TO STUDY MAXIMUM POWER POINT TRACKING IN PHOTOVOLTAIC CELLS

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Abstract— The modeling of PV (photovoltaic) systems is very crucial for embedded power system applications and maximum power point tracking. This paper presents a PV array model using Matlab/Simulink with the assistance of SimPowerSystem toolbox. The PV cell is considered as the main building block for simulating and monitoring the PV array performance. The PV model has been developed and used as Simulink subsystems where the effect of solar insolation and PV array temperature on commercial PV modules have been studied throughout the simulated *I-V* and *P-V* output characteristics. The proposed model facilitates simulating the dynamic performance of PV-based power systems. The effect of different partial shading patterns of PV arrays under different configurations has been studied.

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1 INTRODUCTION

The development of new energy sources is continuously enhanced because of the critical situation of the chemical industrial fuels such as oil, gas and others. Thus, the renewable energy sources have become a more important contributor to the total energy consumed in the world. In fact, the demand for solar energy has increased by 20% to 25% over the past 20 years [1]. The market for PV systems is growing worldwide. In fact, nowadays, solar PV provides around 4800 GW. Between 2004 and 2009, grid connected PV capacity reached 21 GW and was increasing at an annual average rate of 60% [2]. In order to get benefit from the application of PV systems, research activities are being conducted in an attempt to gain further improvement in their cost, efficiency and reliability

With no pollutant emission, Photovoltaic cells convert sunlight directly to electricity. They are basically made up of a PN junction. Figure 1 shows the photocurrent generation principle of PV cells. In fact, when sunlight hits the cell, the photons are absorbed by the semiconductor atoms, freeing electrons from the negative layer. This free electron finds its path through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one.
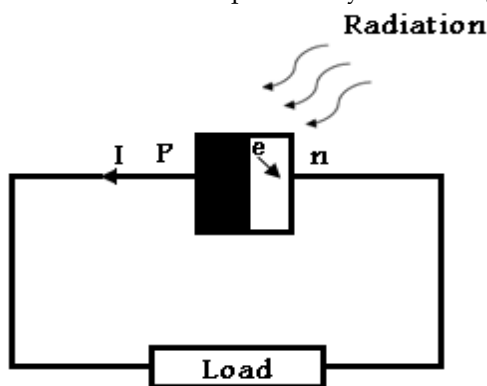

Fig. 1 Photo Current Generation Principal

Typically, a PV cell generates a voltage around 0.5 to 0.8 volts depending on the semiconductor and the built-up technology. This voltage is low enough as it cannot be of use. Therefore, to get benefit from this technology, tens of PV cells (involving 36 to 72 cells) are connected in series to form a PV module. These modules can be interconnected in series and/or parallel to form a PV panel. In case these modules are connected in series, their voltages are added with the same current. Nevertheless, when they are connected in parallel, their currents are added while the voltage is the same.

Three major families of PV cells are monocrystalline technology, polycrystalline technology and thin film technologies. The monocrystalline and polycrystalline technologies are based on microelectronic manufacturing technology and their efficiency is in general between 10% and 15% for monocrystalline and between 9% and 12% for polycrystalline. For thin film cells, the efficiency is 10% for a-Si, 12% for CuInSe2 and 9% for CdTe [3]. Thus, the monocrystalline cell that has the highest efficiency is the focus of this paper. This paper carried out a Matlab/SIMULINK model of monocrystalline PV cell that made possible the prediction of the PV cell behavior under different varying parameters such as solar radiation, ambient temperature, series resistor, shunt resistor, diode saturation current, etc.

The focus of this paper is on solar cell modeling which is discussed in section two. Section three presents the effects of the variation of the solar radiation. In section four, the influence of temperature on the PV cell outputs are investigated. The effects of the series resistance have been presented in section five. Section six focuses on the effects of the shunt resistance. In section seven, the effects of the diode reverse saturation current are studied. The model features and its experimental validation are discussed in sections eight through ten. While conclusions and future works are presented in section eleven.

