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Performance Analysis of Photovoltaic Module at changing Environmental condition using Matlab Simulink

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Abstract

With the growing energy consumption in all most every sector the demand of photovoltaic energy has increased. In this paper only one environmental factor is taken into consideration i.e. solar irradiance. The solar irradiance reaching the earth's surface keeps on changing depending on the climatic condition. During clear weather the amount of sunlight received by the PV panel is more than that during cloudy weather. Hence modeling of PV module is done using the basic equations in MATLAB Simulink environment at different irradiance level. The results of the simulink are verified by conducting a laboratory experiment.

Keywords: Photovoltaic;Fillfactor;diode; bandgap;efficiency.

INTRODUCTION

Non conventional energy is one of the prime area where more focus can be made to decrease the use of fossil fuel. However solar energy find wide application as it is clean, pollution free and available free of cost [1],[2]. Studies show that the short circuit current of the module decreases as the band gap increases. The optimum bandgap for the ideal solar cell is 1.45eV [3]. The photon generated current is directly proportional to the intensity of solar irradiance. Thus the phon generated current, short circuit current and open circuit voltage increases as the insolation level increases keeping other factors like temperature, spectral content constant [4]. The short circuit current has a logarithmically relation with irradiance. Fillfactor is an indicator of quality of cell. Mostly commercially available silicon solar cells have fill factor in the range 0 to 1 [5]. T. Esram and P.L chapman designed two diode model and found better results [6], [7]. But the circuit becomes complex with the design. Many researchers have found that the output efficiency of the pv module depends on a variety of factors like solar irradiance, temperature, presence of dust, shading, panel orientation, tracking, cell structure etc [8] . Solar Irradiance is a positive factor but studies also shows that with increase in irradiance the total amount of energy is not converted to electricity where as it gets converted to heat energy there by increasing the temperature of the module. As a result the module efficiency decreases at high temperature as the band gap reduces [9], [10]. Figure 1 shows the IV curve and a special point called knee point where the curve bends sharply giving the value of maximum voltage and maximum current. This point is called maximum power point.

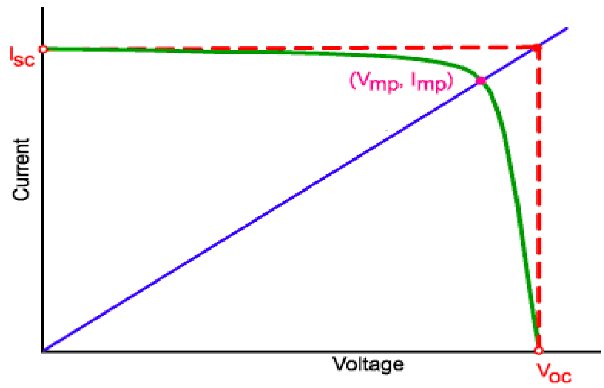

Figure 1: Maximum power point of solar cell

PHOTOVOLTAIC MODULE

A photovoltaic module is made up of 32 to 36 number of crystalline silicon solar cells. It is basically a current source where the energy from the sun is directly converted to electrical energy. The IV characteristics show a non-linear relationship. From the IV curve it is studies that with the increase in voltage the current decreases but at a point called knee point maximum power is produced hence called maximum power point [11], [12]. An ideal solar cell consists of single diode in parallel connection with light generated current source. Here in this case the pv output current is directly the short circuit current. But in real situation the circuit consists of shunt and series resistance hence the output current depends on the shunt branch elements. The photo current depends on solar irradiance and the cell temperature. The reverse saturation current of diode depends on the operating temperature.

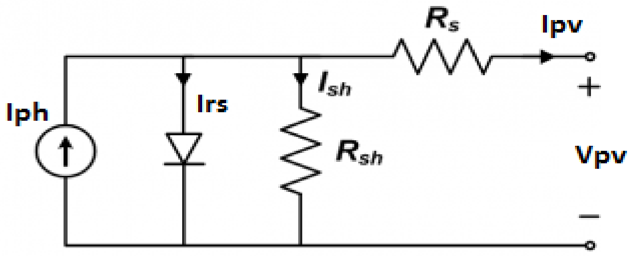

Figure 2: Basic diagram showing practical solar cell

Figure 2 shows one diode model of PV cell considering the series and resistances. The output current of the PV module can be found out by using the below given equations as follows:

$$Ipv = Iph - Is\left[\exp\left(\frac{q \times Vpv + Ipv \times Rs}{Ns \times A \times K \times Top}\right) - 1\right] \quad (1)$$

