MODELING AND SIMULATION OF PHOTOVOLTAIC SYSTEM

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ABSTRACT

As the photovoltaic module exhibits non linear V-I characteristics, which are dependent on solar insulation and environment factors, the development of an accurate power electronic circuit oriented model is essential to simulate studies on the photovoltaic integrated system. A circuit based model of photovoltaic array (PV) suitable for simulation studies of solar [power system is proposed in this paper. The model is realized using power system block set under MATLAB/SIMULINKdetailed modeling procedure for the circuit model with numerical values is presented. The proposed model was found to bebetter and accurate for any irradiance and temperature variations. The proposed model is very use full for PV engineers and expert who requires a simple, fast and accurate PV simulator to design their systems.

Keywords — Photovoltaic Model (PV), MATLAB/SIMULINK, Solar Cell Model, Solar Array Model

I. INTRODUCTION

The field of photovoltaic (PV) has experienced aremarkable growth for past two decades in its wide spread usefor stand alone to utility interactive PV system. Photo voltaiccells convert sun light directly to electricity. They arebasically made up of a PN junction. Figure1 shows the photocurrent generation principle of PV cells. The best way toutilize the electric energy produced by the PV array is todeliver it to the AC mains directly, without using battery banks [1]. A recent study in Germany, of 21PV systems inoperation for 10 years, revealed that inverters contributed for63% of failures, modules 15% and other components 23%, with a failure occurring, on an average, every 4.5 years. [2]At present, the performance analysis of newlydeveloped PV system uses mathematical function models. These developed systems could not be readily adopted by thefield professionals and hence the above difficulty raises hencethe need for simplified Simulink modeling of PV module hasbeen long felt. Simple circuit- based PV models have beenproposed in literature [3]-[8]. Although interesting, suchmethods are impractical, complicated and require highcomputational effort. In all the above, modeling was limited tosimulation of PV module characteristics.

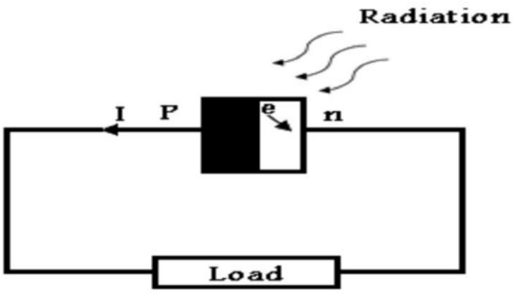


Figure.1. Photocurrent generation principle

In this paper, the design of PV system using simplecircuit model with detailed circuit modeling of PV module ispresented. In section II, equivalent circuit of the PV module & simulink model for each section is presented. In section III, complete circuit oriented model is presented and in section V different simulink model output graphs are presented.

II. MODELING OF THE PV CELL

The PV cell can be represented by the equivalent electriccircuit shown in Figure 2.

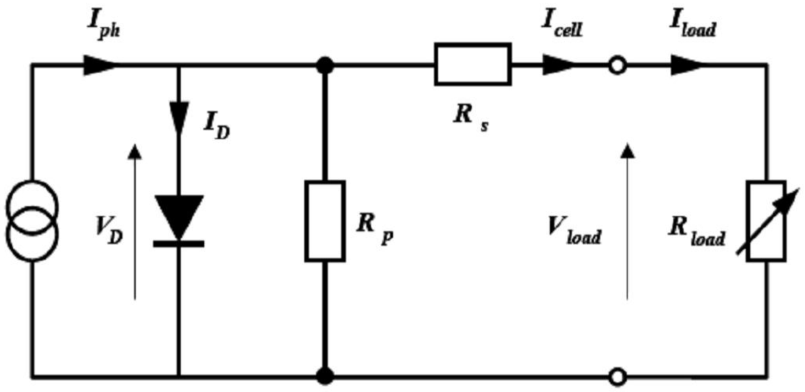


Figure 2: Equivalent electrical circuit of a PV cell connectedto a load.

This circuit consists of a diode which represents the PNjunction of the cell and constant current source whosecurrent amplitude depends on the intensity of the radiation.

