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Research paper

The environment coefficients effect on I-V and P-V characteristics curves of photovoltaic cell using Matlab/Simulink

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Abstract

Many parameters and environments conditions will affect the behavior of the photovoltaic cell. This paper investigates, theoretically the variation of each temperature and irradiation effects on the output of the photovoltaic cell characteristics. Modeling of the photovoltaic cell scheme essentially requires taking weather data (temperature and irradiance) as input variables. The photovoltaic outputs are the current, voltage and power. Though, conclude the characteristics I-V or P-V desires of these important variables. Any variation in the entries directly shows variations in outputs. The characteristic curves are obtained with the use practical readings and measurements are illustrated directly from the solar power plant in the Technical Engineering College of Mosul. The complete modeling is then computer-generated using MATLAB/Simulink software owing to its common use and its helpfulness.

Keywords: *PV Cell; Solar Cell; Single Diode; I-V and P-V Characteristics; PV Temperature PV Irradiation.*

1. Introduction

Solar energy was the one of the important energy resources in the last year's decades. The technology that directly converts free solar energy in to electrical energy without causing any pollution to the environment is termed as photovoltaic cell power generation [1] and [2].

Solar cell is manufactured of a semiconductor layer as like the PN junction diode, it converts the sun light in to electricity by photovoltaic behavior. The consumer, naturally, wants to run the Photovoltaic (PV) array at its maximum energy adaptation output by continuously using the maximum offered solar power of the array [3 and 4]. To have a scientific model of the photovoltaic cell, and to understand the highly nonlinearity behavior from semiconductor PN-junction, several models of equivalent circuits were developed, the single-diode model was simulated to realized and understand the mathematical and physical properties of the solar cell. Mathematical equations developed for modeling the performance of the PV generator are based on current-voltage characteristic of the modules [5] and [6].

2. The mathematical model of photovoltaic cell

Single-diode represents the best model according to the simplicity and accuracy of these models. To obtain the equivalent circuit equations, a mathematical analysis steps must be established [7].

2.1. Ideal single-diode equivalent circuit

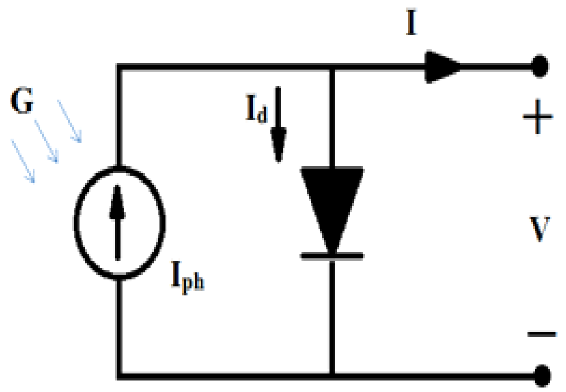

Fig. 1: Photovoltaic Cell Equivalent Circuit.

An ideal single-diode circuit is depicted in figure (1)
This equivalent circuit can be described as:
By applying Kirchhoff's law

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

As

$$I_d = I_0\left(e^{\frac{V}{n_s V_T}} - 1\right) \tag{2}$$

Where

$$V_T = \frac{nkT}{q} \tag{3}$$

2.2. Practical single-diode equivalent circuit

For many literatures as in figure 2 this equivalent circuit is also termed as five unknown parameters (n, I_{ph}, I_0, R_p and R_s).

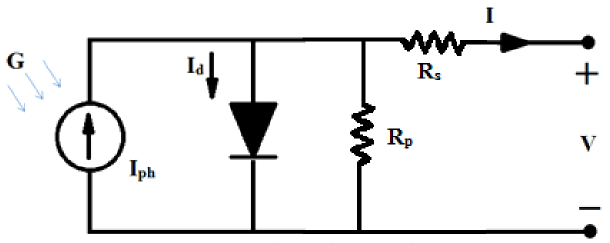

Fig. 2: Practical Single Diode Equivalent Circuit.

