MODELING OF SOLAR PHOTOVOLTAIC PANEL AND PERTURB & OBSERVE MPPT CONTROL ALGRITHM FOR MPP TRACKING

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Abstract - In this paper I proved that the mathematical model can be practically realized as an ideal cell. This paper presents an easy and accurate method of modeling photovoltaic arrays. The method is used to obtain the parameters of the array model using information from the datasheet. The equations of the model are presented in detail. Component simulation model and practical model are also designed and results are compared with mathematical model to prove the ideality of solar cell. MATLAB programs are written to see the effect of temperature and solar irradiation on the output of the solar cell. Finally maximum power point is tracked by using Perturb and Observe power point tracking algorithm for irradiation and temperature values.

***Key Words*: solar panel, mathematical model, component model, practical model, perturb and observe MPPT algorithm**

1. INTRODUCTION

Solar cells are made by two types of semiconductor materials one is N type semiconductor and other is P-type semiconductor material for generation of electricity. Solar cell connection is just like battery connection. When positive terminal of one solar cell is connected to negative terminal of another solar cell then they form series connection. In series connection current is same for all cells and voltage is added by each cell and when all positive terminals of solar cells connected to one terminal and all negative positive terminals of solar cells connected to another one terminal then forms parallel connection.

Solar cell is manufacturing by different materials. The two major technologies are wafer-based silicon and thin-film. Crystalline silicon solar cell is more efficient than thin-film solar cell but that is more expensive to produce. They are most commonly uses in large to medium electric applications like grid connected PV power generation. Mono-crystalline solar cell is manufactured by pure semi-conducting materials so it has higher efficiency (above 17% in industrial production and 24% in research laboratories. Poly-crystalline solar cell is slightly less efficient than Mono-crystalline but less in cost. In thin-film solar cell very thin layers of semiconducting materials are uses so they can be produces in large quantity at lower cost but it efficiency is less. This technology is uses in calculators, watches and toys etc

There are too many other PV technologies available like Organic cells, Hybrid PV cells combination of both mono crystalline and thin film silicon etc

2. MODELLING OF PHOTO VOLTAIC PANEL

Equivalent circuit of solar cell is shown in fig.1.

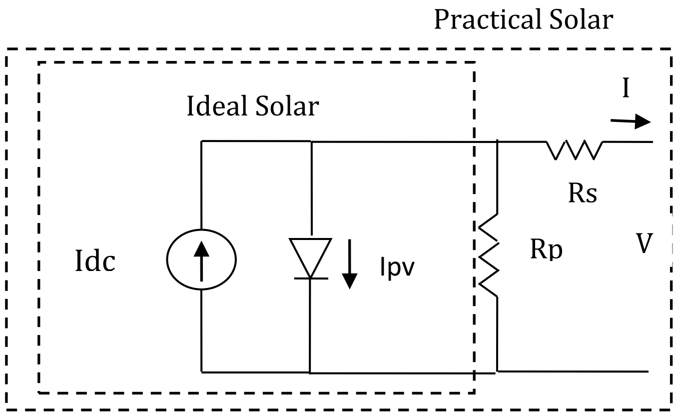


Fig.1 Equivalent circuit of solar cell

2.1 Mathematical Model

Mathematical model of solar cell can be obtained by using the equations(1),(2),(3),(4)and(5) given below.

$$I(or)I_{dc} = I_{pv} - I_0\left[\exp\left(\frac{V + R_s I}{V_t a}\right) - 1\right] - \frac{V + R_s I}{R_p} \quad (1)$$

$$I_{pv} = \left(I_{pv,n} + K_1 \Delta T\right)\frac{G}{G_n} \quad (2)$$

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)\exp\left[\frac{qE_g}{ak}\left(\frac{1}{T_n} - \frac{1}{T}\right]\right. \quad (3)$$

$$I_{0,n} = \frac{I_{sc,n}}{\exp\left(\frac{V_{oc,n}}{aV_{t,n}}\right) - 1} \quad (4)$$

