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TEMPERATURE AND SHADING DEPENDENCE OF THE POTENTIAL INDUCED DEGRADATION EFFECT OF SOLAR PANEL

Kyaw Thu[1], Yin Maung Maung[2], Than Than Win[3]

Abstract

This paper investigates on a simulation model for a PV panel to allow estimate the electrical behavior of the panel with respect changes on parameters of shade and temperature. The simulation model was implemented in Mat lab and accepted the I-V characteristic outputs as variable parameters the effects of shading and temperature of solar PV module. This model is quite and especially useful to analyze the performances of the PV modules under various operating conditions. It is simulating the parameters for the nonlinear I-V equations based on only the solar panel such as open circuit voltage, short circuit current, voltage and current at maximum power point at the standard test condition which are obtained from manufacturer's solar panel. The performance of PV panels is affected by the shading and temperature effect due to trees, passing of clouds, neighboring buildings. The aim of this research work is to use the change in electrical parameters with shading and temperature of PV solar cell and module. The simulation results show that the electrical parameter such as the open circuit voltage, short circuit, maximum power decreases as the shading and the ambient temperature increases.

Keywords: Photovoltaic Solar Module, Solar cells, Temperature, Shade, Simulation.

Introduction

Renewable energy resources are being developed important part of power generation in new centuries. In particular, solar photovoltaic PV is converted solar radiation directly to electricity; most solar power plants are being developed based on photovoltaic technology. For series-connected PV cells, although some the cells are being partially shaded, all the cells carry almost the same amount of current. While a small number of cells under shade produce less photocurrent, these cells are being also forced to carry the same current as the other fully illuminated cells. Moreover, in some cases it is difficult to avoid partial shading of solar panel due to the surrounding and environmental conditions, such as buildings, dust, bird droppings, and cloud cover throughout the day and in all seasons. It is made the study of partial shading of solar PV modules a main key issue. In recent years, the effects on partial shading on the solar PV array system performance have widely discussed [Ekpenyong, E.E, Idriss Hadj Mahammed, L. Fialho and A. Woyte]. The power reduced due to a shadowed panel has already been studied [Smita Ganesh Pachpande].

However, the power of PV modules is yielded a function of different weather conditions, including partial shaded conditions [Chia Seet Chin1] and configuration of PV array and partial shading [A. Woyte]. It is necessary to consider all these parameters to determine the performance of a PV system under the various conditions of shading. In this study, the main objective is to investigate the effects of partial shading and temperature caused by surrounding environmental conditions through the application of predefined configurations of the solar PV module system in series arrays cells. The study aims to find an equivalent electrical circuit model of the PV module when cells in the module are being connected in series in order to analyze the characteristics of the module under uniform operating conditions. All solar module parameters, including short-circuit current, open-circuit voltage, fill factor, efficiency and impact of series and parallel resistances are being changed due to changing the light intensity and temperature [Tuque and Heeds, 2003]. Therefore, it is necessary to study the effect of the light intensity and temperature on the output

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[1] Lecturer, Department of Physics, Monywa University
[2] Dr, Professor, Department of Physics, University of Yangon
[3] Dr, Professor, Department of Physics, Pinlon University

performance of the solar module. The electricity flows through an electrical circuit by changing the speed at which the electrons travel because of temperature effect. This is caused due to an increase in resistance of the circuit that results from an increase in temperature. In this work, the main point aims to investigate a detailed experimental of module PV parameters with light intensity and temperature are being studied.

Materials and Methods

Methods

In field testing, it is difficult to investigate the effects on partial shading and temperature because there are many time and weather conditions. Also, it is being challenged to uniformly measure the different level of intensity of shading and temperature under a number of different configurations of a shaded and temperature of PV module system. Alternatively, it is easily to carry out a simulation study with the help of a computer model. In this study, generalized MATLAB/Simulink models have developed and are capable of simulating any number of cells connected in series for any type of temperature and shading patterns.

Mathematical Modeling of a PV Cell and Module

A PV module consists of a number of solar cells, which convert light into electricity. The solar cell mainly depends on a diode, a photocurrent (I_{ph}), an internal resistor (R_s), and a shunt resistor (R_{sh}). Fig.1 shows a photovoltaic equivalent circuit of a single cell.

