Expt. 5: Study of solar PV panel V-I characteristics

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Outline

- Resources
- Introduction
- Solar photovoltaic (PV) technologies
- Motivation & Objective
- Experimental setup
- Experimental cases
- Results and discussion
- Conclusion
- Report format

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Resources

- NPTEL Lectures
  - https://www.youtube.com/watch?v=Fuyq6WrM1EA
  - https://www.youtube.com/watch?v=TcaZoVniA8Q
- Book - titled "Renewable and Efficient Electric Power Systems"
  - Chapt.8 - Photovoltaic Materials and Electrical Characteristics
  - http://www.a-ghadimi.com/files/Courses/Renewable%20Energy/REN_Book.pdf

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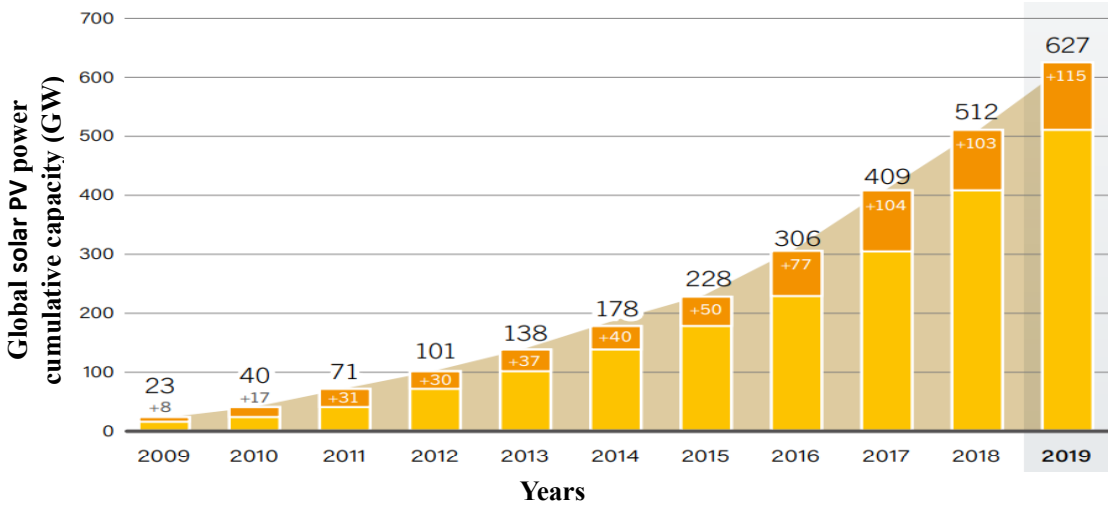
Global solar PV power cumulative capacity



- ***Global solar power cumulative capacity 627 GW (2019)***
- ***Indian solar power cumulative capacity 38.2 GW (2020)***
- ***Indian solar energy tariff Rs. 2 / kWh (2020)***
- ***Average tariff at which Indian states procured non-renewable electricity Rs. 3.60 / kWh (2019)***