Table 1: JJ PV SOLAR JP36C020 MODEL DATASEET

ELECTRICAL PARAMETERS	VALUES
MODEL	JP36C020
Rated Power(Pmax) watt	20 Watt
Volt at Max. power(Vmp in volt)	17 Volt
Open circuit voltage(Voc in volt)	21 Volt
Current at Max. Power(Imp in Amp)	1.19 Amp
Short circuit current(Isc in Amp)	1.3 Amp
Fill factor(FF)	>70
Module efficiency (%)	10~12
No. of Cells in series	36 cells
Ki (temp current constant)	0.00023
A (diode ideality constant)	1.3
Standard Test condition	Irradiance:1000W/m^2, Temp: 25^{0}C
Temp.coeff. Of Pmax(%/K)	-0.44
Temp.coeff. Of Voltage(mV/K)	-2.13
Temp.coeff. Of current(mA/K)	4.46
Max.system voltage (Volt)	600
NOCT (Nominal operating Cell temp in °c)	47.0+2
Tolarence of rated power (%)	+ 3

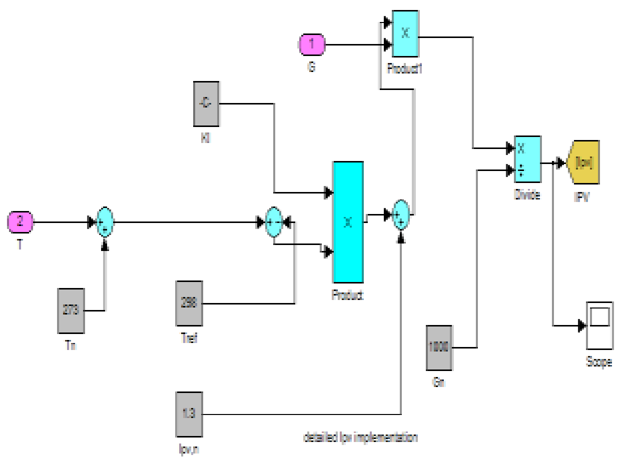


Fig.2 Detailed Ipv implementation

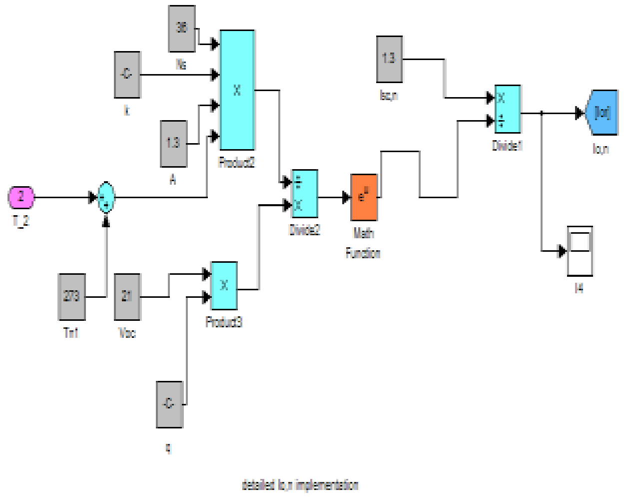


Fig.3 Detailed Io,n implementation

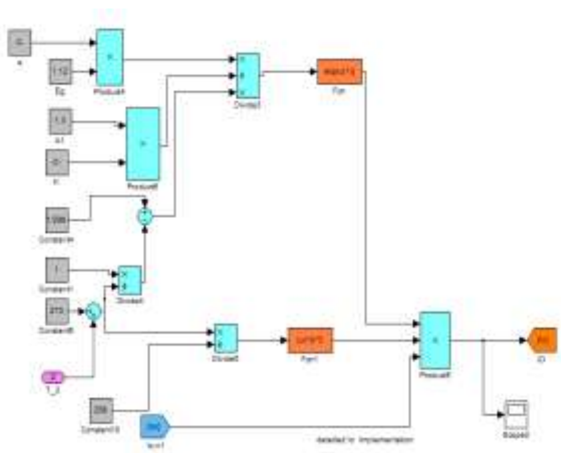


Fig.4 Detailed Io implementation

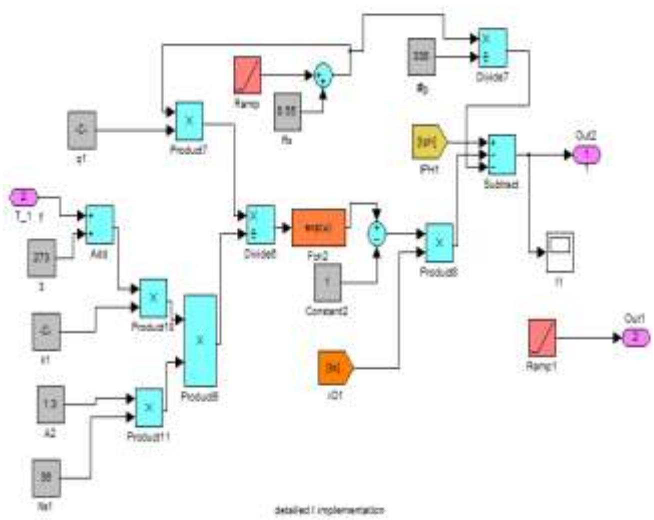


Fig.5 Detailed I implementation

