Insight Solar
Introduction

This experimental manual is prepared specifically for the users of "Insight Solar PV training kit". This manual covers the fundamentals of solar PV system which would be helpful to the engineering students of both undergraduate and postgraduate level. The manual is divided in two parts: Part I focus on the characteristics of PV module at different conditions and Part II focuses on the characteristics of PV system and power flow analysis. All the experiments can be done with the help of digital display meters but some of these can also be performed with logger/plotter system which comes along with the kit.

Part I comprises 5 experiments. Experiment 1 helps to evaluate current-voltage characteristics of single PV module while Experiment 2 focuses on evaluating current voltage characteristics of combination of two PV modules in series and parallel. These two experiments also help to evaluate fill factor of PV module. Experiment 3 explains how incident radiation and power output of module gets changed with change in tilt angle of PV module. Experiment 4 shows the effect of shading of cells of PV module. This experiment uses some shading blades for shading the solar cells. Experiment 5 helps to explain the working of diode as blocking and bypass diode.

Part II consists of 5 experiments. Experiment 1 demonstrates and explains the power flow of PV system when DC load connected to it.

Similarly, Experiment 2 does the same when AC load is connected. These two experiments explain the working of stand-alone PV system with either DC or AC load. Experiment 3 explores the complete stand alone PV system with both DC and AC load. Experiment 4 focuses on the charging and discharging characteristics of battery. This experiment is about voltage and current variation with charging and discharging.

☺ DOs

- *Always perform the experiment with at least two students.*
- *Always start the experiment with PV module cleaning.*
- *Make sure all connections are tight.*
- *Note all readings of different meters simultaneously.*
- *Conduct one set of each experiment within 2-3 minutes.*
- *Follow all the precautions given at the end of experiment.*

⊗ DON'Ts

- *Don't expose the controller unit in water.*
- *Don't short the battery terminals or any other source terminals.*
- *Don't move the halogen or PV module while the experiment is going on.*
- *Don't connect the module o/p to the charge controller before connecting the battery with charge controller.*
- *Don't allow the module temperature above 70°C.*

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Insight Solar
Experiment no. 1

Objective

To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level.

Theory

PV module is characterized by its I-V and P-V characteristics. At a particular solar insolation and temperature, module characteristic curves are shown in Fig. 1.1(a) and 1.1(b) respectively.

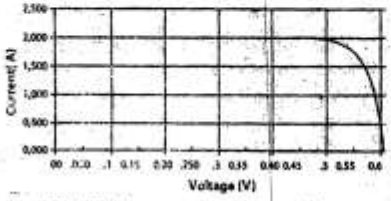

Fig. 1.1(a). I-V characteristic of PV module

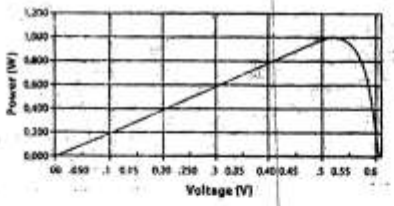

Fig. 1.1(b). P-V characteristic of PV module

Characteristic curves of solar cell

In I-V characteristic maximum current at zero voltage is the short circuit current (I_{sc}) which can be measured by shorting the PV module and maximum voltage at zero current is the open circuit voltage (V_{oc}). In P-V curve the maximum power is achieved only at a single point which is called MPP (maximum power point) and the voltage and current corresponding to this point are referred as V_{mp} and I_{mp}. On increasing the temperature, Voc of module decreases as shown in Fig. 1.2, while Isc remains the same which in turn reduces the power. For most crystalline silicon solar cells modules the reduction is about 0.50%/°C.

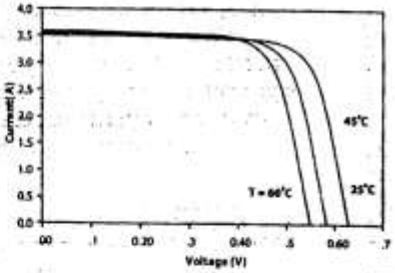

Fig. 1.2. Variation in V_{oc} with change in temperature

On changing the solar insolation I_{sc} of the module increases while the V_{oc} increases very slightly as shown in Fig. 1.3.