Where Iph is the light generated photo current and is given by the equation as

$$Iph = [Iscref + Ki(Top - Tn)]G \quad (2)$$

From equation 1 Is is the current through the shunt branch which is represented by the below equation

$$Is = Irs\left(\frac{Top}{Tn}\right)^3\left[\exp\left(\frac{q \times Eg\left(\frac{1}{Tn} - \frac{1}{Top}\right)}{k \times A}\right)\right] \quad (3)$$

From equation no 3 Irs refers to Reverse Diode current.

$$Irs = \left[\frac{Iscref}{\exp[Ns \times K \times A \times Tn] - 1}\right] \quad (4)$$

Where

Ipv : PV output current in ampere
q : charge of electron, 1.602×10^{-19}
Rs : Shunt resistance in ohm
Ns : No of cells in series
A : Diode Ideality constant, 1.5
Ki : Temperature coefficient, 0.0017
K : current temperature constant, 1.3805×10^{-23}
Top : Operating temperature
Tn : Nominal temperature
k : Constant, 1.6
Eg : Band gap of silicon, 1.1volt
Iscref : Reference short circuit current

Using this fundamental four basic equation the pv system is moduled in the Matlab/Simulink to get the desired PV and IV curve so that the efficiency and fill factor can be studied at various irradiance condition.

MODELLING OF PV

The Photovoltaic system is modeled in MATLAB Simulink using components of power system blocks. In the Figure 2 two number of signal builders are used one for solar irradiance and the other for temperature. As we consider only one environmental factor so the temperature is kept constant i.e at ambient temperature 25°c. The other signal builder is used to provide necessary irradiance signal. Here three cases are taken into consideration 1000 watt/m^2, 600 watt/m^2 and 200watt/m^2. A continuous powergui block is used in the simulation design as shown below. Hence with this simulation design both PV and IV curves are drawn for various insolation conditions.

The specifications of the parameter used for the module is given as below:

Table I: Specifications of the pv module used for design

Type	Vikram Solar
Maximum power	37 watt
Open circuit voltage	21.8 volt
Short circuit current	2.5 ampere
Maximum voltage	17.20 volt
Maximum current	2.20 ampere

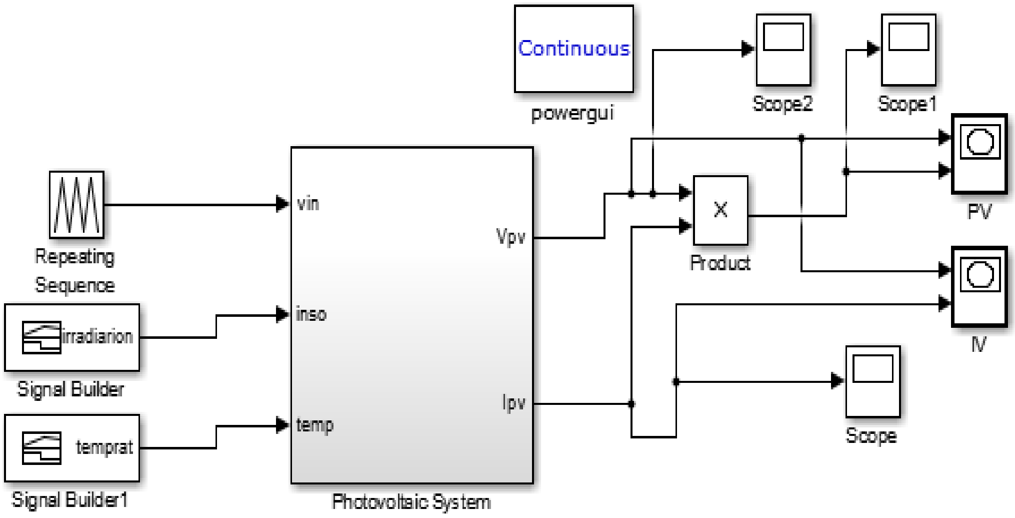

Figure 3: Photovoltaic system modelled in Matlab/Simulink with various irradiance as iput to the system