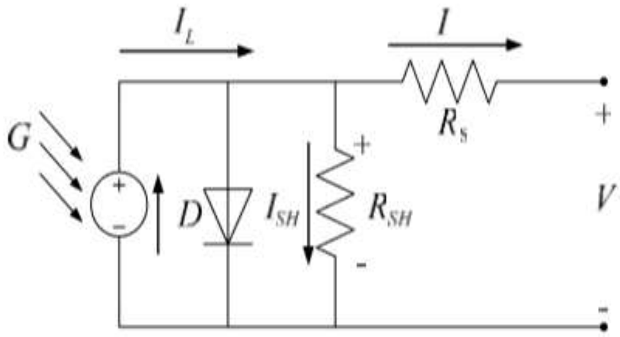

Figure1 Photovoltaic equivalent circuit of a solar cell

When a PV module collects irradiance energy from the sun by individual solar cells, it is charged with electric energy. The output of electric energy depends on intensity of irradiance (W/m^2), temperature (K), material, design of the PV module, and the photocurrent (I_{ph}) in series with the internal resistor (R_s) and parallel with a shunt resistor (R_{sh}). The basic equation of the current at the terminal of the solar cell and the maximum power output are formulated. The photovoltaic panel can be mathematically modelled as:

Basic mathematical equation of the output current (I) in Eq. (1)

$$I = I_{ph} - I_d \tag{1}$$

I_{ph} is the photocurrent, I_d is the diode current, which is related to the saturation current and is described by Eq. (2):

$$I_d = I_0 \left[\exp\left(\frac{V}{A.Ns.V_T.a} \right) - 1 \right] \tag{2}$$

where V is the voltage applied to the diode, then V_T can be expressed by the equation of $V_T = k.\frac{T}{q}$. A is the diode ideality ranged between 1 and 2; N_s is the number of cells in a series for the output current; a is the diode emission coefficient. The photocurrent, I_{ph}, is generated from the incident solar irradiation and affected by the temperature (T). It can be expressed by Eq. (3):

$$I_{ph} = \frac{G}{G_{STC}}\left(I_{ph,STC} + K_I\left(T - T_{STC}\right)\right) \tag{3}$$

Where $G_{STC}\left(\frac{W}{m^2}\right)$ is the irradiation at STC; $I_{ph,STC}$ is the current produced at STC; K_I is the temperature coefficient of the short -circuit current. . The diode reverse leakage current, I_o, is influenced by the actual temperature and can be expressed in Eq. (4):

$$I_0 = \frac{I_{SC,STC} + K_I\left(T - T_{STC}\right)}{\exp\left(V_{OC,STC} + K_V K_I\left(T - T_{STC}\right)\right) - 1} \tag{4}$$

where $I_{SC,STC}$ and $V_{OC,STC}$ are the short-circuit current and open-circuit voltage at STC; K_V is the temperature coefficient of the open-circuit voltage (V/Kelvin). In the PV module, the short-circuit current (I_{sc}) can be described when V_o across the PV module is equal to zero and I_{sc}, as expressed in Eq. (5):

$$I_{SC} = I_{PV} - I_d\left[\left(\exp\frac{I_{SC}R_S}{V_T.a}\right) - 1\right] - \frac{I_{SC}R_S}{R_{SH}} \tag{5}$$

Maximum power point of a PV module in Eq. (6):

$$I_{mp} = I_d\left[\exp\frac{V_{mp} + I_{mp}R_S}{V_T.a} - 1\right] - \frac{V_{mp} + I_{mp}R_S}{R_{SH}} \tag{6}$$

The maximum power, P_m, is calculated by $V_{mp} \times I_{mp}$ and described in Eq. (7):

$$P_m = V_{mp}\left[I_{PV} - I_d\left(\exp\frac{V_{mp} + I_{mp}R_S}{V_T.a} - 1\right) - \frac{V_{mp} + I_{mp}R_S}{R_{SH}}\right] \tag{7}$$

where shunt resistance of the PV module is expressed in Eq. (8):

$$R_{sh} = \frac{V_{mp} + I_{mp}R_S}{\left(V_{mp}I_{PV} + V_{mp}I - V_{mp}I.\exp\left[\frac{q\left(V_{mp} + I_{mp}R_S\right)}{N_s KTa}\right] - P_m\right)} \tag{8}$$

The I-V and P-V characteristics of the PV module operating at various temperatures and intensity of irradiance are determined.

Solar PV Cells and Module System

A solar PV panel module consists of a number of interconnected solar cells encapsulated into a stable module, and an array is constructed with a number of panels interconnected in series or parallel. A solar PV module system is comprised of the following components: (1) a number of solar cells, (2) a cells connected in series, and (3) a module system that includes a charge control system and a storage system based on a DC converter system for transmitting the electricity to a desired place, shown in Fig.2.

