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Investigation of the Photovoltaic performance of Si-based solar cells under different Light Illuminations

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Abstract

Today's solar cells are simply not efficient enough and currently too expensive to manufacture for Large scale electricity generation. However, Nanotechnology may open to the production cheaper and slightly more efficient solar cells. . So I would examine the current solar cell Technologies available. Device performance under extended duration illumination is an essential characterization step for any PV technology, because light exposure can produce a variety of effect which influence the determination of both initial and long term stabilized device performance. For a silicon photovoltaic, light exposure leads to degradation of module power output, while light temperature leads to improvement. So I would like to investigate the performance of photo voltaic cell under different light condition .I also investigate the Photovoltaic performances for a Cell, for a Module, for a Panel, and for two panels with different illuminations. It will be helpful to calculate the efficiency of solar cell. The component which required for my task is very simple and cheap

1. Introduction:

At present century huge population, advanced industrialization, rising number of hunger demands immense power to meet those challenges around the world. Today people developed so many techniques and methods for producing and distributing power from solar system, but most of these methods were costly as well as inefficient and beyond the reach of common people. To make those things better and cost effective people developed so many ideas, application of thin films on solar cell is one of them, it not only increase efficiency of solar cell but make it cost effective and versatile for applying different purposes [1].

The word photovoltaic comes from "photo" meaning light, and "voltaic which refers to producing electricity. Therefore, the photovoltaic process is "producing electricity directly from sunlight."When application require larger amounts of electricity [3].

Photovoltaic's are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons. The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current. The photovoltaic effect was first observed by Alexandre-Edmond Becquerel in 1839. [5]

Solar energy is a clean and carbon-free energy resource with tremendous potential for electricity generation. Light emitted by the sun and falling on the earth is one of the most abundant energy resources. Over 15,000 EJ (1.5x1022 J) of solar energy reaches earth every day, compared to daily energy consumption of approximately 1.3 EJ by human activity [8]Solar cell provides electricity for rural areas or third world countries. Since electricity demand in these areas is not high, and the areas are distantly spaced out, it is not practical to connect them to an electrical grid. However this is an ideal situation for solar energy. [2]

The solar cell which are available in the market are given with rated power ,open circuit voltage, short circuit current, but it is not given how much the solar panel is efficient according to sunlight. The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. To determine the efficiency we have to find I-V characteristics of the cell and fill factor.

2. **Experimental setup**

For my thesis work I have used ET 250 photovoltaic Trainer. The ET 250 trainer contains two such solar modules. The tilt of the module can be adjusted. Cables can be used to connect the two modules in series or parallel. A slide resistor simulates varying loads. Thus the slide resistor makes it possible to record current-voltage curves. The separate measuring unit provides display all relevant variables. Sensors on the solar module detect illuminance and temperature. In order to ensure there is sufficient illuminance, the trainer should be operated with sunlight or the optional light source. In figure we can see the ET 250 Photovoltaic Trainer and in figure 2 its different parts are indicated.

