Innovative Idea

Tilt-A-Whirl: A Method to Demonstrate the Effect of Tilt & Orientation on Solar Module Output

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Introduction/Need for Innovation

Successful installation of a solar photovoltaic (PV) energy system is a culmination of knowledge of several variables (Del Vecchio, 2009). Knowledge of sun location in the sky during different seasons, correct solar PV array tilt angle to align with solar altitude, and aligning with the desired solar azimuth (orientation) in a southernly orientation are the first steps. Since shading is a major issue in evaluating the potential for a solar array installation (Sanchez, 2009), solar PV installers need to consider array placement on roof tops, poles, and ground mount arrangements.

A method to teach the concept of solar PV module tilt (in degrees) and orientation (azimuth degrees) to students in a solar PV energy source lab class is to use a demonstration tilt table. Solar peak sun hour (PSH) sheets (NREL, 1999) for each state present data based on five tilt angles: Flat position (0^{o}), Latitude –15 (degree-latitude minus 15^{o}), Latitude (actual geographic latitude), Latitude +15 (degree-latitude add 15^{o}), and Vertical (90^{o}). A student can take a solar module, lay it out flat, then tip it up. The challenge is supporting the module while holding tools to measure solar irradiance, tilt angle pitch, and solar cell temperature. Plus, adjusting the direction the module faces toward the sun.

How it Works

A round laminate wood disk is mounted to piece of laminated lumber using a "Lazy Susan" to provide 360-degree rotation. We mounted small (1-inch) aluminum angle frames. Measured and cut to fit the length of the solar module. Our goal is to be to rest the module (in a horizontal position) on the wood disk and raise the module to stand in a vertical (90-degree) position. This positioning permits the end of the module to be lifted and tilted in any position from zero to ninety-degrees. The rotating base allows the user to adjust the positioning of the module to any position found on an azimuth compass. In the northern hemisphere, it is common to face solar modules to the south (180-degrees) toward the Equator. As the sun rises and moves across the sky over the course of the day, the module can be tilted to face the module and oriented in a direction to follow the sun.

To determine the optimum module tilt (zero to ninety-degrees), a clamp on digital multimeter is used to measure direct-current (DC) short-circuit current (Isc). The connectors on the leads from the junction box on the rear of the solar module are connected (positive lead to negative lead). The meter dial is moved to DC A current setting. The user will view the solar module cut-sheet to determine the rated module short-circuit current (Isc) value. Solar irradiance (sunlight intensity) is proportional to module current. The brighter the sun, the higher the current output. To obtain optimum module performance, we aim to align the face of the solar module, so its surface is perpendicular to the sun to maximize direct sunlight exposure. A solar irradiance meter measures sunlight intensity in Watt per square-meter (W/m^2). On a clear day, sunlight intensity will reach 1,000 -W/m^2. This is a standard test condition (STC) value for all solar modules.

A second set of angle frames are attached to the round disk. A long-threaded rod with wingnuts attached to each end is passed through holes drilled into the aluminum angle. This permits the angle to lay flat and rotate up to a 90-degree angle. Attach the angle to the sides of the module, then rest It on the disk. Align the two pieces of angle to be mounted to the board to the angle mounted to the solar module. Mark locations for screws and mount the angle to the disk. We are to lay the module flat (0^o) and tilt up to vertical (90^o) position. Use bolt and wing nut to adjust tighten. Use Velcro strips mounted on top edge of solar pv module. One for the irradiance meter, one for angle finder. Another attached to rotating board in front of the module for the Azimuth compass. Used to determine orientation (0^o-360^o). Attach compass. Connect connector cable on the module. Measure short-circuit current. Set DC current on meter. Attach irradiance meter to module. Attach tilt meter to module. Turn on meter. Slowly adjust tilt to find the highest meter reading. Rotate the table. When you find your highest value, stop. Check your angle finder and record the degree tilt. Check the compass to determine the solar orientation. Your orientation values will be between 90^o and 270^o. You can use a solar path chart for your location (by latitude) to determine the values you should be obtaining (based on time of day, month of year).

Results to Date

We constructed one tilt and spin table. We use it during our solar lab for introducing solar hand tools, measuring solar module tilt angle, modeling sun patch charts, and measuring the effect of orientation on power output. In addition to the solar labs, we demonstrate the systems during solar outreach presentations for Cooperative Extension workshops, and invited conference presentation.

Future Plans

Create a learning video for demonstrating the use of this teaching tool for students who are unable to attend a lab in-person and for extension solar outreach programs. Additionally, we plan to create a "how-to" project building activity for teachers attending a solar professional development workshop to construct, demonstrate, and take back to their local program to use for their classes.

Costs/Resources

Primary materials include the "Lazy Susan" ($5.00) hardware, laminated wood disk ($6.00), laminated wood ($8.00), aluminum angle iron ($12.00), assorted fasteners (screws, bolt, wingnut) ($4.00). Items to use in working with the solar module (including measurement tools) are a 10-watt solar module ($30.00), a solar irradiance meter ($165.00), angle finder ($8.00), azimuth compass ($6.00), and Velcro adhesive strips ($7.00) for temporarily mounting the irradiance meter and tilt meter to the top edge of the solar module.

References

Del Vecchio, D. (2009). Optimizing a PV Array with Orientation and Tilt. *Home Power Magazine 130*, p. 52-56.

National Renewable Energy Laboratory (NREL). (1990). *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors*. National Renewable Energy Laboratory.

Sanchez, J. (2009.) Solar Site Assessment. *Home Power Magazine 130*, p. 46-50.

Solar Energy International. (2004). Chapter 3 - The Solar Resource. *Photovoltaics: Design and Installation Manual.* (p.23-36). New Society Publishers, Limited.