The complete PV model is obtained by creating a subsystem and it is presented in fig.5. Irradiance and temperature are the inputs while the outputs are power, current and voltage. Power is obtained by the product of voltage and current

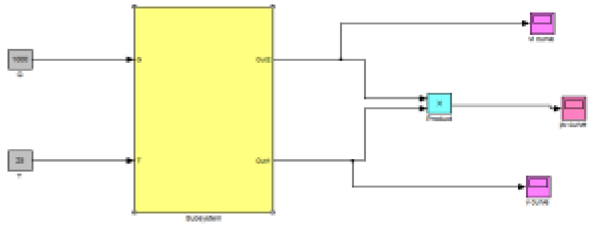


Fig.6 Presentation of whole PV model

2.2 ELECTRICAL COMPONENT MODEL

In this project, with the help of datasheet given by "JJ PV Solar Pvt. Ltd., Rajkot, Gujarat", JP36C020 model solar panel, the characteristic is achieved by designing on MATLAB software as shown in figure 18, some data of that panel from its datasheet is given in table 1.

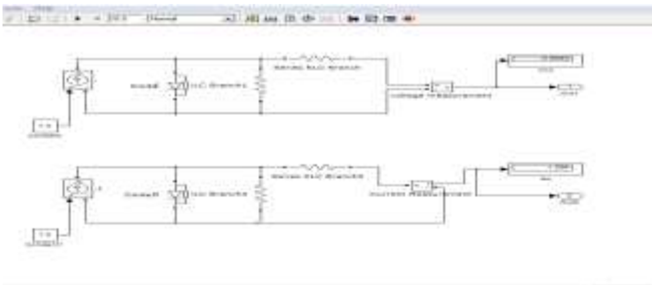


Fig.7 Electrical Component Model Of Single Cell

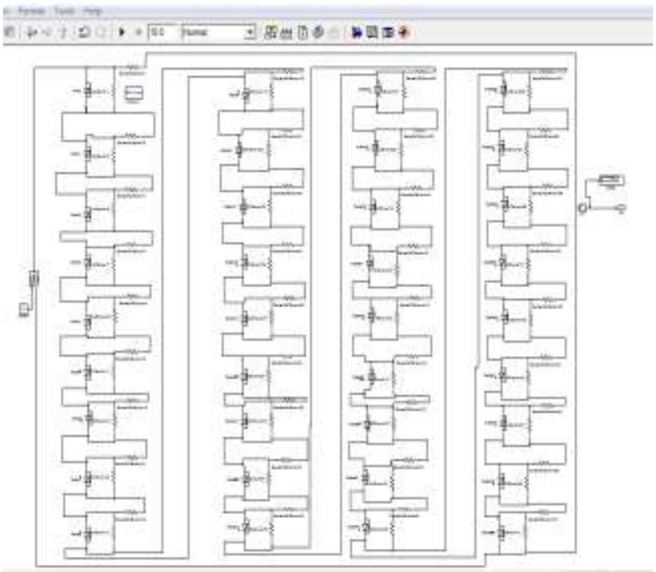


Fig.8 Simulation of 36 cells for obtaining Voc

In figure 8, the negative terminal of one cell is connected to positive terminal of second cell. In this way 36 solar cells are connected in series to achieve the JP36C020 model solar panel characteristic