The parallel resistor Rp characterizes the leakage current onthe surface of the cell due to the non-ideality of the PN junction an impurities near the junction. The series resistor Rs represents the various contact resistances and theresistance of the semi conductor. Current and voltages are:

Table 1: Electrical characteristics data of SOLKAR PV module:

Description Rating

Rated power	37.08 W
Voltage at maximum power(Vmp)	16.56V
Current at maximum power (Imp)	2.25A
Open circuit voltage (VOC)	21.64V
Short circuit current(ISC)	2.55A
Total number of cells in series (Ns)	36
Total number of cells in parallel(Np)	1

Characteristics of Solar Cell:

Solar cells naturally exhibit a non linear I-V and P-Vcharacteristics which vary with solar irradiation and celltemperature. The fundamental parameters related to solar cellare short circuit current (Isc), open circuit voltage (Voc) andmaximum power point (MPP). The typical I-V and P-Vcharacteristics of solar cell are shown in figure 3.

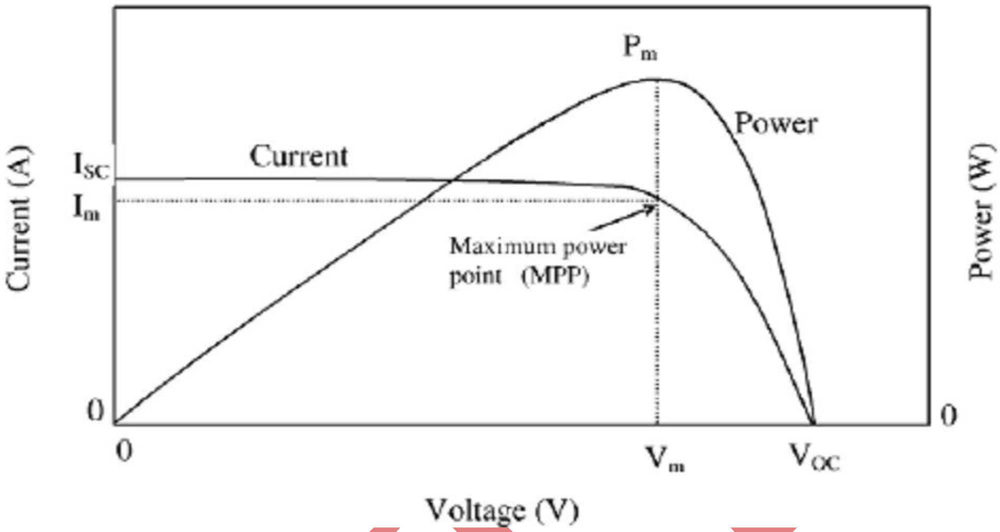


Figure 3: Characteristics of solar cell

Iph : photo current. Ip : current through the diode.
Icell: current delivered by the cell. Vcell: voltage across the cell.

Equation of *PV Model:*

With such an equivalent electrical circuit, one can obtainthe following mathematical model of a PV cell.

$I = Iph – IS[(\exp(Vcell + IcellRS)/Vth) − 1] − (Vcell + IcellRS)/Rp$ --(1)

Where Vth= AKTc/q is the thermal voltage

q: elementary electric charge (1.6.1-10 As)

K: Boltzmans constant (1.38.1023 JK)

T: absolute temperature of the cell (○K)

Is : saturation current of the unlighted junction(A)

A: ideality factor of the junction.

PV module modeling

Photo Current:

The module photo current Iph of the photovoltaicmodule depends linearly on the irradiation and is alsoinfluenced by the temperature according to the followingequation.

$Iph = (ISC + KI(TC − TRef))*G$ – (2)

Where the Isc is the cell short circuit current at 25○Cand 1KW/m2, KI is the cell’s short-circuit current temperaturecoefficient. Tref is the cells reference temperature. and G is thesolar insolation in 1000W/m2. Detailed Simulink model ofequation (2) of photo current Iph is shown in Figure 4.

