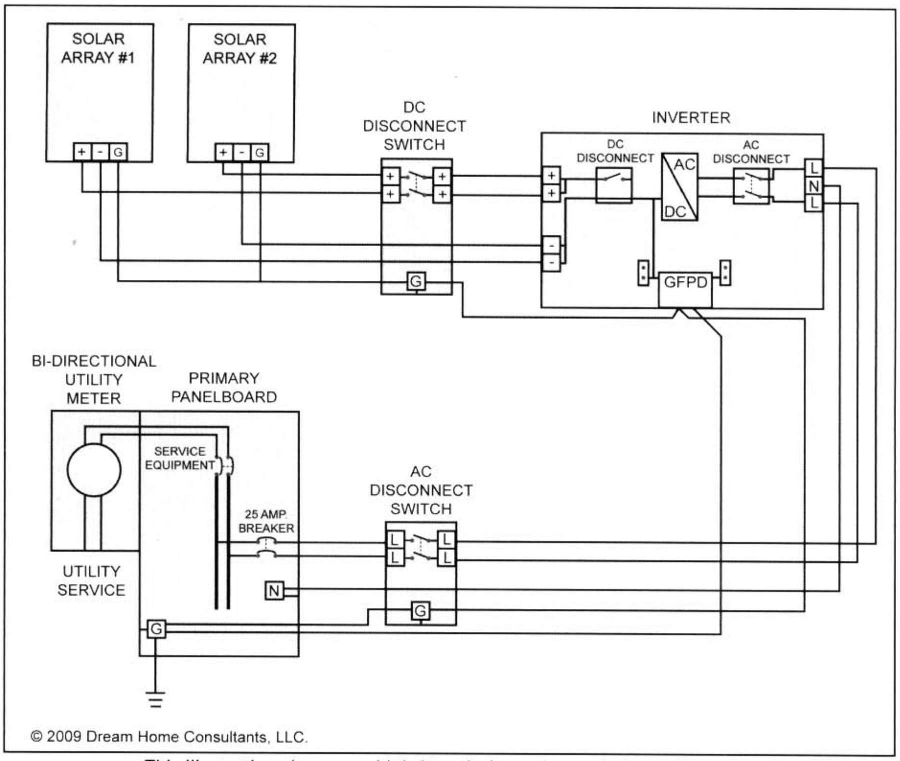
The other grid tie PV system form adds battery backup for power when grid power is interrupted. The PV system still shuts down (in most configurations) when grid power is interrupted, but some power is available depending on the number and size of batteries. The additional cost of batteries and their storage and maintenance makes grid tie battery systems less popular than the regular grid tie system.

The most complex PV system is the hybrid system. This system uses other alternative energy sources in addition to the PV system to provide electricity for immediate use and to charge batteries. These other sources could include a fuel-powered generator, wind turbines and/or a micro-hydro generator (a small water-powered generator). A hybrid system may be stand-alone or grid tie.