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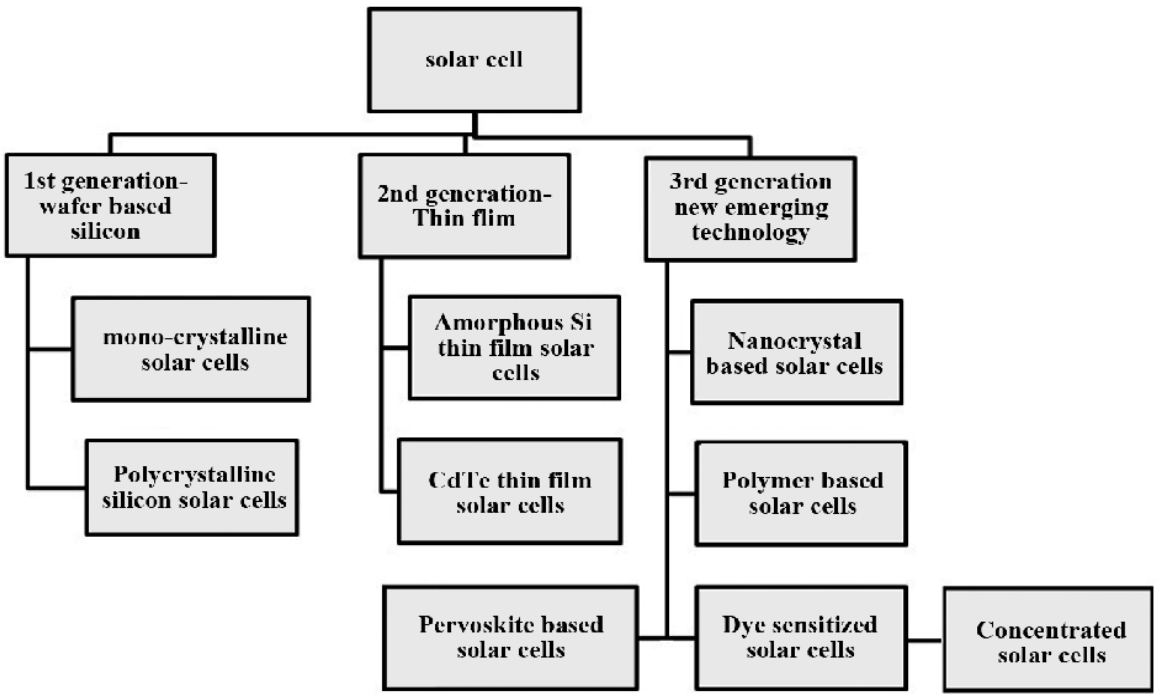
Solar PV Cell technologies



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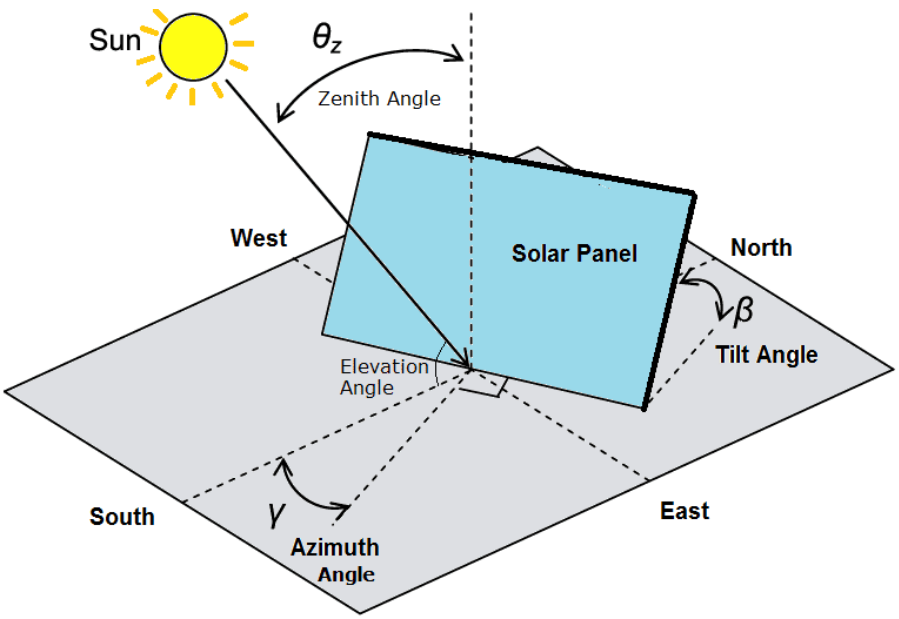
Various Angles related to Solar PV panel



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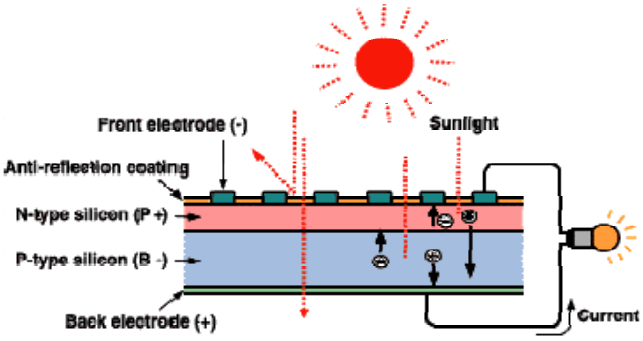
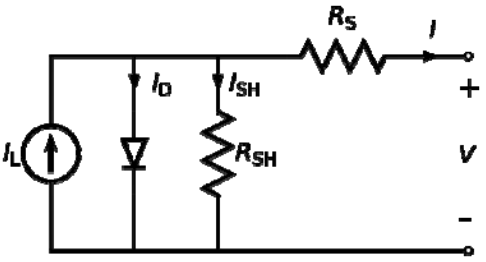
Solar PV working principle and Model