The photovoltaic current can be estimated by the following non-linear equation

$$I = I_{ph} - I_0\left(e^{\frac{V}{n_s V_T}} - 1\right) - \frac{V + IR_s}{R_p} \quad (4)$$

At open circuit situation:

$$I = 0 \quad (5)$$

Hence,

$$0 = I_{ph} - I_0\left(e^{\frac{V_{oc} + IR_s}{n_s V_T}} - 1\right) - \frac{V_{oc} + IR_s}{R_p} \quad (6)$$

At short circuit situation:

$$I = I_{sc} \quad (7)$$

Hence,

$$I_{sc} = I_{ph} - I_0\left(e^{\frac{I_{sc} R_s}{n_s V_T}} - 1\right) - \frac{I_{sc} R_s}{R_p} \quad (8)$$

At maximum power point situation:

$$I_{mp} = I_{ph} - I_0\left(e^{\frac{V_{mp} + I_{mp} R_s}{n_s V_T}} - 1\right) - \frac{V_{mp} + I_{mp} R_s}{R_p} \quad (9)$$

3. Modeling of PV cell

The PV model is simulated using Matlab/Simulink based on equations (1-9) and table 1. The PV model is (LCR-M200-JA-SI). Figure (3) shows the electrical circuit of the PV cell. The simulation of I-V and P-V characteristics curves can be produced by varying a certain parameter with making others constant. In this paper the effect of environmental temperature and irradiation are discussed.

Table 1: Electrical Parameters of (LCR-M200-JA-SI)

Dimensions	1580×808×40 mm
Weight	15.5kg
Cell number	72monocrystallian
P_m	200WP
V_m	37.26V
I_m	5.37A
Short circuit current	5.66A
Open circuit voltage	45.62V

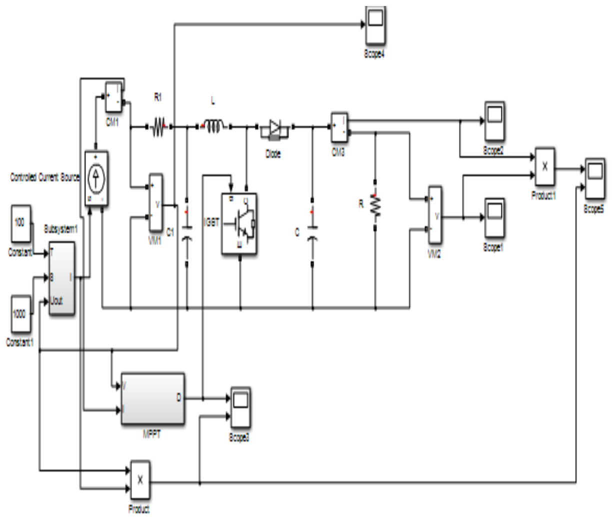

Fig. 3: Presentation of the Whole PV Model.

4. Results and discussion

4.1. The output characteristics of PV cell under different irradiation conditions

As the temperature maintained constant at 25^0C, the irradiation can be changed as (250W/m^2 to 1000W/m^2) by 250W/m^2 steps. The V-I and P-V curves are as shown in figure 4. These curves are shows that the generated current by the incidence sun light (I_{sc}) depends on the amount of the irradiation. The higher value of the generated current is at the higher irradiation. The maximum power point also meets the change when irradiation increased. The output voltage (V_{oc}) will changed slightly [8-9].

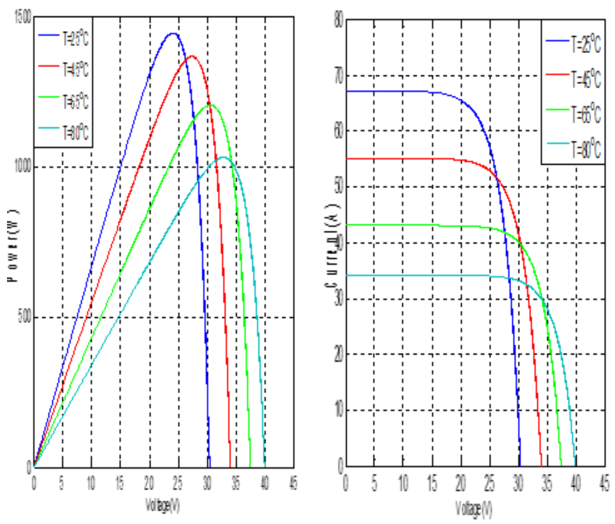

Fig. 4: Influence of Temperature.

