American International University- Bangladesh
Department of Electrical and Electronic Engineering
EEE: Renewable Energy Technology Laboratory

Title: Determination of I-V and P-V Characteristics Curve of a Photovoltaic (PV) Array.

Abstract:

In this experiment students will learn the properties of a photovoltaic (PV) array including its equivalent circuit, I-V and P-V characteristics. The effects of solar irradiance and temperature on a solar panel through the I-V characteristic measurement will also be investigated.

Introduction:

Incident sunlight can be converted into electricity by photovoltaic conversion using a solar panel. The current (I) versus voltage (V) curve of a PV panel represents the possible combinations of its current and voltage output. The power in a DC electrical circuit is the product of the voltage and the current. There are two possible ways to determine the I-V characteristic of a PV panel – (i) by using variable resistor (ii) by using a capacitor as a load. In this experiment, students will use the first method for their practical experiment and using MATLAB Simulink they will simulate the second method. Later on, the effect of solar irradiance and temperature will be investigated.

Theory and Methodology:

A solar panel consists of individual cells that are large-area semiconductor diodes, constructed so that light can penetrate into the region of the p-n junction. The junction formed between the n-type silicon wafer and the p-type surface layer governs the diode characteristics as well as the photovoltaic effect. Light is absorbed in the silicon, generating both excess holes and electrons. These excess charges can flow through an external circuit to produce power.

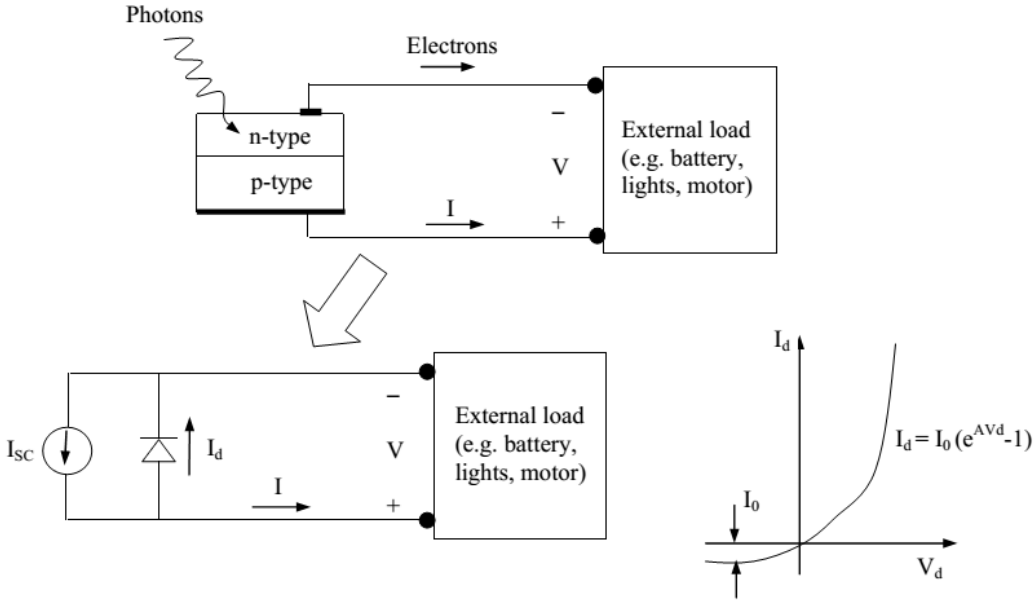

Fig. 1: Equivalent Circuit of a solar cell

Fig. 1 shows the equivalent circuit to describe a solar cell. The diode current can be written as equation (1) which comes from the standard I-V equation for a diode and is also illustrated in fig. 1.

$$I_d = I_o(e^{AV_d} - 1) \quad (1)$$

It is clear that the current I that flows to the external circuit is

$$I = I_{SC} - I_o(e^{AV_d} - 1) \quad (2)$$

Where I_{SC} is the short circuit current, I_0 is the reverse saturation current of the diode and A is temperature-dependent constant, A = q/KT [1].
If the solar cell is open circuited, then all of the I_{SC} flows through the diode and produces an open circuit voltage V_{OC}. If the solar cell is short circuited, then no current flows through the diode and all of the short circuit current I_{SC} flows through the short circuited path.

There are two methods to determine the I-V characteristics curve of a PV arrays.

