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Parameters influence on MPP value of the photo voltaic cell

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Abstract

Solar energy is an important alternate to traditional energy sources to generate electrical power. Electrical power is extracted from solar energy via photovoltaic (PV) cell. However, PV cell maximum output power (MPP) depends on different parameters including weather conditions and internal components of the system. To achieve MPP, we used MatLab simulation to study the effect of the various parameters on PV performance. Results showed that MPP strongly depends on sun irradiance, shunt resistance, series resistance, temperature and ideal factor. These results might be used as a guide to PV system users.

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Keywords: PV; MPP; insolation; solar energy; ideal factor; fill factor; MatLab/simulink.

1. Introduction

Recently, solar energy as a source of renewable energy has attracted a lot of attention due its availability in nature and purity[1]. The mail component of the solar system is the photovoltaic (PV) Module that converts solar energy to electrical energy. PV module is a series-parallel combination of PV cells. The PV module are used in the system due to the low output power achieved by single PV cell. However, the output power of the PV module changes under different conditions including weather conditions as solar irradiation, temperature and partial shading [2]. There are several studies which dedicated to calculate the MPP under various conditions using MatLab/simulink. In previous

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study[3], the mathematical model is simulated using MatLab/Simulink for particular two PV modules. The essential parameters required for modelling the system are taken from the datasheets. The characteristics curves (Power-voltage and current-voltage curves) are obtained for the selected modules from simulation and found to match with the curves provided by the datasheet. In 2012 Khamis et al.[4] investigated the dynamical behavior of PV system using mathematical model of all system components. He used MatLab/Simulink environment and interface with SimPowerSystem toolbox to implement system components. To study the effects of partial shading and different orientation of PV modules, an analytical model of PV system is introduced by Wang and Hsu[5]. Their model is capable to present different characteristic curves of PV system including current-voltage and power-voltage curves in two and three dimensions. Villalva et al.[6] were able to model accurately the behavior of PV arrays that can be simulated using circuit simulator. The model simulation results match with experimental data. The effect of partial shading, temperature, solar insolation and configuration on the PV efficiency is studied by Patel and Agarwal[7]. Extensive study to the effect of partial shading on the MPP of PV array consists of two modules using matLab/Simulink is performed by Matter et al.[8]. Bashir et al. [9] compared the performance of three different materials of PV modules in winter time. Their results assured that the PV output power vary under different outdoor conditions and vary for different modules.

There are certain PV module parameters that affect the values of the output power such as internal resistance, fill factor and ideal factor. Up to our knowledge, these parameters have not been studied in details. In this work, we present a MatLab simulation for studying the characteristics of a PV array under various conditions. The work mainly interested in understanding the changes of MPP when the PV expose to varying solar irradiance, temperature, internal resistance, ideal factor and saturation current. Following section presents the equivalent circuit model of the solar cell abd solar module. The effect of different parameters on the MPP of the PV system is studied in section 3 using MatLab simulation tools. Finally, the paper is concluded by section 4.

2. Equivalent Circuit of a PV Cell and PV Module

PV Cell is the building block of the solar energy system. To understand its behaviour, we used a well-known equivalent circuit of the solar cell. It is called one diode model as displayed in Fig. 1 [10]. It consists of a photo current, a diode, a parallel resistor (R_{SH}) expressing a leakage current, and a series resistor (R_S) describing an internal resistance to the current flow. The mathematical model of the terminal current (I) is [10].

$$I = I_{PH} - I_S \left[exp\left(q \frac{(V + IR_S)}{KT_C A} \right) - 1 \right] - \frac{V + IR_S}{R_{SH}} \tag{1}$$

where I_{PH} is the photocurrent; I_S is the diode saturation current; q =1.6x10^{-19}C is an electron charge; k =1.38x10^{-23}J/K is Boltzmann's constant; T_C is the cell's temperature in Kelvin; A is an ideal factor; R_{SH} is a shunt resistance, and R_S is a series resistance.

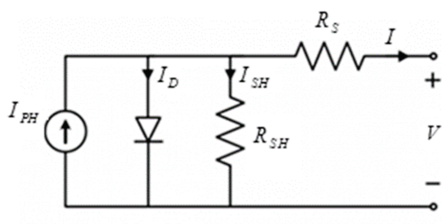

Fig. 1: Equivalent circuit models of a PV cell.

