Effects of Parameter Variations of PV Module based on MATLAB - Simulink Modeling

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ABSTRACT

Recent applications in remote areas need low-cost source of power. Standalone PV system could assure this power. This paper includes the effect of variation of parameters of PV panel model in MATLAB/Simulink. This build model is based on mathematical equations of the equivalent circuits which consists of a current source, series resistance, and parallel resistance along with a diode. The model is built for the predetermination of nature of the Solar-PV module for different radiation, temperature and other physical parameters. Moreover, PV-array system has been studied in the given research work. For the validation of Simulink results, a real time set also has been studied.

Keyword: MATLAB /simulink, solar radiation; series and shunt resistance; saturation current; panel temperature; maximum power point

I. INTRODUCTION

Photovoltaic cell has been widely used because of ability to convert solar energy coming from sunlight into electrical energy [1]. In the constructional theory of photovoltaic cell, it consists of semiconductor materials of p and n type, connected with each other. The basic principle of PV cell is shown in figure 1. It shows, when photons of sunlight strikes on cells, electrons free from the outer layer of the atom. Then electrons starts flowing from negative to positive terminal. The opposite direction of flow of electrons shows the flow of current from positive terminal to negative terminal in the electric circuit.

The "photovoltaic effect" is the fundamental physical and chemical process by which, voltage or electric current is obtained in a solar cell when it is exposed on sun light [2]. As shown in the figure 1, it is a phenomenon through which a collection of light-generated carriers causes flow of electrons and holes towards N-type and P-type of the junction respectively.

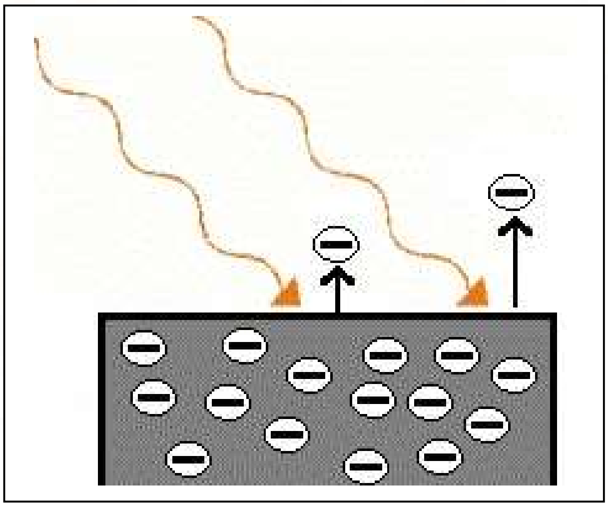

Fig.1. Photocurrent generation principle.

This acts as a source of current. Because of the high cost of PV modules, optimal exploitation of the available abundant solar energy is imperative [3]. This needs a precise, consistent and comprehensive simulation of the designed system before installation. PV panel modeling is a very important factor that affects the output of the PV panel.

The simplest way of representing the solar cell is the single diode model. It is shown with a current source parallel with a diode [2]. A single PV cell generates 0.5-0.8V and therefore, connected in series in a number of 36 to 72 to make PV module. Short circuit current (Ishc), open circuit voltage (Voc) and diode ideality factor are the required parameter for the circuit. Diode ideality factor can be obtained from the principle that describes how nearly it follows ideal diode equation. The basic model is improved for accuracy by introducing the series resistance (Rs). It does not prove to be efficient under temperature variations [4] [5]. To overcome this drawback, an additional shunt resistance (Rsh) is included. This paper carried out a model of PV panel of 72 cells connected in series in MATLAB/Simulink. The Proposed model is used to forecast the PV panel characteristics by varying different physical parameters such as solar radiation and ambient temperature. Moreover, same model is used to predict the behavior of the solar panel by varying circuit parameters such as series resistor, shunt resistor, diode saturation current, etc [6] [7] [8].

The single diode model and double diode model has been extensively used in the many literatures but single diode model is more effective due to its comprehensive approach towards the modeling [9].