Method 1:

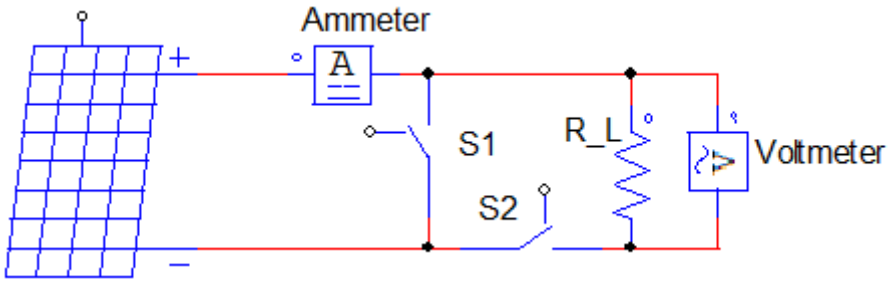

Fig. 2: Circuit diagram for determination of I-V characteristics

curve using variable resistor

- Initially, S1 and S2 are open, measure open circuit voltage and current. i.e. I_L= 0 and V_L= V_{OC}
- Close S2 and measure current and voltage using ammeter and voltmeter while varying R_L
- Finally, Close S1 for a short period of time and record voltage and current. This will provide short circuit voltage and current. i.e. I_L = I_{SC} and V_L = 0

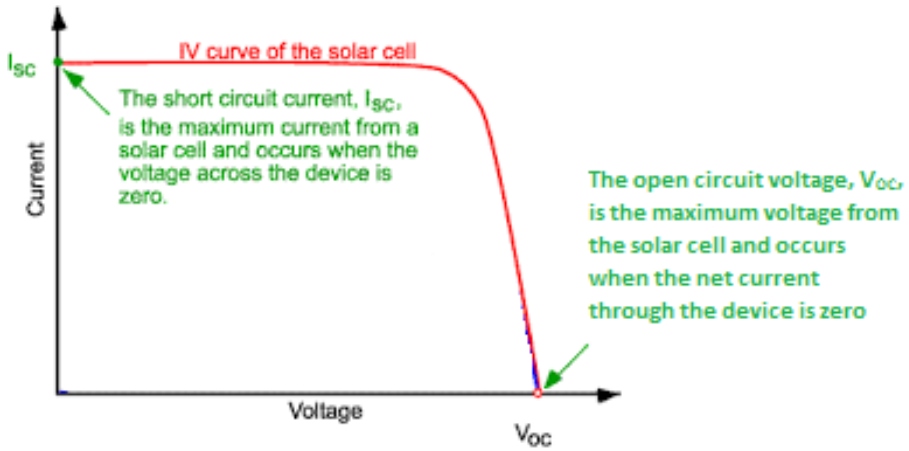

Fig. 3: I-V characteristics curve of PV arrays

Method 2:

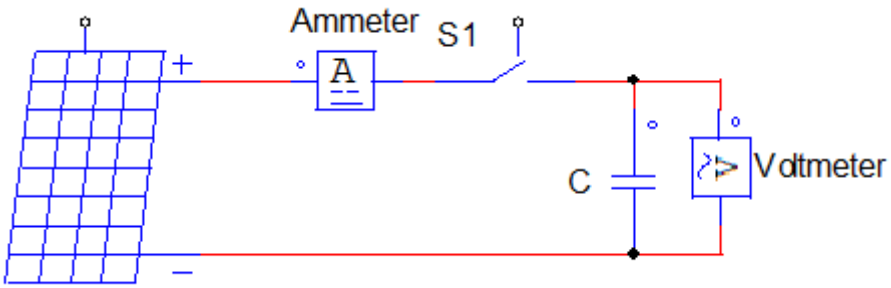

Fig. 4: Circuit diagram for determination of I-V characteristics curve using capacitor

- S1 is closed
- Initially capacitor acts as short circuit path hence I_{SC} can be recorded.
- As the charge of capacitor increases, current decreases
- Continuous data logger is used to record and store the corresponding voltage and current as capacitor's charge increases.
- When capacitor is fully charge, it behaves like open circuit i.e. $V_C = V_{OC}$

Solar radiation must be constant throughout the experiment of both methods.

Pre-Lab Homework:

Students should read the theory before coming to lab.

Apparatus:

1. PV array [20 Wp]
2. Ammeter or Clamp meter
3. Voltmeter
4. Single pole Single Through switch [2 Nos.]
5. Rheostat
6. Light Set

Precautions:

The circuit setup contains 220V. Students should be cautious about this.