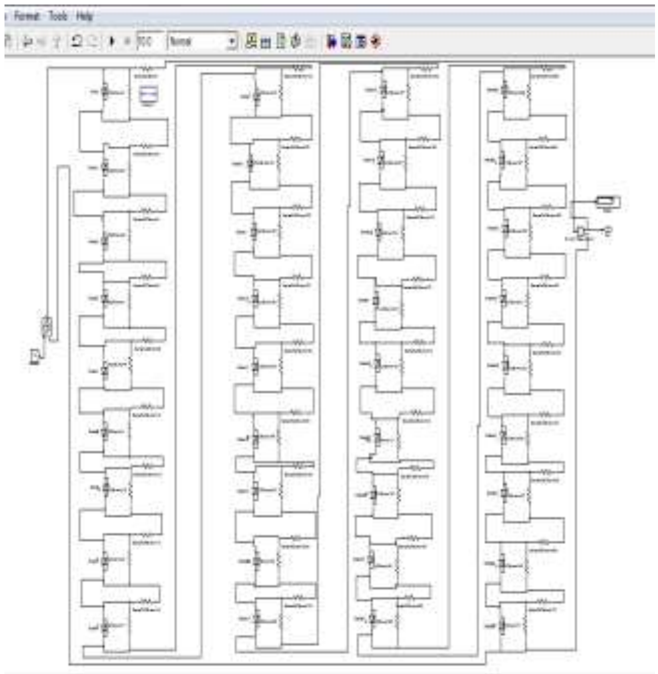


Fig.9 Simulation of 36 cells for obtaining Isc

In figure 9, short circuit current is obtained by connecting 36 cells in series. The short circuit current (Isc) obtained for 36 cells is 1.3A and it is shown in figure 9

2.3 PRACTICAL MODEL

Hardware model is made based on component model by connecting 36 solar cells in series on a printed circuit board (PCB). The cells are connected in series for higher capability.

Fig. 10 Hardware Model

A current source of 1.3A is given at the input and open circuit voltage and short circuit current are measured on the output using multimeters

Fig.11 Measurement of Voc practically

Fig.12 Measurement of Isc practically

As shown in figures 22 and 23, we get Voc= 20.9V, Isc=1.3A. After finding Voc and Isc, a decade resistance box (DRB) is connected across output in the form of a load resistor. For different values of resistance, voltage and current are noted down. Depending on these values power is calculated. These values are shown in table 2.

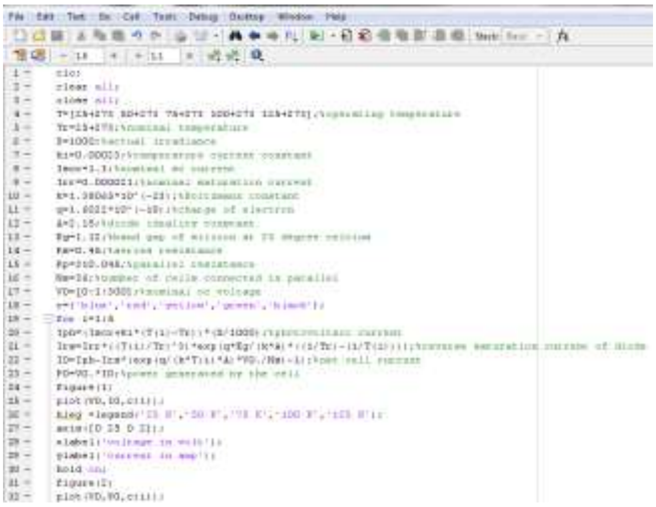
Table 2: Experimental values

s.no.	Resistance(ohms)	Voltage(V)	Current(A)	Power=V*I (W)
1	0	0	1.3	0
2	1	1.7	1.3	2.21
3	5	6.9	1.3	8.97
4	10	13.9	1.3	18.07
5	14	17	1.15	19.55
6	20	19.6	0.86	16.856
7	30	20.4	0.66	13.464
8	60	20.6	0.33	6.798
9	90	20.7	0.22	4.554
10	100	20.75	0.2	4.15
11	200	20.8	0.1	2.08
12	600	20.81	0.03	0.6243
13	1k	20.85	0.01	0.2085
14	3k	20.9	0	0

