Pointing at Maximum Power for PV

Student Investigation Guide

In this experiment, you will measure voltage and current in order to determine the power output of a photovoltaic (PV) panel. You will vary the resistance in a simple circuit connected to the panel to demonstrate the effects on voltage, current, and power output. Then, you will calculate power for each resistance setting, creating a graph of current vs. voltage, and indentifying the maximum power point.

This field of PV panels in Alamosa, CO, is one of the largest PV power plants in the US.

Real-World Applications

Photovoltaic (PV) panels utilize a scientific technology that creates power from solar radiation. Because PV panels are expensive and their power production is limited by the amount of sunlight available, it is important for them to run as efficiently as possible. One way to improve PV panel efficiency is to adjust the resistance in the design of the electrical circuit to create a combination of voltage and current that results in the greatest power output. Engineers must understand how to control a basic circuit in order to design PV arrays that operate as efficiently as possible.

Introduction

Photovoltaic (PV) power is a clean and renewable energy source that is gaining popularity and is predicted to become a cost-effective source of electricity. To maximize the offset of greenhouse gases and minimize the long-term cost (maximize the return on investment) for PV panels, engineers must be sure that they can design solar systems that generate the maximum amount of power in all conditions.

Did you know that PV panels do not always produce the same amount of power? For example, the current produced by a PV panel varies depending on the angle between the PV panel and the sun. A PV panel that faces the sun receives more direct solar radiation than one that does not, and this helps to maximize the current flowing through the panel circuit. Although positioning has a great impact on the power output of PV panels, it is not the only factor that determines the

amount of power generated. Can you think of another factor in our circuit that might affect power? (voltage, resistance) The electrical equations (see below) show us that power (P) is equal to voltage (V) multiplied by current (I), and also that voltage, current, and resistance are all related by Ohm's law. Engineers use these fundamental electrical relationships to be sure that the circuit bringing power from the panel is designed to maximize the power output of the panel at all times.

Today, we'll be working with PV panels. We will record the current and voltage of our PV circuit using a potentiometer that varies the resistance in the circuit, and calculate the resulting power output. If we can find the point with the highest power output, then we have found the maximum power point and we know our panel is running as efficiently as possible for the existing conditions!

Materials List

- mini PV panel
- 4 wires with alligator clips
- multimeter
- potentiometer
- sunlight or a 100-watt incandescent lamp
- worksheet

Related Equations

$$\text{Ohm's law}: V = I \cdot R$$

$$\text{Power}: \mathrm{P} = V \cdot I$$

$V = \text{Potential Difference}$ [Volts, V]

$I = \text{Current}$ [Ampere, A]

$R = \text{Resistance}$ [Ohm, Ω]

$P = \text{Power}$ [Watt, W]

Troubleshooting Tips

- The wire connections are very important. Double check to make sure you have tight connections throughout the experimental set-up.
- Be sure that the wire ends are not touching any other conductive materials such as metal tables.
- The panels do not work well under fluorescent lights due to the reduced light spectrum of those bulbs.
- If the multimeter displays negative numbers, switch the leads.
- To achieve the best results, do not move equipment, so conditions are kept constant throughout the experiment.

Pre-Experiment Notes

The experiment can be conducted either outdoors in sunlight, or indoors using a 100-watt incandescent lamp. Simply place the PV panel under the lamp. **This lamp can become extremely hot! Be careful!** While conducting the experiment, make sure nothing blocks the light from reaching the panel. Try not to modify the position or any other variables that might disrupt the results.

Vocabulary

efficiency	The ratio of the useful energy delivered by a dynamic system to the energy supplied to it.
maximum power point (MPP)	The point on a power (I-V) curve that has the highest value of the product of its corresponding voltage and current, or the highest power output.
photovoltaic cell	A cell of silicone that produces a current when exposed to light.
potentiometer	A device that allows the user to vary the electrical resistances in a circuit.