II. Equivalent Single Diode Circuit of photovoltaic Cell

Figure 2 shows the equivalent circuit of photovoltaic cell. The main components of the circuit have a current source, a diode, a shunt resistance as well as a parallel resistance. The equivalent circuit is based on the equation given below

$$I = I_{ph} - I_D - I_{sh} \qquad (1)$$

$$I = I_{ph} - I_{SC}\left(\exp\frac{q(V + RsI)}{NKT} - 1\right) - \frac{(V + RsI)}{Rsh} \qquad (2)$$

where, Iph represents the photocurrent, denotes the reverse saturation current of the diode, q stands for the electron charge, V is the voltage across the diode, K stands for the Boltzmann's constant, T denotes the junction temperature, N represents the ideality factor of the diode, Rs and Rsh are the series and shunt resistors of the cell respectively [10].

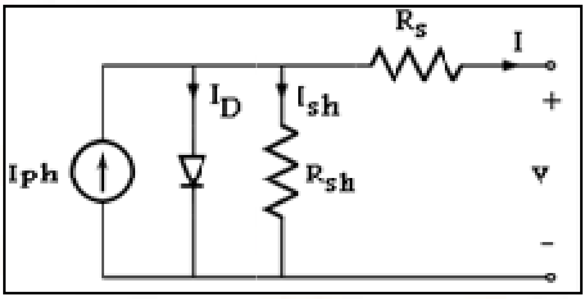

Fig. 2. Equivalent circuit of the solar cell.

The power output of the photovoltaic cell is based on the external input such as solar irradiation, temperature and internal parameters like Iph, Is, Rs & Rsh.

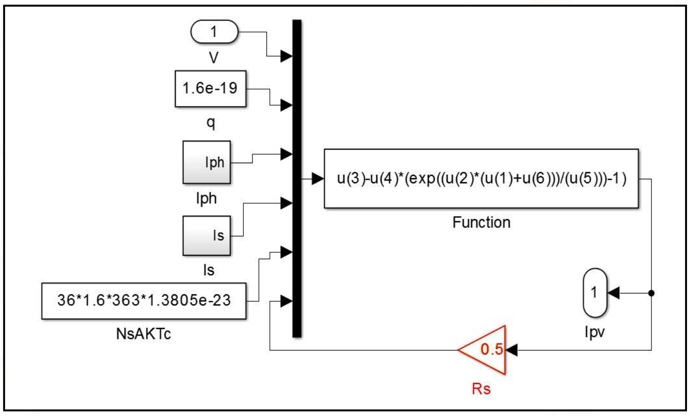

Fig. 3. PV cell MATLAB/Simulink model.

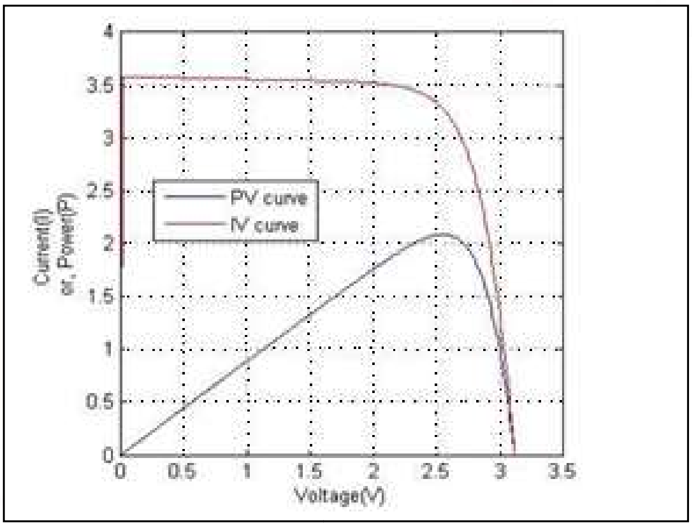

Fig. 4. I-V curves and P-V curves for a given PV cell.

The MATLAB/Simulink model shown in the figure 3 is developed from the equation 1. Figure 4 shows the graph I-V and P-V for some particular values of temperature and irradiation.