3. MATLAB PROGRAMS TO CHECK THE IMPACT OF SOLAR IRRADIATION AND TEMPERATURE ON SOLAR PANEL

The characteristics of solar panel for different solar irradiation levels and temperatures are plotted by writing a MATLAB program as shown in fig.13 and fig.14

Fig.13 MATLAB program for different solar irradiation level



ig.14 MATLAB program for different temperature levels.

4. Perturb and Observe MPPT control algorithm

We know solar panel output changes with change in solar irradiation and temperature. so to extract the maximum power from the solar panel in case of changes in solar irradiation and temperature maximum power point techniques are used. Here in this paper I have used perturb and observe mppt control algorithm. This algorithm starts by settling the computed maximum power Pmax to an initial value. Next the actual PV voltage and current are measured at specified intervals and the instantaneous value of PV power, Pmax and Pact are compared. if Pact is greater than Pmax it is set as new value of Pmax. At every instant the Pact is calculated, and the comparison is continuously executed. Hence the final value of Pmax will be the point at which maximum power transfer across the load. For maximum power transfer across the load the input impedance equal to the load impedance. Based on the mechanism of load matching the duty cycle of the converter is varied so that the output power will almost be equal to the load power MPPT based solar photovoltaic system is shown in fig.15. fig.16 shows the P&O control algorithm along with PWM control technique

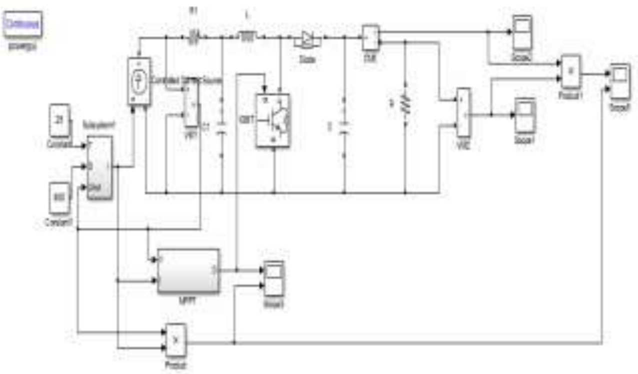


Fig.15 Mppt Based Solar Photovoltaic System

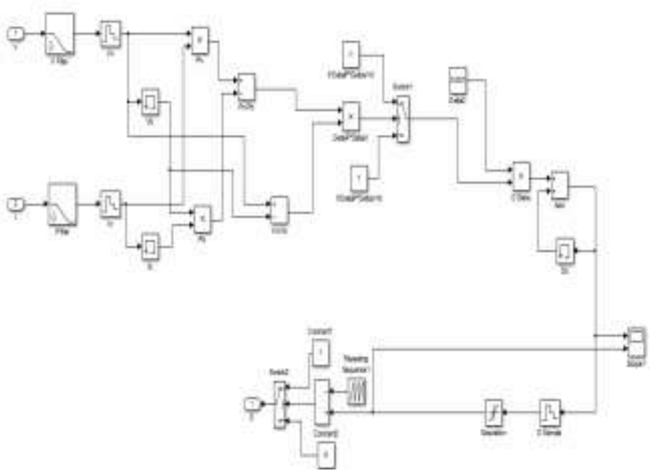


Fig.16 Perturb And Observe MPPT Control Algorithm And PWM Control Technique

5. RESULTS

5.1 Result of mathematical model

PV And IV Curves obtained from the mathematical model of solar panel is shown in fig.17 and fig.18

