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Depiction of V_I AND P_V Characteristics of POLYCRYSTALLINE Solar Photovoltaic Cells / Panels For Different Kinds Radiations

T.Jagan Mohan Raju [1]
Asst. Professor of EEE,
UCEKU, Kothagudem , India

K.Soumya [2]
Associate Professor of EEE
AKITS , Kothagudem

ABSTRACT

"The Solar Photovoltaic Cell / Solar Pannel " is the Most widely heard word now-a-days not only in the area of Power Systems but also in the area of Energy Efficiency across the globe. The Era of changeover of producing the electrical Energy from the Conventional Sources to the Non Conventional Sources has began decades back, but the search for the best alternative is still in progress. A attempt is made here to depict Experimentally the Voltage Current and Power Voltage characteristics of a typical Solar Pannel/module.

PV module is characterized by its I-V and P-V characteristics.

In I-V characteristic maximum current at zero voltage is the short circuit Current(Isc). Which can be measured by shorting PV module and maximum voltage at zero current is the open circuit voltage (Voc). 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 Vmp and Imp. On increasing the temperature Voc of the module decreases as shown in fig while Isc remains same which in turn reduces the power. For most crystalline silicon solar cells modules the reduction is about 0.50%/C.

On charging the solar insolation Isc of the module increases while the Voc increases very slightly.

INTRODUCTION

Photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity.

The photoelectric effect was first noted by a French physicist, Edmund Bequerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use. In the 1960s, the space industry began to make the first serious use of the technology to provide power aboard spacecraft. Through the space programs, the technology advanced, its reliability was established, and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications.

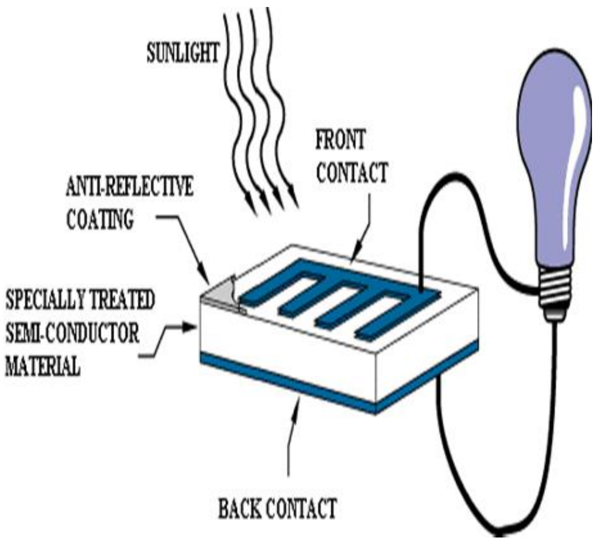

FIG.1 THE BASIC PHOTOVOLTAIC CELL

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The diagram above illustrates the operation of a basic photovoltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current -- that is, electricity. This electricity can then be used to power a load, such as a light or a tool.

A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module. Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module.

Multiple modules can be wired together to form an array. In general, the larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (dc) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.

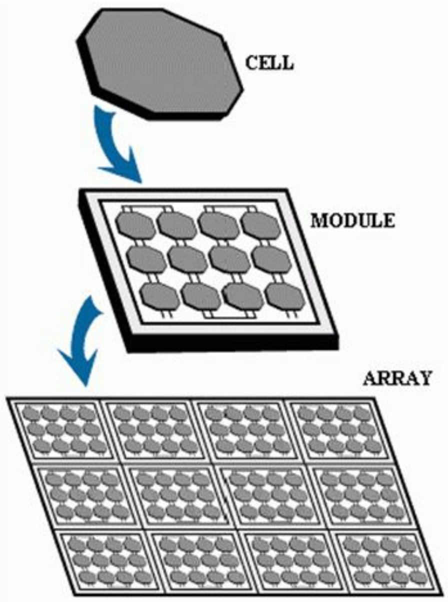

FIG.2 THE BASIC PHOTOVOLTAIC CELL, MODULE AND ARRAY STRUCTURES

In the 1980s research into silicon solar cells paid off and solar cells began to increase their efficiency. In 1985 silicon solar cells achieved the milestone of 20% efficiency. Over the next decade, the photovoltaic industry experienced steady growth rates of between 15% and 20%, largely promoted by the remote power supply market. The year 1997 saw a growth rate of 38% and today solar cells are recognized not only as a means for providing power and increased quality of life to those who do not have grid access, but they are also a means of significantly diminishing the impact of environmental damage caused by conventional electricity generation in advanced industrial countries.

SOLAR RADIATION AND WORKING OF A SOLAR CELL

Most of today's research in solar cells focuses on gallium arsenide as one of the component cells. Other materials amorphous silicon and copper indium diselenide are also studied for making multijunction devices . Such cells have reached efficiencies of around 35% under concentrated sunlight.