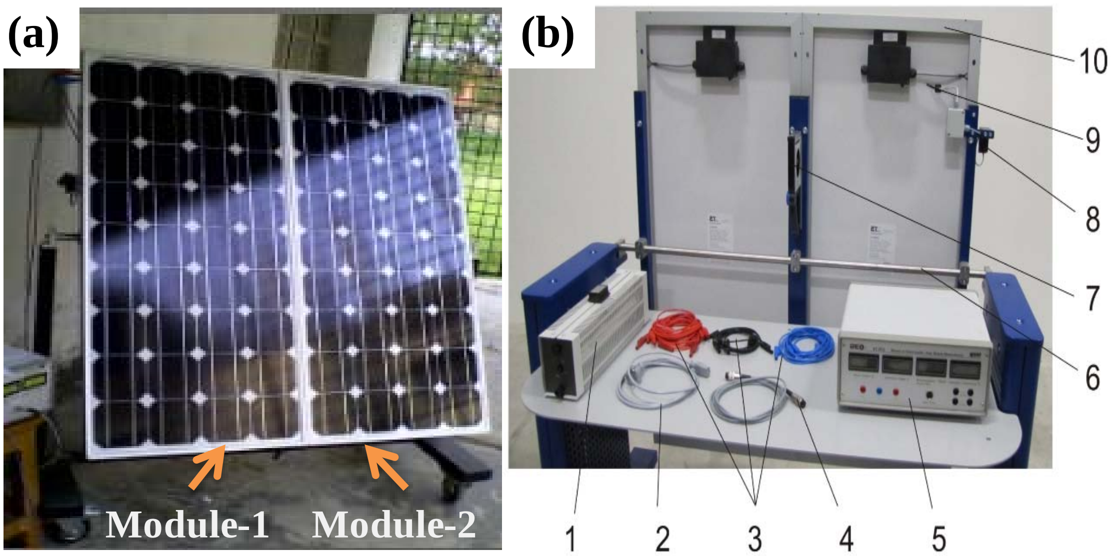

Fig. 1. (A) Front view of two modules of 85Wp (Model ET 250); (b) Back view of solar modules and Unit Layout of ET 250 Photovoltaic Trainers with all accessories.

Fig. 2. Photovoltaic parameters measuring unit.

Figure 1(a) shows front view of two modules of 85Wp (Model ET 250). Each module has 36 cells in series. Figure 1(b) exhibits the Back of PV modules and overall unit layout of ET 250 photovoltaic trainers with all accessories. The numbers 1-10 displays the listed accessories: 1-Variable resistor with slider, 2-Power cable, 3-Set of cables for series and parallel connection, 4-Measuring cable, 5-Measuring Unit, 6-Tilt axis, 7-inclinometer, 8-Illuminance sensor, 9-Temperature sensor, 10-Solar modules. The most important part of the trainer is the combined measuring unit, as shown in Fig. 3. Here the photocurrent (A), photo voltage (V), irradiation intensity (kW/m^2), and environmental temperature have been measured by this measuring unit and digitally displays these data.

The technical Data for solar module is given in Table 1. The short circuit and open circuit voltage of each module is 5.29A and 21.94V, respectively. The overall area of 36 cells is 0.63 m^2. The maximum power of each module is 85W at peak light irradiation.

Table 1. Standard Photovoltaic's parameters of each of the Module of ET 250 Photovoltaic trainer

Number of cells	36(monocrystalline)
Module area	0.63m²
Max. Power	85Wp
Short-circuit current	5.29A
Open-circuit voltage	21.94V
Slide resistor	0...10 Ohm
Measuring ranges Temperature	0…100°C
Voltage	0...20V
Current	0...20A
Illuminance	0...2000W/m²
LCD digital Displays	0…199.9mv DC

3. Characteristics parameters

The solar cells are characterized by the following parameters:

Fill Factor: The fill factor is defined as the ratio of the actual maximum obtainable power to the product of the open circuit voltage and short circuit current. [4] FF describes how closely the current voltage characteristics curve approximates the ideal rectangle form. This is a key parameter in evaluating the performance of solar cell.

$$Fill\ Factor = \frac{\mathrm{Vmp*Imp}}{\mathrm{Voc*Isc}} \tag{1}$$

Where, Vmp is voltage at maximum power point,

Imp is current at maximum power point

Efficiency: The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. [8][6]

$$Effiency, \eta = \frac{\mathrm{Voc*Isc*FF}}{\mathrm{Pin}} \tag{2}$$

Here, Voc= open circuit voltage

Isc=short circuit current,

FF=fill factor

Pmax=maximum power obtained from the curve

Pin=Input power /intensity

Efficiency depends on the type of cell. For the module efficiency value, the output power is divided by the total radiation incident on the module. Because the entire area of the module is not covered by with the solar cells (for example, frames and space between the single solar cells are not active area), the module efficiency value is lower than the efficiency value of the single cell. [9]

4. Result and Discussion:

The result of investigation of solar cell under different light condition is given here