2 PV cell model

The equivalent circuit of a PV cell is shown in Fig. 2. It includes a current source, a diode, a series resistance and a shunt resistance [4, 5].
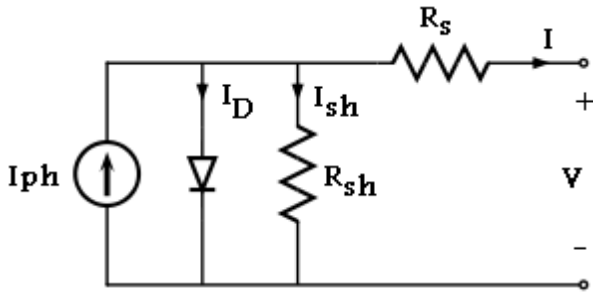
Fig.2. PV cell equivalent circuit.

In view of that, the current to the load can be given as:

$$I = I_{ph} - I_s \left(\exp \frac{q(V + R_s I)}{NKT} - 1 \right) - \frac{(V + R_s I)}{R_{sh}}$$

(1)

In this equation, Iph is the photocurrent, Is is the reverse saturation current of the diode, q is the electron charge, V is the voltage across the diode, K is the Boltzmann's constant, T is the junction temperature, N is the ideality factor of the diode, and Rs and Rsh are the series and shunt resistors of the cell, respectively.

As a result, the complete physical behavior of the PV cell is in relation with Iph, Is, Rs and Rsh from one hand and with two environmental parameters as the temperature and the solar radiation from the other hand.

Based on equation (1), the Matlab/SIMULINK model of Fig.3 was developed. For a given radiation, temperature, Rs and Rsh, the I-V and P-V curves are generated as shown in Fig.4.
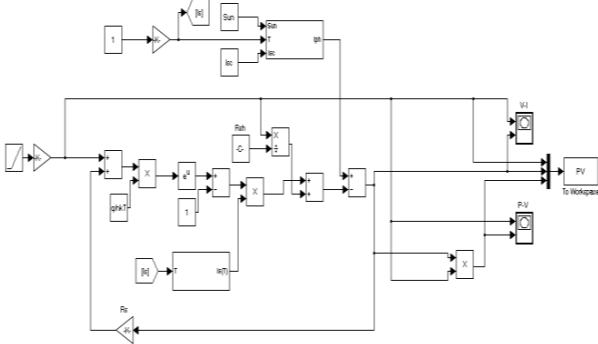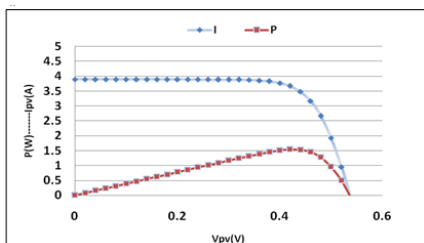

Fig.3 PV Cell Matlab Simulink model

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

3. Effects of Solar Radiation Variation

The above model includes two subsystems: one that calculates the PV cell photocurrent which depends on the radiation and the temperature according to equation (2) [3].

$$I_{ph} = \left[I_{sc} + K_i (T - 298) \right] \frac{\beta}{1000}$$

(2)

Where Ki=0.0017 A/°C is the cell's short circuit current temperature coefficient and β is the solar radiation (W/m2).

Based on the above equation, the subsystem of Fig. 5 is obtained and the model simulation results are shown in Figs. 6 and 7.
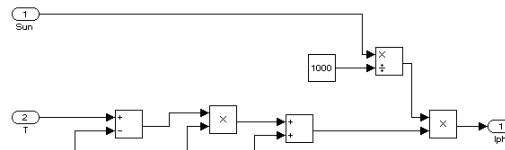

Fig. 5. Iph Matlab/SIMULINK subsystem for varying cell temperature and solar radiation.

As it can be seen from Figs.6 and 7, the PV cell current is strongly dependent on the solar radiation. However, the voltage has a 50 mV increase as the solar radiation increased from 400 W/m2 to 1000 W/m2.
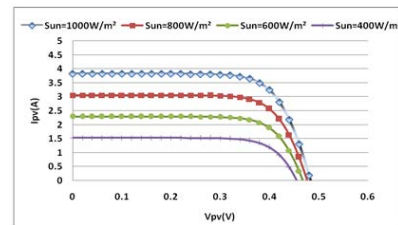

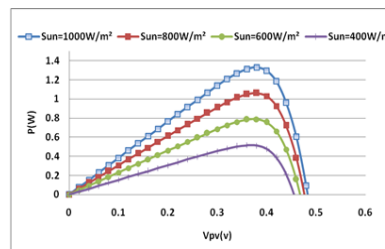Fig.6.I-V curves for different solar radiations.

