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Modelling and Simulation of Photo voltaic System Using Matlab/ Simulink

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Abstract. In regulate to optimize the effectiveness of the solar cell well established and more efficient models are required to develop. In this paper mathematical modelling of solar cell and an algorithm called Maximum Power Point Tracking (MPPT) has been studied. Matlab has been used for the simulation of mathematical modelling. I – V characteristics of the solar cell and MPPT algorithm is studied. The single diode model is used for mathematical modelling of the photovoltaic system. The required parameter for the system is taken from the datasheet of industrialized company. The solar cell highly dependent on the weather condition therefore I – V characteristics studied with the change in temperature and irradiation of the modelled system.

1. Introduction

The increasing energy requirement, high cost and limited amount of fossil fuels worldwide are the main concern for all researchers to save energy and reduce its losses. Therefore, our research is mostly focused to increase the utilization of renewable power sources [1]. Solar energy is comprehensively used in conservative energy sources. Moreover, the solar photovoltaic cell helps to achieve adaption of solar energy into electrical energy [2], which usually converts 3 to 35% of incident irradiation. The solar cell is basically a thin layer P-N connection of semiconducting material, the efficiency of which depends on the incident radiation, material used, temperature and the modeling [3].

1.1 Modeling of Solar Photovoltaic System

A solar photovoltaic is an essential element of the solar cell system. The equivalent single diode model under incident radiation is sufficient to be used for many applications such as voltage, current generation, and power that vary with changes in parameters such as temperature, radiation, and number of cells [4]. A simple system of PV cell circuit model is given in Figure 1, which incorporates a single diode, a source of current, a resister in series and a shunt resistor.

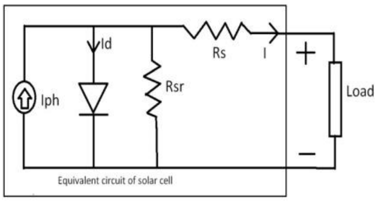


Figure 1. Reference circuit model for modeling of Photovoltaic system.

In Figure.1, I_{ph} is the current source representing the photocurrent. Here I_d denotes the diode current, R_{sr} denotes intrinsic shunt resistor and R_s denotes a series resistor. Usually, the shunt resistor represents the internal resistance and R_s is used for a smooth output I-V curve. The numerical value of R_{sr} is very large in comparison to R_s; therefore R_s can be neglected for the simple analysis [5]. On the basis of the above Fig. 1, Kirchhoff's law is responsible for the I-V characteristics.

1.2 Parameter of the model

a) Equation of Photocurrent

$$I_{ph} = [I_{scc} + k_{isc}(T_{rf} - 298)]I_{rr} / 1000 \tag{1}$$

b) Equation of Saturation Current

$$I_o = (T_{rf} / T_n)^3 \exp[qc.Ege(I / T_n - 1/T_{rf}) / h.k_{bt}] \tag{2}$$

c) Reveres Saturation Current Equation

$$I_{rs} = I_{scc} / \exp(qc.V_{oc} / N_{id}.N_{cs}.K_{bt}.T_{rf}) - 1 \tag{3}$$

d) Equation of Current Passing through Shunt Resistor

$$I_{sr} = (V + I.R_s) / R_{sr} \tag{4}$$

e) Output current Equation

$$I = I_{ph} - I_o[\exp\{qc(V + I.R_s) / N_{id}.K_{bt}.N_{cs}.T_{rf}\} - 1] - Ish \tag{5}$$

f) Thermal voltage equation

$$V_{th} = K_{bt}.T_{rf} / qc \tag{6}$$

g) Output Power

$$P_{out} = V.I \tag{7}$$

Where, I_{ph} = Photo current as function of incident radiation and junction temperature, I_{scc} = Short circuit current, K_{isc} = Short circuit current at room temperature, T_{rf}=Reference Operating Temperature (27C), T_n=nominal temperature (300) K, I_{rr}= Incident Solar irradiation (W/m^2), qc=Charge on electron(C)= 1.6*10^-19, N_{id}= The ideality Factor of diode (1.3), K_{bt} = Boltzmann constant (1.38*10^-23 J/K), E_{ge}= Band gape energy of semiconductor (eV) =1.1, N_{cs}=No. of cell connected in series, N_{cp}= Number of cell connected in parallel, R_s= Series resistance (ohm), R_{sr}= Shunt resistor (ohm) and V_{th} =Thermal voltage (V).