Condition 1: Parallel Connection of two modules

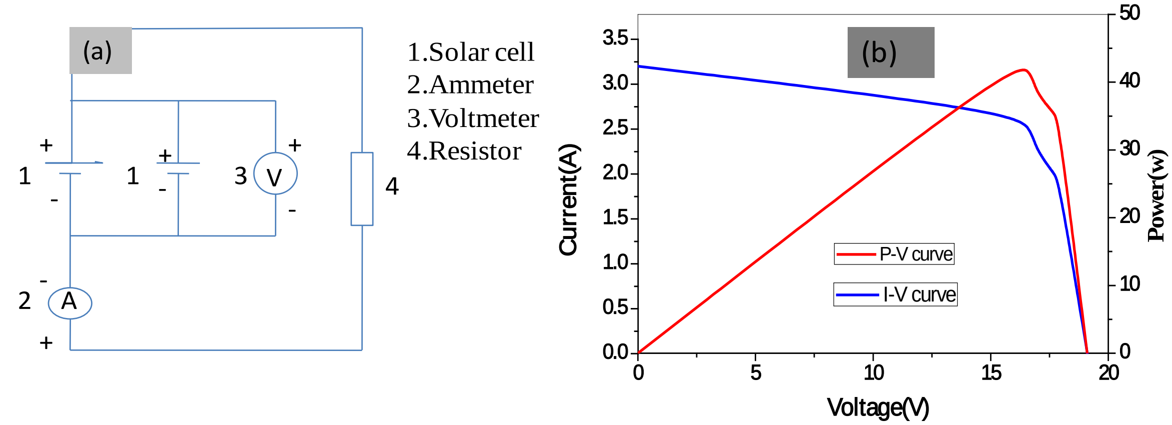

Fig.4 (a) Circuit diagram of the parallel connection of two module (b) I-V and P-V characteristics curves of fig (a)

Figure 4 shows the parallel connection of two modules and the I-V and P-V characteristics curves of parallel connection of two modules at noon when lights was sufficient. In this condition open circuit voltage was19.1V, Short Circuit Current=3.2A, automatically obtained intensity=0.58KW/m^2.Calculated Intensity=0.69kw/m$^{2.}$. In a 10 x 10 cm^2 cell the input power is 100 mW/cm^2 x 100 cm^2 = 10 W. So the fill factor was 0.7023which is calculated from equation (1) , which is good for any solar cell. Finally efficiency was obtained as 4.9% from equation (2)

Condition .2: Series Connection of two modules

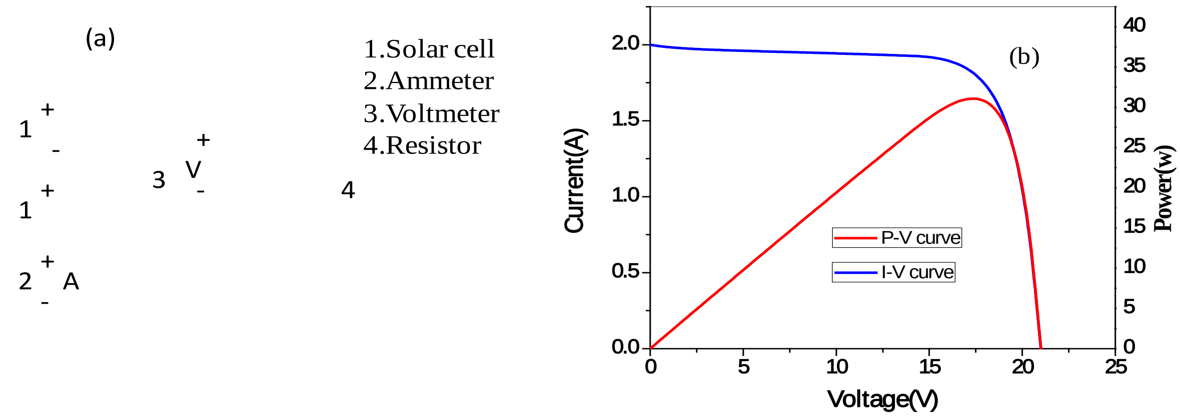

Fig.5 (a) Series connection of the two module (b) I-V and P-V characteristics curve of the connection of fig (a)