Experimental Procedure

1. Obtain a worksheet (one per student) to fill out during and after the activity.
2. Obtain a Student Investigation Guide (one per group) to follow along with the procedure.
3. Bring to your work area the supplies in the Materials List. Then conduct steps 4-9.
4. Turn the potentiometer dial clockwise until it stops.
5. Assemble the circuit, as shown in **Figure** .

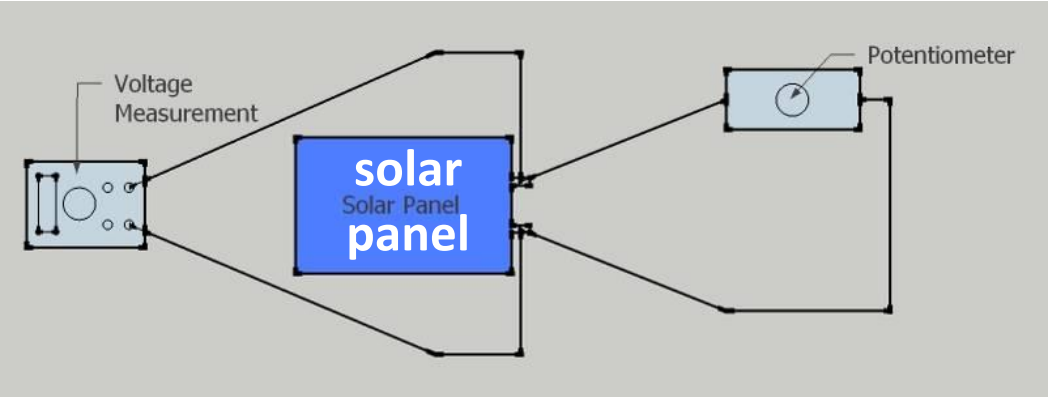

Figure 1: The electrical circuit configuration to measure voltage.

6. Turn the multimeter to volts DC (DCV) and measure the voltage. Record this value in the worksheet table. (Note: If negative value, then switch the leads.)
7. Reconfigure the circuit so that it looks like the diagram provided in **Figure** .

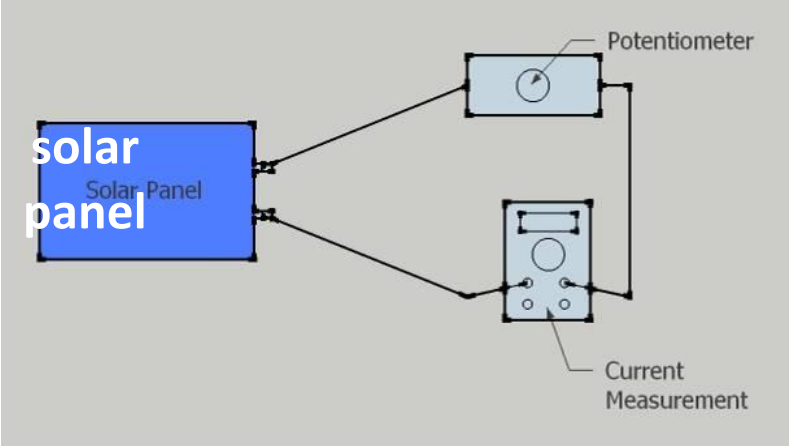

Figure 2. The electrical circuit configuration to measure current.

8. Change the multimeter to read amps DC (DCA) and measure the current. Record this value in the worksheet table.
9. Turn the potentiometer counterclockwise, slowly, in small increments, until the current in the circuit is approximately 0. Note this position; it will be your furthest turning point. The goal is to get 20 evenly-spaced readings, so ideally you will attempt to turn the potentiometer $1/20^{th}$ of its turning potential for each reading. (Note: If the potentiometer reaches the turning limit before 20 voltage and current readings have been taken in the experiment, use evenly-spaced clockwise turns to take the final readings.)
10. Repeat steps 4-9 and record the data for each turn of the potentiometer.
11. After all the data has been collected, return the equipment and clean-up your work area.
12. Complete the post-experiment assignment on the worksheet.