2. MPPT (Maximum power point tracking) Algorithm

We know that solar photovoltaic cell is operated at a meticulous point of current and voltage is called the operating point of solar cell which corresponds to unique I-V value. We know that power is a multiplication of voltage and current, the I-V curve and P-V curve as exposed in figure (a), the distinctive P-V curve is communicated by the operating position of I-V curves. To make sure the solar cell is operated at the highest power point, the solar cell is enforced to apply upto the highest power point or peak value of voltage and current without any electrical manipulation. After forcing the scheme to operate at the highest power point if there is any alteration in the ambient condition of temperature and irradiation, then the highest power point is no longer convincing under these situations. Therefore we required tracing every change observed in I-V curve and determining the maximal power point in order to operate constantly at highest power point through time, this process is named as maximum power point tracking (MPPT) [3-7].

There are many MPPT techniques. And all of them have their individual advantages and disadvantages. The MPPT is basically used of two types one direct and another is indirect. In this paper, the direct tracking method is discussed, which have both current and voltages variable.

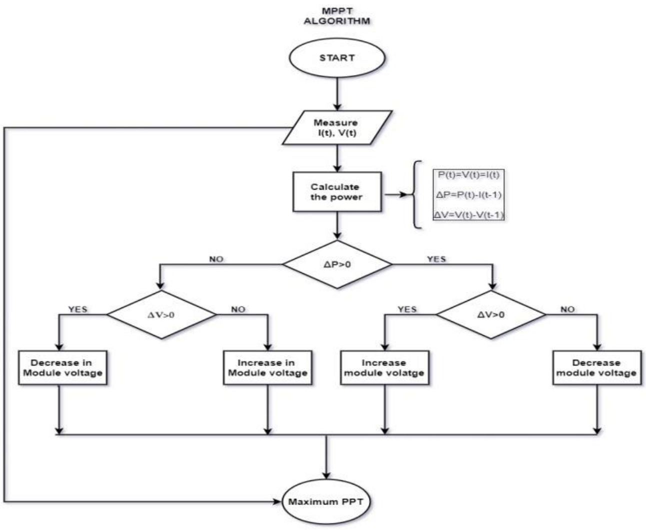


Figure 2. Flowchart for a sequential approach to applying the MPPT algorithm.

2.1. Model of Simulation

The model SW-200-P is taken as reference for simulation, and modeling is done on basis of mathematical equations of different parameter of solar cell shown by equations 1 to 6. The model's reference parameters are specified in Table 1.

Table 1. Values of parameters used in the reference model

Parameters	Values
Highest Power, P_{max}	200W
Voltage at P_{max}, V_{mp}	29.5V
Current at P_{max}, I_{mpp}	6.78A
Voltage at open circuit, V_{oc}	36V
Short Circuit Current, Is	7.06A
Number of Cell, N_{cs}	60

Step 1. Simulink Model for Photocurrent**:** The model shown in figure 3 is a subsystem of the solar photovoltaic system which is modeled using the mathematical equation for photocurrent shown in equation (1). This simulink model of photocurrent shows the linear behavior with incident solar irradiation and also possess by the operating temperature. This subsystem of photo voltaic system also affected by the input parameter like saturation current, operated temperature, short circuit current at room temperature [14].

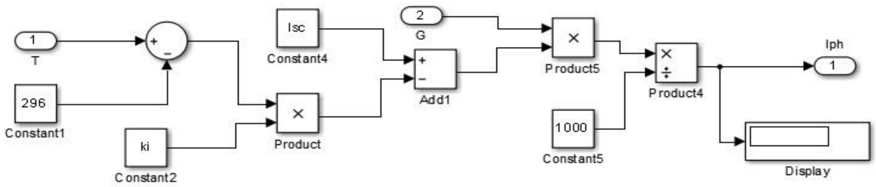


Figure3. Photocurrent model for simulation.

Step 2. Simulink Model for Reverse Saturation Current: The model shown in figure 4 is modeled using the mathematical equation of reverse saturation current shown by equation 3. The modeling parameter for this subsystem is used from the data sheet of reference model [11, 13].

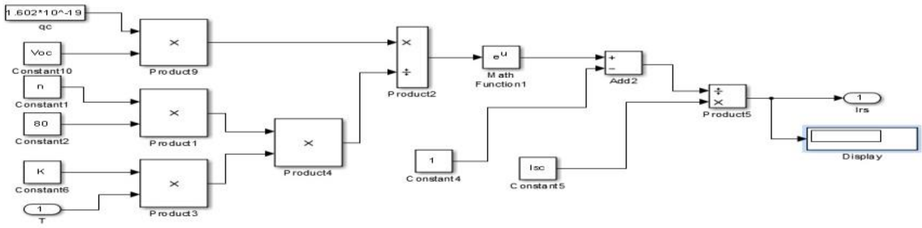


Figure 4. Reverse saturation current model simulation.

Step 3. Simulink Model for Saturation Current: The figure 5 is a subsystem of photo voltaic system. This simulation model is modeled using the mathematical equation for saturation current shown by equation 2. This model used band gap, reference temperature and charge on electron etc [12, 15].