Fig.7.P-V curves for different solar radiations.

4. Effect of Varying Cell Temperature

The diode reverse saturation current varies as a cubic function of the temperature and it can be expressed as:

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

where Is is the diode reverse saturation current, Tnom is the nominal temperature, Eg is the band gap energy of the semiconductor and Vt is the thermal voltage. The reverse saturation current subsystem shown in Fig.8 was constructed based on equation (3).
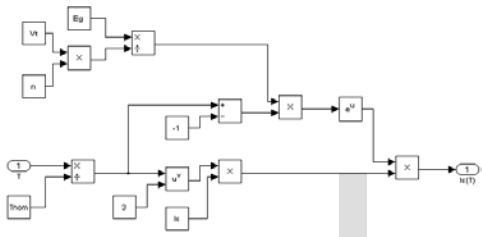
Fig. 8. Matlab/SIMULINK temperature effect subsystem on diode reverse saturation current.

In general, for a given solar radiation, when the cell temperature increases, the open circuit voltage Voc, drops slightly, while the short circuit current increases. This behavior is validated and presented in Figs. 9 and 10.
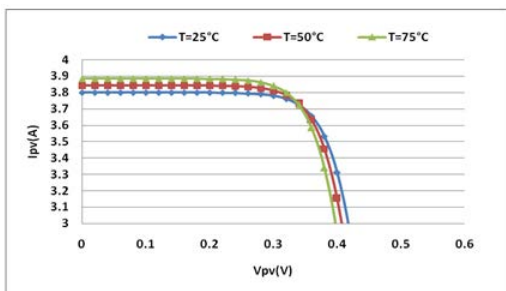

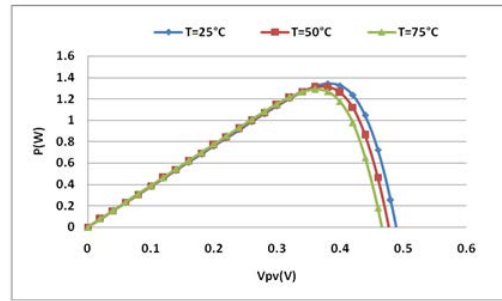**Fig.9.** *I-V* curves for different cell temperatures.

Fig.10. *P-V* curves for different cell temperatures.

5. Effect of Varying Rs

The series resistance of the PV cell is low, and in some cases, it can be neglected [3]. However, to render the model suitable for any given PV cell, it is possible to vary this resistance and predict the influence of its variation on the PV cell outputs. As seen in Figs.11 and 12, the variation of Rs affects the slope angle of the I-V curves resulting in a deviation of the maximum power point.
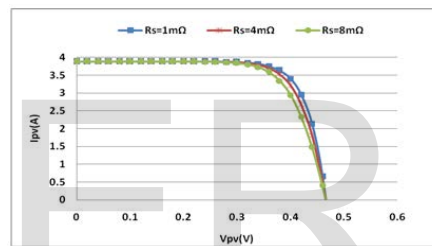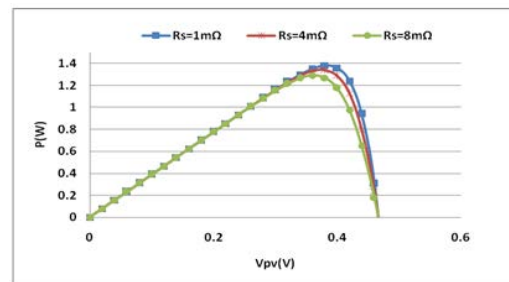

Fig.11. *I-V* curves for different Rs.

Fig.12. *P-V* curves for different Rs

The simulation was performed for three different values of Rs, namely 1mΩ, 4mΩ and 8mΩ. It was shown that higher values of Rs reduce the power output of the PV cell. According to equation (4), the fill factor, given by equation (4), decreases as Rs increases.

$$FF = \frac{P_{\max}}{V_{oc}I_{sc}}$$

(4)