Solar cell working principle



Solar cell equivalent circuit model

❖ **Output Power of Solar PV:**

$P = VI$, where output current,

$$I = I_L - I_0\left[e^{\left(\frac{V+IR_S}{nV_T}\right)} - 1\right] - \frac{V + IR_S}{R_{SH}}$$

n = Diode Ideality Factor

V_T = Thermal Voltage

I_L - Photovoltaic Current
I_D - Diode Current
I_{SH} - Shunt Current
I_0 - Reverse Saturation Current
I - Cell Output Current
R_{SH} - Shunt Resistance
R_S - Series Resistance
V - Cell Voltage

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Motivation & Objective

❖ Study of a solar PV energy conversion system (SPVECS) to understated its basic characteristics and working Principle

- To familiarize with the Solar PV based experimental setup.
- To understand the experimental procedure for measurement and observation.
- To realize the experimental cases for characterization under three different study conditions
  - Varying the load,
  - Under different intensity of light
  - Under dark conditions

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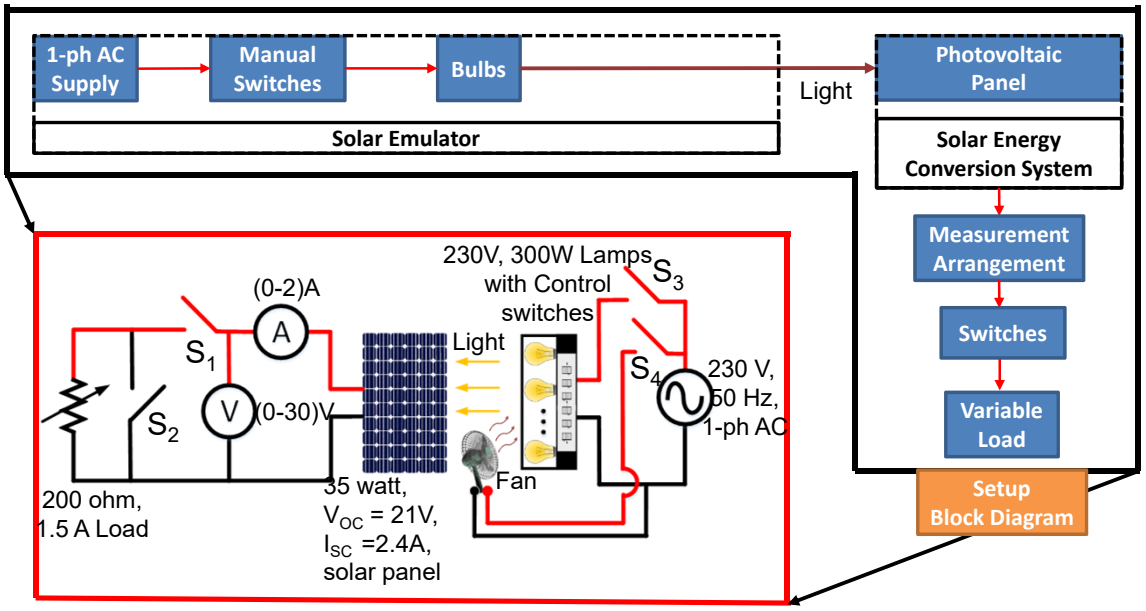
Schematic of Experimental setup



