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Hand Tools Used For Solar Photovoltaic (Pv) Systems

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Introduction

Hand tools are available to assist the solar energy system owner to measure the power output of their system, or to make adjustments in the tilt and orientation of a solar module or array to maximize the energy production of their system.

Placement of a solar module or an array to capture the sun's energy and transform it into direct current electricity, determining the suitability of a site as location for a solar module or an array, or measuring voltage and amperage are best accomplished with the right tools. These tools are easy to use and readily accessible.

Figure 1. A digital multimeter with leads connected. This tool can be used to measure circuit voltage, continuity, and resistance. Source: Author

Digital Multi Meter

One of the most versatile and ultimately a "must-have" tool is the digital multimeter. To check the energy output of a PV module, a digital multimeter with both alternating current (AC) and direct current (DC) capabilities is an important tool to have on hand. Direct current voltage can be measured using the multi meter. Refer to the fact sheet on the back of the solar module to determine the value for Open-Circuit Voltage (Voc). This is a voltage value when the module is not connected to a load. This value will be higher than the value for Voltage Max Power (Vmp) – when a load is connected to the module - because there is no resistance. More information about how temperature affects module performance may be found below.

Always check the operation of the digital multimeter to make sure it is functioning properly. Select a known operating circuit. Be sure to set the voltage to DC. Place the leads of the multimeter on the terminals of a D cell battery. The positive terminal will be on end, and the negative terminal will be on the other end. Check to see what the rated voltage is for the battery before testing to see if the value on the meter is consistent. Reverse the leads to see if the value changes (a negative sign appears when the positive lead is placed on the negative terminal). Plug the red and black leads into the ports on front of the meter. Turn on the meter.

Turn the dial to V for voltage. Check to make sure the meter mode is in Volts DC. Locate the positive (+) connector on the PV lead connected to junction box on the rear of the PV module. Touch the point of the positive (red) lead of the multimeter, and the negative (-) connector lead of the module to the common (black) lead of the multimeter.

Open-circuit voltage is checked when there is no load connected to the module. At full sun, the rated open-circuit voltage value will be higher than the voltage value (under load) at maximum power. Full sun is defined by the manufacturer as 1,000 watts per square meter (1,000 w/m2) which typically occurs between 9:00 AM and 3:00 PM on a clear, sunny day. A Pyranometer (see below) is used to measure the level of sunlight intensity (irradiance) that is hitting the earth at this location. The use of the instrument is described below. To see the effect of module tilt on output, adjust the module angle and observe the voltage values on the meter. Check the open-circuit (OC) voltage of a module when lying flat (0o), at 45o tilt, and standing vertical (90o).

Figure 2. The open-circuit voltage (Voc) of a 20-watt solar PV module is measured connecting the positive lead of the meter to the positive connector, and the negative lead to the negative connector. The reading is 21.10 Voc in full sun during the middle of the day. In this photo, a digital clamp-on ammeter with leads is used to perform the circuit measurements. Source: Author

Clamp-On Ammeter

Solar modules produce direct current (DC) electricity when phA digital clamp-on ammeter can be used to measure circuit voltage (as with the digital multi-meter) as well as circuit amperage. Circuit amperage (or current) is safely checked with a clamp-on ammeter. The ammeter is used to measure direct current (DC) amperage moving through the circuit while wired to a load. Set the meter to a setting higher than the expected current level of the circuit to be measured to prevent damaging the meter. On this model of meter the lowest DC amperage setting is “40 A” (40 amps). Make sure the meter is reading DC amperage.

Prior to taking any measurements, always check the operation of the digital multimeter to make sure it is functioning properly. Select a known operating circuit. Be sure to set the voltage to DC. Place the leads of the multimeter on the terminals of a “D” cell battery. The positive terminal will make contact with one end (+) and negative terminal will be on the other end (-). Check to see what the rated voltage (expected value) is for the battery before testing to if the value on the meter is consistent. Revers the leads to see if the values changes (a negative sign appears when the positive lead is placed on the negative terminal.

Check the style of connector on the end of the PV cable on your modules. Some lower watt model modules may come with alligator clips, or round eyelet connectors (to be placed over a threaded bolt). A larger-watt model may have a MC-4 plastic (see photo) connector attached. This type of connector is common to commercial solar PV modules and requires the use of a plastic key to unlock and disconnect the male from the female end connector.