6. Effect of Varying Rsh

The shunt resistance of any PV cell should be large enough for higher output power and fill factor. In fact, for a low shunt resistor, the PV cell current collapses more steeply which means higher power loss and lower fill factor. These results can be seen in Figs.13 and 14.
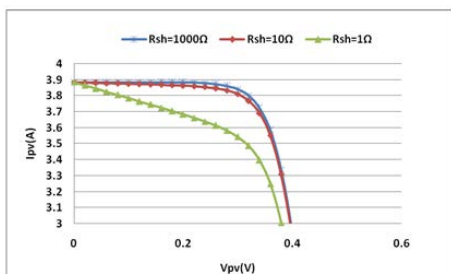

Fig.15.I-V curves for different Is

Fig.13. *I-V* characteristics for different Rsh
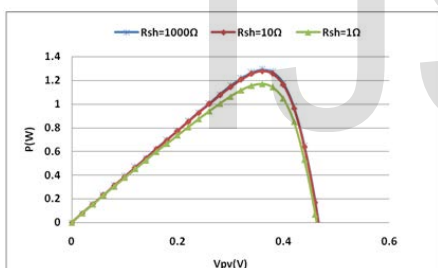

Fig.16.P-V curves for different Is

Fig.14. *P-V* curves for different Rsh

7. Effects of Varying Is.

The model assists in expecting the behavior of the PV cell for different reverse saturation currents of the diode. The curves of Figs.15 and 16 were plotted for three different values of Is: 100nA, 10nA and 1nA. The influence of an increase in   evidently seen as decreasing the open-circuit voltage Voc.

8. PV Module

As previously mentioned, a PV module is a connection of tens of PV cells. Figure 17 shows the bloc diagram of Matlab/SIMULINK model of a PV module.
This model contains an external control block permitting an uncomplicated variation of the models' parameters. In this model, 36 PV cell are interconnected in series to form one module. As a result, the module voltage is obtained by multiplying the cell voltage by the cells number while the total module current is the same as the cell's one. The results are shown in Figs.18 and 19.
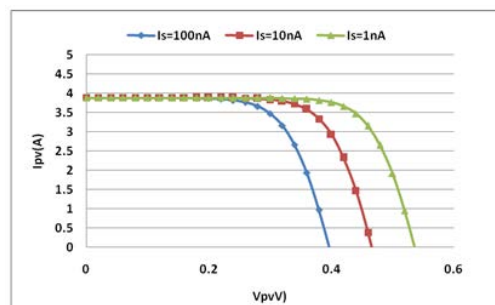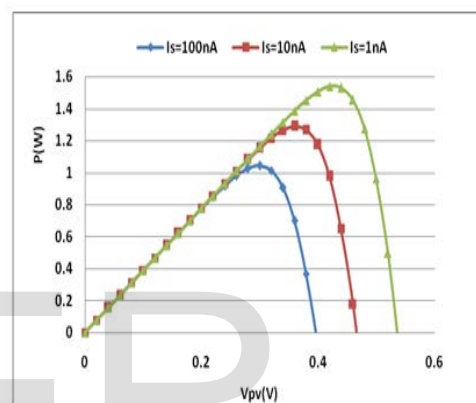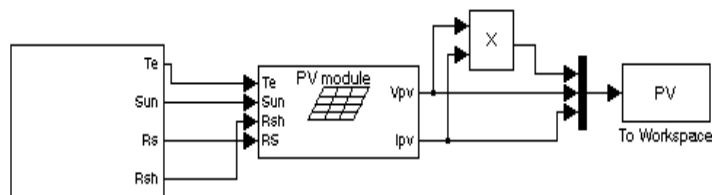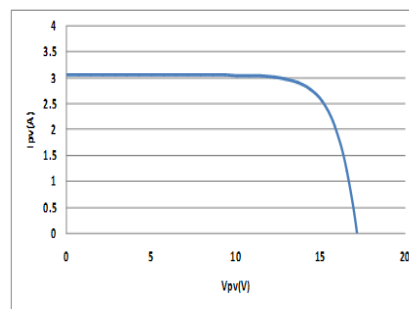

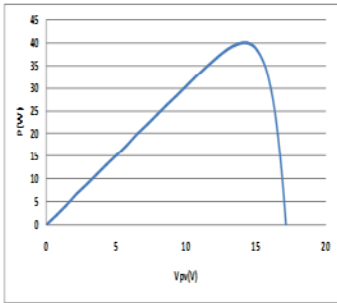Fig.17 SIMULINK model for the PV module.

