An Improved Approach to Design a Photovoltaic Panel

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Abstract

In this paper, modeling and simulation of the solar photo-voltaic (PV) power generator is observed using Matlab-Simulink environment. The study the fore-mentioned photovoltaic systems in an efficient manner the knowledge of I-V and P-V characteristics is a prerequisite. Effect of environmental parameters of temperature and irradiance variations could also be observed from simulated characteristics.

Keywords: Photovoltaic panel, PV Curves, IV Curves, Modelling, Simulation,Matlab/Simulink.

1. Introduction

The onward march of human civilisation has come at the cost of environment.One of the biggest concerns of today is environment safety, and as time progresses this need will grow bigger and greater. Thus the present scenario calls for greener energy resources [1] [2]. There are many energy sources such as solar photo-voltaic system, wind turbine, and energy storage system used for generation of electricity. Solar cells are used in various field of application both residential and industrial. D.C power is more preferred than A.C because of lower losses. Photovoltaic systems are most useful generally [3] [4]. Now a day's a lot of research is going round for modelling of photovoltaic devices. Modelling of photovoltaic devices and simulating their behaviour represent a significant portion of today's research in the field of solar energy. Naturally the major issue of PV panel is it's dependence on weather conditions which greatly alter the output power. In this model a clear procedure is mentioned on how to create pv panel through matlab simulation which is simple yet effective under varied environmental conditions. An equivalent circuit is used for modelling as because it allows performing a joint simulation of a photoelectric device with power electronics interfaces [5-9]. Such simulations allow optimising the design of solar arrays and power systems. The most crucial component that affects the accuracy of the simulation is the PV cell model. Modelling of PV cell involves several steps majorly concerning the estimation of the I–V and P–V characteristics curves to emulate the real cell under various conditions of temperature and irradiance. The most popular approach is to utilise the electrical equivalent circuit, which is primarily based on the diode. Many models have been proposed by various researchers; of which the simplest is the basic single-diode model. It comprises of a linear independent current source in parallel to a diode [10].

2. Mathematical Representation of Boost Converter

A basic single-diode model is chosen for Matlab simulation and analysis [3]. The desired power output is obtained by joining the PV cells in series. The group of these PV cells is known PV module and group of PV modules is known PV array. To understand PV panel features we first observe a simplified PV cell. A simplified model of a solar cell is shown Figure 1.
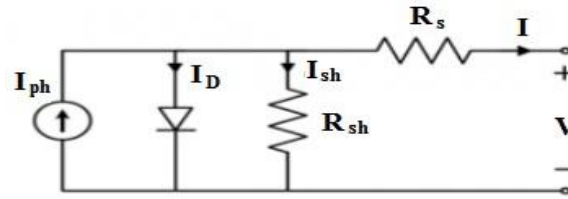
Figure 1. Simplified Equivalent Circuit of a PV Cell.

Where I_{ph} = photon generated current

The mathematical modeling of photovoltaic array can be described as:

$$I = N_p I_{ph} - N_p I_d \left(e^{\left(\frac{qV_{pv}}{kTAN_s} \right)} - 1 \right)$$

(1)

N_s and N_p determine the number of cells connected in series and parallel in the given PV module to achieve the desired output. R_s and R_p are the intrinsic parallel and series resistances associated to the panel. 'A' is the actualisation factor which determines the deviation of the characteristics of an ideal p-n junction. K and q represent Boltzmann constant and charge on an electron respectively.

The photon generated current I_{ph} depends on temperature and solar irradiance.

$$I_{ph} = \left[I_{scr} + KI \left(T_{op} - T_{ref} \right) \right] \frac{S}{100}$$

$$I_{ph} = \left[I_{scr} + KI \left(T_{op} - T_{ref} \right) \right] I_{rr}$$

(2)

I_d = the diode reverse saturation current varies with temperature as follows based on the equation between current and voltage of a solar panel:

$$I_d = I_{rr} \left[\frac{T}{T_r} \right]^3 \exp \left(\frac{qE_g}{kA} \left[\frac{1}{T_r} - \frac{1}{T} \right] \right)$$

(3)

In the above expression Eg is the energy gap of the semiconductor.

$$E_g = E_g(0) - \frac{\alpha T^2}{\beta + T}$$

(4)

The final output power is obtained as the product of load current and thermal voltage. It's governed by the following equation:

$$P = VI = N_p I_{ph} \left[\frac{qV}{kTAN_s} - 1 \right]$$

(5)

I_{sh} is the shunt current. $I_{sh} = (V + IR_s)/R_p$

(6)

I is the load current.

$$I = (I_{ph}N_p - (I_{sh} + I_d)) \qquad\qquad (7)$$

where N_p is the number of cells in parallel.