Figure 5 shows the series connection diagram of two modules. Figure 6 shows the I-V and P-V characteristics of two modules connected in series .This data was taken during time period 10.30 in morning. In this condition fill factor was 0.882 and efficiency was 3.75%.Here Open Circuit Voltage=21V, Short Circuit Current=2A, automatically obtained intensity=0.78KW/m^2 .Average intensity: 54388lx .Calculated Intensity=0.776kw/$m^{2.}$

Condition 3: One module with at 11.30A.M

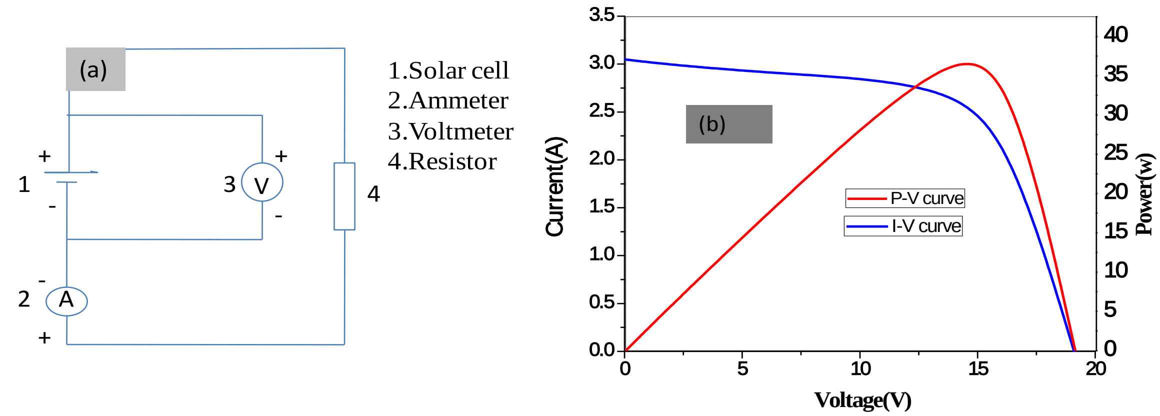

Fig.6 (a) Circuit diagram of one module (b) I-V and P-V characteristics curves of the connection of fig. (a).

The I-V and P-V curves of one module of a solar cell are shown in fig.6.The experiment was performed at 11.30A.M.The light was sufficient. Open Circuit Voltage=19.1V, Short Circuit Current=3.05, automatically obtained intensity=0.58KW/m^2.Calculated Intensity=0.69kw/$m^{2.}$,fill factor was 0.663 and efficiency was 8.8%.

Condition: 4: Characteristics of one module with column 1 and 4 closed

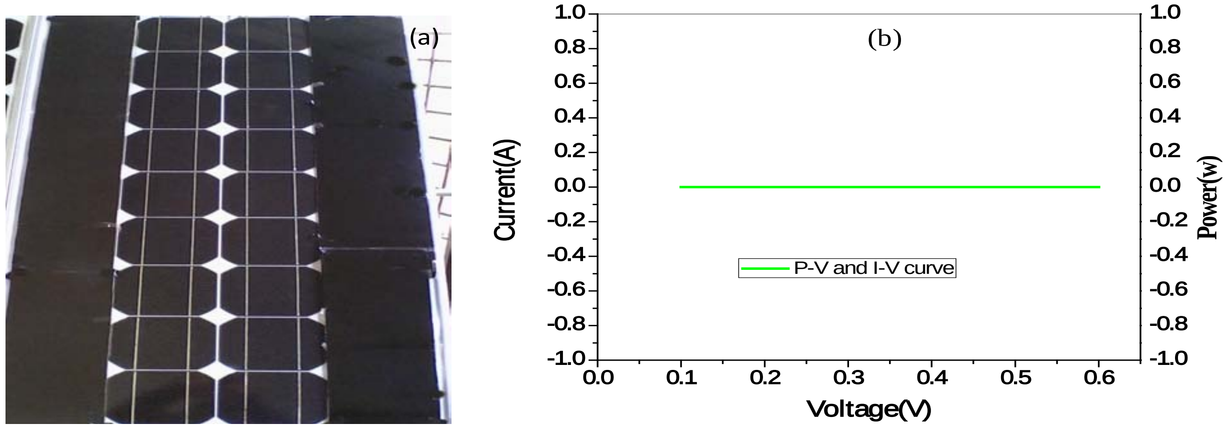

Fig.7 (a) One module with column 1 and 4 closed (b) I-V and P-V characteristics curves of the connection of fig. (a)