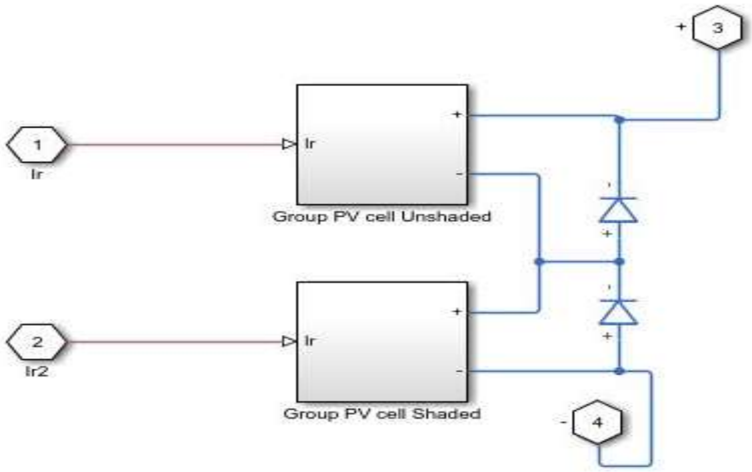

Figure 2 Solar PV Cells array configuration and system

Table 1 Typical electrical characteristics of 34 Watt PV panel

Parameter	Variable	Value
Maximum Power	P_m	34 W
Maximum Voltage	V_{mp}	5V
Maximum Current	I_{mp}	6.8A
Open Circuit Voltage	V_{oc}	6.3 V
Short Circuit Current	I_{sc}	7.3 A

A commercial PV module is interconnected in series, and this standard is used to investigate the effects on maximum power points reached while under partial shading conditions. A single PV module is constructed from 12 PV cells derived from a mono-crystalline material. Table 1 shows the electrical characteristics of 34 Watt module used in this research work under standard test conditions (STC), indicating that irradiance G = 1000 W/m^2 with temperature (25 °C to 37 °C), and AM = 1.5(Air Mass). These conditions define performance at incident sunlight of 1000 W/m^2 to 400 W/m^2 with decreasing 200 W/m^2 and temperature of 25°C. This research adopts the notions and characteristics of a simplified PV system that a single PV module 34 W is interconnected with PV cells. The Simulink models for the various configurations in series combination are shown below in Fig.3.