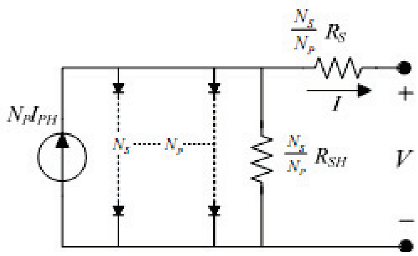

Fig. 2: Equivalent circuit models of PV module.

when $R_{SH}=\infty$ and $R_S=0$, the model reduces to an ideal model [11]. However, the ideal model is so simple to represent real system. Thus, we used the one diode model in our calculations. PV cells are usually connected in series-parallel configuration on a module to produce enough high power as in Fig. 2. A PV array is a group of several PV modules which are electrically connected in series and parallel circuits to generate the required current and voltage. The mathematical model for the terminal current (I_m) of a PV module arranged in N_P parallel and N_S series cells is [12]

$$I_m = N_P I_{PH} - N_P I_S\left[exp\left(q\frac{\left(\frac{V}{N_S}+\frac{IR_S}{N_P}\right)}{KT_C A}\right)-1\right]-\frac{\frac{N_P}{N_S}V+IR_S}{R_{SH}} \tag{2}$$

where I_S is defined by equation (3) [4,13].

$$I_S=\frac{I_{sc,n}+K_i\Delta T}{\exp\left(q\frac{V_{oc,n}+K_v\Delta T}{AV_{Th}N_S}\right)-1} \tag{3}$$

where $I_{SC,n}$ is the short circuit current at the nominal condition (usually 25 ^{0}C and 1000 W/m^2), $V_{oc,n}$ is the open-circuit voltages at the nominal condition, K_v is the open-circuit voltage/temperature coefficient, K_i is the short circuit current/temperature coefficient, $\Delta T=T-T_n$ where T and T_n are the actual and nominal temperatures [K], and N_S is number of cells in series. These values are taken from Kyocera KC200GT series model [14]. The light generated current I_{PH} is defined by equation (4) [4,13].

$$I_{PH}=\left(I_{PH,n}+K_i\Delta T\right)\frac{G}{G_n} \tag{4}$$

where G_n is nominal irradiance [W/m^2].

3. Simulink Model of the Solar PV Module

The mathematical model of the PV module current (I_m) in equation (2) is developed by MatLab/Simulink as in Fig. 3. The model parameters are taken from table 1. The effect of different parameters including solar irradiance, cell temperature, internal resistance, identity factor, and saturation current on the power-voltage and current-voltage characteristic curves of solar module are studied in the following subsections using the model in Fig 3.

3.1 Effects of Solar Radiation Variation

Fixing all other parameters, we can observe the effect of radiation variation on the characteristic curves of the solar modules in Fig. 4 (a) and Fig. 4 (b). The power-voltage and current-voltage characteristic curves are plotted for solar irradiance equals 1000 W/m², 800 W/m² and 600 W/m^2. The results are summarized in Table 2. The fill factor (FF) is defined as

$$FF=\frac{MPP}{P_T}=\frac{I_{MP}V_{MP}}{I_{SC}V_{OC}} \tag{5}$$

where MPP is the power calculated at maximum current value I_{MP} and maximum voltage value V_{MP}, and P_T is the power calculated at short current value I_{SC} multiplied by open voltage V_{OC}. We conclude from Fig. 4 and Table 2 that the PV cell current and MPP are highly dependent on solar radiation. When the irradiance increases the output current increases, the open-circuit voltage increases slightly, and the short circuit current increases. MPP also increases but *FF* decreases as irradiance increases. Table 2 shows that MPP at standard irradiance 1000W/m² equals 200.1W and decreased to 118.7W when the irradiance decreases to 600W/m². Thus, we conclude that as irradiance increases the output power increases.