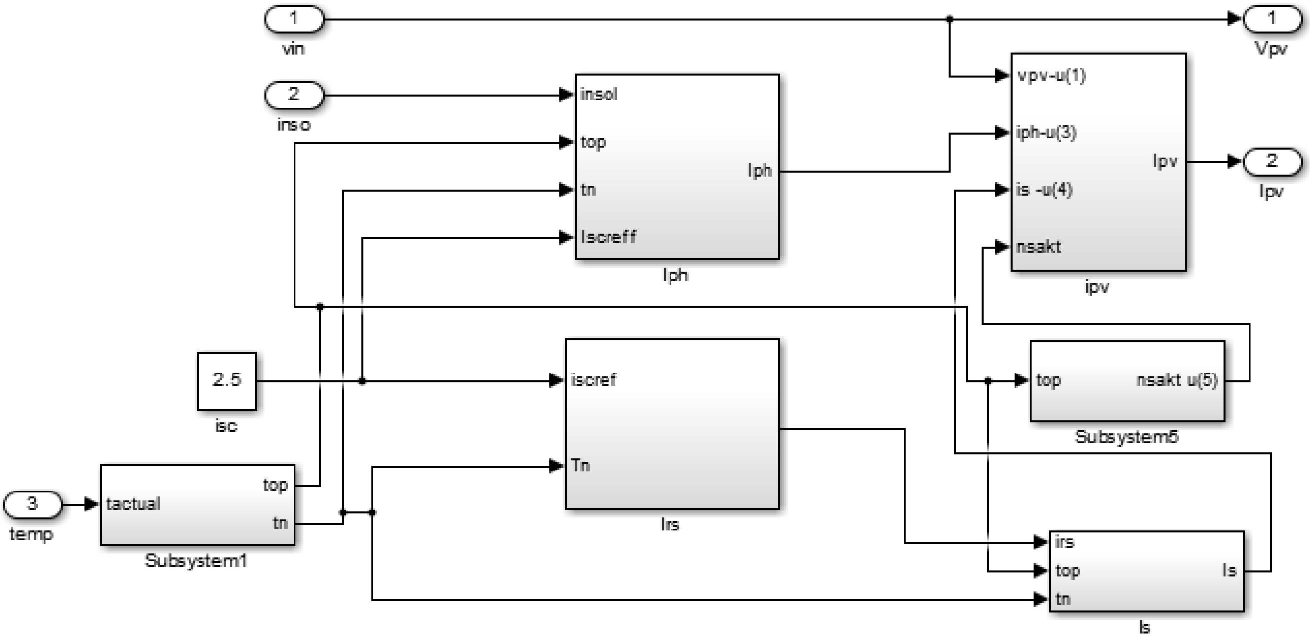

Figure 4: Various substsems modelled inside the photovoltaic system as shown in figure 3

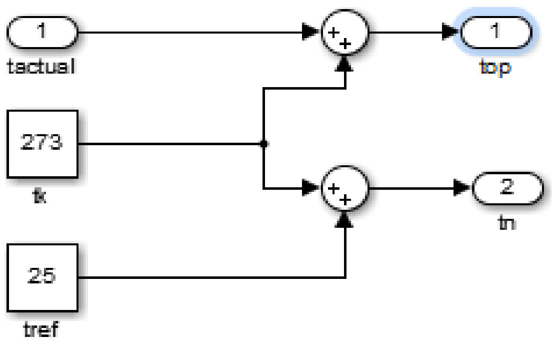

Figure 5: Subsystem 1 showing operating temepearture top and nominal temperature tn.