To check short-circuit current (Isc) value of the module, carefully connect the positive lead to the negative lead (make sure the panel is turned over --- not facing the sun --- when making the connections). Urn the panel back over after making the connections. This will make a complete circuit. Place the clamps near the conductor and zero out the meter

Figure 3. Example of an AC/DC Clamp-On Meter. This model shows no leads connected to the meter. This style meter may be used to measure voltage and amperage. Source: Author

Figure 4. MC-4 multi contact connectors (male on left and female on right) are commonly found on commercial solar PV modules. The interlocking connectors prevent accidental disconnecting while under load. Source: PV-Cables, Inc.

Figure 5. This plastic key (Multi-Contact Spanner) is used to unlock the MC-4 solar PV end connectors. Source: PV-Cables, Inc.

by pushing the button until a zero reading is visible. Open the jaws of the meter and enclose the conductor. Make sure only one conductor is in the clamp. Determine what the expected short-circuit current (Isc) value should be for the circuit. For example, a 20-watt module with a rated short-circuit current of 1.21 amps should measure a value close to this number when a reading is taken in full sun. Lower numerical values may be a result of low sunlight intensity. If two modules are connected together in series (wired positive to negative), the expected amperage values should be the same as one module under maximum power (Imp). If the same two modules are connected together in parallel (leads are connected positive to positive and negative to negative), the expected amperage values will be added. Wiring module in series (a series string) is used to build voltage. Wiring modules in parallel is used to build amperage. In a PV system the strings of modules are connected a combiner box. Inside the box, all of the positive leads are landed on a bus bar. The negative leads are landed on a grounded bus bar. Collectively, this is called the source circuit.

Figure 6. Measuring the short-circuit current (Isc) of a 20-watt solar module with a digital clamp-on meter. The module leads are connected together and the meter clamp encircles one of the conductor leads. The reading is DC current of the module when there is no load. Source: Author

Figure 7. The sunlight irradiance level is read with the pyranometer. The meter rests on the frame of the solar PV module and pointed toward the sun. As the level of the sunlight intensity approaches 1,000 W/m2, the solar PV module is producing at the manufacturers rated power. Source: Author

Figure 8. The angle finder is an expensive tool used to check the tilt angle of the module. The finder is set on the frame of the module and the angle in degrees can be read on tool. Source: Author

Pyranometer

Solar PV module power ratings are based on solar industry-recognized standard test conditions (STC). One condition is the level of sunlight intensity (irradiance). At midday, on a cloudless sky, the irradiance level is measured at 1,000 W/m2. Sunlight intensity changes over the course of the day. From dawn to dusk, sunlight irradiance will go from "0" to over 1,000 W/m2, and back down to "0" at sundown. A cloud moving in front of the sun and resulting in shade may result in a drop in the irradiance level. When the cloud clears the sun, the value may increase again. To take a measurement, turn on the unit and direct the top end of the meter toward the sun. To determine the level of sunlight shining directly on the module, rest the meter on the frame of the module with the top toward the sky.

Read the meter. See what happens when the tilt or angle of the module is adjusted. A meter reading of 500 W/m2 equates to 50% of the sunlight intensity. The energy output of a module at 500 W/m2 can be expected to produce 50% under this condition. When the light intensity changes, so does the power output of the solar module. A pyranometer can be purchased online for a cost in the range of $100.00 to $165.00.

Angle Finder

Setting the solar module at the optimum tilt angle increases the power output. Depending on the time of year the sun may be higher or lower in the sky. Adjusting the tilt angle by 15 degrees (latitude) can result in an increase in the energy output of the solar module. A module set at a tilt orientation of 0 degrees (horizontal) will produce power. However, a solar module mounted in a flat position is subject to collecting dust which can turn into mud and result in shading, and reduced power output. A solar module mounted in a vertical position (90 degrees) may not be positioned to capture maximum sunlight exposure, or a limited amount of sun it passes across the sky. Use the latitude of the geographic location as a recommended mounting tilt and orient the module to the south. To check the effect of module tilt angle on power output, set a module at three tilt angles and take voltage readings. Set the module at 0o (flat, horizontal) 45o (angle to the ground), and 90o (vertical, end of module resting on the ground). A tilt meter can be purchased at a local hardware store for as low as $5.00.

Non-Contact Thermometer

The standard test condition (STC) for temperature of a solar cell is 25o C (77o F). A 20-watt solar module capable of producing 17 volts is doing this assuming the cell temperature is no higher than 25o C (770 F). This is the surface temperature of the cell, not ambient air temperature. Exposure to the sun will heat up the module. As the temperature of the solar cells increase, the voltage of solar module will decline.