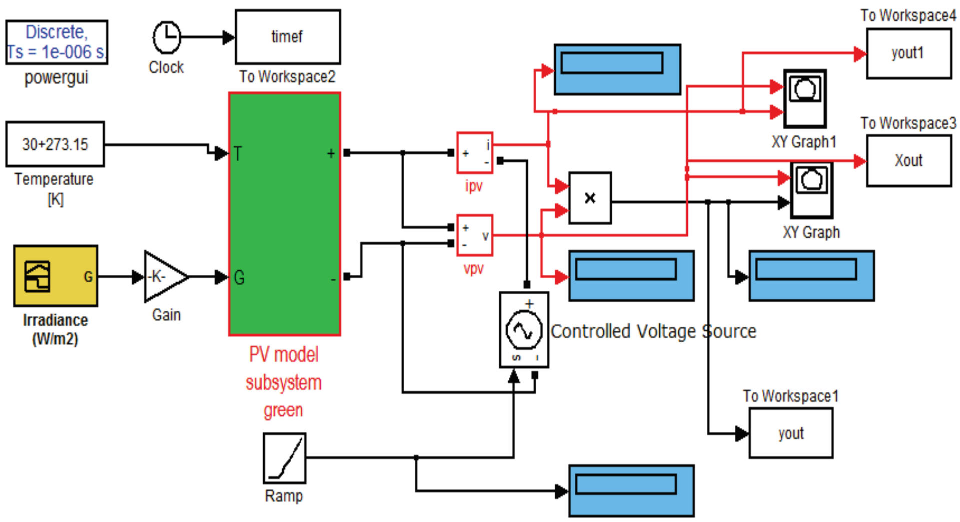

Fig. 3: Simulink model of the solar PV module current I_m

Table 2. MPP at different irradiance conditions

Irradiance [W/m^2]	*MPP* [W]	V_{MP} [V]	I_{MP} [A]	V_{OC} [V]	I_{OC} [A]	Fill factor [FF]
1000	200.1	26.3	7.61	32.8825	8.21	.741
800	159.4	26.3	6.061	32.4765	6.568	.747
600	118.7	26.3	4.512	31.9585	4.943	.751

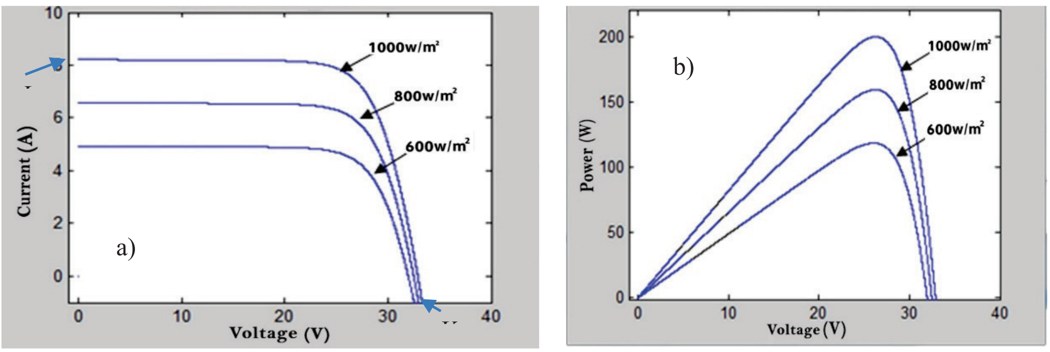

Fig. 4: a) Current-Voltage characteristic of a cell under varied irradiance. b) Power-Voltage characteristic of a cell under varied irradiance

3.2 Effect of Varying Cell Temperature

For a given solar radiation, we can observe the effect of temperature variation on the characteristic curves of PV module as shown in Fig. 5 (a) and Fig. 6 (b). Table 3 summarizes the main results at different temperature. The temperature is given values equal 30°C, 25°C and 20°C. We realize that the voltage is highly dependent on the temperature. When the cell temperature increases, the I_{SC} increases slightly, the V_{OC} decreases and MPP decreases.

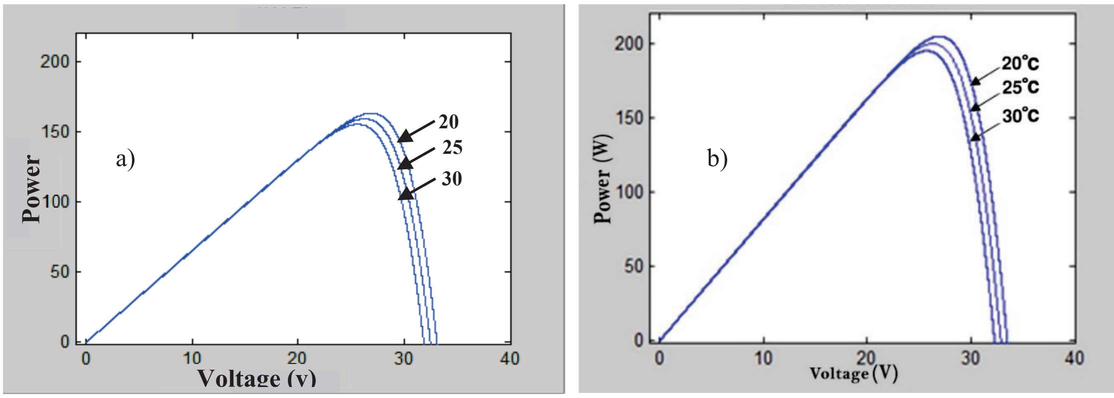

Fig. 5: a) Current-Voltage characteristic of a cell under varied temperature. b) Power-Voltage characteristic of a cell under varied temperature