V is the output voltage across the load and I is the load current. Graphs are generated for I vs V (current and voltage) characteristics and P vs V characteristics (power and voltage).

3. Research Method
3.1 Model Formulation in MATLAB-Simulink Enviornment

Modelling of total PV system, including subsystems is shown in Figure 2 with the help of Equation 1 to Equation 7 the PV panel is designed and simulated in MATLAB Simulink environment. The major factors affecting the efficiency of the PV panel are Irradiance and Temperature. Using mathematical tool blocks, the Photon Generated, shunt current as well as the Load current can be obtained by modelling and calculated as shown in Figure 3 to 5 respectively. A Sim-Out block is present through which the data obtained during simulation is captured and is saved to the workspace. Modelling of I_{ph} is shown in Figure 3.
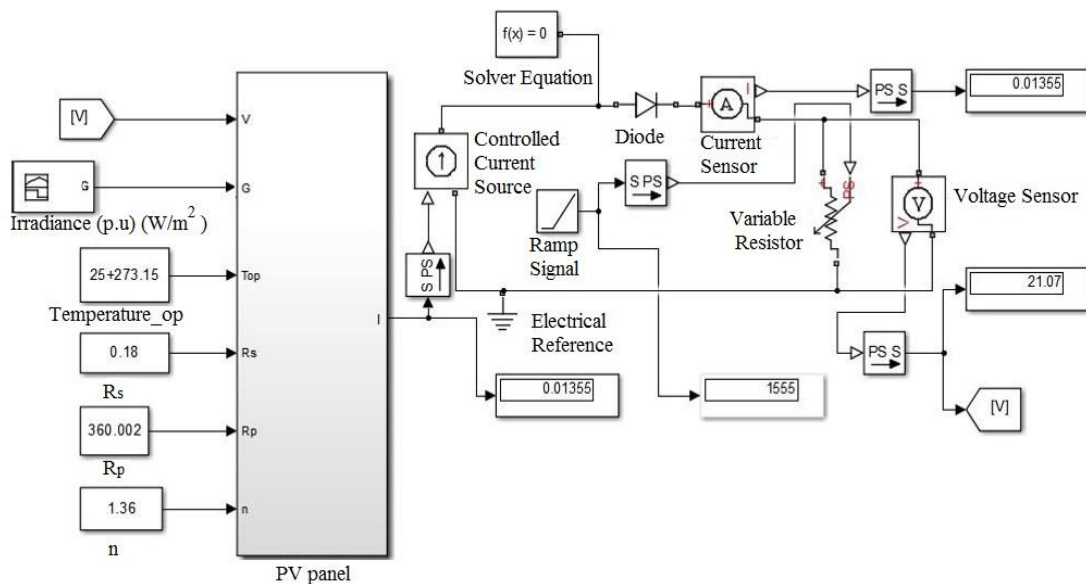

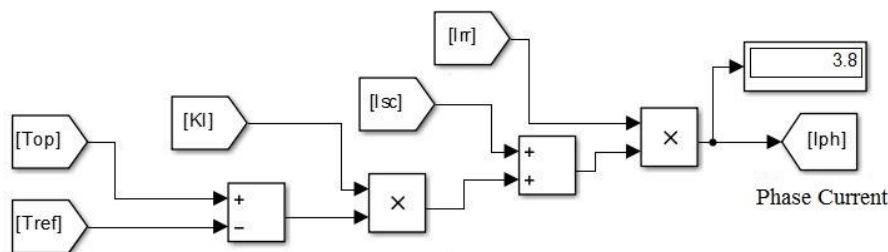Figure 2. Modelling of Solar Photovoltaic System

Figure 3. Modelling of Photon Generated Current in Solar Photovoltaic Panel.

Modelling of shunt current is shown in Figure 4 and it is obtained by the following equation:
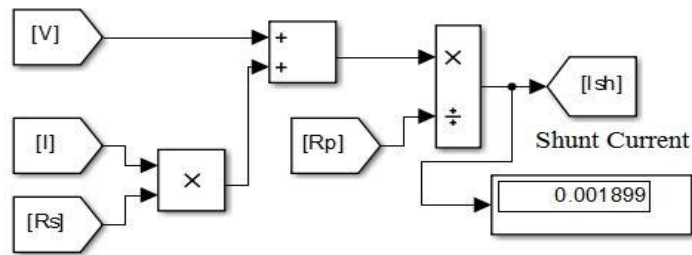
Figure 4. Modelling of Shunt Current in Solar Photovoltaic Panel.