III. Impact of Change in Solar Radiation

Influence of spectral distribution of solar irradiance widely effects the output performance of a solar panel [11]. The equivalent circuit shown in figure 2 have a current source showing Iph which depends on temperature and irradiation as shown in equation 3.

$$I_{ph} = \frac{B}{1000}[I_{SC} + K_i(T_j - 298)] \quad (3)$$

where, B is solar irradiation in (W/m^2) and Ki = 0.0017 A/°C stands for the cell short circuit current.

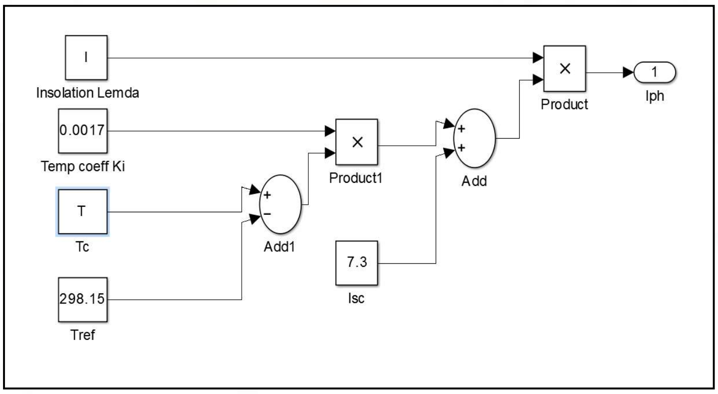

Fig.5. Iph MATLAB/Simulink model.

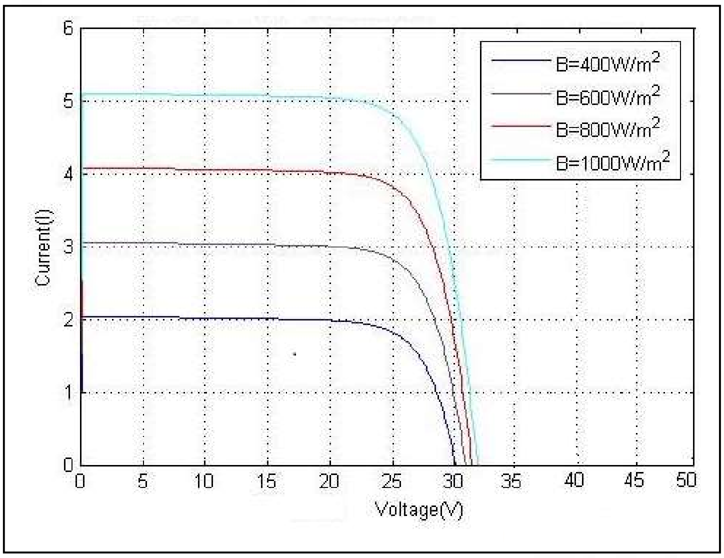

Fig. 6. I-V curves for different solar radiations.

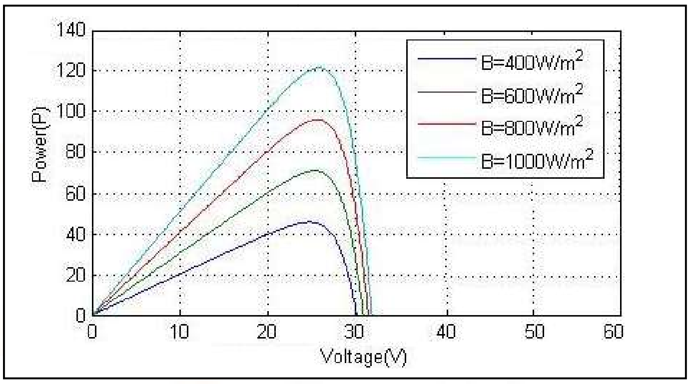

Fig. 7. PV when solar irradiation varies

It can be clearly observed from the model in figure 5, figure 6 and figure 7 that PV panel current and output power is directly varies with the solar irradiation. Moreover, It also shows that, as solar irradiation on the solar panel increases, the open circuit voltage (Voc), short circuit current (Ishc), Maximum current and maximum power also increases.

