Simulate the Performance Analysis of a PV Module with Consideration of Environmental Factors and Modelling Solar Photovoltaic Cell

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Abstract—This paper presents mathematical model of solar photovoltaic (PV) cell and to simulate its behavior and performance analysis of Photovoltaic Cell(PV) module on different temperature conditions and irradiance levels. The model is used to study different effects on the PV array including operating temperature and solar irradiation level is able to simulate both the I-V characteristics curves and the P-V characteristics curves. The model was developed by using Matlab /Simulink software.

Key words: Photovoltaic (PV) Module, Irradiance, Temperature, MATLAB/SIMULINK, Solar Cell Modelling

I. Introduction

Energy is a basic need for human activity, economic and social development for the betterment of human life. But due to growing population attached with global warming an depleting fossil resources. fossil fuels responsible for many environmental hazards like carbon emissions and global warming. The renewable energy sources emerged from the need to search for alternate green sources of energy.

Solar energy is green energy and environmentally friendly. Photovoltaic (PV) energy is a source of non-polluting energy. Photovoltaic(PV) systems have been the worldwide fast growing energy source because of the increase in energy demand and the fact that fossil energy sources are limited. Photovoltaic (PV) power systems are becoming increasingly in electrical grids. Solar PV cell is not constant all the time is affected by external conditions like solar irradiance and temperature.

This paper presents mathematical model of solar photovoltaic (PV) cell and to simulate its behaviour and performance analysis of Photovoltaic Cell(PV) module on different temperature conditions and irradiance levels. It was applied to develop a 200W PV module in order to simulate its behaviour. The model is able to simulate both the I-V characteristics curve and the P-V characteristics curve. The Simulation model is used to study different parameters effects on the PV array including operating temperature, solar irradiation level. Matlab/Simulink software is used to implement the models and obtain simulation results.

Section II describes the mathematical model and simulation results of the photovoltaic cell. Section III focuses on the effects on different solar irradiance on the module. Section VI analyses the effects of different temperature on the module. Conclusions of the study are stated in section V.

II. Modeling Solar Photovoltaic Cell

The equivalent circuit shown in fig. 1 can represent of the PV cell. It includes a current source, series and shunt resistance and diode.

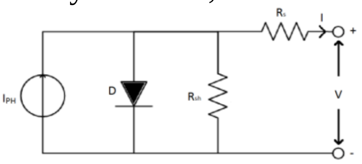

Fig. 1: Equivalent circuit of a solar PV cell

In the equivalent circuit, the current delivered to the external load equals the current I_{PH} generated by the illumination, less the diode current I_d. The output character of a single PV cell is show in eq. (1).

$$I = I_{PH} - I_S \left[\exp \frac{q(V+IR_S)}{NKT} - 1\right] - \frac{q(V+IR_S)}{R_{sh}} \quad (1)$$

This equation, I is the load current(A), I_{PH} is the photocurrent(A), V is the Cell terminal voltage (V) , I_S is the Short circuit current (A), q is the electron charge (1.602 x 10-19 C), N is the diode ideality factor, K is the Boltzmann constant(1.38 x 10-23 J/K), T is the cell temperature(K), R_S and R_{SH} is the series and shunt resistance respectively. So, the behaviour of a solar PV cell is completely dependent on these parameters.