Circuit Diagram:

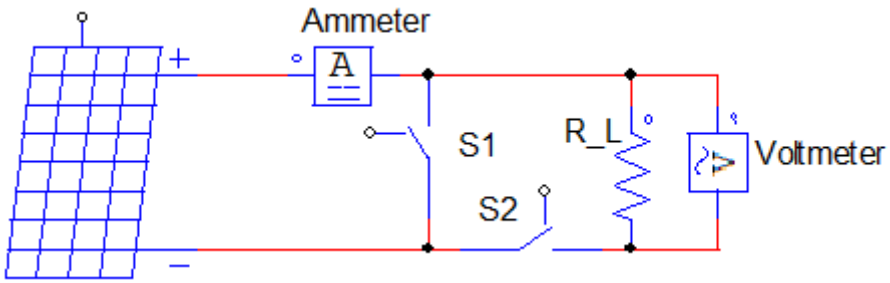

Fig 5: Complete experimental setup

Experimental Procedure:

1. Construct the circuit as shown in Figure 5.
2. Initially keep the S_2 switch open and close the S_1 switch for very short period of time.
3. Quickly record the ammeter / clamp meter and voltmeter reading and open the S_1 switch.
4. Set the value of rheostat at its minimum value and close the switch S_2.
5. Again record the ammeter / clamp meter and voltmeter reading.
6. Now vary the value of rheostat from its minimum to maximum value (until you get almost zero ampere current reading) and fill up the data table.
7. Finally plot voltage vs. current in graph paper.

Data Table:

No.	Value of Rheostat (Ω)	Current (A)	Voltage (Volt)
1	0 (Short Circuit)		
2			
3			
4			
5			
6			
7			
8			
9			
10	Infinity (Open Circuit)		

Simulation:

In simulation, method 2 (as described in theory section) will be used to obtain I-V characteristics curve. Simulation result will be used to evaluate the experimental result. MATLAB Simulink or PSIM can be used to simulate the circuit as shown in figure 4.