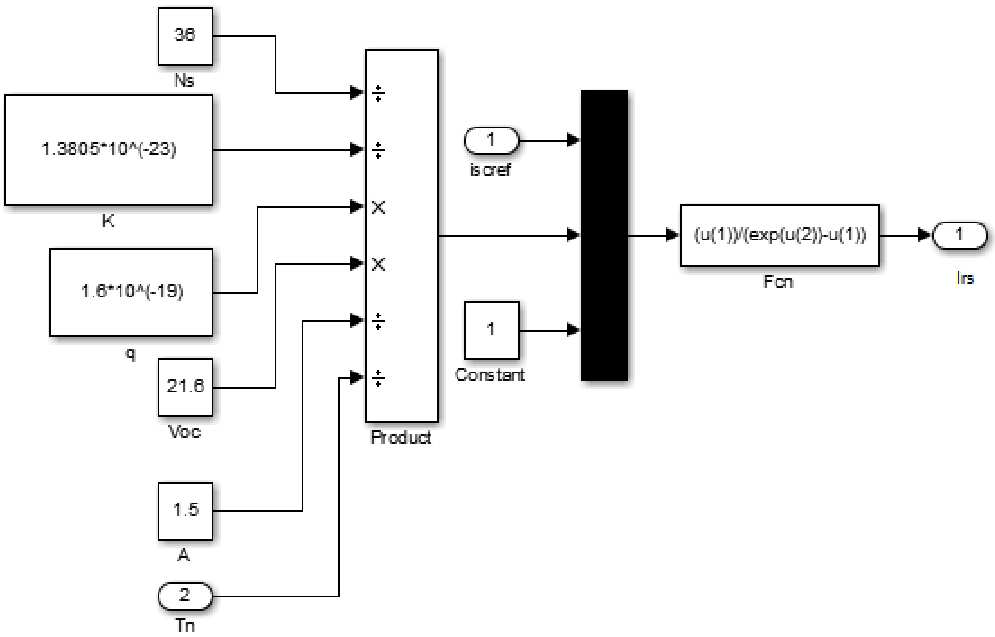

Figure 6: Modelling of Irs using the equation 4.

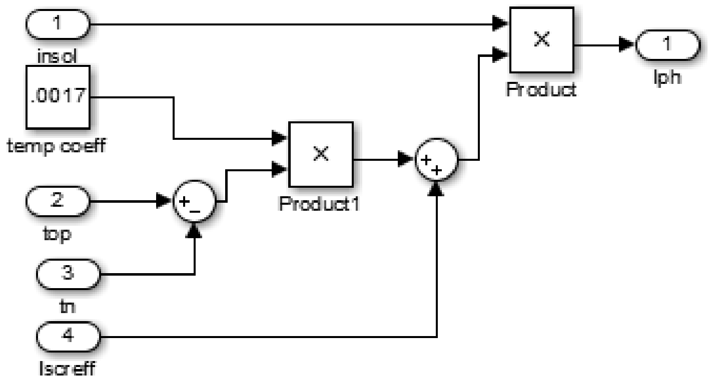

Figure 7: Modelling of photocurrent Iph using equation no 2.

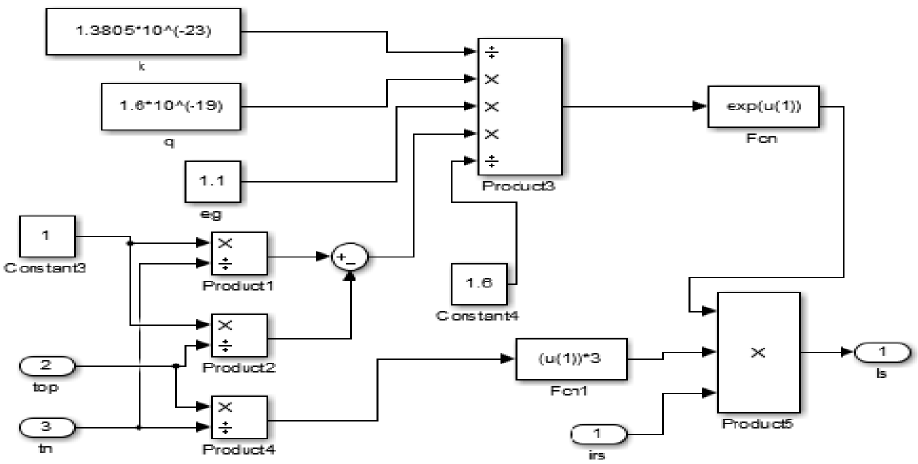

Figure 8: Subsystem showing Is using equation 3.

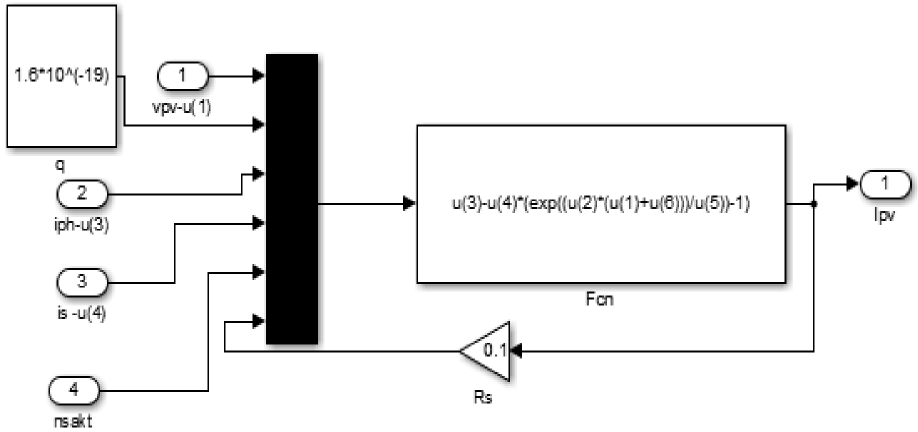

Figure 9: Shows the modelling of Ipv using equation no 1.