The I-V and P-V characteristics curves are shown in the figure (7).There is no variation of current when resistance was varied. So the fill factor and efficiency in this case is zero. This is because, PV cells are connected in series and two columns are closed there existing an open circuit .So the current becomes zero. In this period light was enough.

Table 2. Comparison between all conditions:

Conditions	Open circuit voltage, Voc(V)	Short circuit current, Isc(A)	Obtained Intensity KW/m^2	Calculated Intensity KW/m^2	Fill Factor, FF	Efficiency, η
Parallel Connection of two module at 12.30 A.M with sufficient light	19.1	3.2	0.58	0.69	0.7023	4.9%
Series connection of two module at 10.30A.M	21	2	0.78	0.776	0.882	3.75%
One module at 11.30AM	19.1	3.05	0.58	0.69	0.663	8.8%
One module with column 1 and 4 closed	15	0.1	0.40	64.8	0	0%

5. Conclusion:

From the I-V curves at different condition we can see that there is a significant effect of intensity of light. In addition to reflecting the performance of the solar cell itself, the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. Therefore, conditions under which efficiency is measured must be carefully controlled in order to compare the performance of one device to another. Changing the light intensity incident on a solar cell changes all solar cell parameters, including the short-circuit current, the open-circuit voltage, the FF, the efficiency etc.The solar cell available at the market are given with their open circuit voltage, short circuit current, maximum power etc. But efficiencies are not given. So the efficiency calculated in this way will be helpful for us to compare the performance of one device to others. Fill factor is the key parameter in evaluating the performance of solar cell, Typical commercial solar cells have a fill factor >0.7.Grade B solar cell have a fill factor usually between 0.4 to0.7. [7]

References

[1] Grätzel, M., “Photoelectrochemical Cells.” Nature 414, 338-344, 2001.
[2] Choi, Charles. “Nanotech Improving Energy Options.” Space Daily. New York: May
27, 2004. <http://www.spacedaily.com/news/nanotech-04zj.html>.
[3] Alfred Smee (1849). *Elements of electro-biology,: or the voltaic mechanism of man; of electro-pathology, especially of the nervous system; and of electro-therapeutics*. London: Longman, Brown.
[4] Shockley W., J. Bardeen and W. Brattain, “The Theory of P-N Junctions in Semiconductors and P-N Junction Transistors,” *Bell System Technical Journal*, Vol 28: 1949, pp. 435 Semi conductive Materials Transistor. ISSN : 0005-8580.
[5] The photovoltaic effect. Encyclobeamia.solarbotics.net. Retrieved on 12 December 2010.
[6] Cheng-Hsiao Wu and Richard Williams (1983). "Limiting efficiencies for multiple energy-gap quantum devices". *J. Appl. Phys.* **54**: 6721. Bibcode:1983JAP....54.6721W. doi:10.1063/1.331859.
[7] T.Bazouni: What is the Fill Factor of a Solar Panel". http://www.solarfreaks.com/what-is-the-fill-factor-of-a-solar-panel-t138.html. Retrieved 2009-02-17.
[8] R. R. King, et al., "40% efficient metamorphic GaInP/GaInAs/Ge multifunction solar cells," *Appl. Phys. Lett*., vol. 90, 2007 pp. 183516-1.[9] Nikhil Jain, “Design of III-V multifunction solar cells on silicon substrate” May 6, 2013 ,Blacksburg, VA
[9] A.Gotezberger,V.U.Hoffmann,”Ptotovoltaic Solar Energy Generation”2005,ISSN 0342-4111