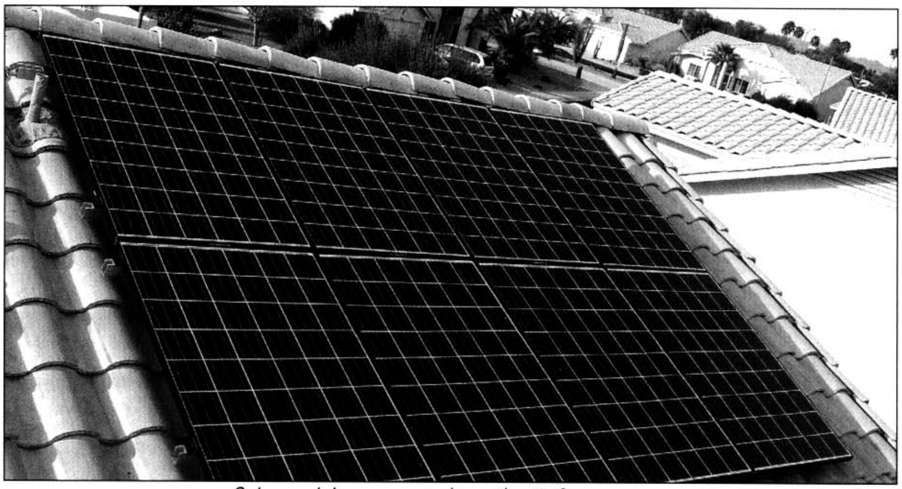
COMMON PHOTOVOLTAIC SYSTEM COMPONENTS

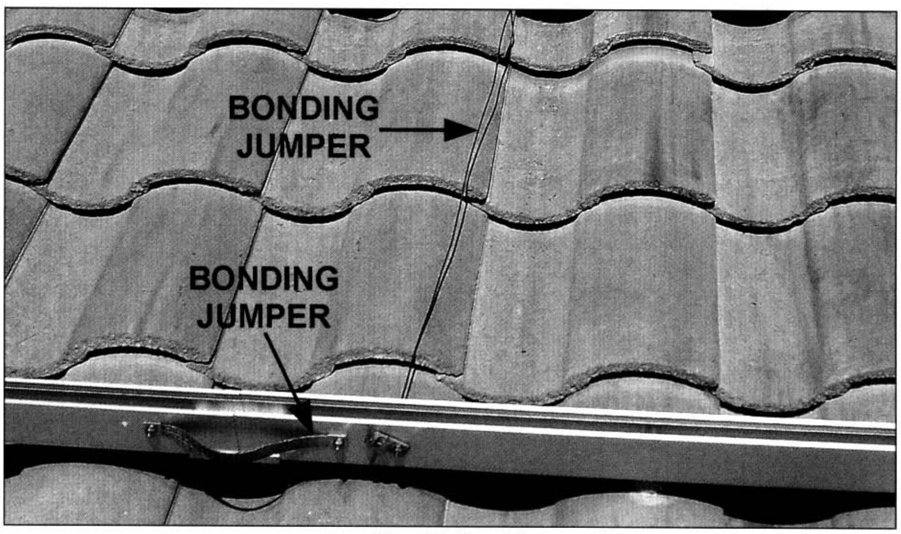
A PV system may contain the following components.

1. Solar modules (one or more) connected together to make an array. Modules may be connected in series or in parallel, and arrays of modules may be connected in series or in parallel depending on the DC voltage input requirements of the inverter(s). Connection of modules in series produces a voltage equal to the sum of the voltages of the individual modules, similar to batteries in a flashlight *(see photo middle, right).* ▶▶▶



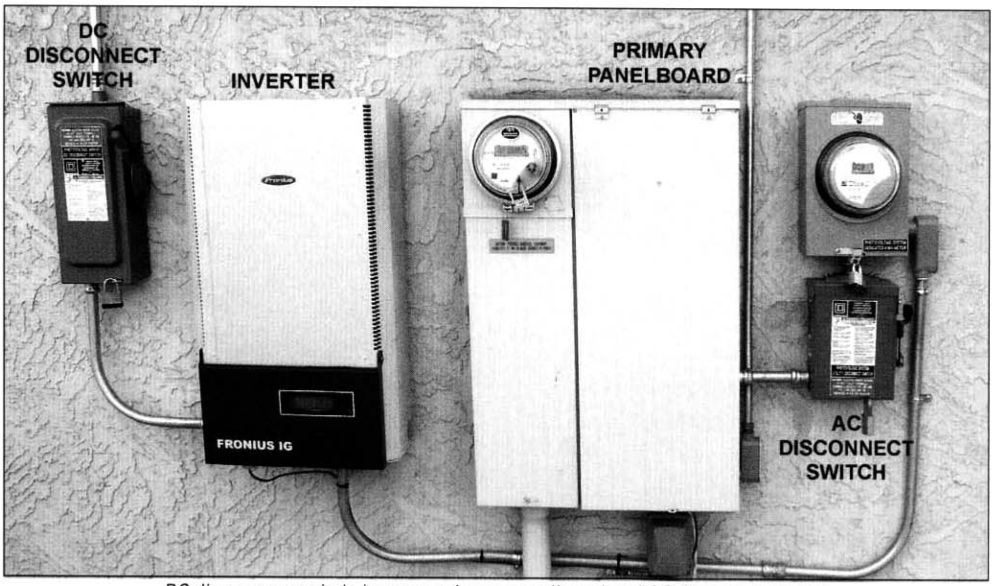
This illustration shows a grid tie/stand-alone photovolatic configuration.


Solar modules connected together to form an array



Mounting brackets

DC disconnect switch



DC disconnect switch, inverter, primary panelboard and AC disconnect switch

2. Mounting brackets and hardware that are compatible with the solar modules and with roof covering on which the modules will be installed. Many roof-mounted modules will sit a few inches above the roof and at the same slope as the roof. Some roof-mounted modules, particularly on low-slope roofs, may have supports that tilt the panels and improve the array tilt angle toward the sun *(see photo, bottom of previous page).*

3. Conduit (tubing) and wires that are compatible with the mounting brackets and the solar modules, and that are large enough to handle the anticipated current generated by the PV system. Most normal wire protection and wire size rules apply to PV systems.

4. A DC disconnect switch that disconnects the output from the arrays and isolates the arrays from the rest of the system *(see photo above, left).*

5. Inverters (one or more) that convert the DC voltage from the arrays into AC voltage. The required DC ground-fault protection device is usually contained in the inverter *(see photo above, right).*

6. An AC disconnect switch that disconnects the output from the inverter and isolates the inverter from the building wiring and from the utility service.

7. A circuit breaker (fuse) that connects the output from the inverter to the building wiring. This circuit breaker is usually installed in the primary panelboard, but it could be installed at any panelboard in the building wiring.

8. A tracker supporting one or more modules. A tracker is a motorized mounting device that moves the modules to follow the sun and maximize power output from the module(s).

9. Batteries to provide power at night and on cloudy days. PV system batteries are designed to last longer under the charging and discharging cycles common with PV systems.