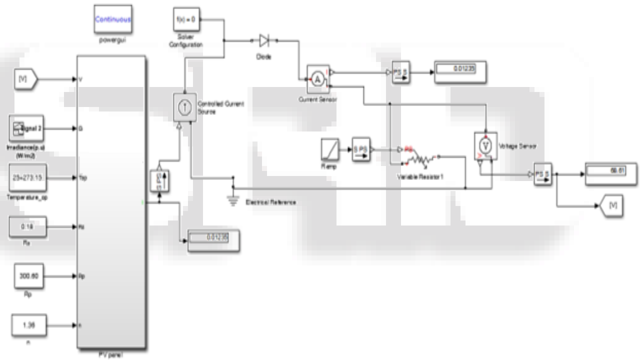

Fig. 2: Simulation model of solar photovoltaic (PV) cell

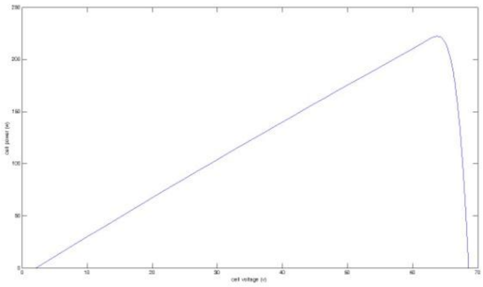

Fig. 3: P-V characteristics

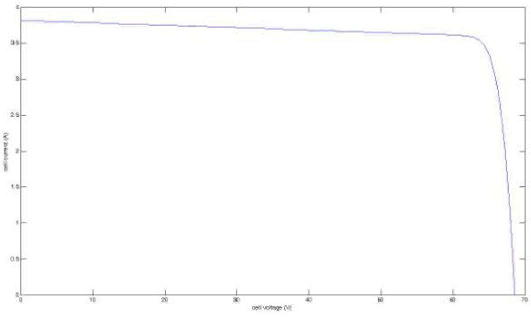

Fig. 4: I-V characteristics

Fig. 2 shows the Simulink subsystem for solar PV cell. Fig.3 and 4 respectively generated output results in P-V and I-V characteristics curves are given.

III. EFFECTS OF DIFFERENT SOLAR IRRADIANCE

The above model of PV cell in Fig. 2 is play a great effect on the behavior of PV module. In eq.(1) of them calculates the photocurrent I_{PH}. The photocurrent I_{PH} depends on the solar irradiance and cell temperature. The output of the PV module different solar irradiance level and constant temperature which can be obtained from the following eq. (2).

$$I_{PH} = [I_{SC} + K_i(T - T_{ref})]\,\frac{B}{1000} \qquad (2)$$

In this equation, I_{SC} is the short circuit current(A), K_i is the temperature coefficient of short circuit current(A/^{0}C), T is the cell temperature(K), T_{ref} is the reference temperature(K) and B is the solar irradiation in W/m^2.

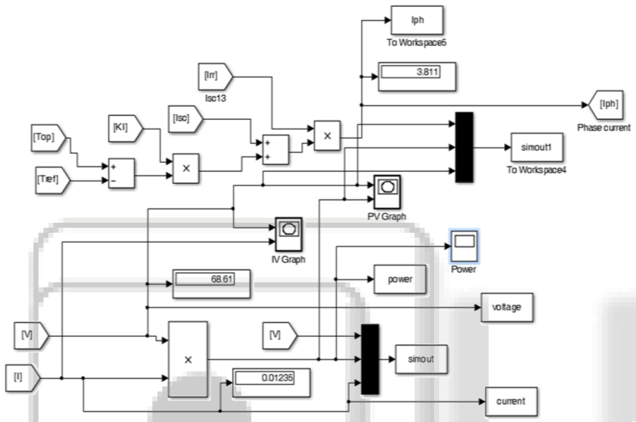

Fig. 5: Simulation model for photocurrent (I_{ph})

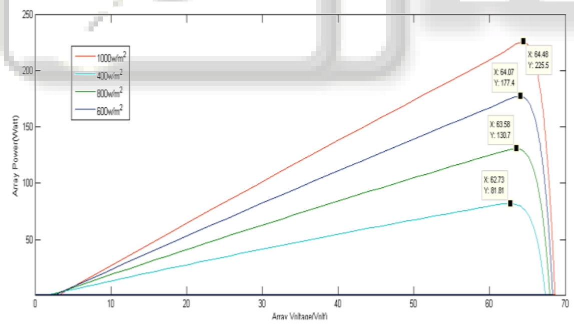

Fig. 6: Generated P-V characteristic for different solar irradiances

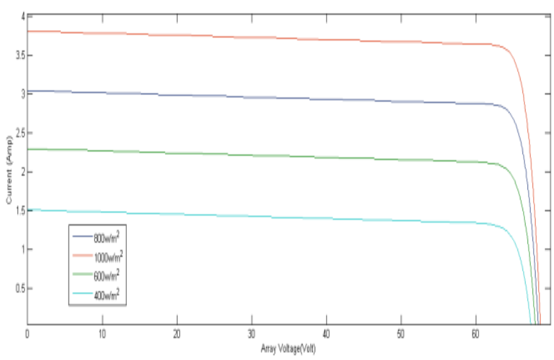

Fig. 7: Generated I-V characteristic for different solar irradiances

Generation of I-V and P-V characteristics for different solar irradiances and constant temperature.

Shows the I-V and P-V characteristics generated by the simulation for a constant temperature of 25°C (T=298°K) and different irradiance values = 400,600,800 and 1000 W/m^2 for Fig. 6 and 7. Table 1 gives the values for Open Circuit Voltage, Maximum Power Voltage and Maximum Power for the same condition.