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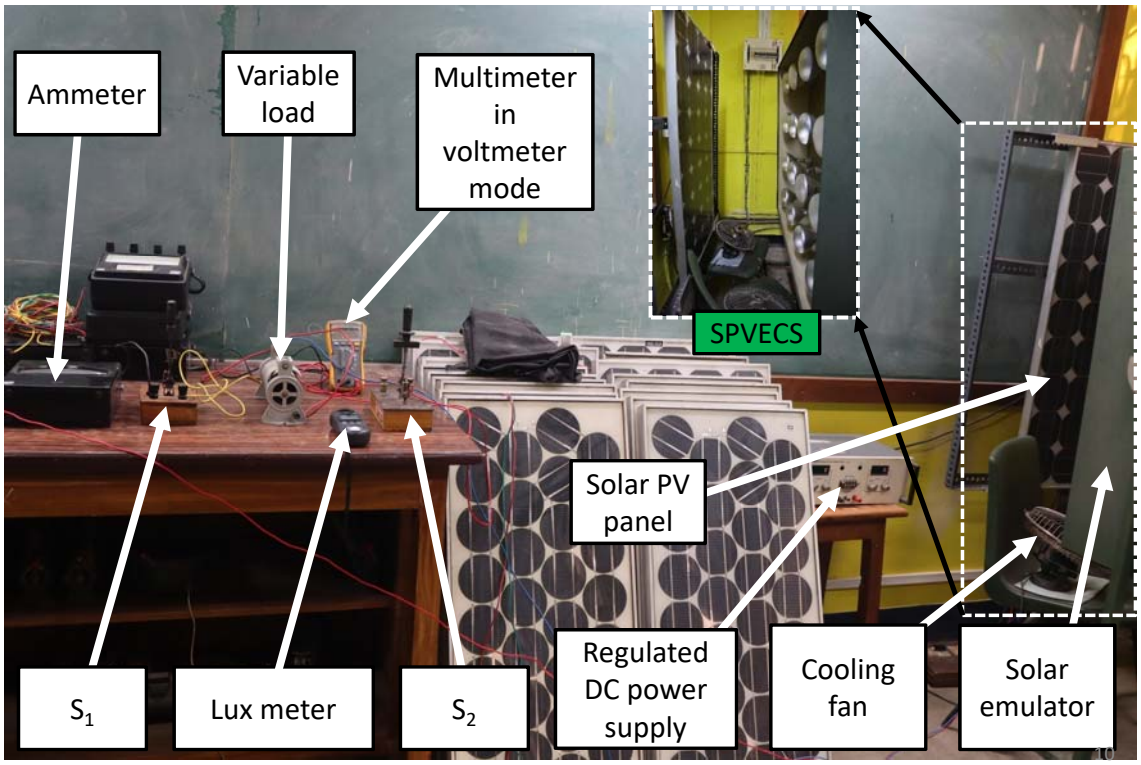
Experiment Setup



UV Lamp for artificial insolation

Lamp Specifications

Nominal voltage	230 V
Lamp voltage	230 V
Construction voltage	230.00 V
Lamp current	1.3 A
Nominal wattage	300.00 W

Photometrical data

Radiated power 315...400 nm (UVA)	13.6 W
Radiated power 280...315 nm (UVB)	3.0 W

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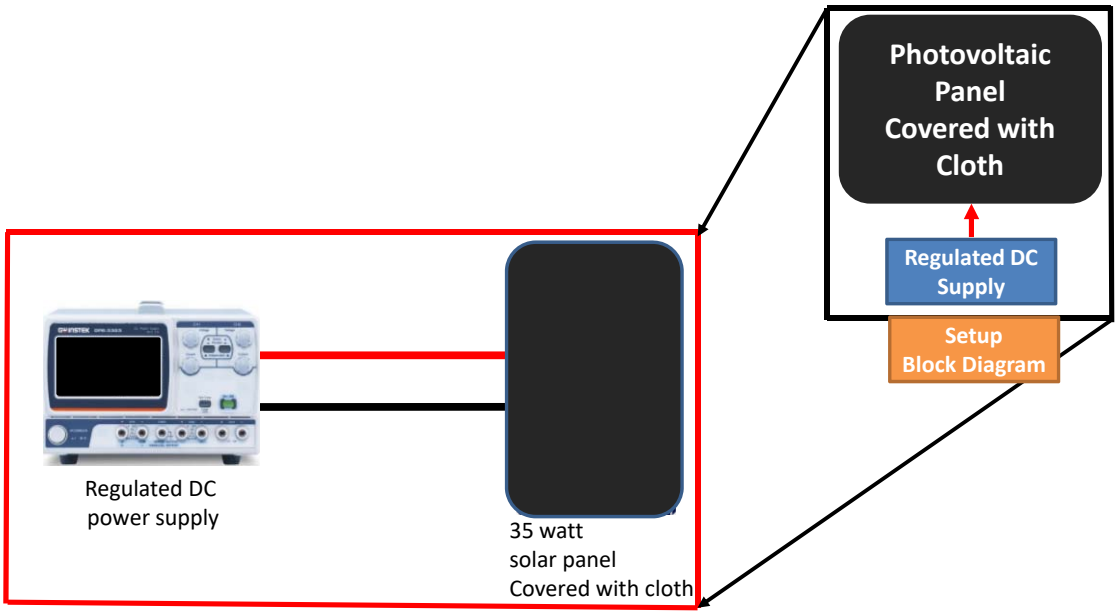
Experiment Setup (Dark Test)