The MPP at the standard temperature 25°C equals 200.1W. As temperature decreases to 20°C, the MPP increases to 205W. While the MPP decreases to 195.3W when temperature increases to 30°C.

Table 3. MPP at different temperature

Temperature [°C]	MPP [W]	V_{MP} [V]	I_{MP} [A]	V_{OC} [V]	I_{OC} [A]	Fill factor [FF]
20	205	26.94	7.61	33.4985	8.194	.747
25	200.1	26.3	7.61	32.8825	8.21	.741
30	195.3	25.66	7.61	32.2700	8.226	.736

3.3 Effect of Varying Shunt Resistance (R_{SH})

We can observe the effect of variation of R_{SH} on current-voltage and power-voltage characteristic curves of PV module as shown in Fig. 6 (a) and Fig. 6 (b). Table 4 summarizes the main results at different values of R_{SH}. R_{SH} allowed to assume different values as in Table 4. From the figures and considering the values of Table 4, we notice that the small value of R_{SH} causes PV module current to fall more steeply indicating higher power loss and low fill factor. As shunt resistance increases to 20000Ω, the maximum output power increases to 201.8W. This result happens at output voltage of = 26.3V and output current = 7.671A. We also observe the voltage at MPP doesn't change with changing the values of the shunt resistance.

Table 4. MPP at shunt resistance

R_{SH}[Ω]	MPP [W]	V_{MP} [V]	I_{MP} [A]	V_{OC} [V]	I_{OC} [A]	Fill factor [FF]
5	80.53	20.35	3.957	7.867	30.4605	0.336
50	188	26.3	7.376	8.178	32.7495	0.724
215.405	198.6	26.3	7.551	8.206	32.8685	0.736
415.405	200.1	26.3	7.61	8.21	32.8825	0.741
615.405	200.7	26.3	7.631	8.212	32.8895	0.744
815.405	201	26.3	7.641	8.212	32.8930	0.744
10000	201.7	26.3	7.671	8.214	32.9000	0.747
20000	201.8	26.3	7.672	8.214	32.9	0.747

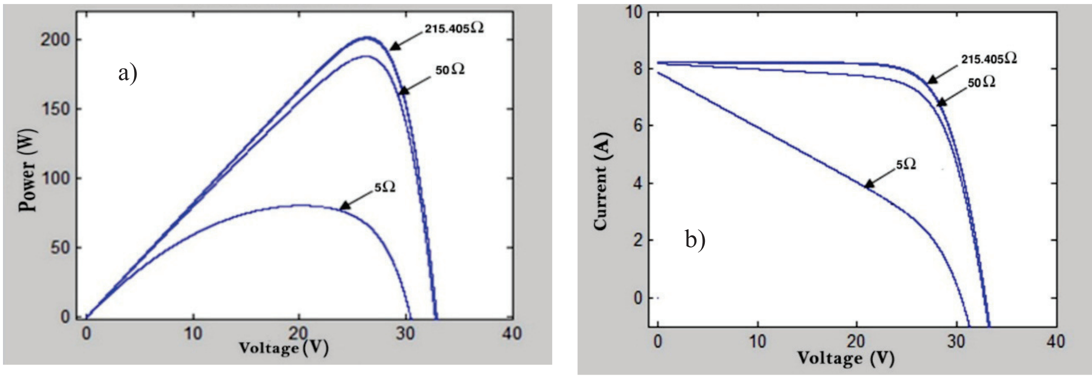

Fig. 6: a) Power-Voltage characteristic of a cell under varied R_{SH}. b) Current-Voltage characteristic of a cell under varied R_{SH}.

