PV Hands-on Lab Activity Form

Date: February 15, 2012

Instructor: Peter T. Parrish, College of the Canyons Class: Solar 050 “Photovoltaics”

Lab Title: #2 PV Module Electrical Characteristics: Effect of azimuth, tilt, orientation and temperature on production Time Allotted for Lab: 12 hours

1. Lab Introduction / Description:

This lab is the second in a 8 lab-sequence that I have developed at College of the Canyons. It is preceded by a lab on the *Sun as a Resource*. This precursor lab deals with the sun’s path through the sky as a function time of day and time of year. It investigates the concepts of solar irradiance, solar power and solar energy. It introduces the “gnomon,” a vertical rod that casts a shadow on the ground, which in turn allows us to determine the elevation (altitude) and azimuth of the sun. In turn, if we know our local latitude, we can determine the time of day and (theoretically) the day of the year.

In this the second lab, the gnomon is placed perpendicular to the plane of a PV module and the ratio of the length of the shadow cast to the height of the gnomon determines the angle between the sun’s rays and the normal to the surface of a PV module ($\cos\Theta = L_{gnomon}/L_{shadow}$). This allows us to convert the basic irradiance of the Sun to the irradiance normal to the plane of the PV module in question.

The module for this lab is comprised of 36 each 125mm x 125 mm mono-crystalline silicon cells. This PV module is mounted on a two-axis tripod allowing the PV module to be adjusted in tilt angle and azimuth. The PV module is also equipped with a DayStar irradiance meter, that is attached to the PV module and oriented perpendicular to the plane of the module, and a thermocouple affixed to the module back frame.

2. Performance Objectives:

The student will measure a number of electrical characteristics: Isc and Voc, and a number of operating voltages and currents for different load resistances. The student will measure the ambient and back plane temperature (using the thermocouple and an IR thermometer) and the irradiance perpendicular to the plane of the module.

These measurements are then repeated for a range of tilt angle and azimuth.

3. Safety:

Gloves, long sleeve shirt, hat/cap, sunblock.

4. Equipment/ Facilities/ Supplies:

- Equipment: PV module, tripod, thermocouple, gnomon, variable load box (1Ω, 2Ω, 3 Ω, 4Ω, 8Ω, 16Ω), PV module datasheet.
- Tools: irradiance meter, digital multi-meter, infrared thermometer, ruler

5. Procedures:

(a) Align PV module to point directly at sun by using a gnomon and/or irradiance meter; lock module in place. (b) Record the irradiance. (c) Wait five minutes and then measure the back plane temperature using the thermocouple/DMM and the IR thermometer. (d) Measure I_{sc} and V_{oc} using the DMM. (e) Measure I_L and V_L using the DMM and variable load box for the six load impedances. (e) Change the tilt-angle and/or azimuth so that the sun's rays are at least 30 degrees off the normal to the PV module, as determined by a measurement of the shadow cast by the gnomon ($L_{gnomon}/L_{shadow} = \cos\Theta$). (f) Repeat steps (a) through (d).

6. Activity:

(a) Plot the measured current/voltage pairs to produce a scatter plot of the I-V characteristic of the module. (b) Draw a smooth curve through the data points. (c) Measure the power I_L*V_L delivered to the load by the PV module for each of the five load impedances. (e) Identify the maximum power delivered P_{max} and the value of the load impedance for P_{max}. (f) Using the STC value for V_{oc} and the temperature coefficient for V_{oc}, correct V_{oc} for the measured back plane temperature and compare with the measured value. (g) Using the STC value for I_{sc}, correct the I_{sc} for the measured irradiance assuming I_{sc} is strictly proportional to the irradiance. (h) Using the STC value for P_{max}, correct P_{max} for the measured back plane temperature and irradiance and compare with the maximum value of I_L*V_L. (i) Repeat steps (g) and (h) using the new value of irradiance.

7. Documentation:

- Data recording requirements: notebook, pencil, ruler, Casio fx-260 solar calculator.

- Observations: (a) Verify that $V_{oc,cell\ at}$ STC is approximately 0.62 volts/cell. (b) Verify that the short circuit current at STC is approximately 340 A/m^2. (c) Understand the role of module temperature and irradiance on module electrical characteristics by comparing measured I-V characteristics with PV module data sheets. (d) Determine the accuracy of temperature coefficients for V_{oc} and P_{max}. (e) Determine the extent to which I_{sc} is strictly proportional to irradiance. (f) Compare the ambient temperature to the PV module back plane temperature and come up with reasons for the fact that they differ.

8. Results/ Conclusion/s:

Gain a clear understanding of PV module I-V characteristics, and how they depend on module back plane temperature and irradiance. Determine the open circuit voltage per cell and the short circuit current per unit area of one cell. Determine the approximate value for P_{max} for the total cell area (area of a single cell times the number of cells in the module). Compare this value to P_{solar}, the total solar power incident on the cells (area of a single cell times the number of cells in a module times the irradiance in the plane of the module).

Express the ratio of electrical P_{max} to P_{solar} as a percentage. Compare with values given on the data sheet

9. **Student Evaluation**:

Verify that the students make accurate measurements of I_{sc}, V_{oc}, I_L, V_L, L_{shadow} and correct observations and results/conclusions.