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Modeling and Simulation of Solar Photovoltaic (PV) Cells to Estimate Energy Production based on Local Solar Resources and Weather Data

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ABSTRACT

In today's era, energy from solar plays a vital role to fulfill the power shortage of any country. The solar photovoltaic system converts solar energy into electrical energy, which highly depends on environmental factors like irradiance and temperature. This paper analyzes the simulation model of a PV cell for estimation of total energy production based on the local solar resources and weather data at BBSBEC, Fatehgarh Sahib, Punjab, India. For this, PV modeling and simulation results are carried out in MATLAB/Simulink.

Keywords: PV Cell, Modeling, Irradiance, Temperature.

1. INTRODUCTION

The use of renewable energy resources like solar energy and wind energy is increasing rapidly for electricity generation purpose. Renewable energy with the largest power generation capacity installed is wind power; however, solar energy is growing at a faster rate than any other form of renewable energy. Photovoltaic (PV) power generation is a reliable and economical source of electricity in rural areas. But the solar energy always varies instantaneously and the current and power of PV array varies non-linearly with the terminal voltage, solar radiation, and temperature [1]–[4].
As solar photovoltaic cells have significant nonlinear output characteristic, the photoelectric conversion efficiency is still very low. Therefore, so far the research of output characteristics of photovoltaic cells is an important topic in the industry[4]–[7]. This paper proposes a mathematical model of PV array based on the principle of photovoltaic cells and establish the simulation model in Simulink. The output characteristic curve of the photovoltaic cells is obtained with different solar radiation and temperature data of Fatehgarh Sahib, Punjab, India. The meteorological data is obtained from [8].

2. MODELLING OF PV CELL

Solar panels are active solar devices that convert sunlight into electricity. Solar panels are made up of solar cell which is a device that converts sunlight into direct current (DC) electricity. The circuit diagram of a solar cell is given below:

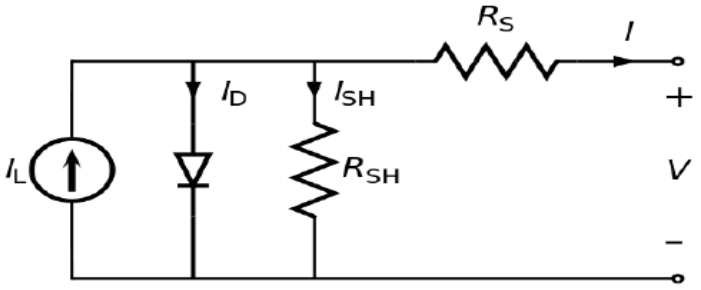

Figure 1. Equivalent circuit solar cell

The above model can be mathematically expressed as:

$$I = I_L - I_0 \left\{ \exp \frac{[q(V + IR_S)]}{n * K * T} - 1 \right\} - \frac{V + IR_X}{R_{SH}} \quad (1)$$

Where

I:	output current (A)
V:	Voltage Across the output terminal (V)
RS:	series resistance (Ω)
n:	diode ideality factor
q:	electronic charge (1.6×10-19 C)
K:	Boltzmann's constant (1.38×10- 23 JPK)
T:	Absolute Temperature (K)
RSH:	Shunt resistance (Ω)

The steps involved in MATLAB/Simulink modeling of PV module are as follow:

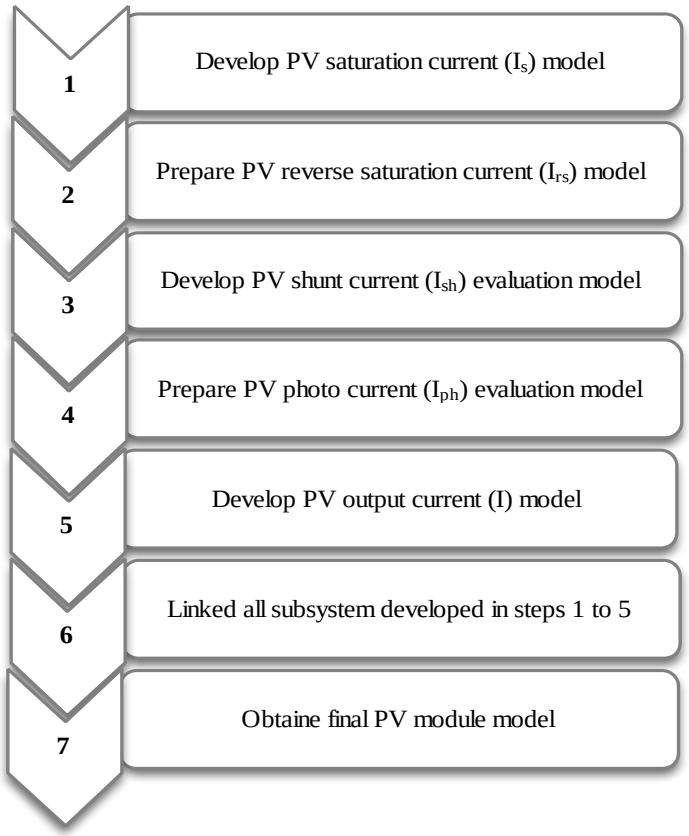

Figure 2. Flowchart for step involve in modeling of PV module in MATLAB/Simulink

Simulation of PV cell has performed in MATLAB Simulink and MATLAB M-file software system, as shown in figure 3. Parameters of physical solar blocks are defined by short circuit current and open circuit voltage pre-set values. The parameters and their input values are mentioned in the table given below:

Table 1: Electrical parameters of solar PV module

S. No.	Parameters	Value
1	Rated Power (Pmp)	200 W
2	Voltage at maximum power (Vmp)	26.4 V
3	Current at maximum power (Imp)	7.58 A
4	Open circuit voltage (Voc)	32.9 V
5	Short circuit current (Isc)	8.21
6	Total no. of cells in series (Ns)	54
7	Total no. of cells in parallel (Np)	1
8	Ideality factor of diode (n)	1.3
9	Temperature coefficient of Isc	0.0032
10	Series resistance (Rs)	0.221 Ω
11	Shunt resistance (Rsh)	415.405 Ω

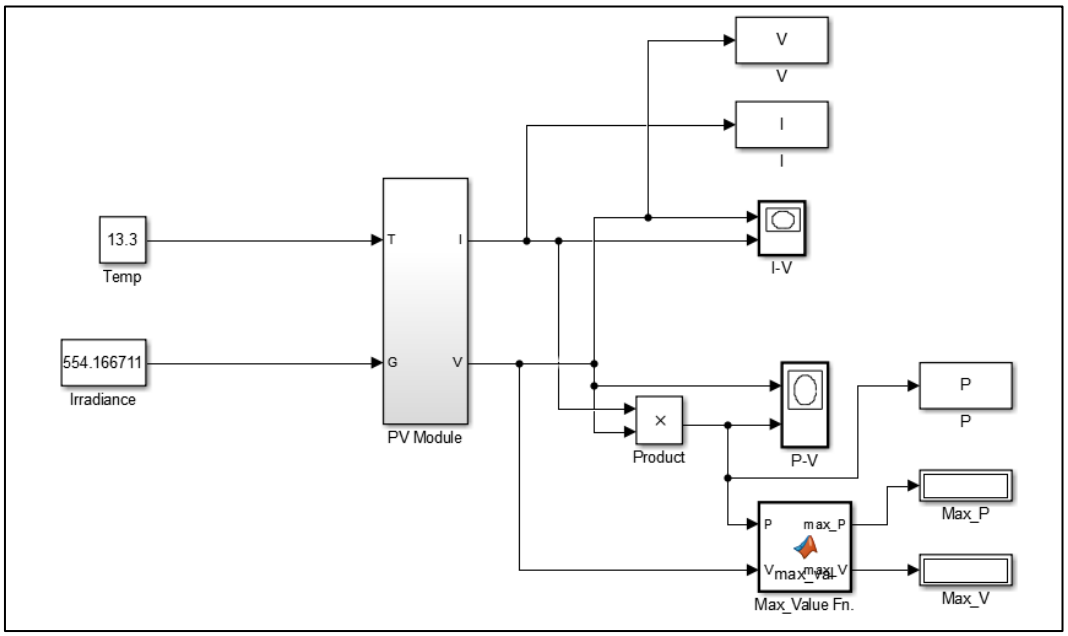

Figure 3. Final PV module model in MATLAB/Simulink interface

3. SIMULATION RESULTS AND DISCUSSION

Solar PV module model is developed under Matlab/Simulink environment by using the previously discussed mathematical equations of solar cells. The final Solar PV model as depicted in figure 3 are simulated and obtained output results as current, voltage and power, due to the variation of radiation and temperature as input parameters. The metrological data for BBSBEC, Fatehgarh Sahib, Punjab, India site has been obtained from [8]. Demographic details are as follow:

Table1: Demographic position of BBSBEC, Fatehgarh Sahib, Punjab, India [9]

Site Name:	BBSBEC, Fatehgarh Sahib
District:	Fatehgarh Sahib
State:	Punjab
Latitude:	30.6435° N
Longitude:	76.3970° E
Elevation:	246 m amsl.

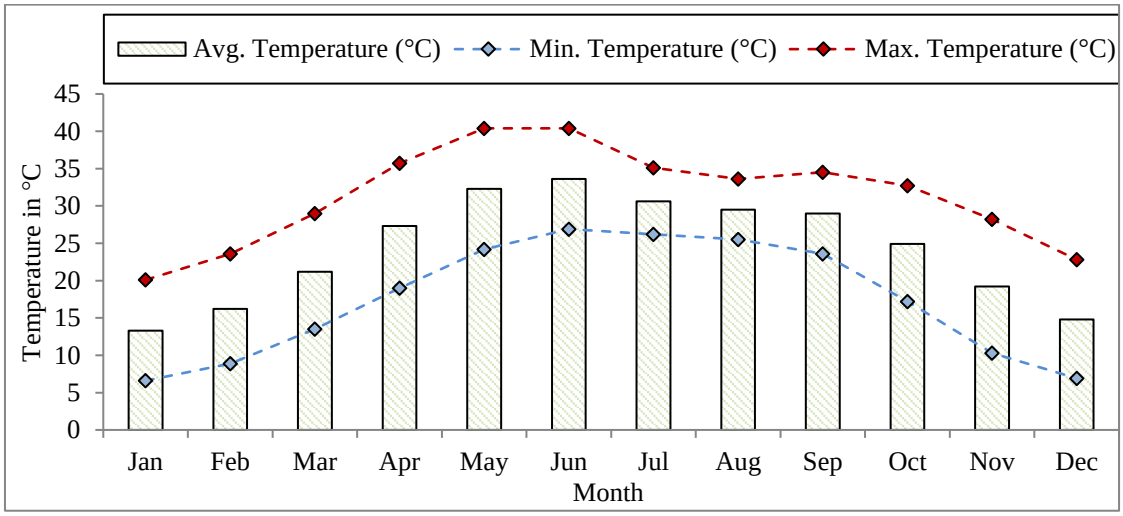

Figure 4. Month wise temperature data at Fatehgarh Sahib, Punjab

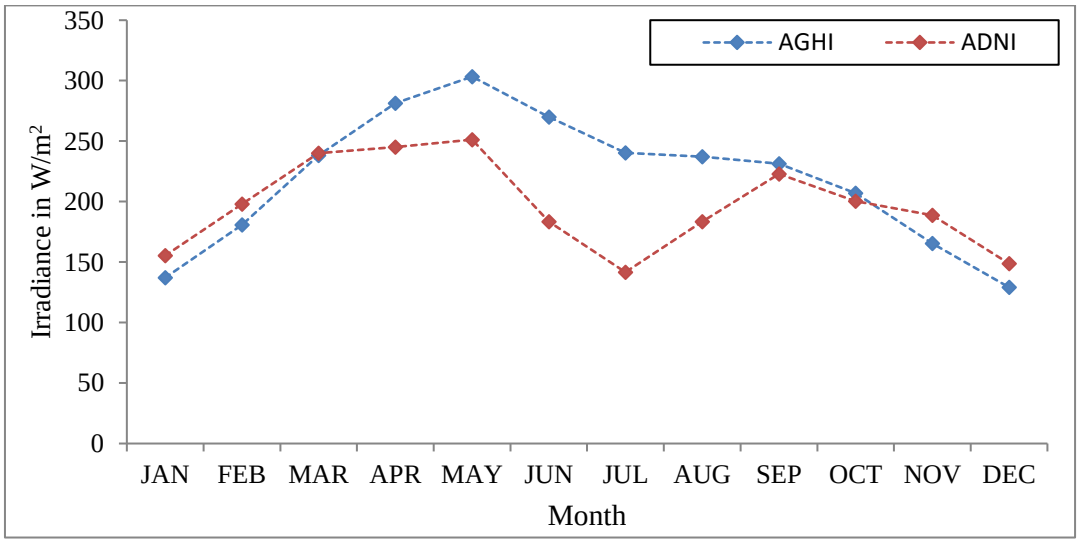

Figure 5. Month wise average irradiance data at Fatehgarh Sahib, Punjab

The performance of solar PV module has been determined in Matlab/Simulink by using the monthly average values of irradiance and temperature for the demographic location. A month wise temperature data (i.e. average temperature, minimum and maximum temperature) has been shown in figure 4. In Figure 5, average global horizontal irradiance (AGHI) and average direct normal irradiance data has been depicted.

