ENVIRONMENTAL AND MECHANICAL ENGINEERING LABORATORY
Solar Energy Systems – Week 2
Effect of Shading on PV Panel Performance

General description

Solar energy systems are a viable option to produce zero-emissions, environmentally sustainable energy. There are two main kinds of generators that produce electricity and heat from solar energy: photovoltaic (PV) and solar thermal. PV panels are composed of many semiconductor wafers, convert solar energy directly to electricity without moving parts and are modular/scalable. In this laboratory experiment we will study several aspects of PV performance that inform the design and implementation of solar PV power plants to ensure that the maximum amount of energy is produced.

During your second laboratory section (Week 2) you will investigate the effect of shading on PV panel power output and efficiency. You will see that shading even a small portion of the panel area can significantly reduce the electrical performance and efficiency of the panel.

Objectives

1. Obtain baseline electrical performance data for an un-shaded PV panel.
2. Measure the reduction in panel power output and efficiency as a function of shaded area of the PV panel.
3. Investigate the effect of shading different portions of the panel on the power output and efficiency.

Procedures (Read all procedures carefully before beginning the experiment)

1. The general procedure for operation and measurement with the MP-170 is the same as during Week 1. Refer to your Week 1 lab handout for instructions on how to use the MP-170 PV performance testing device.
   Open the MP-170 and remove the cables from the compartment underneath the sensing unit. Take inventory of the cables to make sure they are all there. If any cables are missing please inform a course instructor immediately.
   - □ Power supply (black)
   - □ Grounding cable (green with yellow stripe) and clip
   - □ 2 PV leads (red and black with alligator clips)
   - □ RS-485 cable for sensor unit (white telephone cable)
   - □ USB-MiniUSB cable (grey)
   - □ 2 thermocouple wires (brown)

2. Locate a sunny spot in the EBU2 quad within reach of a power supply (you will probably need an extension cord). **NOTE:** If it is overcast or partly cloudy you should still do the experiment.

3. Place the 10 W Unisolar PV panel on a flat surface and set up the MP-170 for measurement. The general layout of the US-10 panel is shown in the diagram (below), where individual cells are labeled using standard matrix notation, i.e. *(row #,column #)*.

Refer to this diagram for the instructions in the following steps.

(1,1)	(1,2)
(2,1)	(2,2)
(3,1)	(3,2)
⋮	⋮
(11,1)	(11,2)

4. Take a baseline performance measurement when the panel is un-shaded.

5. Vertical shading – Begin by partially shading the first column of cells on the panel in increments of two cells. Using a completely opaque material cover cells in the following order: (1,1), 1 cell; (1,1) through (3,1), 3 cells; (1,1) through (5,1), 5 cells; (1,1) through (7,1) 7 cells; (1,1) through (9,1) 9 cells; (1,1) through (11,1) 11 cells.

6. Horizontal shading – Begin by partially shading the first row of cells on the panel. Using a completely opaque material cover cells in the following order: Row 1, 2 cells; Rows 1 through 2, 4 cells; Rows 1 through 3, 6 cells; Rows 1 through 4, 8 cells; Rows 1 through 5, 10 cells.

Error analysis

1. Calculate any systematic errors in the measurements you take.
2. Determine random errors from repeated samples.
3. Plot all data with appropriate error bars.

Questions

1. On a single graph plot and label the I-V curves for the measurements in Procedure step 5. On a second graph plot and label the I-V curves for the measurements in Procedure step 6. Plot the I-V curve for the un-shaded panel on both graphs for reference.
2. On a single graph plot and label the panel output power as a function of the load voltage for the measurements in Procedure step 5. On a second graph plot and label the panel output power as a function of the load voltage for the measurements in Procedure step 6. Plot the Power-Voltage curve for the un-shaded panel on both graphs for reference. MP-170 has an internal dummy load device (an "electronic load") that simulates loading on an electronic circuit. Electronic loads are used in place of traditional ohmic load resistors (e.g. potentiometer) and can handle large power inputs on the order of 10 kW. You are plotting the voltage of this electronic load.
3. On a single graph plot the ratio of the power at the maximum power point (P_{mpp}) of the shaded panel divided by the unshaded P_{mpp} as a function of the ratio of shaded area to total panel area for the measurements in Procedure steps 5 and 6 (make a separate line for the data from each step). Fit each line using a linear, least-squares regression. Which data fit the linear regression best? Discuss reasons for the different trends observed in the two datasets.
4. On a single graph plot the reduction in electrical conversion efficiency (η) as a function of the ratio of shaded area to total panel area for the measurements in Procedure steps 5 and 6 (make a separate line for each step). Fit each line using a linear, least-squares regression. Which data fit the linear regression best? Discuss reasons for the different trends observed in the two datasets.
5. Discuss the implications of your results in the context of PV system design.

Definitions

Electrical power (P) is related to current and voltage by

$$P = IV, \tag{1}$$

where I is the current and V is the voltage.

$$\eta = P_{mpp}/(GI_{POA}A), \tag{2}$$

where P_{mpp} is the power at the maximum power point on the I-V curve, GI_{POA} is the incident irradiance in the same plane as the surface of the PV panel and A is the panel surface area.

NOTE: η is automatically calculated during the measurement sequence of the MP-170, but you may want to check the value using Equation 2.