Irradiance (W/m^{2})	Open Circuit Voltage	Maximum Power Voltage	Maximum Power
1000	68.61	64.48	225.5
800	68.31	64.07	117.4
600	68.00	63.58	130.7
400	67.53	62.73	81.81

Table 1: Different Values of Solar Irradiance for Constant Temperature of 25 °C

IV. EFFECTS OF DIFFERENT SOLAR TEMPERATURE

The other Simulation of PV cell model calculates the diode saturation current I_S for different as a cubic function of the temperature and it can be expressed as the following eq. (3).

$$I_s = I_{RS}\left(\frac{T}{T_{ref}}\right)^{\frac{3}{N}} e^{-\frac{qV_t}{NK\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)}} \qquad (3)$$

In this equation, I_{RS} is the diode reverse saturation current (A) and V_t is the thermal voltage (V). The cell reverse saturation current can be obtained from the eq.(4) given below.

$$I_{RS} = \frac{I_{SC}}{[e^{qV_{OC}/NKT}]} \qquad (4)$$

Thermal voltage V_t can be obtained from the following eq. (5).

$$V_t = \frac{KT}{q} \qquad (5)$$

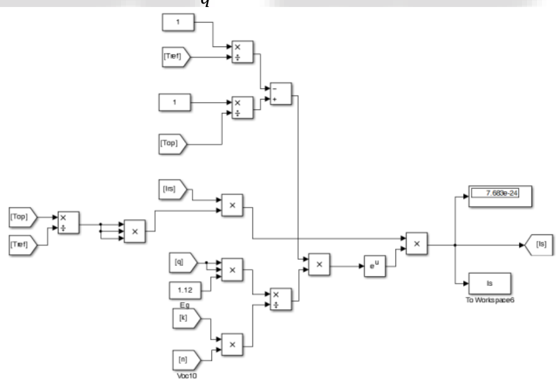

Fig. 8 Simulation model for diode saturation current(I_s)

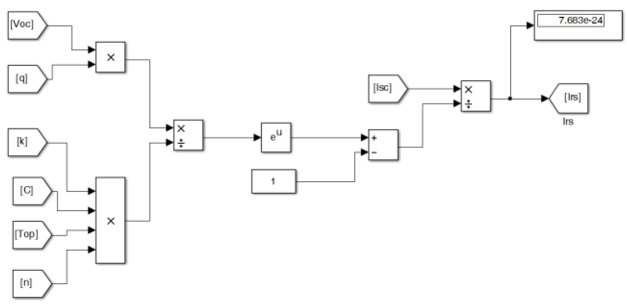

Fig. 9 Simulation model for reverse saturation current(I_{rs})

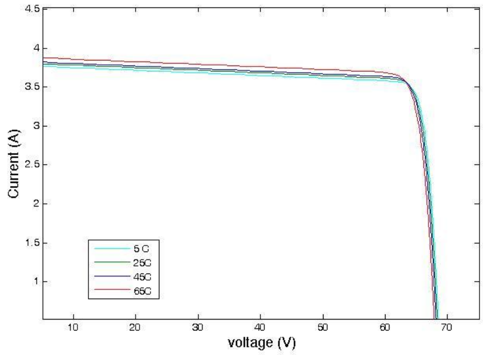

Fig. 10 Generated I-V characteristic for different temperature level

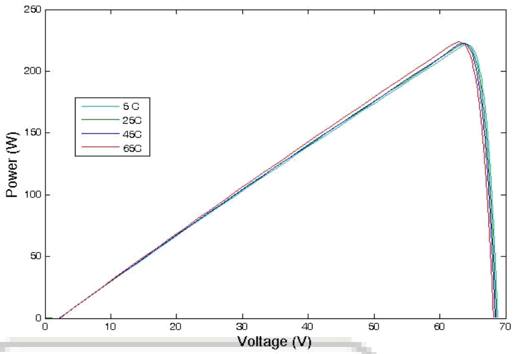

Fig. 11 Generated P-V characteristic for different temperature level

Generation of P-V and I-V curves for different temperature and constant solar irradiance. Shows the I-V and P-V characteristics generated by the fixed solar irradiance of =1000 W/m^2 and different temperature values of 5, 25, 45 and 65 °C for Fig. 10 and 11. Table 2 gives the values for Open Circuit Voltage, Maximum Power Voltage, Maximum Power for these conditions.

Temperature (^{o}C)	Open Circuit Voltage	Maximum Power Voltage	Maximum Power
5 (278K)	68.78	64.41	221.6
25 (298K)	68.60	63.72	222.4
45(318K)	68.42	63.66	222.7
65(338K)	68.16	62.91	223.6

Table 2: Different Values Of Temperature For Solar Irradiance Of 1000 W/M^2

V. Conclusion

The paper presents a simulation model of solar photovoltaic (PV) cell based on mathematical expression from an equivalent circuit. The model is implied to simulate the characteristics of solar PV cell. This model can generate the behaviour of PV cell depending on different solar irradiation and temperature conditions. It can be used to develop PV modules of any rated size. also, the implied simulation model can be extended to any desired level for further research and studies.

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