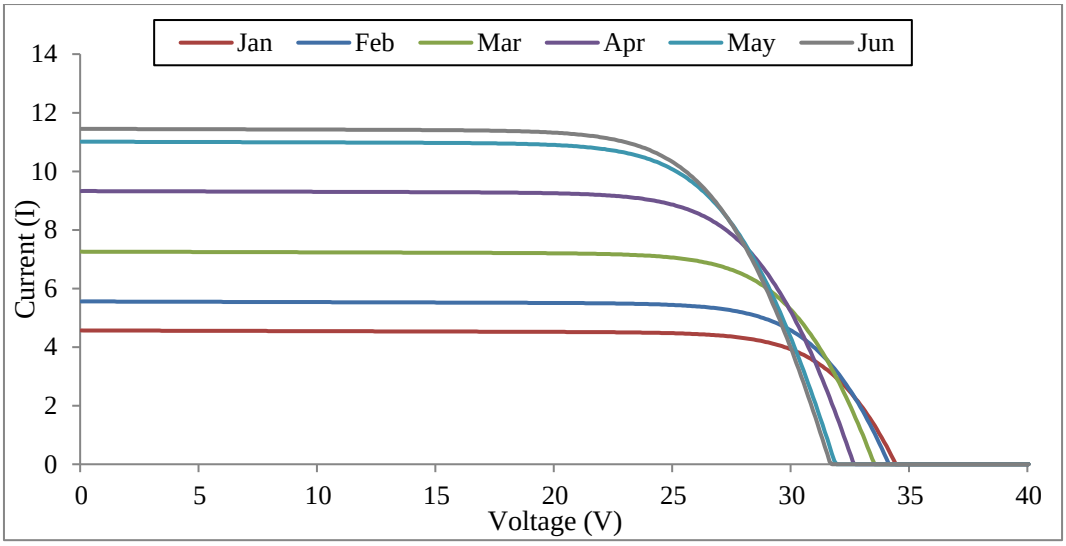

Figure 6. Current-Voltage graph for the month of Jan to Jun

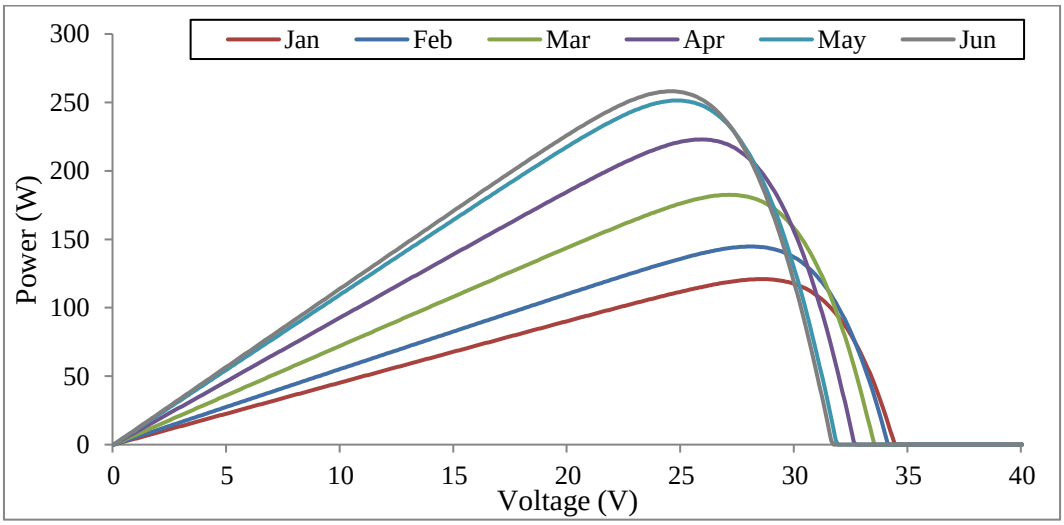

Figure 7. P-V graph for the month of Jan to Jun

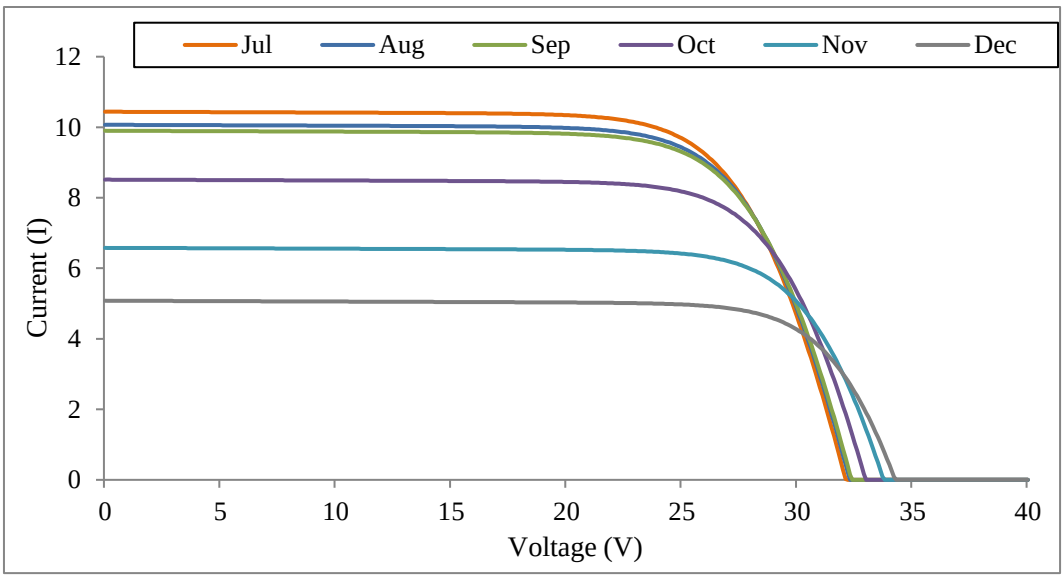

Figure 8. Current-Voltage graph for the month of Jul to Dec

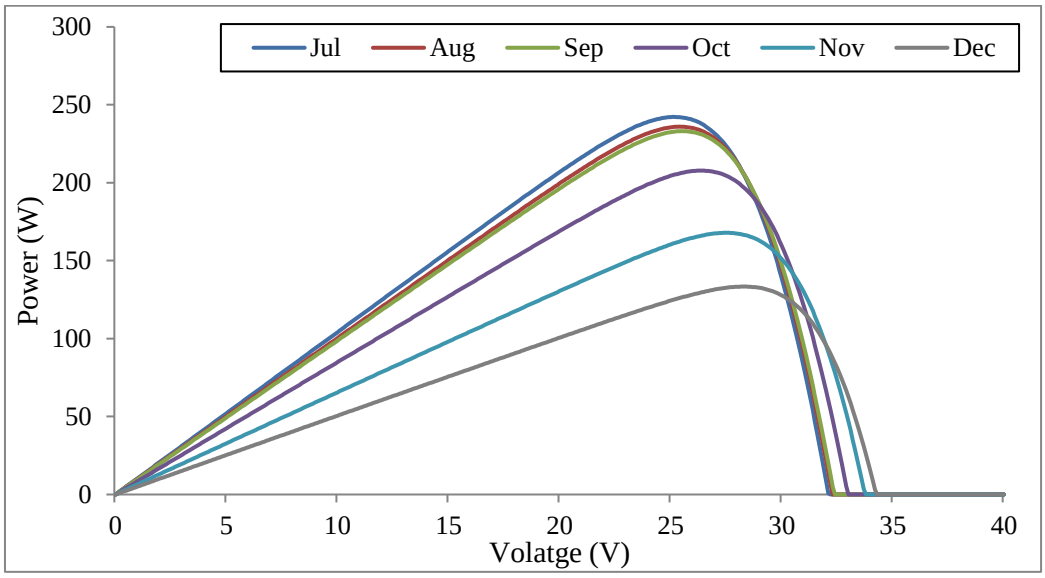

Figure 9. P-V graph for the month of Jul to Dec

The I-V and P-V graphs of a year (moth wise) are illustrated in figures 6-9. It can be observed that, as irradiance increases the output current of PV module increases. The output power is more in summer months (Apr to Jun) as