PHOTOVOLTAIC PANEL CHARACTERISTICS

The objective of this experiment is to determine the voltage/current characteristics of a photovoltaic panel.

Background:

A simplified equivalent circuit of a PV cell is shown below. The equation describing the operation of the cell is:

\[ i_d = I_0 (e^{k \cdot v_d} - 1) - I_L \]

The current \( i_d \) and the voltage \( v_d \) are defined in the equivalent circuit. For an amorphous silicon cell of 1 cm\(^2\), the light dependent current, \( I_L \), is 22mA for a solar radiation level of 100mW/cm\(^2\). The constant \( k \) is 20 and the saturation current \( I_0 \) is \( 300 \times 10^{-12} \) A.

Laboratory Equipment:

This lab will make use of:

1) multi-voltage PV panel
2) flood light
3) dc voltage supply
4) 2 digital volt/amp meters
5) 0-10 kΩ resistance box

The photovoltaic panel has three voltage levels, 3V, 6V, and 9V. Your lab TA will instruct you which one of the voltages is to be used by your group. The flood light will be connected to the dc voltage supply. This will allow you to adjust the light output. You will load the photovoltaic panel by connecting a resistance box to its output leads and varying the resistance from an open circuit to a short circuit. You will do this three times for three different light levels.

Procedure

1) Set the PV panel to your assigned voltage level. Place the panel on the bench so that the face of the panel is at the left hand edge of the left instrument connection panel.

2) Construct a circuit to measure the PV panel's voltage/current characteristics. Your TA will provide you with guidance. You will need to connect the 120V, single phase to the bench to power the volt/amp meters and the supply for the lamp.

3) Place the flood light so that the light shines on the PV panel and so that the front of the light is at the right hand side of the left instrument connection panel. Connect the light to the dc voltage supply. Turn on the voltage supply and adjust the light so that the open circuit voltage of the panel is equal to the voltage level that it is set to. (Use the maximum voltage if the light is not bright enough.) Have your lab instructor measure the light intensity. Record this value, being careful to note units.

NOTE: You are using a dc voltage on a light designed for ac voltage. A dc voltage of 120V should give you approximately the same light output as 60 Hz, 120V rms.
4) Starting at an open circuit and working to smaller resistances, record **Resistance**, **Voltage**, and **Current**. Record a range of current values from 0 A to a short circuit (with the ammeter acting as the short). Record enough data in order to make an accurate graph, keeping in mind the shape of the characteristic of the PV cell.

5) Adjust the dc voltage supply on the light to about 100V. Have your lab instructor measure the light intensity. Record the light intensity and the voltage on the light. Repeat Part (4).

6) Repeat Part (5) for a dc supply voltage on the light of about 80V.

7) Disconnect the power to the bench and clean up your lab station.

**Report**

1) Graph the current voltage characteristic of the cell described in the background section from \( v_d = 0 \text{V} \) to \( i_d = 0 \text{A} \). Use a computer program to generate the plot. Find the point where maximum power is generated. Calculate the efficiency of the cell at this point (electrical power out/solar power in). Take note of the shape of the voltage/current characteristic. Determine how the curve would change if the incident light intensity would change. **Sketch** the voltage/current curve for 2 other light levels, one which is brighter and one which is dimmer than 100mW/cm\(^2\). (The sketch can be done by hand on the computer printout. The magnitudes of the voltage and current are not important. What is important is the general shape and how the curves change with light input.)

2) On a single graph, plot the 3 voltage/current curves with the voltage on the x axis. Use a spreadsheet or similar program to plot the data. **Hand drawn curves are unacceptable!**

3) Calculate peak power point and fill factor for each curve. (See paper "Photovoltaics: Unlimited Electric Energy from the Sun", by J.L. Stone, pg. 4, for the definition of fill factor.)

4) The equation below can be used to approximate the I-V performance curves of a solar cell. Use your data determine the value of \( I_L \) for each lighting level. (Hint: you do NOT need to know the values of the constants \( I_0 \) and \( k \))

\[
i_d = I_0 [e^{kV} - 1] - I_L
\]

5) From the 3 values of \( I_L \) found in Part 4, try to determine an equation for \( I_L \) as a function of light intensity.

6) From your equation from Part 5, extrapolate the lighting intensity that would be required to produce the rated output current for the solar cell (either 50mA for the 9V and 6V setting, or 100 mA for the 3V setting). Compare this to the light intensity of full sunlight (approximately 10 000 foot-candles). Approximate the current output in moonlight (approximately 0.5 foot-candles). Comment on the accuracy of your model. What would you attribute any inaccuracies to?