3.4 Effect of Varying Series Resistance (R_S)

The effect of the variation of R_S on the characteristics of PV module is shown in Fig. 7 (a) and Fig. 7 (b). The value of R_S assumed different values as in Table 5 which summarizes the main results. From both figures and Table 5, we notice that large values of R_S causes PV module current and voltage to fall more steeply indicating higher power loss and low fill factor. Thus, series resistance must be low, if we take it into consideration. From Table 5, the MPP at series resistance 0.121Ω equals 205.9W at the output current 7.645A and the output voltage 26.94V. As R_S increase to 0.221Ω, the MPP decrease to 200.1W at the output voltage = 26.3V and output current = 7.61 A. When series resistance increases to 1Ω, the MPP decreases to 157W at output voltage equals 21.77V and output current equals 7.209A.

Table 5. MPP at different series resistance

R_S [Ω]	MPP [W]	V_{MP} [V]	I_{MP} [A]	V_{OC} [V]	I_{OC} [A]	Fill factor [FF]
0.121	205.9	7.645	26.94	8.212	32.8825	0.763
0.221	200.1	7.61	26.3	8.21	32.8825	0.741
0.321	194.4	7.54	25.78	8.208	32.8825	0.72
1	157	7.209	21.77	8.195	32.8825	0.582

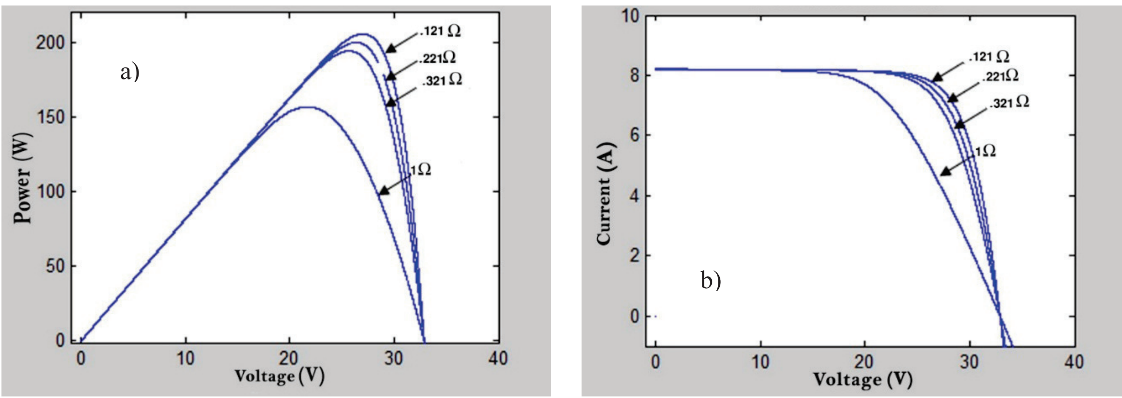

Fig. 7: a) Power-Voltage characteristic of a cell under varied R_S. b) Current-Voltage characteristic of a cell under varied R_S

3.5 Effect of Varying Ideal Factor (A)

The effect of the variation of ideal factor on the characteristics of PV module is shown in Fig. 8 (a) and Fig. 8 (b). Ideal Factor varies as shown in Table 6. The results are summarized in Table 6. From the figures and considering the values of Table 6, we notice that as the value of ideal factor increases, the value of the MPP decreases. Also, we notice that the open circuit voltage decrease while short circuit current doesn't change as ideal factor increases.

Table 6. MPP at different ideal factor (A)

Ideal Factor (A)	MPP [W]	V_{MP} [V]	I_{MP} [A]	V_{OC} [V]	I_{OC} [A]	Fill factor [FF]
1	209.1	27.1	7.715	8.21	32.8860	0.774
1.3	200.1	26.3	7.61	8.21	32.8825	0.741
1.6	192.1	25.86	7.428	8.21	32.8790	0.712