OBSERVING A PHOTOVOLTAIC SYSTEM

I use the term observe for a reason. Unless you have training or experience with PV systems, I do not recommend that you claim to inspect them. You may, however, elect to observe the PV system and alert your client to have it evaluated by a qualified specialist if you observe potential issues. Here are some potential issues to look for in grid tie and stand-alone PV systems.

1. Module physical condition

- Check for cracked or damaged modules and for evidence of moisture intrusion on the inside of the modules.
- Verify that the mounting brackets are securely fastened to the structure and that the modules are securely attached to the brackets. If accessible, check in the attic for water infiltration under the modules and where any wires enter the building.

2. Bonding of current-carrying metal parts

- Verify that metal parts of the arrays, mounting brackets, conduit, tubing, switches, cabinets and inverters are bonded together, both physically and electrically, to provide a path to ground for fault current.

3. Grounding of PV equipment

- Verify that DC source(s) (arrays and batteries) and the AC output (inverters) are connected to grounding electrode(s). Grounding usually occurs at the primary building panelboard or at the service equipment. The PV system's grounding electrode wire(s) are usually the same size as the service grounding electrode wires. If separate DC and AC grounding electrodes are installed, bond the electrodes together using the same size wire as the service grounding electrode wire.

4. Protection of wires


Conduit pipe containing PV system wires

- Verify that individual wires are protected in conduit or tubing that is appropriate for the environment. Individual wires may run for short distances between modules if the wires are sunlight-resistant. Exterior cables such as UF and SE may be used for the PV source (array) circuits.
- Verify that DC source wires run inside the building are protected in metal conduit or tubing.
- Verify that PV system wires are not in the same conduit or tubing as other wires such as lighting and appliance branch circuit wires. Normal rules for conduit and tubing installation apply to PV systems *(see photo above)*.

5. Disconnecting equipment

- Verify the presence of disconnecting equipment between the array(s) and the inverter (or load if no inverter), between any batteries and the inverter, and between the inverter and the AC load (panelboard). The disconnecting equipment must disconnect only the hot (ungrounded) wires.
- Verify that the disconnecting equipment is readily accessible and that it is permanently labeled to identify the function of the equipment with a permanent label. The disconnecting equipment need not be readily accessible if is within sight of a grid tie inverter that is not readily accessible.
- Verify that the output from an inverter is not connected to the load side of a GFCI circuit breaker.
- Verify that the maximum six disconnecting means rule is followed.

6. Batteries

- Verify that batteries are connected to operate at not more than 50 volts.
- Verify that the live parts of batteries and wires are protected against accidental contact, dropped tools and similar dangers. ▶▶▶
- Verify that the tops of metal racks that support batteries are at least six inches above the tops of the battery cases.
- Verify that automotive batteries are not used. These batteries do not work as well in PV systems and could be dangerous if improperly charged.

PHOTOVOLTAIC SYSTEM DESIGN AND INSTALLATION CONSIDERATIONS

The following are some design and installation considerations that will help you or your client begin evaluating PV systems:

1. Array orientation. An array should face as close to due south (180°) as possible. An array that is off azimuth (facing other than south) is less efficient.

2. Array tilt angle. An ideal array will have the sun directly overhead (180° angle to the sun) for as much of the day as possible. Few PV systems have an ideal tilt angle. An array with a more oblique tilt angle is less efficient.

3. Shade. Trees, buildings, chimneys and other things that cast a shadow on the array at any time during the day will reduce system efficiency.

4. System efficiency. Indicated wattage ratings for modules and inverters are measured under ideal conditions. Real-system performance may be less than indicated by 30 percent or more. Projected actual system efficiency at the PV system site is important when determining system size.

5. Roof covering age. Modules may last twenty-five years or more. This is longer than the design life of most roof-covering materials. Consider the condition of the roof-covering materials before installing a PV system.

6. Net metering. Some utilities offset the power that your PV system generates against your electricity bill at the same rate they bill you for their power. This is called net metering. Some utilities offset your power at a lesser rate and some reset to zero any positive balance in your account at year-end. Utility terms and rates affect your payback period and may affect the optimum system size.

7. Cost per kWh. Electricity is usually billed in kilowatt hours (kWh). A kWh is when 1,000 watts are used for one hour, or 100 watts are used for 10 hours and so on. Utility bills contain fixed costs that do not vary with usage and variable costs that vary with usage. Finding all of the variable costs may require digging into the utility's tariff filings with the local utility regulator, but this information may be helpful when calculating the optimum system size and calculating the payback period.

PHOTOVOLTAIC SYSTEM SUMMARY

Recent federal tax law changes have significantly increased PV system tax credits. Many states and utilities also offer PV-system incentives that can reduce the net cost of a PV system and make the payback period more realistic. For these and other reasons, we will see more PV systems on homes we inspect. Inspectors who have a basic understanding of PV systems can improve service to their clients. ■

Bruce Barker, Dream Home Consultants, Peoria, Ariz., has been building and inspecting homes since 1987. He is the author of Everybody's Building Code and currently serves as chair of the Standards Committee.