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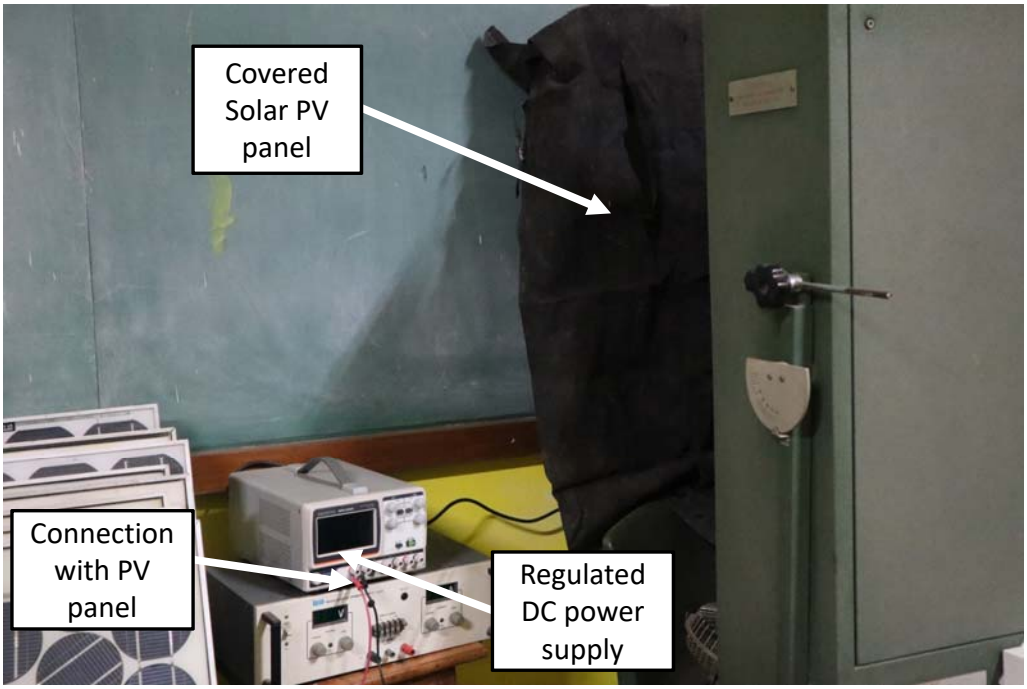
Experiment Setup (Dark Test)



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Experimental Setup

Video

Experimental Cases

- **Load (R ohm) Variation (Case - 1)** *Video 1*
- Dark Test (Case - 2)

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Experimental Case 1

Video

Experimental Case 1 Result

- **Load (R ohm) Variation (Case - 1)**

Result 1

Number of UV bulbs ON	Insolation (lux) Available
4	12700
10	30000
12	38000
16	43000