IV. Impact of change in temperature of the panel

The relation between temperature of the panel and reverse saturation current (Isc) is shown in the equation 3 as:

$$I_S(T) = I_S(\frac{T}{T_{nom}})^3 \exp[(\frac{T}{T_{nom}} - 1)\frac{E_g}{N.V_t}] \quad (4)$$

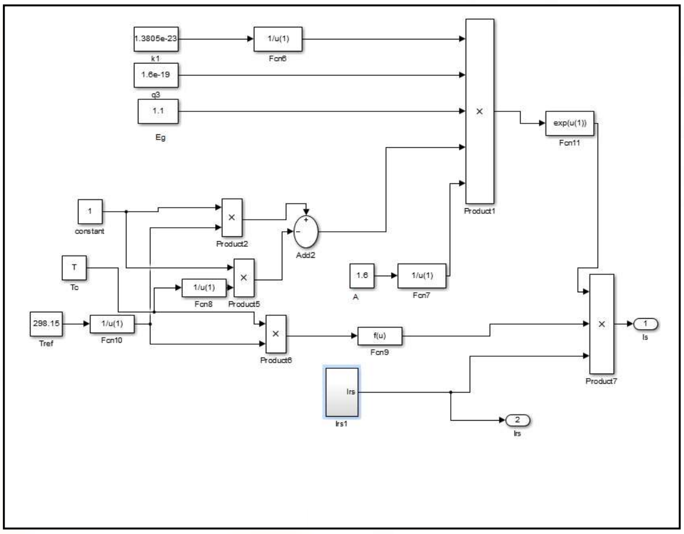

Fig. 8. MATLAB/Simulink on diode reverse saturation current.

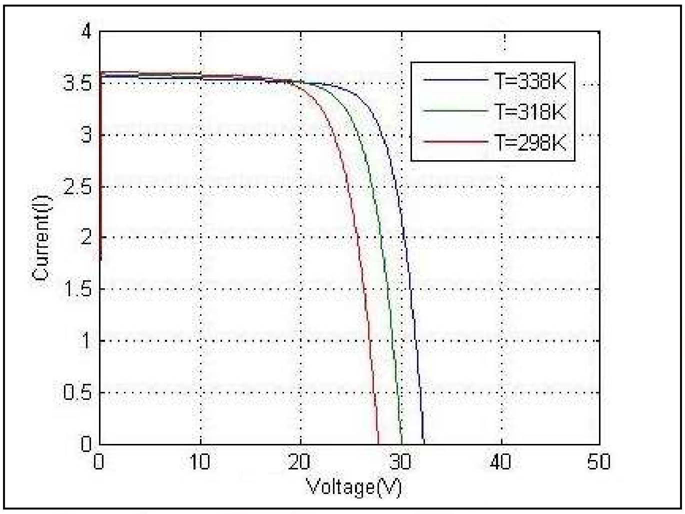

Fig. 9. I-V curves for different panel temperatures.

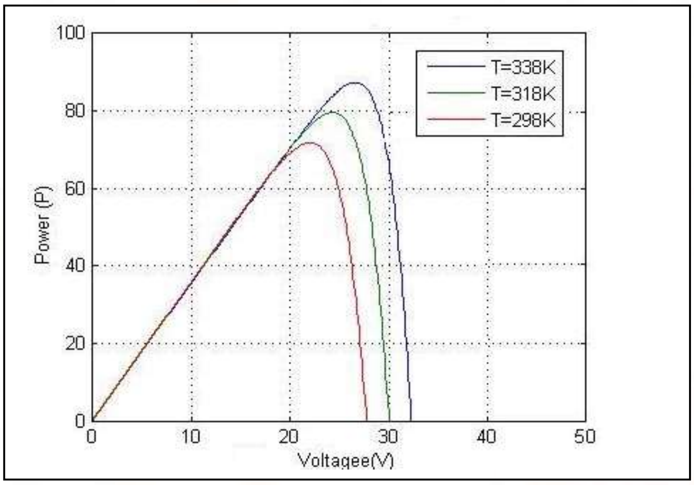

Fig. 10. P-V curves for different panel temperatures.