Step 4. Simulink Model for Shunt Current: The Figure 6 is the sub system of the photovoltaic module. This simulink model is modeled using the mathematical equation for shunt current shown by equation 4. This model used output current and voltage as input parameter.

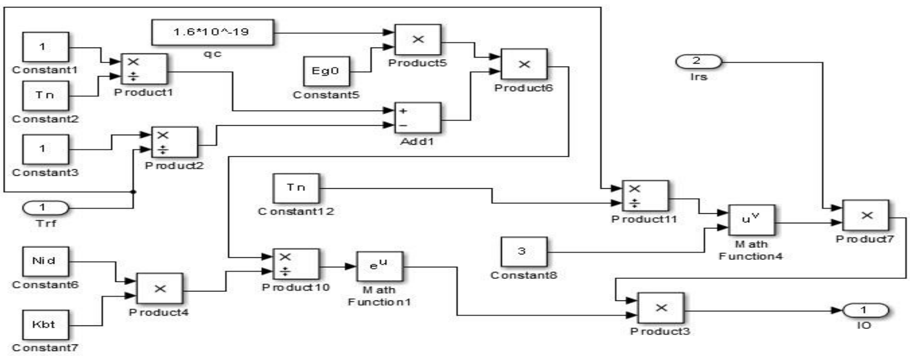


Figure 5. Saturation current model for simulation.

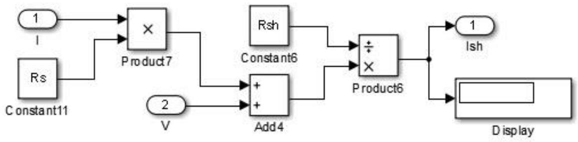


Figure 6. Shunt Current model for simulation**.**

Step 5. Complete Photovoltaic System: The figure 7 shows complete photovoltaic module which is addition of simulation models of Photocurrent, Reverse Saturation Current, Shunt Current and Saturation Current. This complete system is takes incident irradiation and input temperature as input parameter and gives out voltage and current as output.

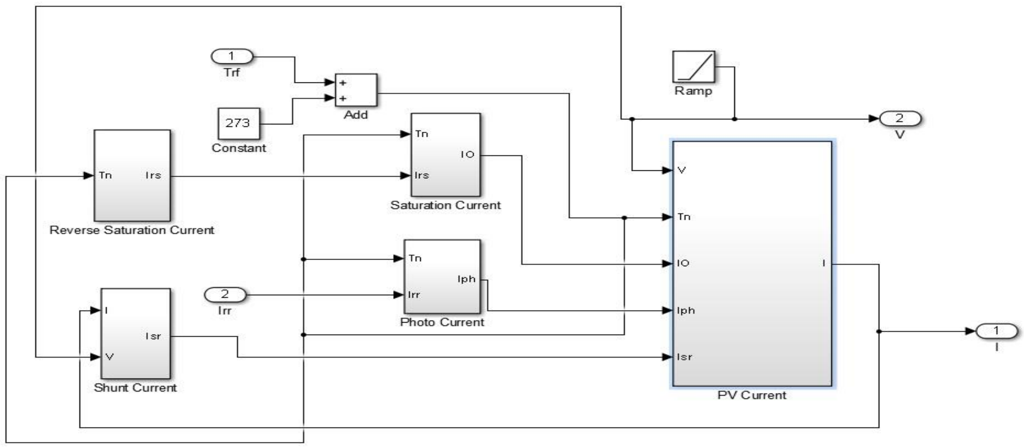


Figure 7. Complete Simulation model for Photovoltaic system.

3.6 Simulink model for MPPT algorithm:

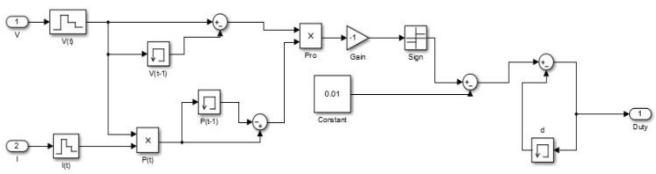
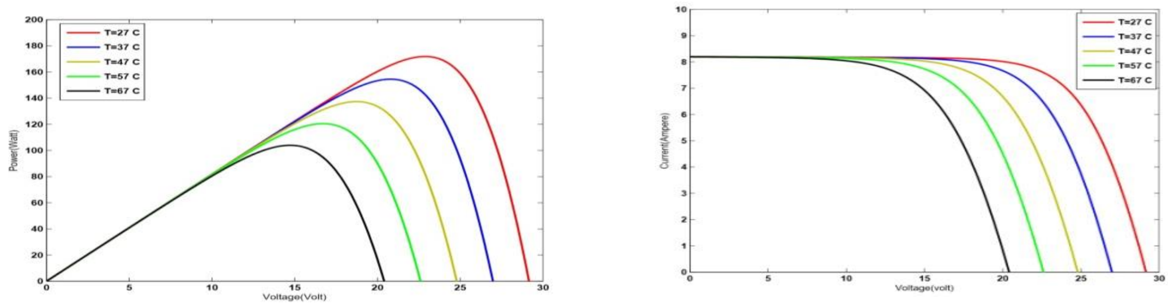


Figure8. Simulink Model for MPPT Algorithm.