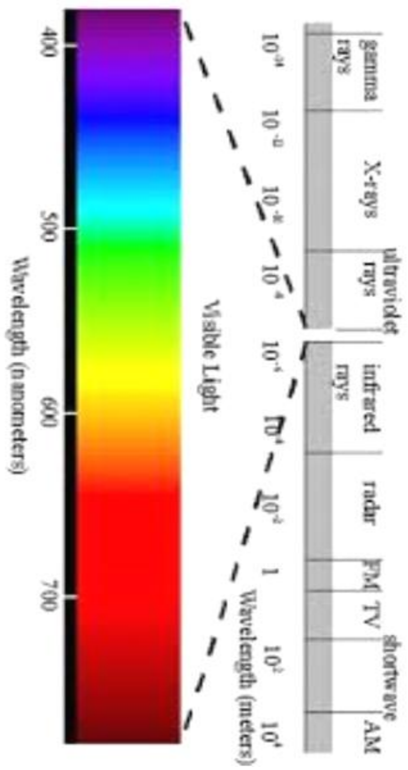

FIG.3 THE COMPLETE SPECTRUM OF LIGHT

PROPERTIES OF LIGHT

ENERGY OF THE PHOTON

$$E = hc / \lambda \ eV \quad (1)$$

ALTERNATIVELY

$$E=1.24 / \lambda(\mu m) \quad (2)$$

$$1eV = 1.602*10e-19 \ J$$

PHOTON FLUX IS DEFINED AS

$$\phi = \text{Number of Photons} / (sec. \ m^2) \quad (3)$$

SPECTRAL IRRADIANCE (F) IS DEFINED AS

$$F = q \ \phi \ E^2 / 1.24 \quad (4)$$

F is measured in W m^{-2} µ m^{-1}

FILL FACTOR OF SOLAR CELL

The ratio between product of current and voltage at maximum power point to the product of short circuit current and open circuit voltage of the solar cell.

$$Fill\ Factor = \frac{P_m}{I_{sc} \times V_{oc}}$$

Short Circuit Current of Solar Cell Isc

The maximum current that a solar cell can deliver without harming its own constriction. It is measured by short circuiting the terminals of the cell at most optimized condition of the cell for producing maximum output. The term optimized condition I used because for fixed exposed cell surface the rate of production of current in a solar cell also depends upon the intensity of light and the angle at which the light falls on the cell. As the current production also depends upon the surface area of the cell exposed to light, it is better to express maximum current density instead maximum current. Maximum current density or short circuit current density rating is nothing but ration of maximum or short circuit current to exposed surface area of the cell.

$$J_{sc} = \frac{I_{sc}}{A}$$

Where, I_{sc} is short circuit current, J_{sc} maximum current density and A is the area of solar cell.

Open Circuit Voltage of Solar Cell

It is measured by measuring voltage across the terminals of the cell when no load is connected to the cell. This voltage depends upon the techniques of manufacturing and temperature but not fairly on the intensity of light and area of exposed surface.

Maximum Power Point of Solar Cell

The maximum electrical power one solar cell can deliver at its standard test condition. If we draw the v-i characteristics of a solar cell maximum power will occur at the bend point of the characteristic curve. It is shown in the v-i characteristics of solar cell by P_m.

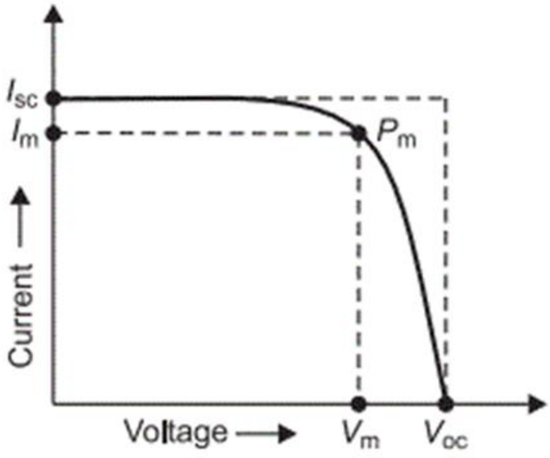

FIG.3 CURRENT AT MAXIMUM POWER POINT

The current at which maximum power occurs. Current at Maximum Power Point is shown in the V-I characteristics of solar cell by I_m.

Voltage at Maximum Power Point

The voltage at which maximum power occurs. Voltage at Maximum Power Pointis shown in the v-i characteristics of solar cell by V_m.