4.2. PV characteristics under different temperature conditions

As the irradiation maintained constant at 1000W/m^2, the temperature was varied as (20^0C to 80^0C) by 20^0C steps. The curves of V-I and P-V curves are as shown in figure (5). The generated current that produced by the incident sun light (I_{sc}) will stay slightly increased and can be neglected, as well as the temperature increase. The output voltage (V_{oc}) will changed and decreases. The temperature increase will decrease the voltage and hence the power [10].

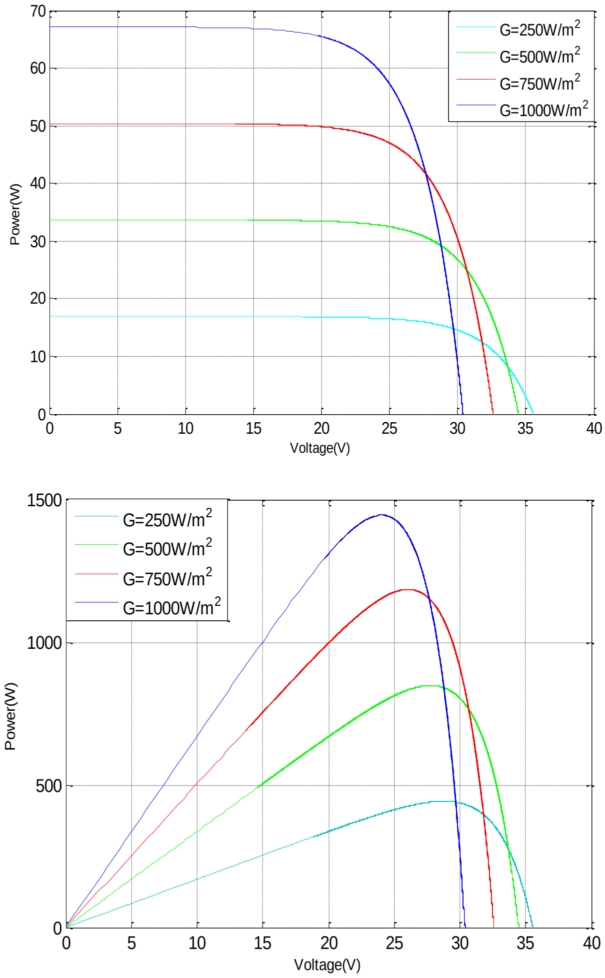

Fig. 5: Influence of Irradiation.

5. Practical model of solar power plant

The real practical structure of the solar power plant in the (Technical College of Mosul) is shown in figure (7 and 8).

Fig. 6: The Real Practical Structure of the Solar Power Plant (Technical College of Mosul).

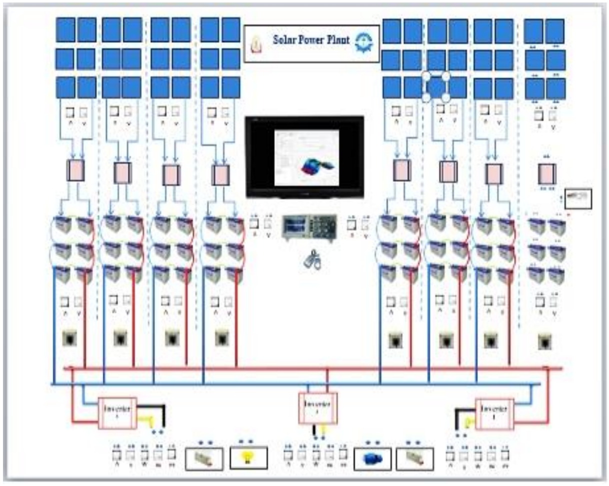

Fig. 7: Schematic Diagram of Solar Power Plamt.

6. Practical results

Table 2 and 3 shows the practical measurements of I-V and P-V characteristics that implemented on the Solar Power Plant in (Technical College of Mosul) with temperature influence.
The I-V and P-V curves are depicted in figure (9) at constant irradiation (1000W/m^2). The related values of I-V and P-V curves of solar cell at irradiation of 1000W/m^2 and constant temperature of 25^{0}C are shown in table 4 and 5.