The model shown in figure 8 is developed from equation 3. As shown in figure 9 and figure 10 of I-V & P-V graphs, the open circuit voltage as well as the short circuit currents increases and decreases with increasing of the temperature of the panel.

V. Impact of Changing of Series Resistance (Rs)

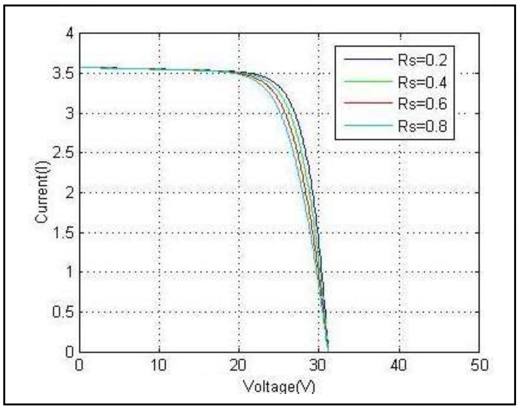

Fig. 11. I-V curves for different Rs.

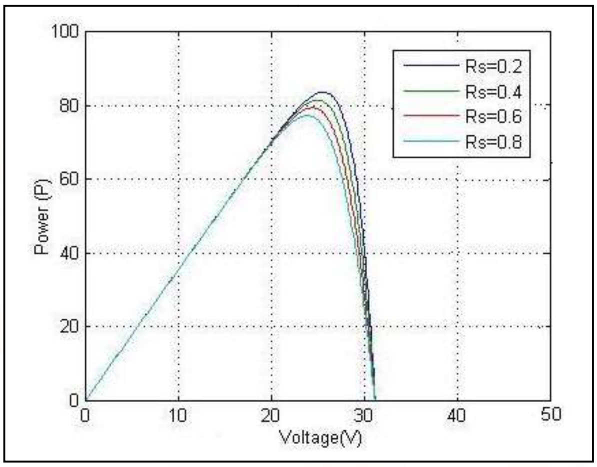

Fig. 12. P-V curves for different Rs

The resistance connected in series is generally low. As shown in the figure 11 and 12, the short circuit current and open circuit voltage remain same with the small change in series resistance. Maximum power point shift from lower to higher value with small increase in series resistance.

VI. Impact of Change in shunt resistance(Rsh)

As shown in figure 13 and figure 14, with the increase in shunt resistance the power output increases. With the low value of shunt resistance large drop in the output power in the open circuit voltage can be seen.

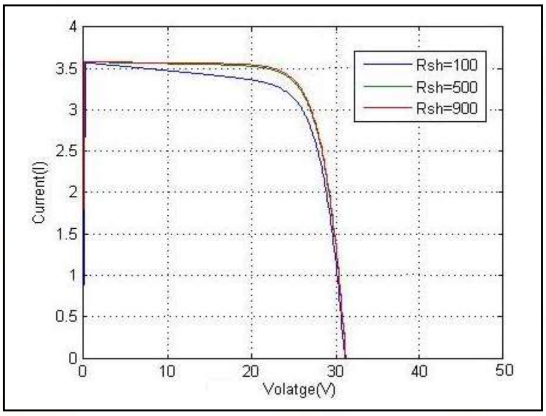

Fig. 13. I-V characteristics for different Rsh

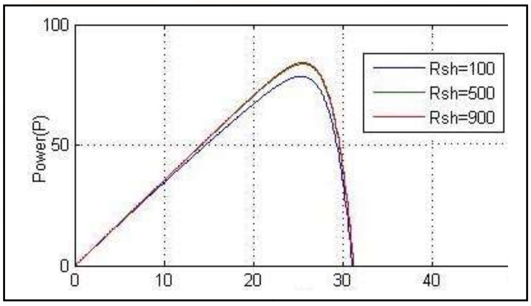

Fig. 14. P-V curves for different Rsh

VI. Effects of Varying reverse saturation current(Isc)

In the short circuited solar panel, voltage across the panel becomes zero. The current through the solar panel in this condition is referred as short circuit current and usually denoted by as Isc as shown in figure. 15.