Changing cell temperatures can result in fluctuating voltage changes of around 15 to 20% both higher and lower than the module STC rating (SEI, 2013). A module fact sheet may feature temperature coefficient values. These values are typically listed as a percentage and represent the possible change in module performance (maximum power (Pmp), open-circuit voltage (Voc) and short-circuit current (Isc) when the temperature is above or below 250C (770F). For example, a module with a temperature coefficient value for maximum power with a rating of TkPmp: - 0.45%/0C, means for every degree Celsius the module cell temperature is above 250C, maximum power of the module will decline by 0.45%. A TkVoc: - 0.33%/0C equates to a decrease in the open-circuit voltage of 0.33% for each degree the module cell temperature is above 250C. These calculations are taken into consideration in the design of a PV system and include the record high and low temperature values for the geographical region.

Mounting solar modules to permit air circulation helps to cool solar modules. To check the cell temperature, use a non-contact thermometer and point to the white back sheet of the module. This tool is relatively inexpensive (approximately

Figure 9. A non-contact thermometer is simple to use to record the surface temperature of the solar cell when taken from the back side (white) of the module.Source: Author

Figure 10. The Solar Pathfinder™ is a site assessment tool used to help the PV system installer determine the suitability of a site by examining the amount of potential shading cast on the location from nearby trees, buildings, utility poles, lines, chimneys, and vent stacks. Source: Author

$45.00), and easy to use. Set the temperature to Celsius or Fahrenheit. Point the meter to the back side of the module and pull the trigger. Locate the red laser dot. Read the thermometer. Check at various locations on the module, and at various times of the day to observe how the temperature of the solar cell increases with very little sun. Because the voltage decreases when the temperature increases, to compensate for the loss of voltage, a system design may call for the addition another module to make up for the loss. Check the expected voltage (from the back sheet of the module) or calculated voltage if measuring an array, to the actual measured voltage value. Large differences between calculated or expected values and measured voltage may suggest a module that is not operating or a wiring connection that may be loose.

Solar Pathfinder

When selecting a site for mounting a solar module or array, there are several factors to consider: type of mounting system, location from the residence or building, and the amount of shading the location experiences over the course of the year. When considering a site, take a 360-degree view of the area. Are there objects nearby that will cast shade on a solar array? Are there trees, utility poles, or buildings that may cast shade onto the site? Shade results in decreased power output. Sometimes, a site location is limiting, such as a residential roof mounting system. When an east or west-facing sloping roof is considered, the amount of direct sun light (total peak sun hours) needs to be calculated.

The Solar Pathfinder takes a 360-degree view of the location. A sun chart for the desired latitude is placed on the Pathfinder, and the plastic dome is set in place. Around the border of the dome, any visual obstacles such as trees, shrubs, poles, buildings, that are seen in the skyline can be seen on the dome. The dark area is cast over the sun chart. Using a white chalk marker, the outline of the landscape against the sky can be traced. Once the plastic dome is removed, the user can see the shaded areas and calculate the percentage of shade over the course of a 12-hour period (during daylight hours) and over the course of the year (12-months) by counting and summing the numerical values in the grid (time of day and months of year). The lower the calculated shading percentage, the better the site is for a solar module or array.

Conclusions

As my father always told me, use the right tool for the job. Before using any tool to take measurements such as voltage or amperage, or to determine continuity, or to make adjustments on a solar module or array, safety precautions must be taken to prevent from receiving an electrical shock. When making connections to a solar module, turn the module away from the sun or cover it with a dark cloth or cardboard. If possible, make the adjustment when the sun is not shining (at night). When working with an array, de-energize the system by using the disconnect switch. Turn off the switch and connect the leads of your multimeter to your switch terminals to determine if voltage traveling into your system. Use clamp on meter to see if any electrical current is moving through the conductors. If the readings are zero (0.00) your system should be de-energized. If you have any questions or doubts, always consult an electrician. Also, to protect the metal contacts in the tips of the connectors from arcing and causing carbon deposits, use PV cable leads between the module cables and the load.

An understanding of the solar PV system and the associated hand-tools used to take measurements, to determine the sunlight intensity, check tilt-angles, and measure solar cell temperature are important to determine if your solar PV system is functioning properly. Inspecting the condition of the PV cables, and checking the array surface for build-up of dust are simple methods to maintain a solar PV system.

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