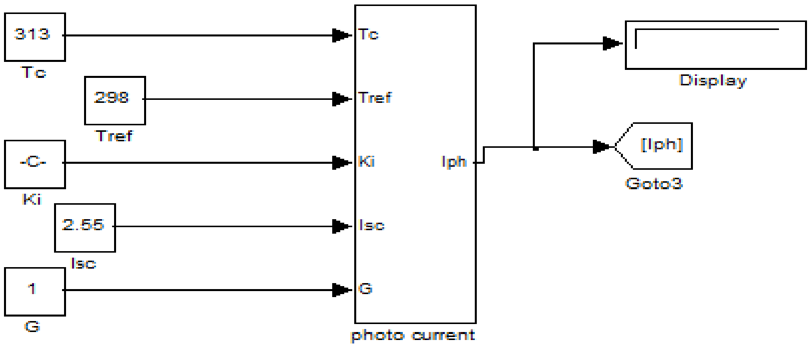


Figure 4: Module Photo current

III. MATLAB/SIMULINK MODEL

The figures 4 are inter connected to get Ipvsimulinkmodel of PV module. This Ipvsimulink model is simulatedwith the step up shown in the Figure-5. Ipvsimulink modeltakes insolation, temperature and Vpv as inputs to calculate Ipv.The Vpv is varied from 0-21.7V. The compact form is shown in figure 5.

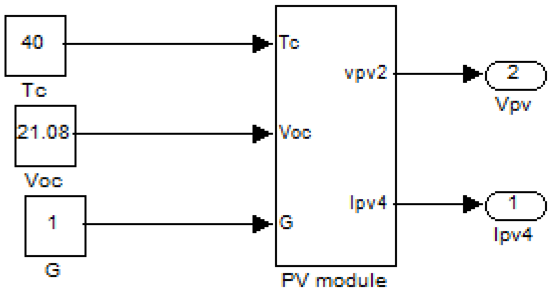


Figure 5: Simulink model

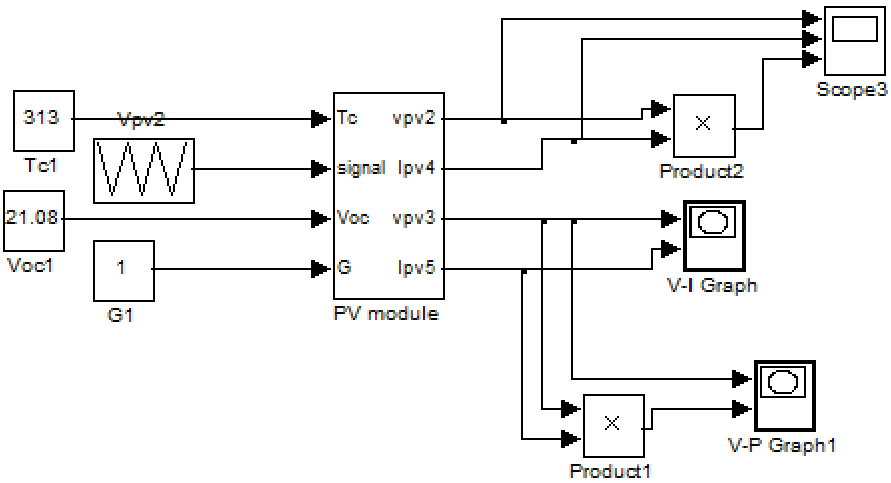
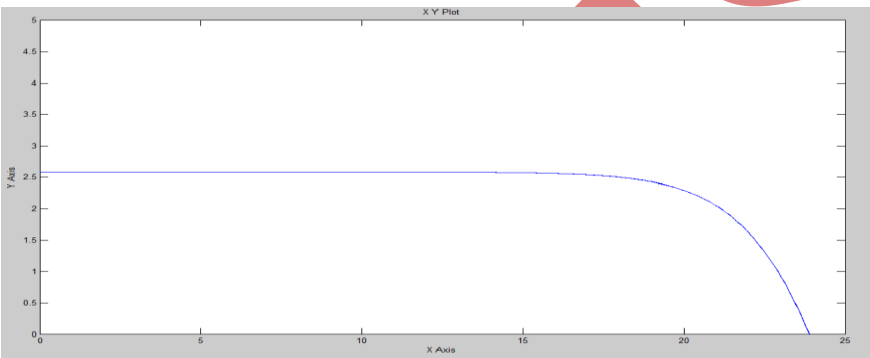


Figure 6: I-V and P-V characteristics setup of PVmodule

The above figures 5 shows the general simulinkmodel of PV array and figure 6 shows the simulink model toobtain I-V and P-V characteristics setup of the PV module andrelated graphs are shown below.