4. Simulation Result

4.1 At constant radiation and variable Temperature

The I-V and P-V characteristics are studied at different temperature and as for output incident irradiation is fixed at 1000W/m^2 and the temperature is fixed at 27, 37, 47, 57, 67C. Figure (5) shows the P-V and I-V characteristics of the modeled photovoltaic system. This is clear from Figure (5), on an increase in the temperature, there is a fall in output voltage and current which leads to a drop in power of the photovoltaic system.

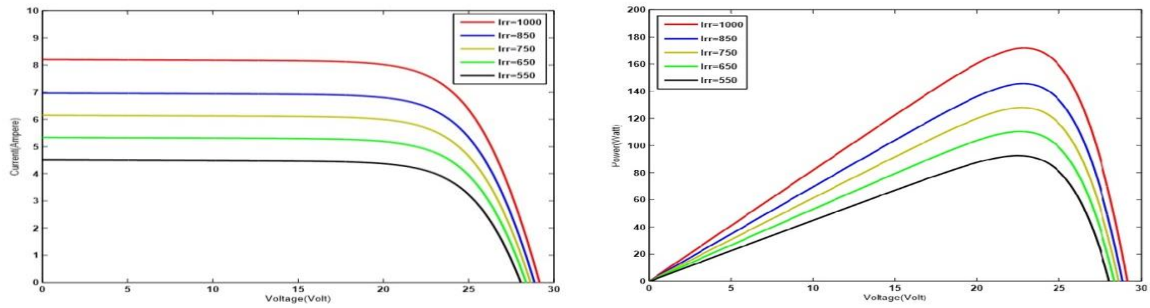


(a) (b)

Figure 9. (a) P-V and (b) I-V characterstics of photovoltaic voltaic system at different temperature.

4.2 At constant temperature and variable irradiation

The I-V and P-V characteristics are studied with varying in incident irradiation and for output, the temperature is fixed at 27C and the incident irradiation is fixed at 1000, 850, 750, 650, 550W/m^2. Figure. (6), demonstrates the I-V and P-V characteristics of the modeled photovoltaic system. This is clear from Fig. (6), as a decrease in the incident irradiation, there is a drop in output voltage and current which leads to drop the output power of the photovoltaic system [11].

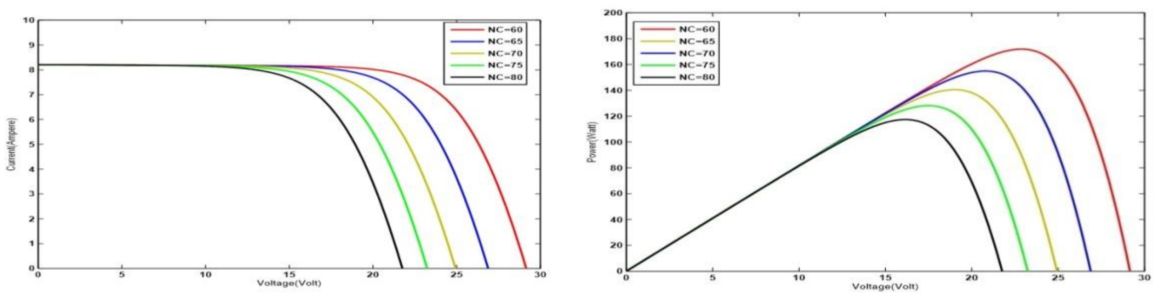


(a) (b)

Figure 10. (a) Variation in I-V characteristics at changed incident irradiation and (b) Variation in P-V characteristics at changed incident irradiation.

4.3 On varying number of cells of the photovoltaic system

The I-V and P-V characteristics are studied with change in the number of cells used to modeling the photovoltaic system at room temperature 27C and incident irradiation 1000 W/m^2. This is clear from Fig. (7), on increasing the number of cells the output voltage and current are going to decrease rapidly which leads to a decrease in the power of the photo voltaic system [11].



(a) (b)

Figure 11. (a) Variation in I-V characteristics at the variant number of cell and (b) Variation in P-V characteristics at variant number of cells.

5. Conclusion

Using Matlab a sequential approach has done in the modelling of solar photovoltaic system. The modelling procedure makes a clear understanding of the I-V and P-V characteristics of any photovoltaic system. This is clear from the I-V and P-V characteristics of the photovoltaic system; as temperature varies, incident irradiation and the number of cells used in modelled system, there is also variation in output voltage and output current of model which results to change in output power [8-11].

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