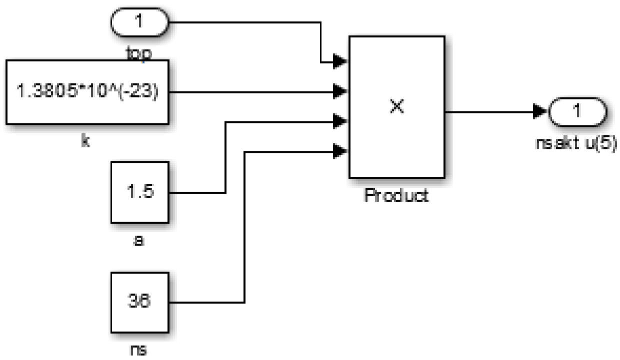

Figure 10: Subsystem 5

EXPERIMENTAL METHOD

A similar solar PV module of same parameter rating is tested in the laboratory for different values of irradiance keeping the temperature constant. In this case halogen bulbs are used to get the desired irradiance in place of sunlight. By varying the variac connected with the halogen bulb the desired irradiance can be achieved. The Ecosense PV Analyser with its various units like power generation, power sensing, control and monitoring along with other accessories is used to record the voltage and current reading and draw the desired pv and iv curve.

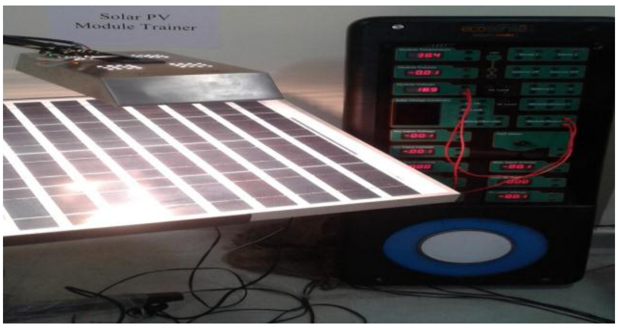

Figure 11: Experimental setup for conducting the pv test.

The values of voltage and current are noted down for three different irradiance i.e 1000 watt/m^2, 611 watt/m^2, 210 watt/m^2. The solar irradiance was checked with the help of solar meter. Maximum power is calculated from the value of maximum voltage and maximum current. Hence Efficiency of the module and fill factor is calculated by the following equations:

$$Efficiency\,(\%) = \frac{Pmax}{Irradiance \times Area} \tag{5}$$

$$Fillfactor = \frac{Vm \times Im}{Voc \times Isc} \tag{6}$$

Where Vm is the maximum voltage, Im: maximum current of pv module, Voc: Open circuit voltage, Isc: Short circuit current.

RESULTS AND DISCUSSIONS

The output PV and IV curve for both modeling and experimental work is represented as below.

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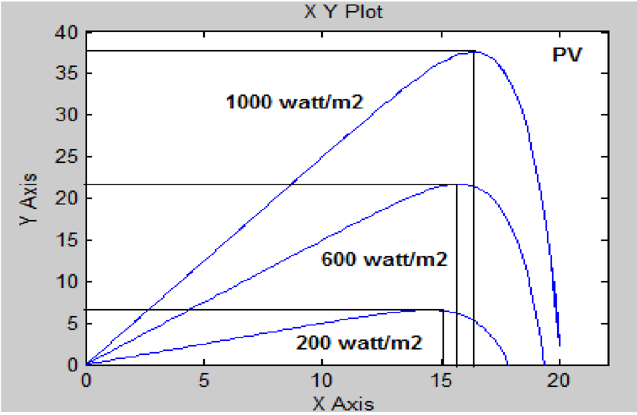