IV. THE SIMULATION RESULTS

The model of the PV module was implemented usinga MATLAB/SIMULINK model. The model parameters areevaluated during execution using the equations listed in theprevious section. The PV module chosen for this simulation isSOLKAR [11], which provides 37W nominal Max power andhas 36 series connected cells. The parameter specification ofthe module is as shown in table-1. The model was built fromstarting stage to the final stage shown in figure 4-6.Thesubsystem contains all the mathematical equations of eachmodel. Figure 7&8 shows the I-V & P-V outputcharacteristics of PV module and I-V & P-V outputcharacteristics of PV module at different temperatures areshown in figure .The voltage, current and power ofthe PV array is shown in the figure. It shows that theoptimum operating point changes with the solar insolation, temperature and load conditions. The voltage input Vin for Ipv SIMULINK model is fed back from the voltage output of themodel. A small resistance of 0.221Ω is added in series to thecircuit to aid the charging of capacitor.



Voltage

Figure 7: I-V curve

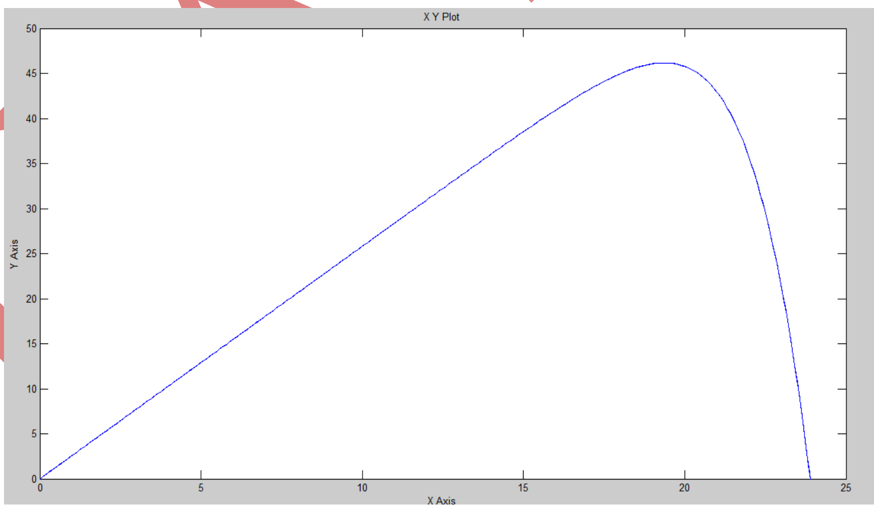


Figure 8: P-V curve

The figure 9 shows the PV module for differenttemperatures at 25, 35,45,55,65 and 750c.The related graphsare shown in figures 10 and 11. From figure 10 it isunderstood that as the temperature increases the maximumpower generation slightly decreases. Similarly in figure 11 it isobserved that as the temperature increases the PV moduleoutput voltage slightly drops.