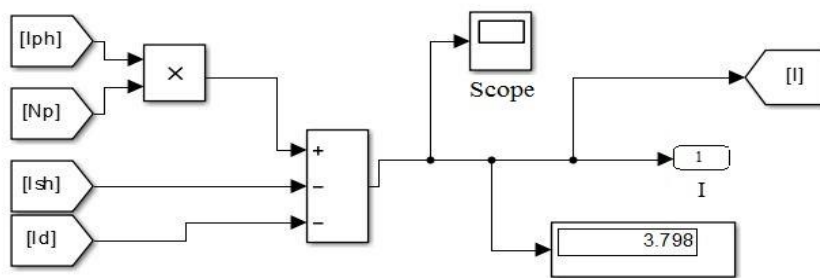Modelling of load current is shown in Figure 5 and its obtained as follows:

Figure 5. Modelling of Load Current in Solar Photovoltaic Panel

4. Results and Discussion

Temperature and Irradiance are the input of the solar photo-voltaic system. There are three remarkable points in the P-V characteristic V_{oc} =21.1 V, I_{sc} =3.8 A, and maximum power 60W at irradiation 1000W/m^2 and temperature 25^{0}C. Figure 6 to 12 show the I-V and P-V characteristics of Solar photo-voltaic panel at different irradiations and temperatures.
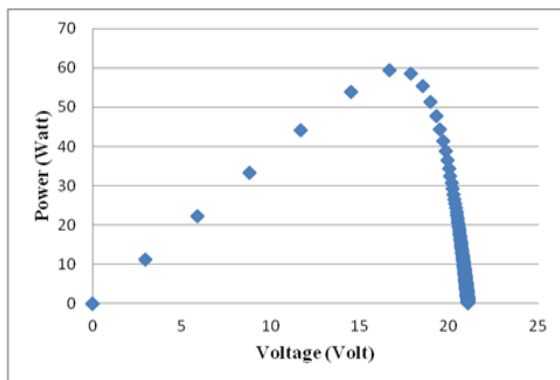

Figure 6(a). P-V Characteristic at 25^0 C
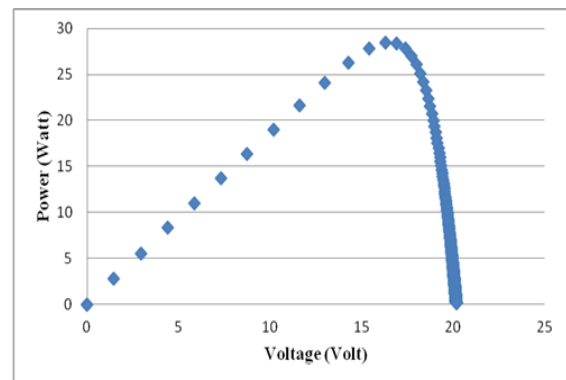Temperature and 1000W/m^2 Irradiance.

Figure 6(b). P-V Characteristic at 25^0 C
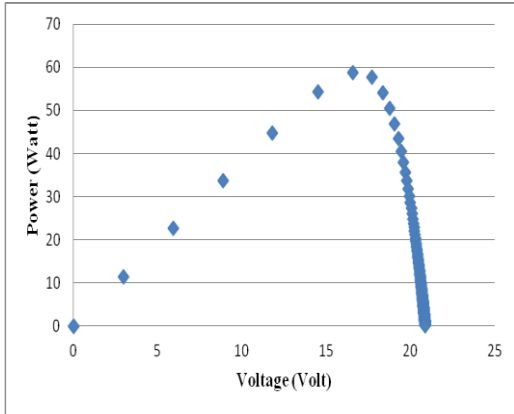Temperature and 500W/m^2 Irradiance

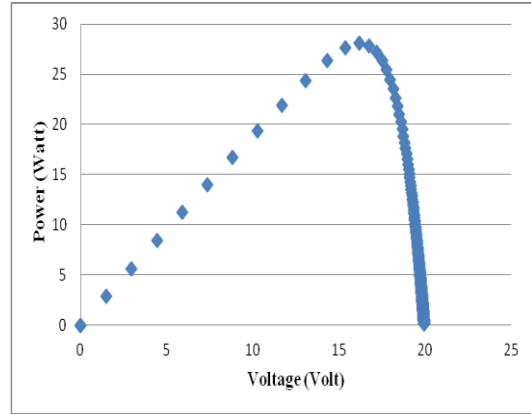Figure 7. P-V Characteristic at 40^0 C
Temperature and 1000W/m^2 Irradiance