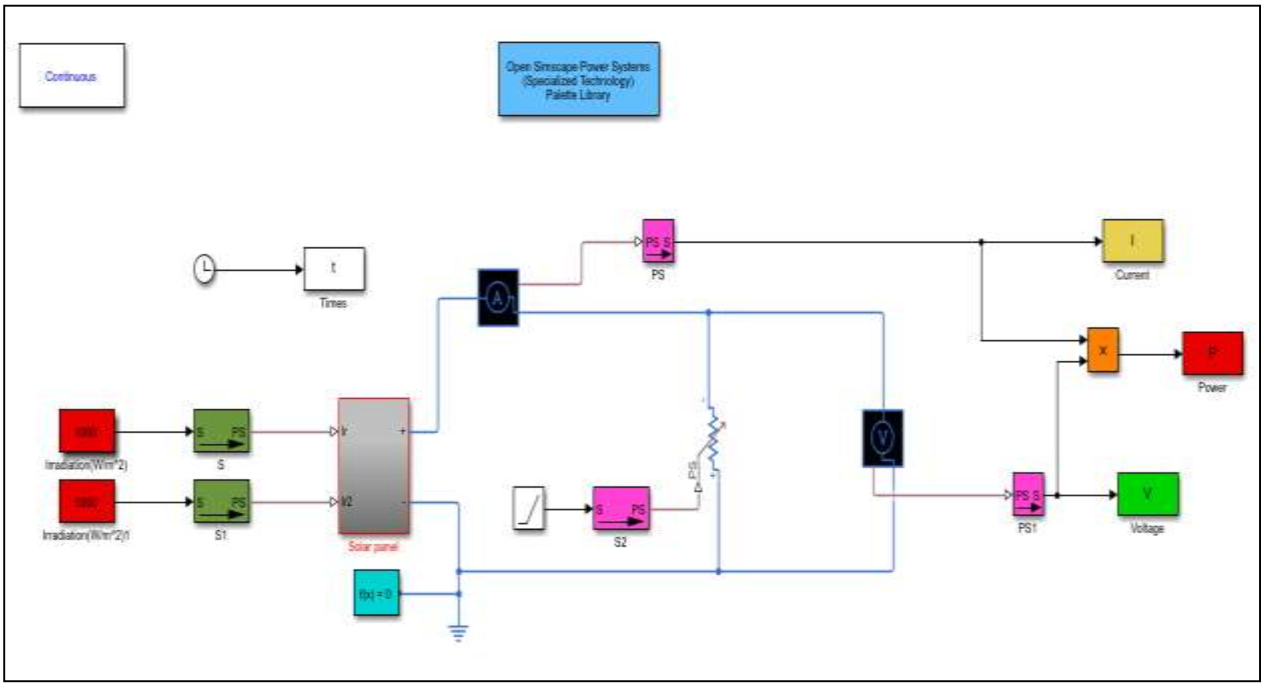

Figure 3 Simulink model with respect to PV module configuration

The module has been used for the panel configurations. For comparing the various configurations, several unique possible scenarios have been studied. I-V and P-V graphs for each of these possible scenarios have been simulated, and values of maximum power, voltage, and current obtained from the model has been simulated in this work. Table 1 Studies The series configurations of cells have been simulated. It is finding the parameters for the nonlinear I-V equations based on only the solar panel data such as open circuit voltage, short circuit current, voltage and current at maximum power point and temperature coefficient for voltage and current at the normal condition or the standard test condition which are obtained from manufacturer's solar panel.

Results

Simulation results show that when the panel temperature is 25 ºC, short circuit current and maximum current of the panel increase as proportional to solar radiation level. On the other hand, there is a little increase in open-circuit voltage and maximum voltage of the panel. When the solar radiation level is increased from 200 W/m² to 1000 W/m², panel power increases. The solar radiation level is unchanged with $1000 W/m^2$ gradually increase from 25 °C to 37 ºC panel temperature, but little decrease in open-circuit voltage and maximum voltage is observed. When the panel temperature under 25 ºC and 37 ºC are compared it is observed that as the panel temperature increases there is a little decrease in short circuit current and the maximum current values are nearly the same. On the contrary, open-circuit and maximum voltage values decrease in proportion to the increase in panel temperature. Therefore, panel power decreases.