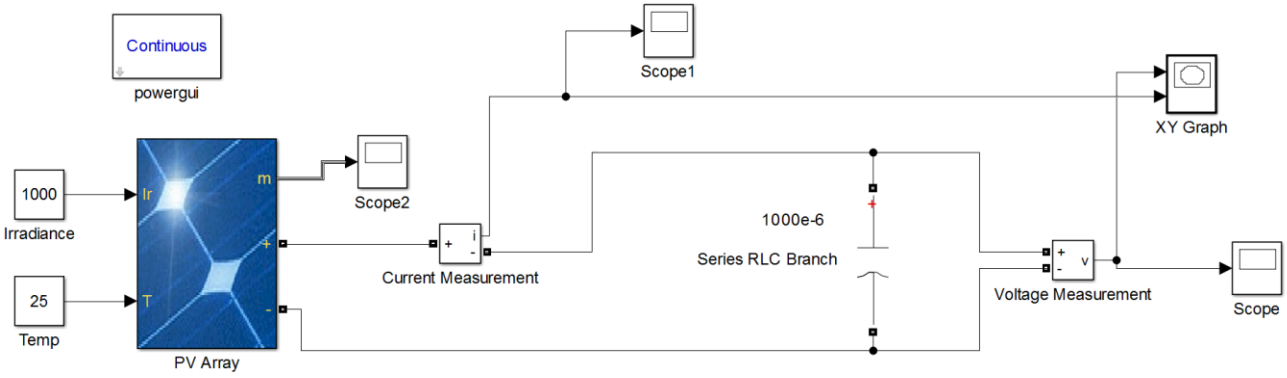

Fig. 6: MATLAB Simulink Circuit for determining I-V curve of a PV array

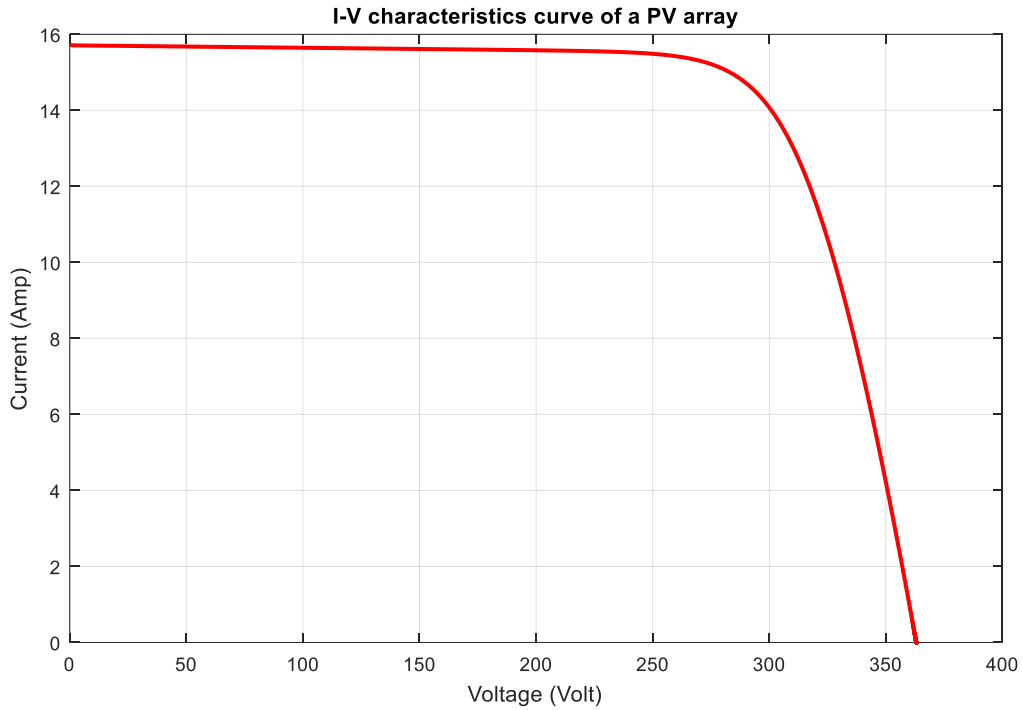

Fig. 7: I-V characteristics curve of a PV array obtained from MATLAB Simulink circuit

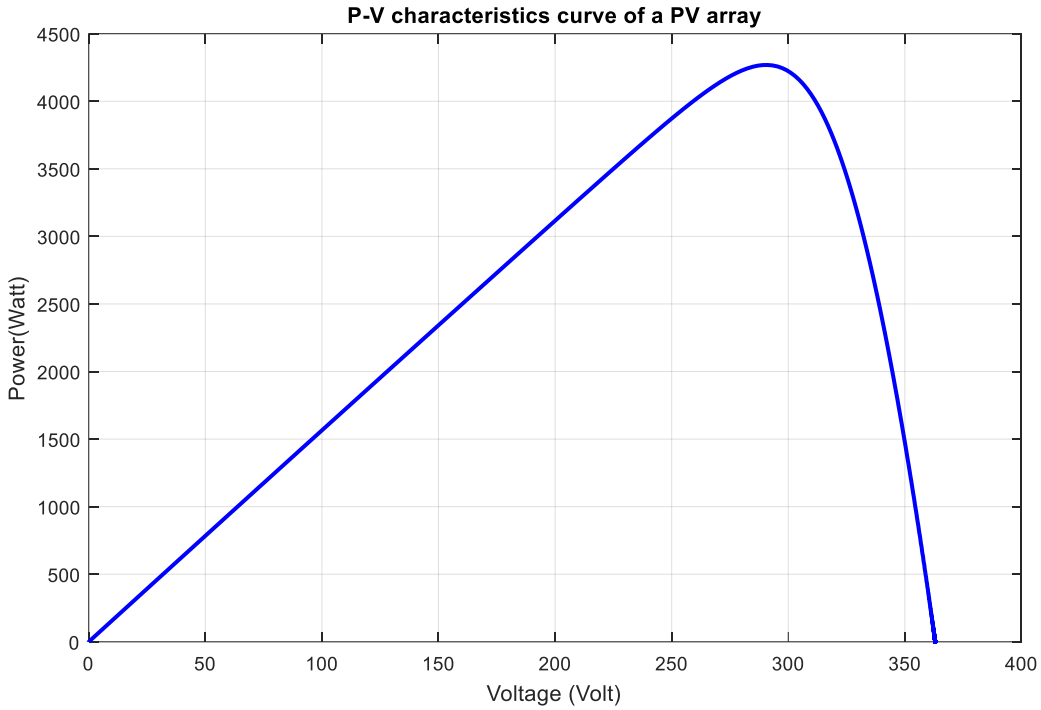

Fig. 7: P-V characteristics curve of a PV array obtained from MATLAB Simulink circuit

Questions for report writing:

1. Find out the Open circuit voltage and short circuit current of the PV array from experimental and simulation result.
2. Find out the Maximum Power Point Voltage (V_{mpp}) and Maximum Power Point Current (I_{mpp}) of the PV array from experimental and simulation result.
3. Calculate the Maximum Power (P_{mpp}) of the PV array.
4. Why the irradiance is kept constant throughout the experiment?
5. Vary the irradiance in your simulation and find out the effect of solar irradiance on I-V characteristic curve.
6. Similarly vary the cell temperature in your simulation and find out the effect of temperature of I-V characteristic curve.

Discussion:

Two different methods are used for determination of I-V characteristics curve. Discuss the differences between these two methods. Also discuss the reasons behind using method 1 for experiment and method 2 for simulation.

Reference(s):

[1] Gilbert M. Masters, "Renewable and Efficient Electric Power System," Wiley, 2004
[2] Kalogirou, Soteris A. Solar energy engineering: processes and systems. Academic Press, 2009.