Fig.18 RESULT

Fig.19 RESULT

9. PV Array

In order to get benefit from these developed models, an array of 6 PV modules has been constructed. In fact, these PV modules were interconnected in series and all of them are connected to the external control block as shown in
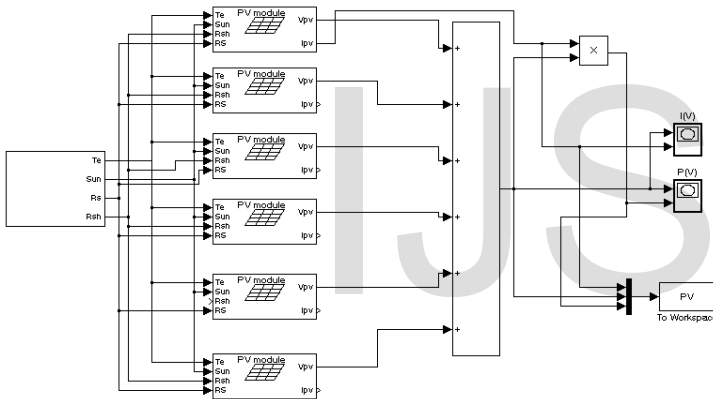

Fig.22 RESULT

Fig.20 PV Array model

The PV array model was simulated similarly to the model of the PV module and the obtained results are shown in Figs.21 and 22, respectively.
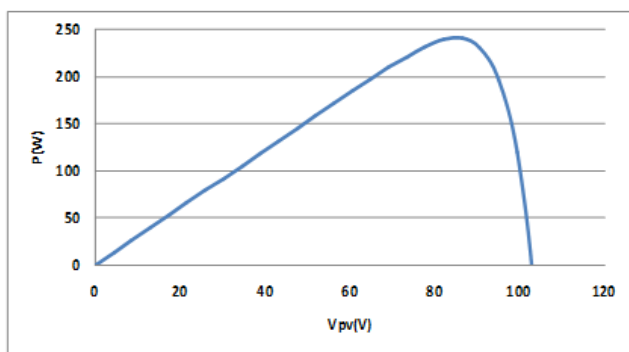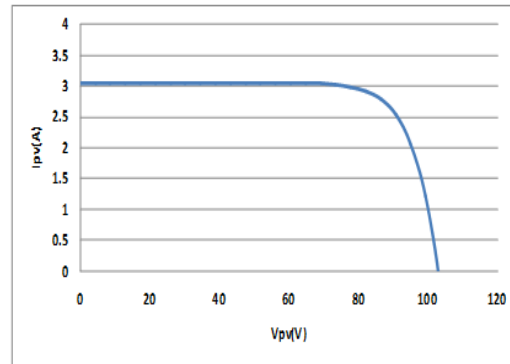
11. Conclusion

A Matlab/SIMULINK model for the solar PV cell, modules and array was developed and presented in this paper. This model is based on the fundamental circuit equations of a solar PV cell taking into account the effects of physical and environmental parameters such as the solar radiation and cell temperature. The module model was simulated and validated experimentally using the high efficient PVL-124 solar laminate panel.

As a result of the study, one can benefit from this model as a photovoltaic generator in the framework of the Sim- Power-System Matlab/SIMULINK toolbox in the field of solar PV power conversion systems. In addition, such a model would provide a tool to predict the behavior of any solar PV cell, module and array under climate and physical parameters changes.
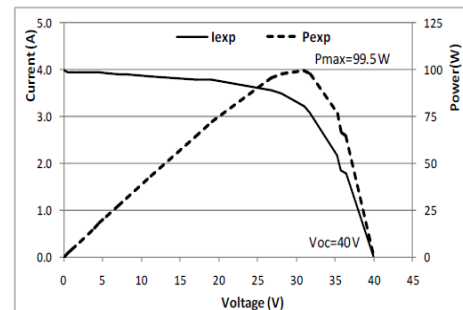

Fig.21 RESULT

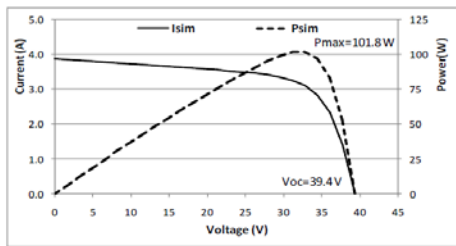Fig. 25.PVL-124 solar laminate panel experimental results.

Fig.24.MATLAB simulation results.

12. References

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