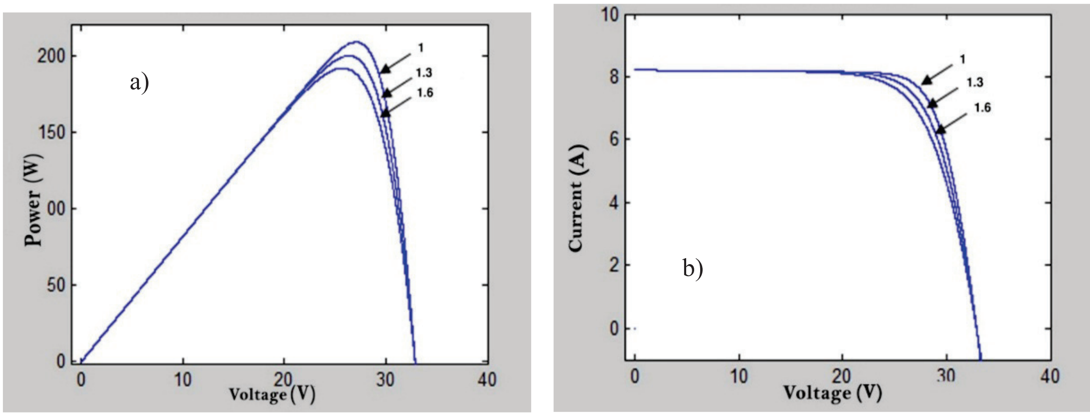

Fig. 8: a) Power-Voltage characteristic of a cell under varied ideal factor. b) Current-Voltage characteristic of a cell under varied ideal factor

3.6 Effect of Varying Saturation Current (IS)

We can observe the effect of variation of I_S on I-V characteristic of PV module in Fig. 9 (a) and Fig. 9 (b). I_S varies as shown in Table 7 from 98.252x10^{-8}A down to 9.8252x10^{-8}A and finally to 0.98252x10^{-8}A. Table 7 summarizes the main results at different values of I_S. From the figures and Table 7, we realize that as the value of I_S increases, the MPP decreases, the open circuit voltage decreases, and the short circuit current doesn't change.

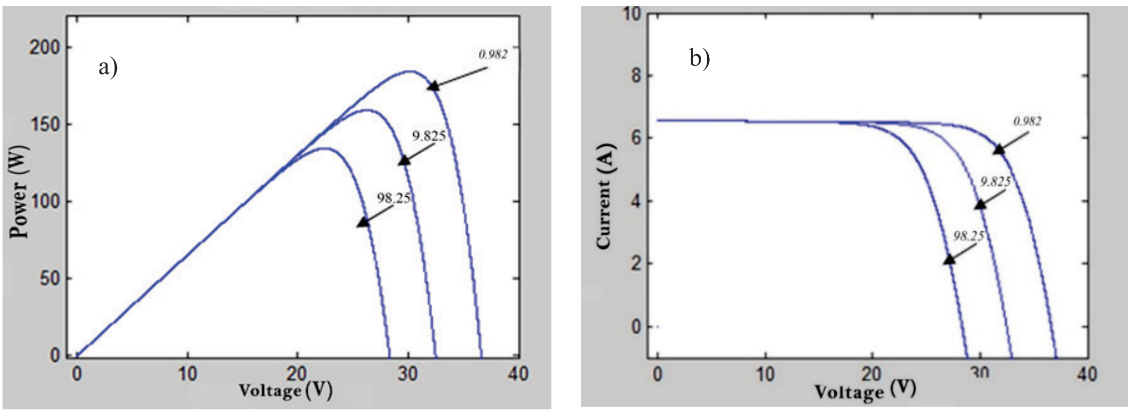

Fig. 9: a) Power-Voltage characteristic of a PV cell under varied I_S. b) Current-Voltage characteristic of a PV cell under varied I_S

Table 7. MPP at different I_S

IS [A]	MPP [W]	VMP [V]	IMP [A]	VOC [V]	IOC [A]	Fill factor [FF]
$0.98252x10^{-8}$	231.6	30.2	7.667	8.21	35	805
$9.8252x10^{-8}$	200.1	26.3	7.61	8.21	32.8825	741
$98.252x10^{-8}$	169	22.63	7.466	8.21	28.7315	0.716

4. Conclusion

In this work, we used MatLab/Simulink to study the effect of different parameters on the performance of PV module including solar irradiance, temperature, internal resistance, ideal factor and saturation current. The simulation used one diode model and parameters are taken form data sheet of KC200GT module. The results show that when the irradiance increases the output current increases, the open-circuit voltage increases slightly, short circuit current increases, MPP increases but FF decreases. The MPP decreases, the short circuit current increases slightly and the open circuit voltage decreases as the temperatures of the PV array increases. Also, we notice that small values of R_{sh} causes PV module current to fall more steeply indicating higher power loss and low fill factor. Thus, shunt resistance must be large to increase output power and fill factor. While large values of R_S causes PV module current and voltage to fall more steeply indicating higher power loss and low fill factor. Thus, to maximize the output power of the module, the series resistance must be low. Moreover, MPP decrease as ideal factor increases and saturation current increases. The results might be used as guide for the solar system users.

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