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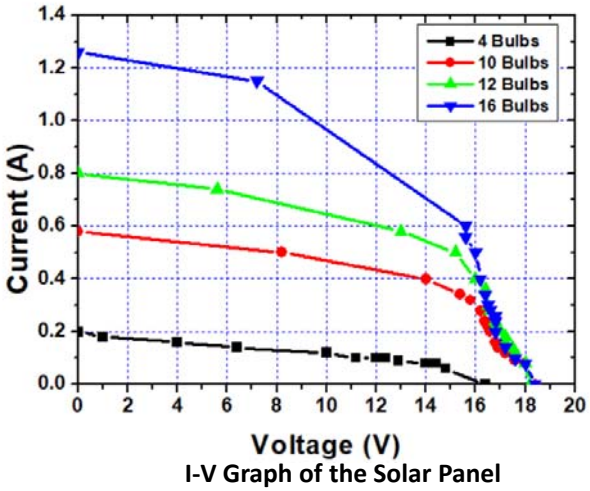
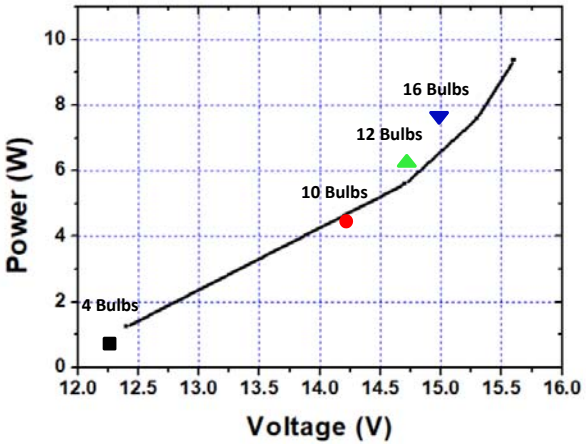
Experimental Case 1 Result

4 Lamps ON		10 Lamps ON		12 Lamps ON		16 Lamps ON	
Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
16.4 (V_{OC})	0	18.4 (V_{OC})	0	18.2 (V_{OC})	0	18.4 (V_{OC})	0
14.8	0.06	18	0.08	18	0.08	18	0.08
14.4	0.08	17.6	0.09	17.6	0.12	17.6	0.1
14	0.08	17.2	0.12	17.5	0.14	17.2	0.14
12.9	0.09	16.9	0.14	17.2	0.18	16.8	0.26
12.4	0.1	16.8	0.16	17	0.2	16.6	0.28
12	0.1	16.6	0.2	16.8	0.22	16.5	0.3
11.2	0.1	16.5	0.22	16.6	0.28	16.4	0.34
10 (Vm)	0.12 (Im)	16.4	0.24	16.4	0.36	16.2	0.4
6.4	0.14	15.4	0.34	16	0.4	15.6	0.56
4	0.16	14 (Vm)	0.4 (Im)	13 (Vm)	0.58 (Im)	15.6 (Vm)	0.6 (Im)
1	0.18	8.2	0.5	5.6	0.74	7.2	1.15
0	0.2 (I_{SC})	0	0.58 (I_{SC})	0	0.8 (I_{SC})	0	1.26 (I_{SC})

Experimental Case 1 Result



I-V Graph of the Solar Panel



MPP Curve of the Solar Panel

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Experimental Case 2

- Load (R ohm) Variation (Case - 1)
- **Dark Test (Case - 2)**

Video 2

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Experimental Case 2

Video

Experimental Case 2 Result

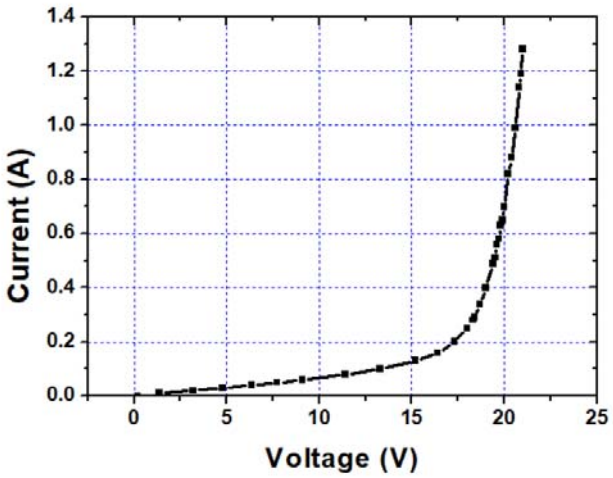
- **Dark Test (Case - 2)**

Result 2

Experimental Case 2 Result

Voltage (V)	Current (A)	Voltage (V)	Current (A)
0.18	0	18.7	0.34
1.35	0	19	0.4
1.36	0.01	19.4	0.49
3.19	0.02	19.5	0.51
4.8	0.03	19.6	0.56
6.35	0.04	19.7	0.58
7.73	0.05	19.8	0.63
9.09	0.06	19.9	0.65
11.4	0.08	20	0.7
13.3	0.1	20.2	0.82
15.2	0.13	20.4	0.88
16.4	0.16	20.6	0.99
17.3	0.2	20.8	1.14
18	0.25	20.9	1.19
18.4	0.29	21	1.28