Efficiency of Solar Cell

It is defined as the ratio of maximum electrical power output to the radiation power input to the cell and it is expressed in percentage. It is considered that the radiation power on the earth is about 1000 watt/square metre hence if the exposed surface area of the cell is A then total radiation power on the cell will be 1000 A watts. Hence the efficiency of a solar cell may be expressed as

$$Efficiency(\eta) = \frac{P_m}{P_{in}} \approx \frac{P_m}{1000A}$$

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THE EXPERIMENTAL SETUP

The circuit diagram is shown in the fig. from a PV system which includes PV module and variable resistor (Pot meter) with Ammeter and Voltmeter for measurement. Pot meter in this circuit works as variable load for the module.
When load on the module is varied by Pot meter the current and voltage of module gets changed which shift the operating point.
The Voltage, Current and Power can be achieved by following the connections in control board.
One can also take V-I 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 plotters which will plot the curves of V-I and P-V.
NOTE: The most important point to be noted is that for indoor experimentation the radiation used is of a halogen lamp. A total of four halogen Lamps are used with each module.

OBSERVATIONS:

Tabulations for Indoor Experiment (When exposed to Halogen Lamps) of PV module:

MODULE 1

Inclination 0°

S.no.	Radiation (W/m²)	Temperature (°C)	V (Volts)	I (Amperes)	P (Watts)
1			Voc	0	0
2	76	35.7	0	0.06	0
3	83	36.2	0	0.06	0
4	103	37.2	1.6	0.09	0.144
5	118	37.8	1.2	0.05	0.06

TABLE 1

Inclination 10°

S.no.	Radiation (W/m²)	Temperature (°C)	V (Volts)	I (Amperes)	P (Watts)
1			Voc	0	0
2	96.2	37.4	0	0.04	0
3	120.2	38	1.2	0.06	0.072
4	139.1	38.3	1.4	0.07	0.098
5	148.9	38.7	1.6	0.08	0.128

TABLE 2

Inclination 20°

S.no.	Radiation (W/m²)	Temperature (°C)	V (Volts)	I (Amperes)	P (Watts)
1			Voc	0	0
2	96.2	37.4	0	0.04	0
3	120.2	38	1.2	0.04	0.072
4	139.1	38.3	1.4	0.07	0.098
5	148.9	38.7	1.6	0.08	0.128

TABLE 3

Tabulations for Outdoor Experiment (Exposed to Direct Sun Light) of PV Module 1:

At 11.26 Am

Inclination (Degree)	Radiation (W/m²)	Temperature (°C)	V (Volts)	I (Amperes)	P (Watts)
0	418.30	44.8	19.2	0.98	18.816
10	418.30	45.7	19.2	0.96	18.432
20	418.30	46	19.2	0.95	18.24
30	418.30	44.4	19.1	0.93	17.763

TABLE 4

At 03:26 Pm

Inclination (Degree)	Radiation (W/m²)	Module Temperature (°C)	V (Volts)	I (Amperes)	P (Watts)
0	545.32	52	30.2	1.78	53.576
10	545.32	52	30.2	1.78	53.576
20	545.32	52	30.2	1.77	53.454
30	545.32	52	30.2	1.77	53.454

TABLE 5

MODULE 2

Tabulations for Indoor Experiment (When exposed to Halogen Lamps) of PV Module 2:

Inclination 0°

S.no.	Radiation (W/m²)	Temperature (°C)	V (Volts)	I (Amperes)	P (Watts)
1			Voc	0	0
2	49.2	36.9	0.4	0.02	0.008
3	60.3	37.2	0.6	0.02	0.012
4	68.9	37.7	0.7	0.03	0.021
5	79.2	38	0.8	0.04	0.032

TABLE 6

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Inclination 10^0

S.no.	Radiation (W/m^2)	Temperature (^{0}C)	V (Volts)	I (Amperes)	P (Watts)
1			Voc	0	0
2	50.4	38.3	0.4	0.01	0.004
3	70.2	38.4	0.7	0.03	0.021
4	100	38.4	1.1	0.05	0.055
5	130.6	38.5	1.6	0.08	0.128

TABLE 7

Inclination 20^0

S.no.	Radiation (W/m^2)	Temperature (^{0}C)	V (Volts)	I (Amperes)	P (Watts)
1			V_{oc}	0	0
2	50	38.2	0.4	0.02	0.008
3	70.5	39.4	0.6	0.03	0.018
4	100	39.8	1.2	0.06	0.072
5	119.7	40.1	1.6	0.08	0.128

TABLE 8

Tabulations for Outdoor(Exposed to Direct Sun Light) Experiment of PV Module 2:

At 11:27am

Inclination (Degree)	Radiation (W/m^2)	Temperature (^{0}C)	V (Volts)	I (Amperes)	P (Watts)
0	418.30	44.5	19.3	0.97	18.721
10	418.30	45.2	19.3	0.96	18.528
20	418.30	45.6	19.2	0.96	18.432
30	418.30	45.6	19.1	0.95	18.145

TABLE 9

At 03:26 Pm

Inclination (Degree)	Radiation (W/m^2)	Module Temperature (^{0}C)	V (Volts)	I (Amperes)	P (Watts)
0	545.32	52	30.2	1.78	53.576
10	545.32	52	30.2	1.78	53.576
20	545.32	52	30.2	1.77	53.454
30	545.32	52	30.2	1.77	53.454

TABLE 10

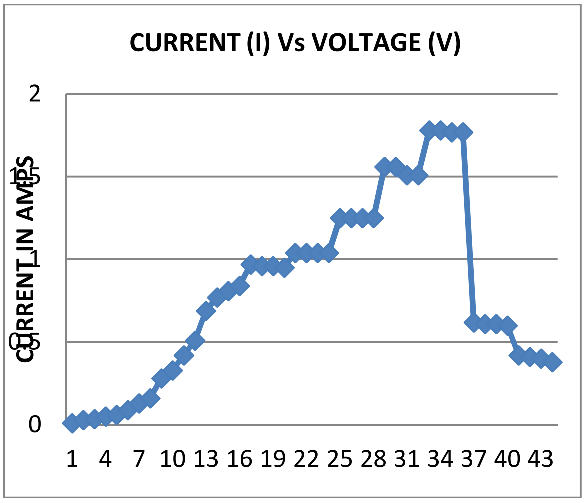

FIG.4 V-I CHARACTERISTICS _OUTDOOR EXPERIMENT

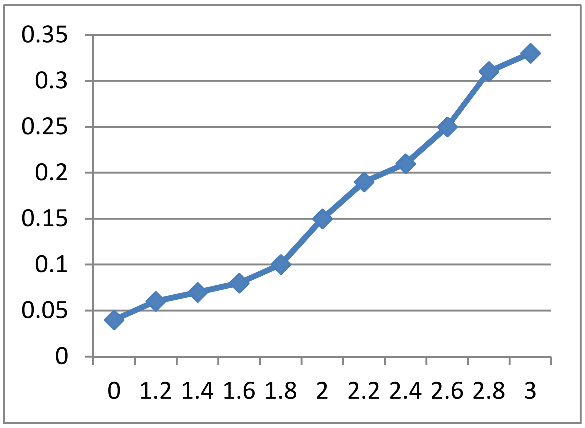

FIG.5 V-I CHARACTERISTICS _INDOOR EXPERIMENT

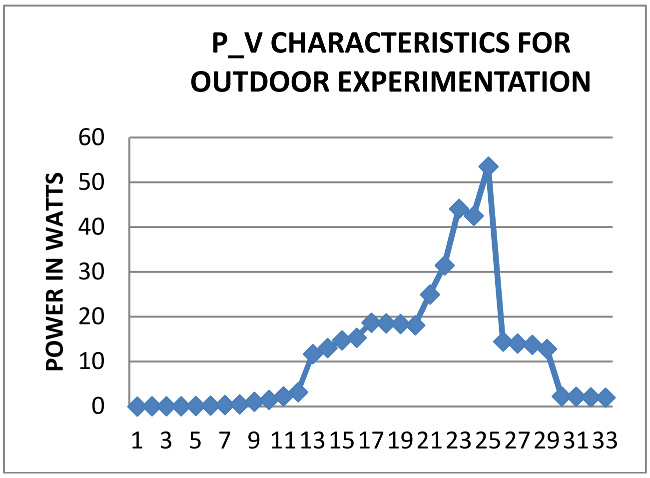

FIG.6 P-V CHARACTERISTICS _OUTDOOR EXPERIMENT

CONCLUSIONS

After a series of experimentations done on the Polycrystalline PhotoVoltaic Module it is found that the OutPut of the Solar PV Module clearly depends upon the frequency / wave length of the radiation to which it is exposed to. In this experiment as the halogen lamps consists of only one wavelength of radiation the output voltage got limited to a maximum of 3 volts and the current to a maximum of 0.35 amps which is very less when compared to the values obtained when exposed to direct sunlight where the maximum voltage obtained is 30.2 volts and current obtained is 1.78 Amps.

The maximum value of power obtained with outdoor experimentation is 53.576 watts and with Indoor experimentation ie. When the modules are exposed to halogen lamps is only 1.05 watts.

NOTE : The different reading presented are an outcome of the experimentations carried out in the Solar Power Research Lab of the Department of EEE , University College of Engineering , Kakatiya University , Kothagudem, Bhadradri Kothagudem (Dt) of the State of Telangana, India.

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