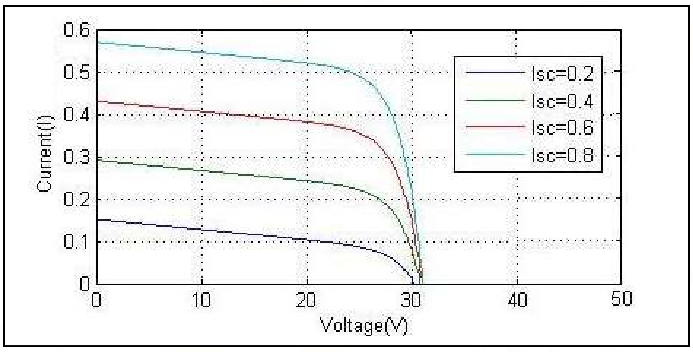

Fig. 15. I-V curves for different Isc

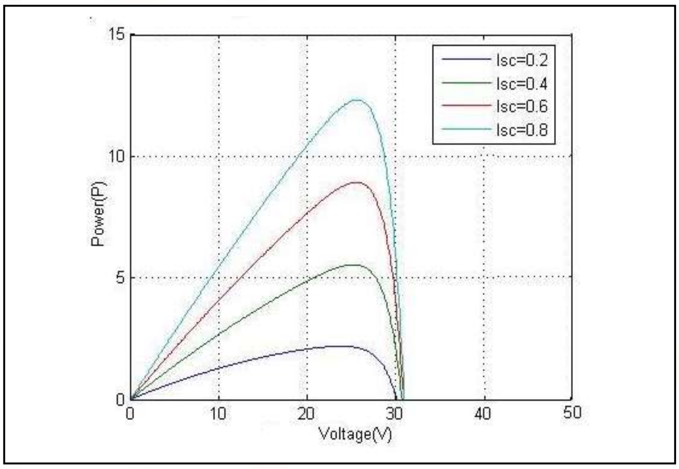

Fig. 16. P-V curves for different Isc

Light generated carriers produced by the light incident on it causes the production of short circuit current. The short circuit current and the light generated current are same for an ideal solar panel at most reasonable resistive loss systems. Hence, Ishc is the largest current that can be drawn from the solar panel.

The curves of figures.15 and 16 were plotted for four different values of Is: 0.2A, 0.4A, 0.6 and 0.8A. The influence of an increase in Is is evidently seen as decreasing the open-circuit voltage *Voc.*

VIII. PV Array

The identical 6 PV panels connected in series with different MPPT topologies [12][13][14]. Figure 21 and figure 22 shows that different output current Vs voltage and power Vs Voltage graph.