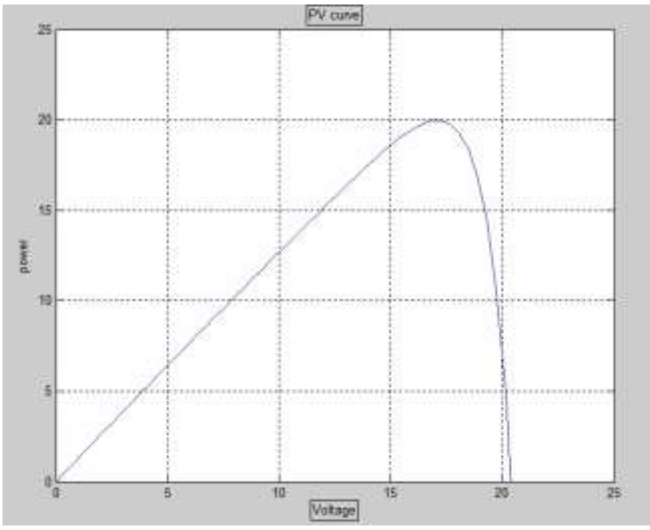


Fig.17 PV curve obtained from mathematical model

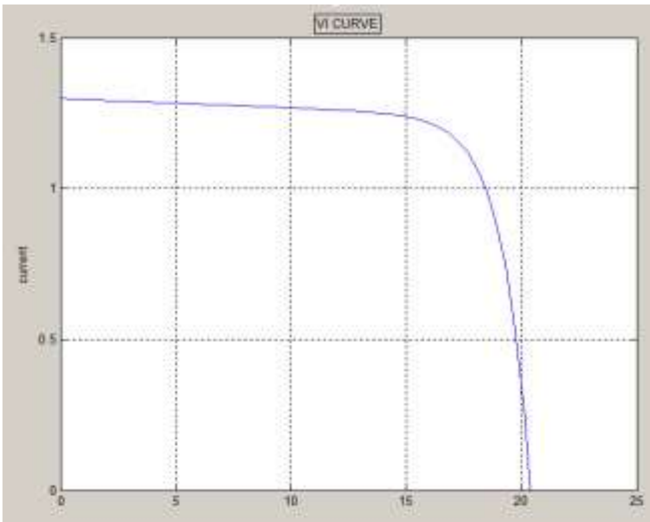


Fig.18 IV curve obtained from mathematical model

The open circuit voltage (Voc) and short circuit current (Isc) obtained for 36 cells is 21.07V and 1.33A respectively and it is shown in figure 18.

As we can see in figure 17, maximum power is 20V.

5.2 Result of electrical component model

By connecting 36 solar cells in series and simulating n MATLAB as shown in section (2.2), we obtain Voc and Isc values.

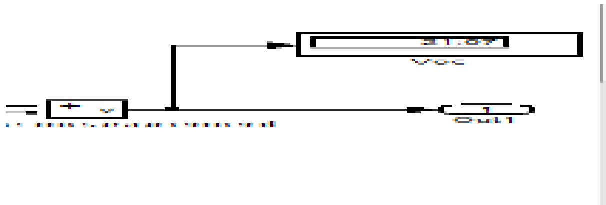


Fig.19 Voc

By connecting 36 cells in series, in MATLAB, Voc obtained is 21.07V, as shown in fig.19

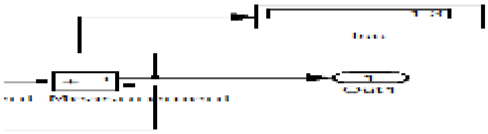


Fig. 20 Isc

By connecting 36 cells in series, in MATLAB, Isc obtained is 1.3 V, as shown in fig. 20

5.3 Result of practical component model

As shown in section (2.3), a set of values are obtained which are tabulated. By taking the values of table 2 into consideration PV and IV characteristics are plotted