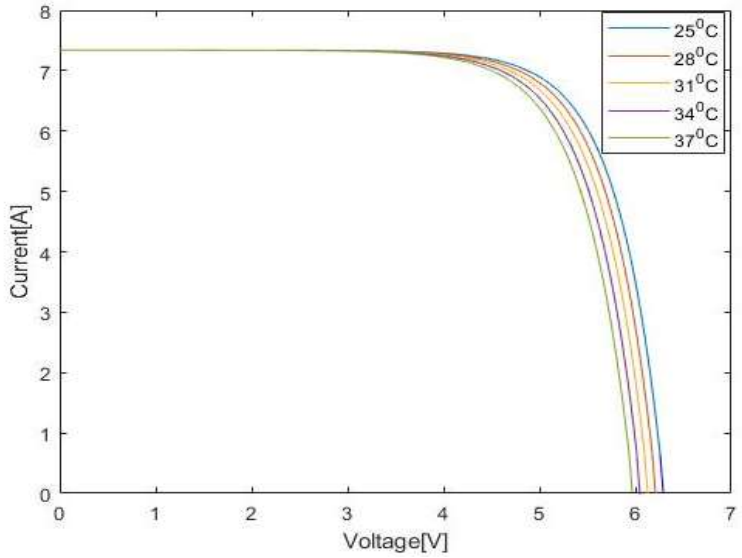

Figure 4 The I-V characteristics of PV panel at 25 °C to 37 °C temperatures

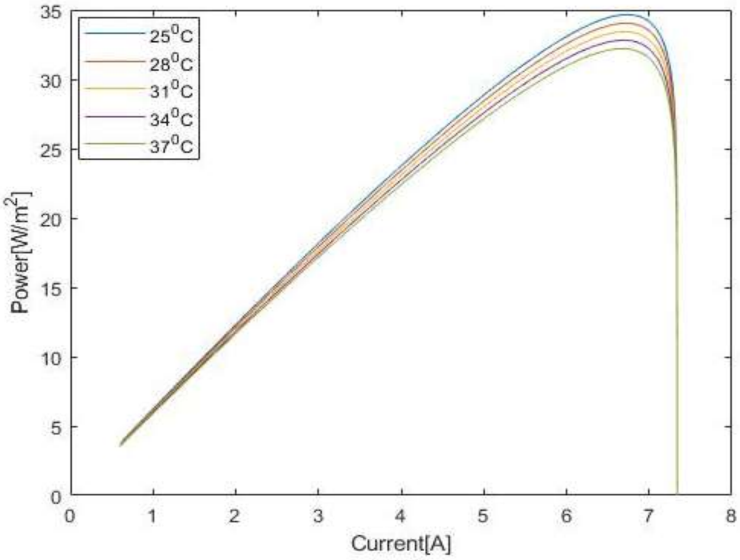

Figure 5 The P-I characteristics of PV panel at 25 °C to 37 °C temperatures

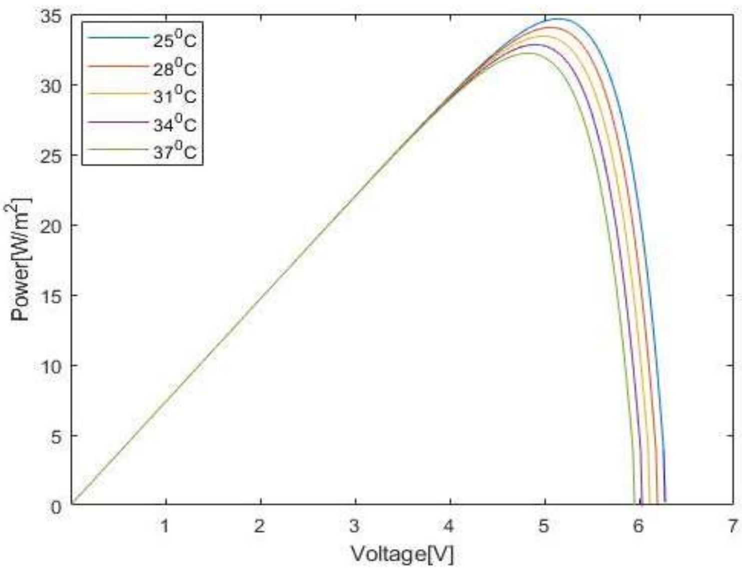

Figure 6 The P-V characteristics of PV panel at 25 °C to 37 °C temperatures

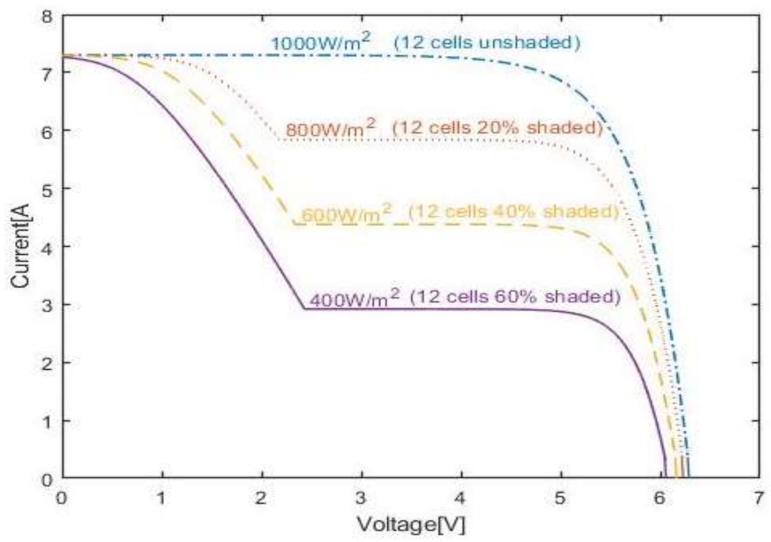

Figure 7 Simulated and the I-V curves without shading and simulated with shading.