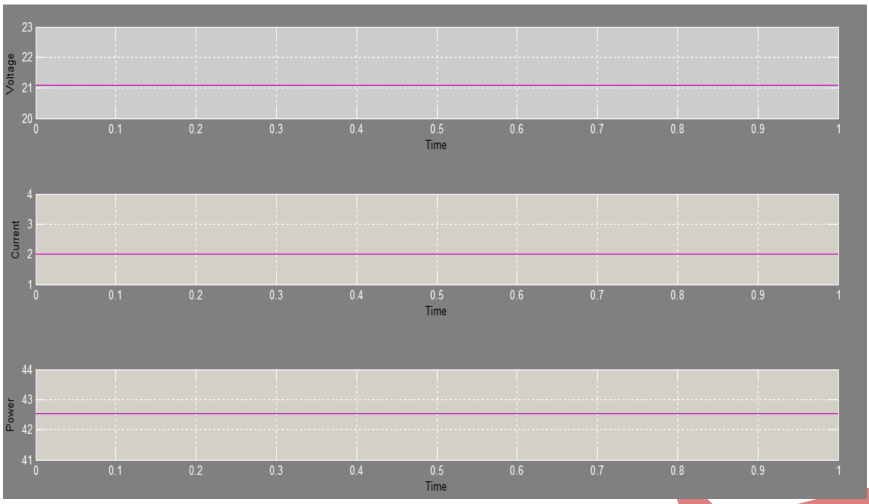


Figure 9: Voltage, Current, Power curves

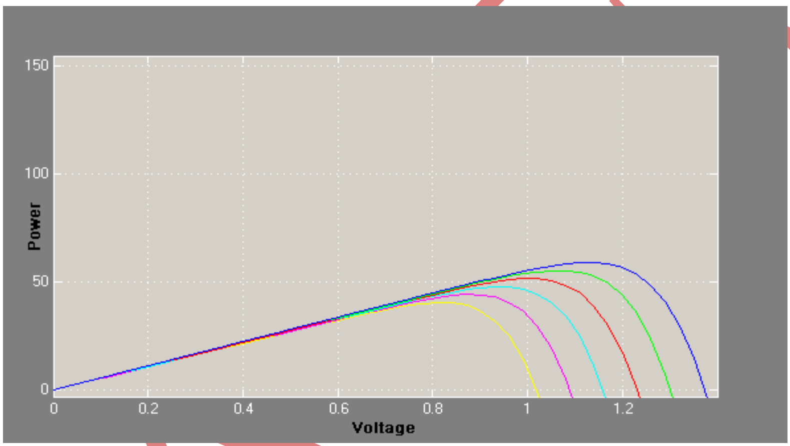


Figure 10: P-V curves of different temperature

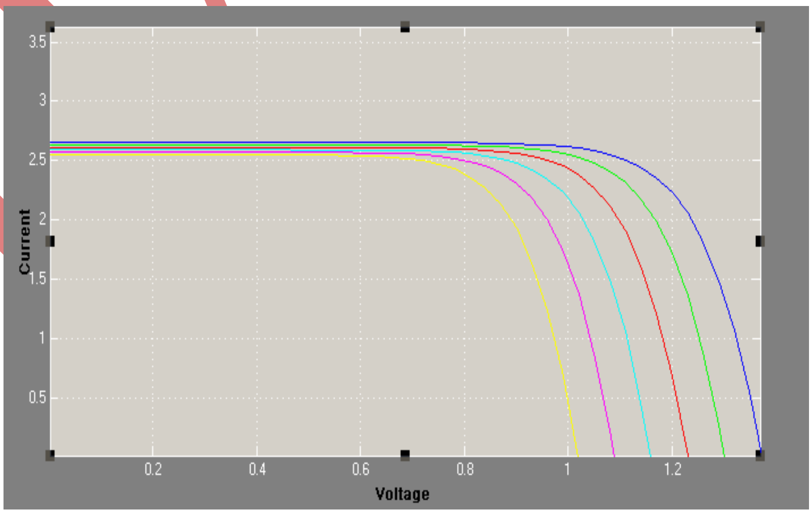


Figure 11: I-V curve of different temperature

V. RESULTS

From the modeling of PV array the following resultsare obtained.

Photon current Iph : 2.581 A

Reverse saturation current Irs: 2.317*10-6 A

Saturation current Is: 0.552*10-6 A

Photovoltaic current Ipv: 2.018 A

Photovoltaic voltage Vpv : 21.08 V

Photovoltaic power Ppv : 42.58 W

VI. CONCLUSION

In this paper MATLAB/SIMULINK models of thesolar PV cell, module and array developed and presentedbased on the mathematical equations. The essential inputparameters such as VOC, ISC, NS, TC and G are taken frommanufactures datasheet for the typical PV modules. The I-Vand P-V characteristics output are generated using thedeveloped model. Finally the model is used to verify the effectof temperature, insolation.

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