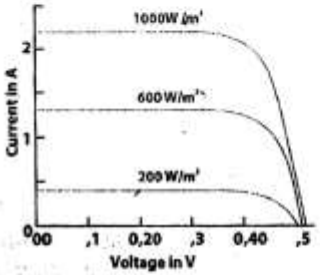

Fig. 1.3. Variation in I-V characteristic with insolation

Fill factor: The Fill Factor (FF) is essentially a measure of quality of the solar cell. It is the ratio of the actual achievable maximum power to the theoretical maximum power (P_T) that would be achieved with open circuit voltage and short circuit current together. FF can also be interpreted graphically as the ratio of the rectangular areas depicted in Fig.1.4. A larger fill factor is desirable, and corresponds to an I-V sweep that is more square-like. Typical fill factors range from 0.5 to 0.82. Fill factor is also often represented as a percentage.

$$FF = \frac{P_{MAX}}{P_T} = \frac{I_{MP} \cdot V_{MP}}{I_{SC} \cdot V_{OC}}$$

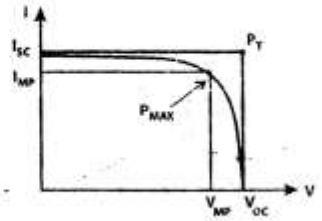

Fig. 1.4. Graphical interpretation of the Fill factor (FF)

Experimental set-up

The circuit diagram to evaluate I-V and P-V characteristics of a module is shown in Fig.1.5. Form a PV system which includes PV module and a variable resistor (pot meter) with ammeter and voltmeter for measurement. Pot meter in this circuit works as a variable load for the module When load on the module is varied by pot meter the current and voltage of the module gets changed which shift the operating point on I-V and P-V characteristics.

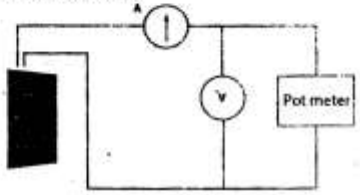

Fig. 1.5. Circuit diagram for evaluation of I-V and P-V characteristics

PV characteristics evaluation can be achieved by following connections in control board (as shown in Fig.1.6).

ontroller connections

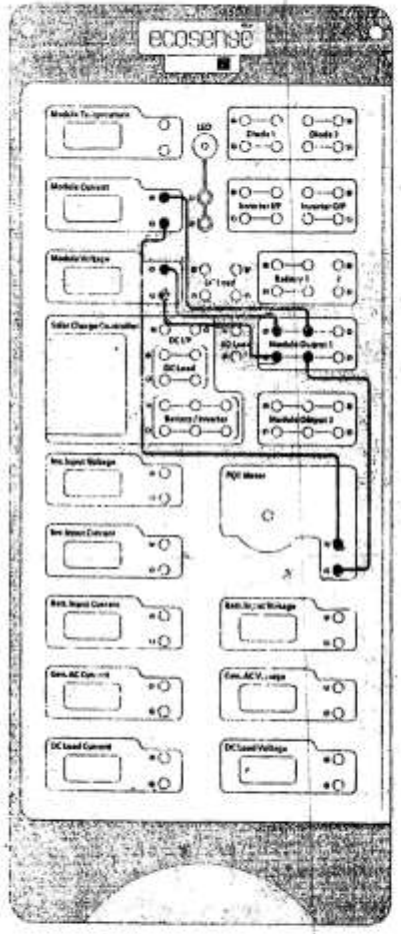

Fig. 1.6. Control board connections to get I-V and P-V characteristics

One can also take I -V and P-V data from Logger and Plotter by connecting the Logger Plotter Box with module output.

Values of current and voltages can be taken from the data logger and then I-V curve can be plotted at different radiation and temperature levels.

One can also use Real time plotter which will plot the curve of I-V and P-V

Fig. 1.7. Logger plotter box with power supply

Observations:

Table for I-V and P-V characteristics of PV module :

Set- 1					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set- 2					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set- 3					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set- 4					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

These 4 sets are for different radiation and temperature levels but in one set the values of radiation and temperature will be constant.