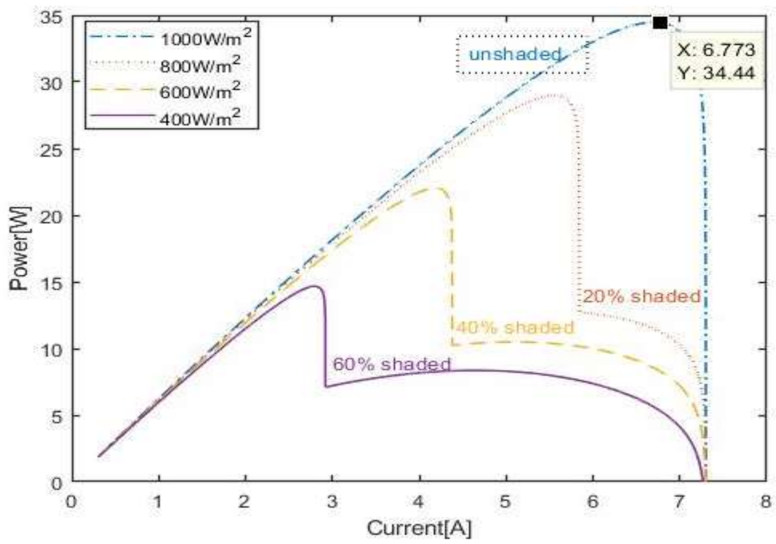

Figure 8 Simulated and P-I curves without shading and simulated with shading

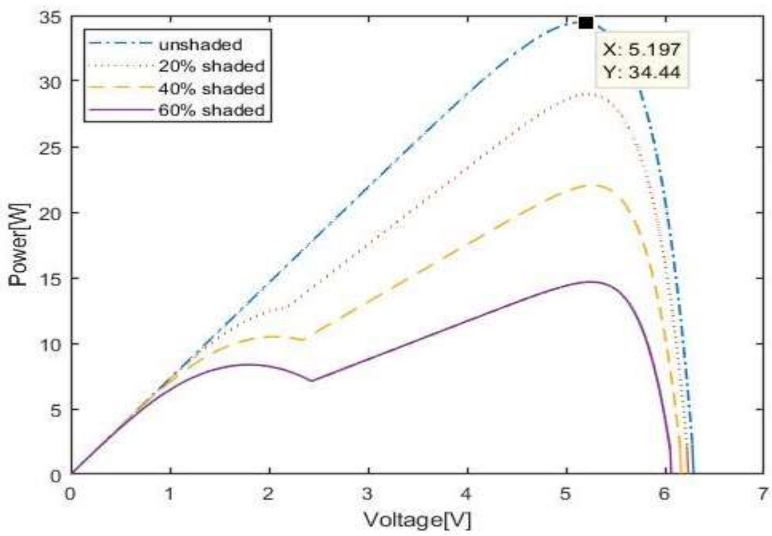

Figure 9 Simulated and P-V curves without shading and simulated with shading

The partial shading is given by the settings: G = 1000 W/m^2 to G=400 W/m^2 with decreasing 200 W/m^2 each. The I-V curves simulated and without shading and simulated with shading are respectively shown in Fig.7. When solar PV system is shaded partially, the power output decreases. The number of shaded modules increases, the number of peaks in power output more decreases. Position of maximum power point is independent with varying number of shaded cells. However, in case study of shading modules under varying solar irradiation, PV curve peaks are tended to be around 20 % ,40% and 60% of W/m^2. A Matlab/Simulink model for the solar PV cells and modules is developed and presented in this research work. This model is based on the fundamental circuit equations of a solar PV module taking into the effects of physical and environmental parameters such as cell temperature, solar irradiation and shading condition. In addition, the proposed model is also used effectively to study the effect of shadow on operating characteristics of solar PV system. The higher percentage of shaded cells is the lower value of power output.

Conclusion

Analysis of various configurations with respect to environmental parameters has been investigated and more realistic models using MATLAB/Simulink have been developed. Solar cells are connected in a PV module with series were studied. The PV module electrical model is presented and demonstrated in Matlab for a typical 34W solar panel. Simulation results show that when the panel temperature is increased gradually 25 ºC to 37 °C, open circuit voltage and maximum voltage of the panel decreases and also panel power decreases. Also, a Simulink model has been developed to simulate the behavior of PV modules with different configurations under variable shading conditions with temperature constant. In order to collect the maximum possible power output from partial shading caused by environmental conditions, it is recommended that the connection of a bypass diode in anti-parallel with a module or group of cells is required to avoid the stress on the shaded cells. This approach to PV module design would solve the problem of sensitivity of hot-spot as well as provide a higher power supply when compared to a solar PV module system without considering the configuration of bypass diode.

The results obtained from the Matlab model are quite credible and suitable for the manufacturer’s solar panel kit. Model’s aim is to achieve I-V characteristics similar to the data that presents the manufacturer's solar panel. An advantage of the presented simulation procedure is that the model developed here can be used for any cell and for any module by simply changing the specifications of the module used in the program.

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