Figure 12: Simulation result showing pv curve

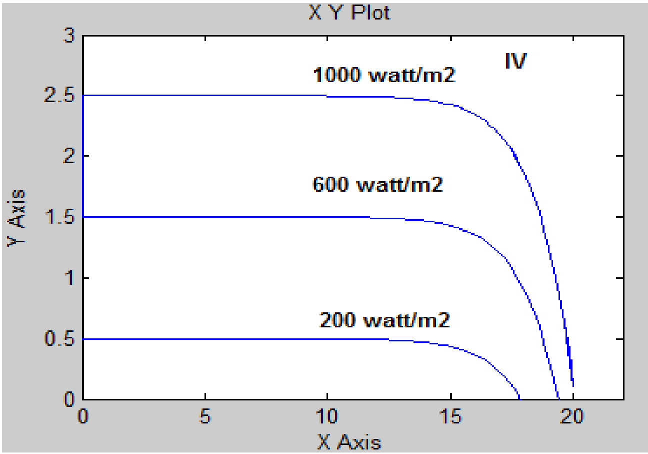

Figure 13: IV curve at different irradiance

Figure 12 and 13 shows the simulation modelling result for the the system as shown in the figure 3. From the figure 12 it was seen that the maximum power increased with increase in irradiance hence the mppt point shifts from the initial value. In figure 13 changing irradiance makes a remarkable change in module short circuit current where as a very little increase was found in case of open circuit voltage.

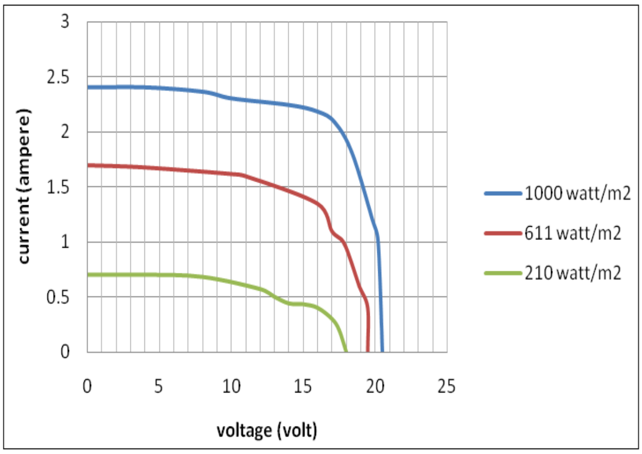

Figure 14: IV curve at real irradiance condition

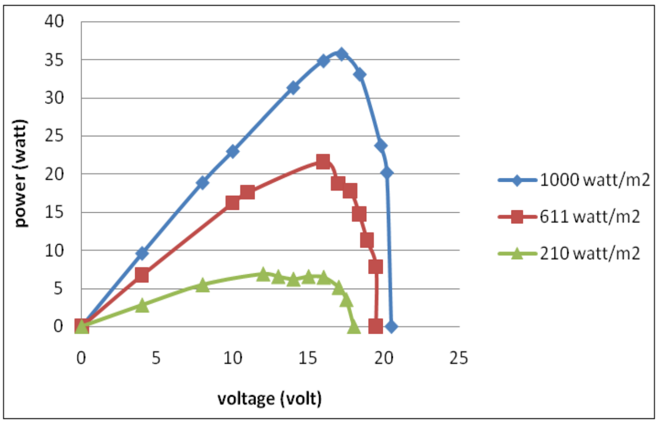

Figure 15: PV curve at real irradiance condition

Table II: Values of Maximum power, efficiency, fill factor as per the simulation result

Sl no	Irradiance	Maximum power(watt)	Efficiency	Fillfactor
1	1000	37	10.08%	0.97
2	600	22	9.9%	0.58
3	200	7	9.5%	0.18

Table III: Values of maximum power, efficiency, fillfactor as per the experimental readings

Sl no	Irradiance	Maximum power(watt)	Efficiency	Fillfactor
1	1000	36.1	9.8%	0.95
2	611	21.7	9.5%	0.57
3	210	6.6	8.6%	0.17

Table 2 and 3 shows the values of maximum power, efficiency and fill factor for both the simulation model and experimental method at various irradiance.

CONCLUSION

Solar Irradiance is one of the important factor for determining the performance of the solar module. As the amount of irradiance reaching the panel surface and the amount converted to useful electricity varies it is important that the module must operate at maximum power point condition i.e at maximum voltage and maximum current. Both the Matlab Simulation result and experimental result shows similarity in terms of efficiency and fill factor at the defined the irradiance condition.

It is also concluded that as the irradiance increases the maximum power increases. Even a remarkable change is observed in short circuit current with very less changes in open circuit voltage. The maximum efficiency at standard operating condition i.e 1000 watt/m^2 is around 10% and the fill factor is 0.97. Hence the modeling done in the paper using the four basic equations holds good and true to the result.

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