Data obtained



Graphical Representation

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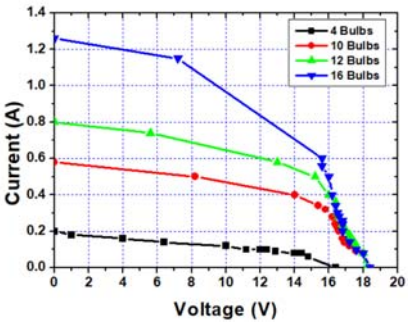
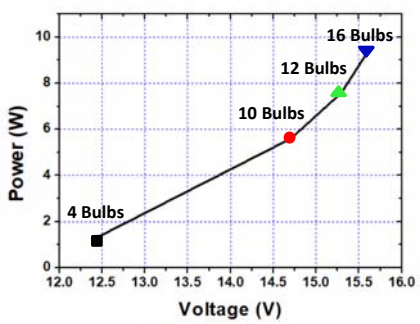
Results and discussion

Case 1

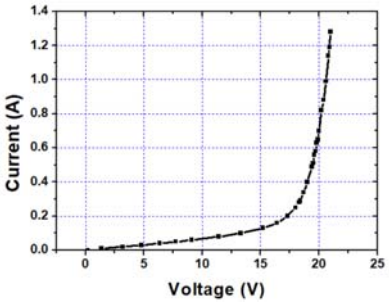


I-V Graph of the Solar Panel



MPP Curve of the Solar Panel

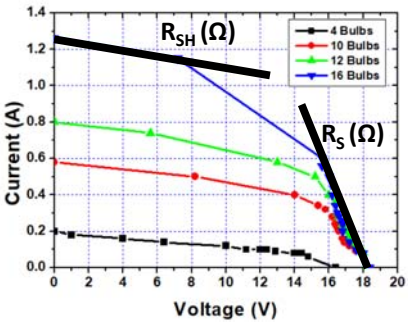
Case 2



Dark Test Graphical Representation

SL. No.	Test
Case-1	I-V Characteristics determination
Case-2	Dark Test

Results and discussion



I-V Graph of the Solar Panel

Fill factor,

$$FF = \frac{V_M \times I_M}{V_{OC} \times I_{SC}}$$

R_S (Ω),
Inverse of slope at I_{SC}

R_{SH} (Ω),
Inverse of slope at V_{OC}

Bulbs	Insolation (lux)	V_{OC} (V)	I_{SC}(A)	P_M(W)	FF	R_S (Ω)	R_{SH} (Ω)
4	12700	16.4	0.20	1.24	0.38	26	120.0
10	30000	18.4	0.58	5.60	0.52	40	80.00
12	38000	18.2	0.80	7.60	0.52	10	55.38
16	43000	18.4	1.26	9.36	0.40	20	66.67

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Conclusions

- Case-1: Varying a load connected to the PV panel, the I-V characteristics is observed in various insolation. Again, the approximate trajectory of the maximum power point with respect to changing insolation is also observed.
- Case-2: Dark test is performed.

❖ The characteristics of a solar panel is studied, by varying the load, in different intensity of light and in zero intensity of light to study the dark characteristics of the panel.

Discussion Questions

1. What is the impact of the Band gap energy on the efficiency of a Solar PV cell?
2. Draw the generic and accurate equivalent circuit for a Solar PV Cell with the equation for current and voltage. Also explain the significance of all four components represented in the circuit.
3. What is the significance of Fill factor (FF)? What is difference between efficiency and FF of a solar Cell?
4. What is the impact of ambient temperature and solar insolation on solar PV cell performance? Draw and Explain it with the I-V curves.
5. What is the purpose of bypass diode and blocking diode in a solar PV system?

Report format

- Objectives of the experiment
- Experimental setup
- Experimental cases and results
- Discussion Questions

Instructions for report submission

- Scan copy of Handwritten report and plots
- One single PDF file with name- ”Expt.no._RollNo._Name_”
- Roll no and Name of student must be written on top of each page and plot with Black pen in Bold
- Report must be uploaded on MOODLE before the next experiment class as per instructions given under expt.5 in MOODLE.