compare to winter months (Dec to Feb). Maximum power that can be obtained in particular month is portrayed in figure 10; also present the corresponding voltage level. It can be noted that, the maximum power can be extracted from PV module at ambient temperature ranges 24.3ºC to 28.5ºC, refer figure 10. The data obtained from simulation can be used for estimation of energy produced from solar PV module.

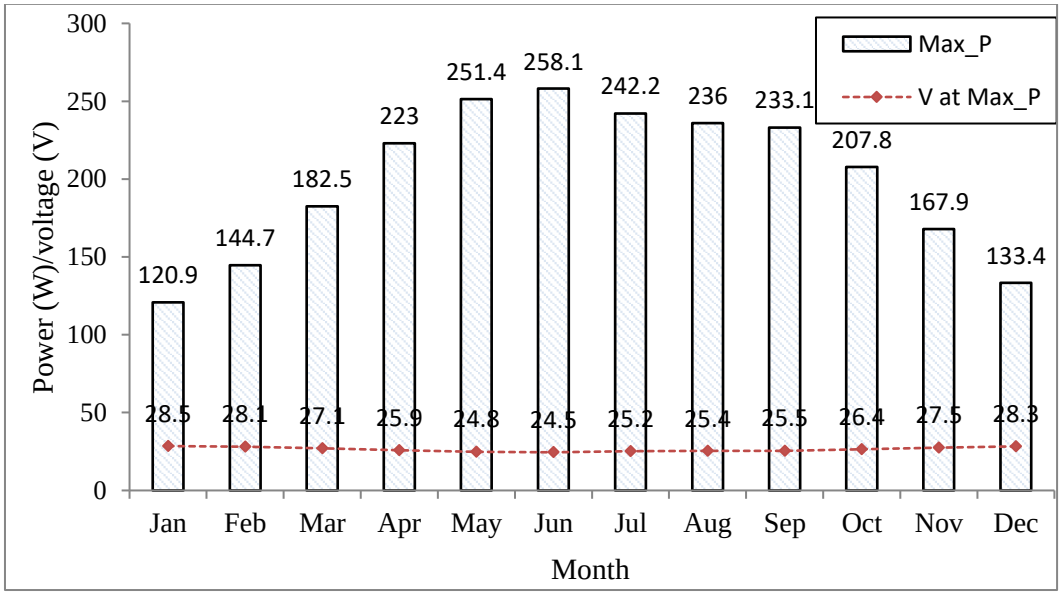

Figure 10. Month wise maximum power obtained from a PV array and its corresponding voltage (Fatehgarh Sahib, Punjab)

4. CONCLUSION

Output characteristic of photovoltaic cells is not only related to its parameters but also associated with the environmental factors like irradiation and temperature. Based on the mathematical model of PV, the simulation model has been established using the Matlab/Simulink. The simulation results presented the output characteristic for different irradiation and temperature for metrological data of BBSBEC, Fatehgarh Sahib, Punjab, India. It can be concluded that the temperature changes mainly affect the PV output voltage, while the irradiation changes mainly affect the PV output current.

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