Table 2: I-V Characteristics at 1000W/M2

Current (A)	Voltage (V)
66.5	0
66.25	5
66	10
65.8	20
64	21.5
62	23.5
56	25
50	27
40	28
30	28.5
20	29
5	30

Table 3: P-V Characteristics at 1000W/M2

Power (W/m^2)	Voltage (V)
0	0
250	3.8
500	7.5
750	11.5
1000	15
1250	19
1450	23.5
1400	26
1200	27.5
1000	28
750	29
500	29.5
250	30

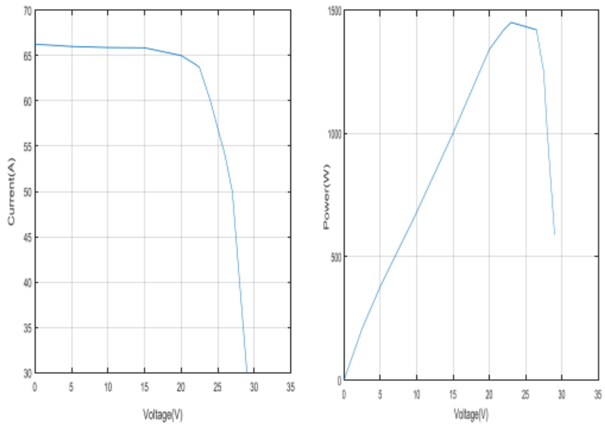

Fig. 9: Practical Influence of Temperature.

The influence of irradiation at constant temperature are shown in figure10. These values are measured practically from the solar power plant in Technical College of Mosul.

Table 4: I-V Characters-Tics at 250C

Current (A)	Voltage (V)
66.52	0
66	5
65.88	10
65.85	15
65	20
64	22
63.7	22.5
60	24
57	25
54	26
50	27
40	28
30	29

Table 5: P-V Characteristics at 250C

Power (W/m^2)	Voltage (V)
0	0
210	2.5
380	5
500	7
680	10
1000	15
1340	20
1420	22
1450	23
1420	26.5
1250	27.5
1000	28
590	29

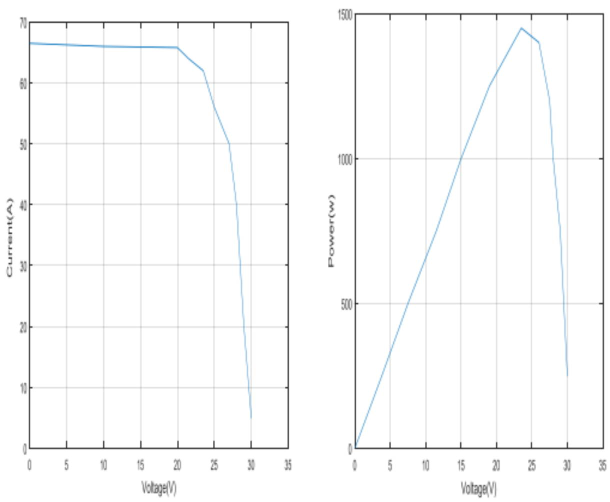

Fig. 10: Practical Influence of Irradiation.

7. Conclusion

The proposed models of that simulated using Matlab/Simulink is gave a perfect result. The equivalent circuits are analyzed, the effects of the solar irradiation intensity and cell temperature as input. The output of photovoltaic cell is the I-V and P-V characteristics curves at various conditions.

As the increase in irradiation the photovoltaic cell output voltage will increase in slightly manner, also, higher magnitude of power will be produced. The change in temperature will affect the behavior of the solar cell, the output current will increase but in negligible value, while the output voltage will decrease, and this will affect the photovoltaic cell efficiency.

Through the results that obtained from each the equivalent circuit of single-diode, which described and modeled using the mathematical equations in Matlab/Simulink environments, and the results that measured and obtained directly from the Technical College of Mosul solar power plant obtainable that the effect of each change in the values of temperature and irradiation are identical quite through characteristics curves of I-V and P-V.

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