Results:

1. Draw the I-V curves of all the sets on a single graph and show the characteristics at different radiation and temperatures levels (by using digital meters and data logger separately).
2. Draw the P-V curves of all sets on a single graph and show the characteristics at different radiation and temperatures levels (by using digital meters and data logger separately).
3. Calculate the fill factor for the given module (by using digital meters and data logger separately).
4. Also get all above mentioned curves from the Real time plotter.

Precautions:

1. Readings for one set should be taken within 1-2 minutes (for indoor experiment) otherwise temperature of the module may vary as radiation source used is halogen lamp.
2. Halogen lamp position should not be changed during one set otherwise radiation on modules will change.
3. Connections should be tight.

Notes

Insight Solar
Experiment no. 2

Objective

To demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.

Theory

PV module is characterized by its I-V and P-V characteristics. At a particular level of solar insolation and temperature it will show a unique I-V and P-V characteristics. These characteristics can be altered as per requirement by connecting both modules in series or parallel to get higher voltage or higher current as shown in Fig. 2.1(a) and 2.1(b) respectively.

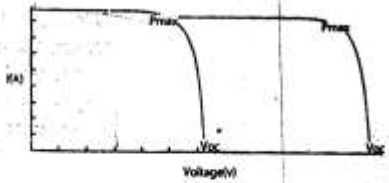

Fig. 2.1(a). I-V characteristic of series connected modules

On increasing the temperature, V_{oc} of modules decrease while I_{sc} remains same which in turn reduces the power.

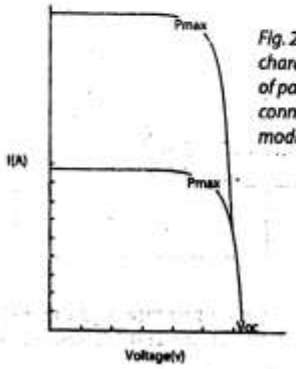

Fig. 2.1(b). I-V characteristic of parallel connected modules

Therefore, if modules are connected in series then power reduction is twice when connected in parallel.

On changing the solar insolation, I_{sc} of the module increases while the V_{oc} increases very slightly, therefore there is overall power increase. In parallel connection power increment is twice than when connected in series.

Experimental set-up

The circuit diagram to evaluate I-V and P-V characteristics of modules connected in series and parallel are shown in Fig. 2.2(a) and 2.2(b) respectively.

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Form a PV system with modules in either series or parallel and a variable resistor (Pot meter) with ammeter and voltmeter for measurement. Modules in series or parallel are connected to variable load (pot meter). The effect of load change on output voltage and current of the modules connected in series or parallel can be seen by varying load resistance (pot meter).

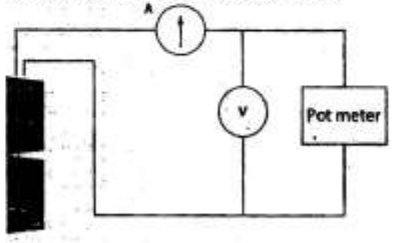

Fig. 2.2(a). Circuit diagram for evaluation of I-V and P-V characteristics of series connected modules

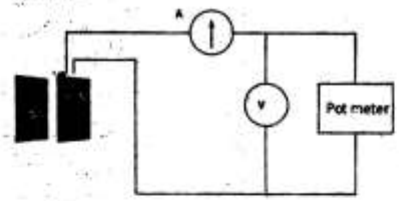

Fig. 2.2(b). Circuit diagram for evaluation of I-V and P-V characteristics of parallel connected modules

I-V and P-V characteristics of the modules connected in series or parallel can be achieved by connections shown in Fig. 2.3(a) and (b) respectively.