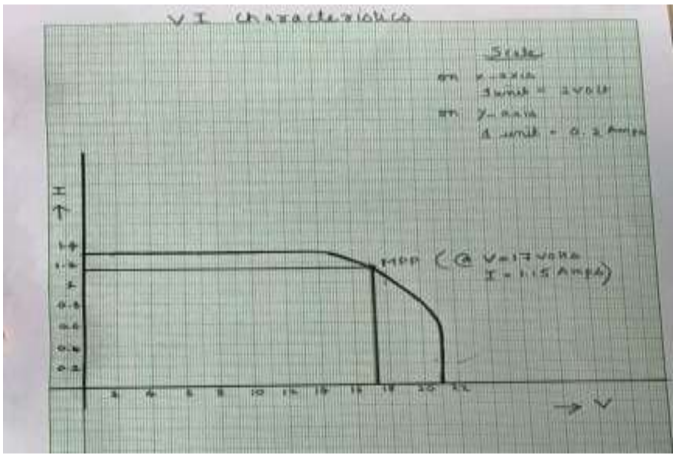


Fig. 21: V-I characteristics plotted from practical model

In fig.21 the maximum value of voltage at which the current drops is taken as maximum power point (MPP) (Vmp Imp).
Open circuit voltage (Voc)=20.9 V
Short circuit current (Isc)= 1.3A
Voltage at max. power (Vmp)= 17 V
Current at max. power (Imp)= 1.15A
These results are compared with the datasheet.