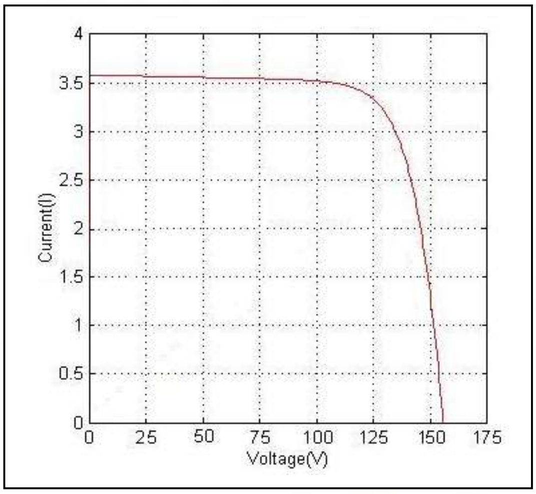

Fig. 17. I-V curves for the PV panel

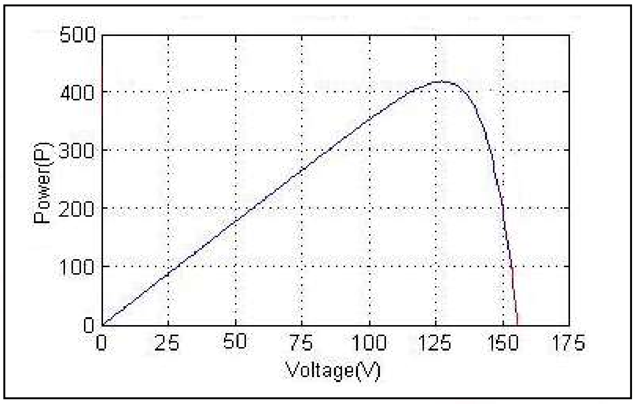

Fig. 18. P-V curves for the PV array model

The PV modules connected in series can have faults consist of open circuits, short circuits, mismatch between PV modules, and partial shading. Mismatch faults are generally caused by encapsulant degradation, antireflection coating deterioration, manufacturing defects[15].

IX. Experimental Results and Validation

In the real time experiment, a PV Module (model number: JP36F150) as shown in the figure 19 has been tested under the solar radiation with multimeter and thermometer to measure the temperature listed in the Table 1.

The JP36F150 model is developed in the MATLAB/Simulink with the same specifications.

Under the similar input conditions in the MATLAB Simulink model and real time experiment on the model number JP36F150, results are shown in the figure 20 and figure 21.

Fig. 19. Setup of the JP36F150 solar laminate panel.

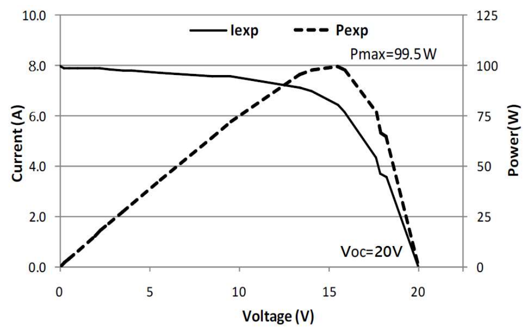

Fig. 20. JP36F150 solar laminate panel experimental results.

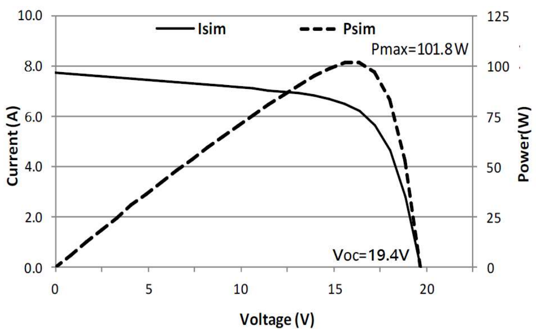

Fig. 21. MATLAB simulation results.

As per the Experimental and Simulation results, it has been clearly shown that the open circuit voltage, short circuit current, maximum power and maximum voltages are approximately same in both results.

Rated Power(Pmax) watt	150
Volt at Max. power(Vmp in volt)	18.03
Open circuit voltage(Voc in volt)	22.12
Current at Max. Power(Imp in Amp)	8.32
Short circuit current(Isc in Amp)	8.68

Table 1. Parameters of solar panel

X. Conclusion

In this paper, a PV module and array MATLAB/Simulink model was proposed. Basic equivalent circuit equations of solar panel was used to develop the model. The model was simulated under different environment conditions and physical parameters like solar irradiations and ambient temperature. The JP36F150 panel of solar was used to verify experimentally with the developed simulated MATLAB/Simulink model.

The proposed study presents a comprehensive approach of the modeling of photovoltaic power generation system in the MATLAB/Simulink model with respect to PV power utilization. Moreover, it demonstrates the characteristics of basic components of a PV array under the different weather and physical parameters which would be very much effective to forecast the performance of any solar panel.

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