Series connected modules

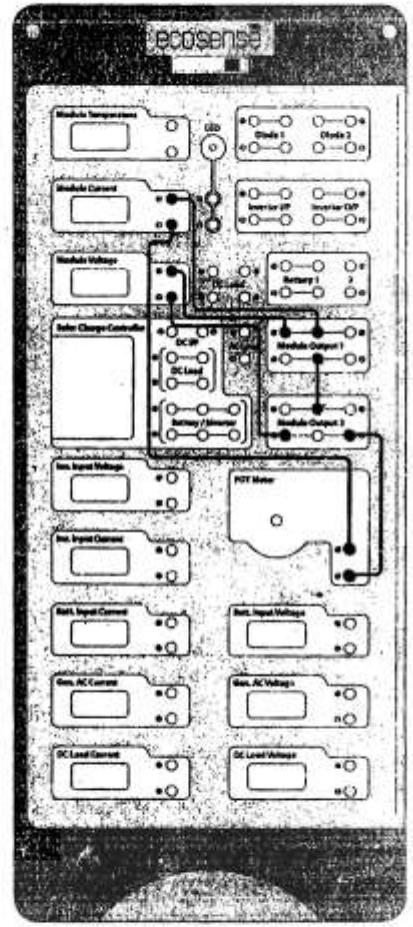

Fig. 2.3(a). Control board connections for modules connected in series

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Parallel connected modules

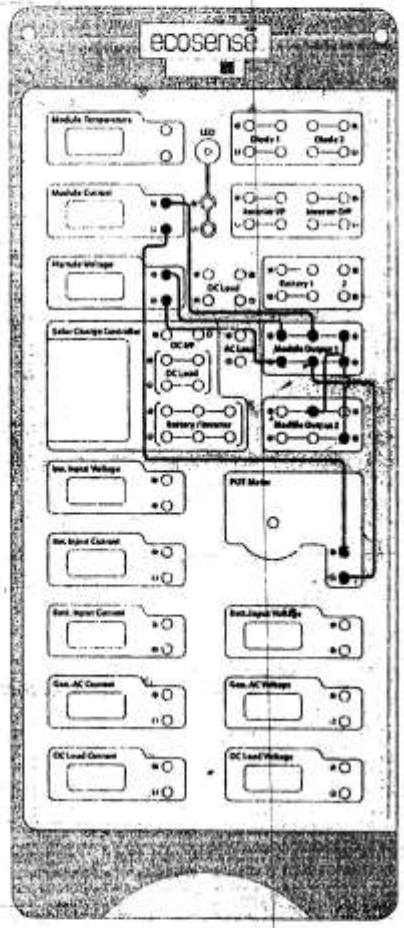

Fig. 2.3(b). Control board connections for parallel connected modules

One can aiso take I -V and P-V data from Logger and Plotter by connecting the Logger Plotter Box with module output.

Values of current and voltages can be taken from the data logger and then I-V curve can be plotted at different radiation and temperature levels.

One can also use Real time plotter which will plot the curve of I-V and P-V.

Fig. 2.4. Logger plotter box with power supply

Observations:

Table for I-V and P-V characteristics of PV modules in **series:**

Set-1					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set-2					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set-3					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

These 3 sets are for different radiation and temperature levels but in one set the values of radiation and temperature will be constant.

Table for I-V and P-V characteristics of PV modules in **parallel:**

Set-1					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set-2					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

Set-3					
S.No.	Radiation	Temperature	V	I	P
1			Voc	0	
2					
3					
4					
5					
6			0	Isc	

These 3 sets are for different radiation and temperature levels but in one set the values of radiation and temperature will be constant.

Results:

1. Draw the I-V curves of all the 3 sets on a single graph for series and parallel connected modules and show the characteristics at different radiation and temperatures level (by using digital meters and data logger separately).
2. Draw the P-V curves of all the 3 sets on a single graph for series and parallel connected modules and show the characteristics at different radiation and temperatures level (by using digital meters and data logger separately).
3. Also get all above mentioned curves from the Real time plotter.

Precautions:

1. Readings for one set should be taken within 1-2 minutes (for indoor exp.) otherwise temperature of the module may change as radiation source used is halogen lamp.
2. Halogen lamp position should not be changed during one set otherwise radiation on modules will change.
3. Connections should be tight.

■

Notes