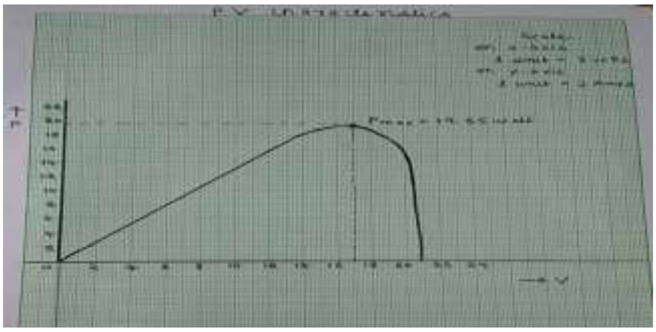


Fig.22 P-V characteristics plotted from practical model

Maximum power obtained practically is 19.55 as shown in fig.22

5.4 Result of MATLAB program

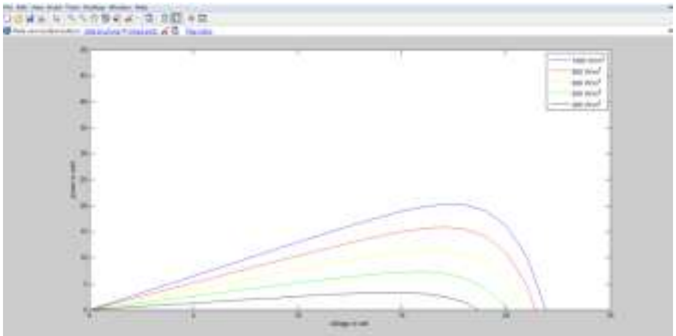


Fig.23 P-V Characteristics For Different Solar Irradiation Levels

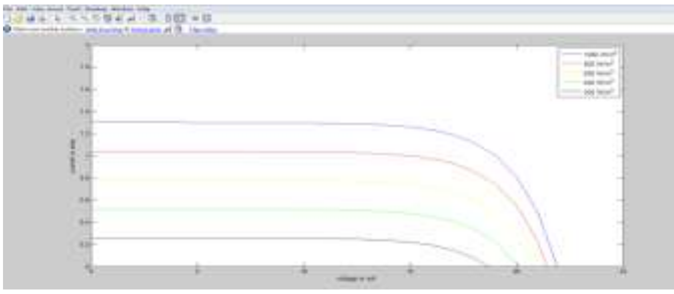


Fig.24 I-V Characteristics For Different Solar Irradiation Levels

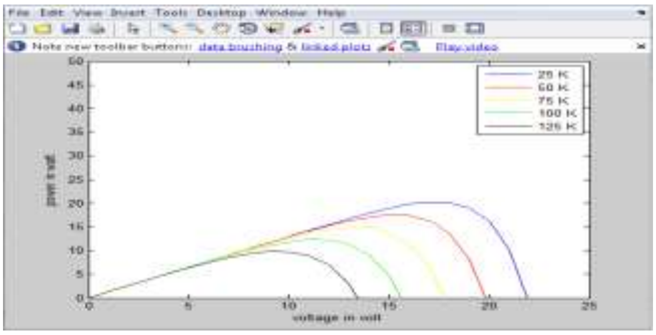


Fig.25 P-V Characteristics For Different Temperature Levels

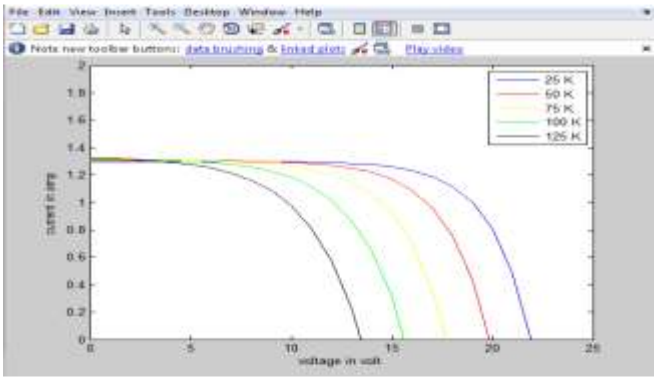


Fig.29 I-V Characteristics For Different Temperature Levels

5.4 Result of P&O MPPT Control algorithm

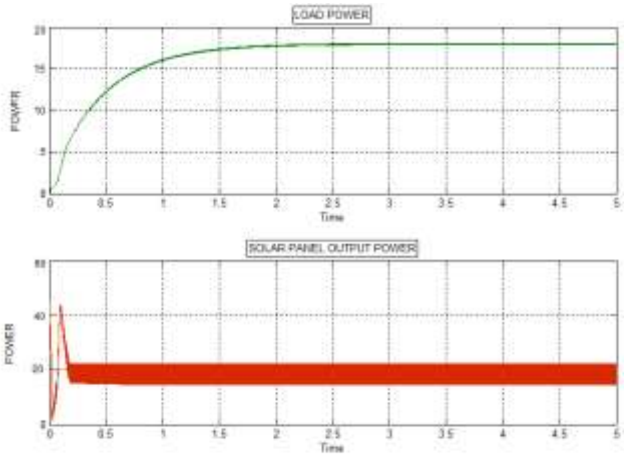


Fig.30 Output power of load and solar panel

By using P&O MPPT control algorithm power is improved from… to….. as shown in figure 30

5.5 Comparison of results

The results obtained in mathematical model, component model and practical model are compared with the datasheet as shown in table 3.

Table 3: Comparison of results

Parameters	datasheet	Mathematical model	Component model	Practical model
Voc	21 Volt	20.5 Volt	21.07 Volt	20.9 Volt
Isc	1.3 Amp	1.33 Amp	1.3 Amp	1.3 Amp
Maximum Power	20 Watt	20 Watt	19.55 Watt	19.55 Watt

By comparing the results in the above table we can see that the values are almost equal. Hence, it is proved that the mathematical model can be practically realized as an ideal solar cell.

Table 4: Comparison of results

Parameters	Irradiation =1000	Irradiation =800 Without controller	Irradiation =800 With P&O control algorithm
Maximum Power	20 Watt	15 Watt	19.55 Watt

By using P&O MPPT control algorithm power is improved from 15 to 19.55 as shown in table 3

6. CONCLUSION

The results of mathematical model have been compared with the component simulation model and the practical model as can be seen from table (3). Thus the mathematical model can be practically realized as an ideal solar cell. This work provides all necessary information to develop a single-diode photovoltaic array model for analyzing and simulating a photovoltaic array. It means that for any type of PV module, one can use this model and determine all the necessary parameters under any new conditions of irradiance and temperature and then, obtain the I(V) and P(V) characteristics. This model can be considered as a tool which can be used to study all types of PV modules available in markets, especially, their behavior under different weather data of standard test conditions (STC).The maximum power point is also obtained by using perturb and observe MPPT control algorithm.

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