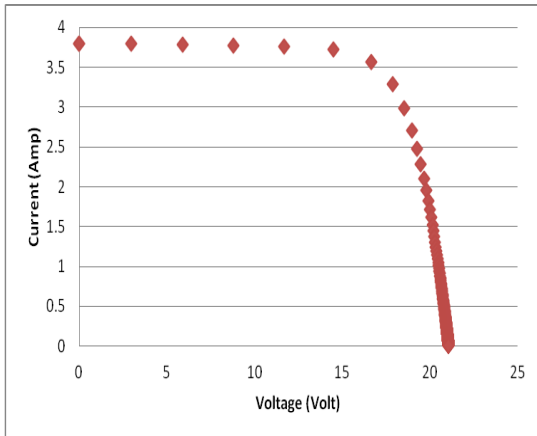Figure 8. P-V Characteristic at 40^0 C
Temperature and 500W/m^2 Irradiance

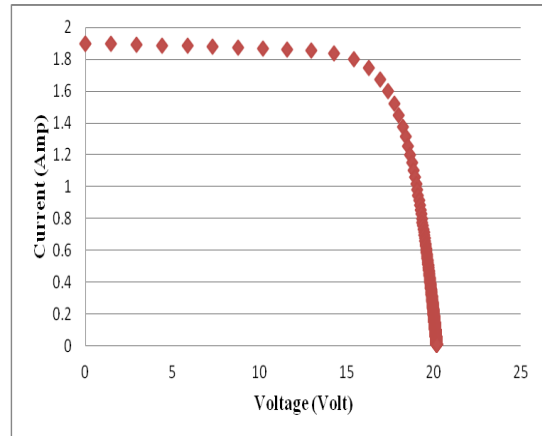Figure 9. I-V Characteristic at 25^0 C
Temperature and 1000W/m^2 Irradiance

Figure 10. I-V Characteristic at 25^0 C
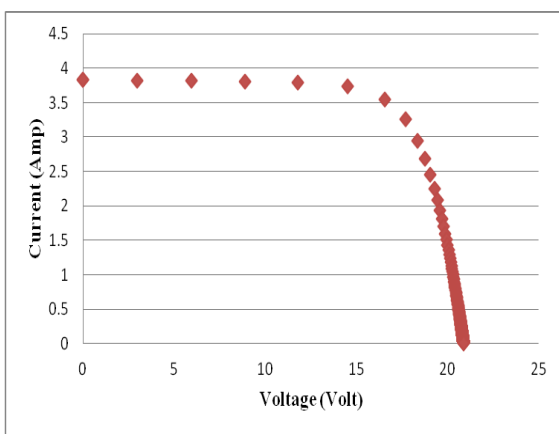Temperature and 500W/m^2 Irradiance

Figure 11. I-V Characteristic at 40^0 C
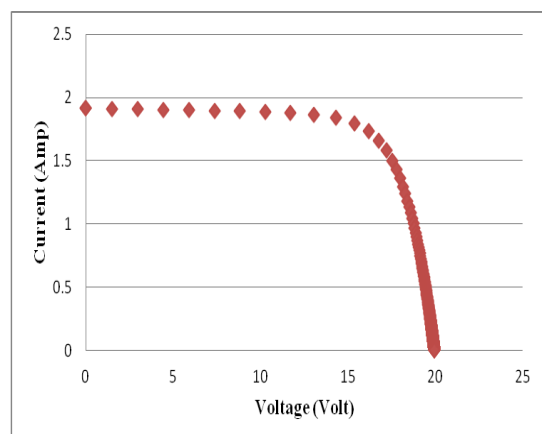Temperature and 1000W/M^2 Irradiance

Figure 12. I-V Characteristic at 40^0 C
Temperature and 500W/M^2 Irradiance

From Figure 6 to 8 it is clear that if the irradiance decreases at a fixed temperature, power from the PV panel decreases and From Figure 9 to 12 it has been observed that the photovoltaic current generated decreases proportionally with the decreasing irradiance. The different variations can be clearly observed from the graphs under varied temperature conditions and different irradiance.The simplicity of the model makes it's implementation easy and efficient.

5. Conclusion

In consideration with the present on-going demand for power as well as keeping the environmental safety concerns in mind solar energy stands out as one of the most viable option. Hence solar photovoltaic system is considered as a primary resourceThe primary aim of this paper is to simulated a pv cell and recording the variation of current and power with voltage establish the P-V and I-V curves at varied temperature conditions I-V and P-V characteristic curves of PV panel with different environmental parameters of temperature and irradiance also be observed here. Simscape based models have its intrinsic advantages that researcher has several in built tools to further develop the model.

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