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Analysis and Mathematical Modeling of Stand alone PV cell

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ABSRACT

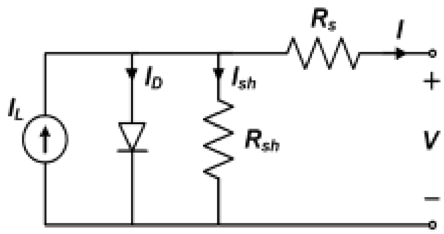
This paper presents the mathematical modeling and simulation of photo voltaic cell using MATLAB / simulink software. The main objective of this paper is to explore I-V and P-V characteristics of solar module. Single diode equivalent circuit is used for the analysis of various characteristics of PV cell. The output of PV cell is boosted by BOOST converter. The effect of temperature and irradiance on PV cell are obtained. P-I current controller is used. The equation of proposed model are represented and simulated in detail.

1. INTRODUCTION

Lightning progress in technology and increase in demand of power supply has led us to discover alternate forms of energy resources, since the available resources are on the verge of extinction. The biggest and the everlasting source of energy is solar energy. In order to extinguish Green House effect and reduce the use of fossil fuels, solar energy is developed. PV module is the basic building block used to convert solar energy into electrical energy.

2. BASICS OF PV CELL

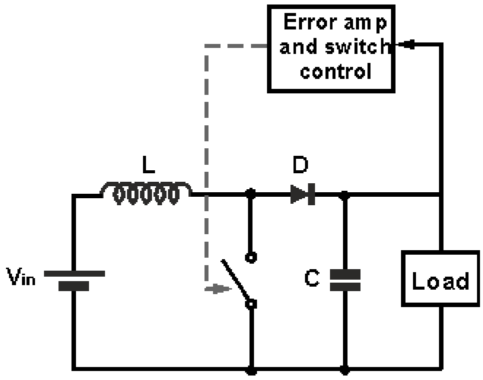
PV cell using a single diode module is as shown in the figure.



The model consists of current source connected in parallel with diode. The two resistors R_p connected in shunt and R_s connected in series are also included in the circuit. A combination of such PV modules is known as PV array.

3. BASICS OF BOOST CONVERTER

BOOST converter or step up converter using switch mode power supply is as shown below.



The working of a BOOST converter can be divided into two modes.

3.1 MODE 1(When the switch is closed):-

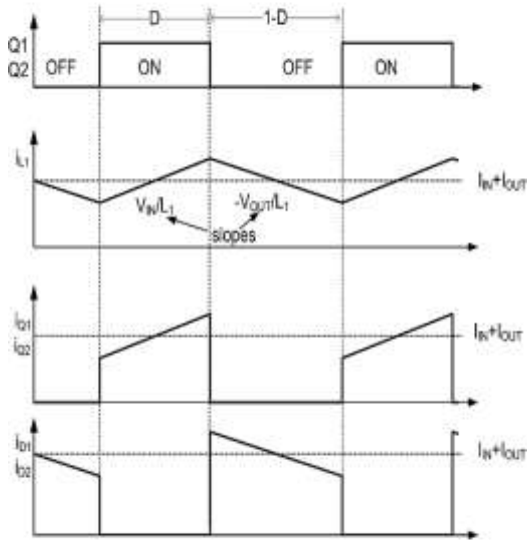
When the switch is closed the inductor begins to energize through the supply voltage V_{in}. The voltage at the output is zero due to short circuit the current does not flow through diode, hence current through diode is also zero. Current only flows through inductor.

3.2 MODE 2 (When switch is open) :-

When the switch is open, the inductor begins to de-energize and current begins to flow from diode as well as load. The voltage appearing across the load is the sum of voltage across inductor and supply voltage

$$V_o = V_L + V_{in}$$

The voltage and the current characteristics are as shown below



4. SIMULINK MODELING FOR PV MODULE

MXS 60 PV Module is taken as the reference module for simulation and the data sheet details are given in **Table-1**. A block diagram of the stage by stage model based upon the equations of PV model is represented in Simulink environment as given in Figures 3 to 9. These models are developed in moderate complexity to include the temperature dependence of the photo current source, the saturation current through the diode, and a series resistance is considered based upon the shackle diode equation as in (1)-(8) (Ishaque K, Zainal Salam, 2011; Dell R. V. *et al* ., 2010; Da Silva R. M. *et al*., 2010; Jung J. H. and Ahmed S., 2010 and Walker G., 2001; Pandiarajan N. *et al*., 2011). Since the main objective is to develop a functional PV model for the Simulink environment, the system is modeled to supply power to the load.

Table-1 Parameter specification of MXS 60 PV module (Pandiarajan N. *et al*., 2011).

Parameter	Variable	Value
Maximum power	P_m	60W
Maximum voltage	V_m	17. 1V
Current at max power	I_m	3. 5A
Open cct voltage	Voc	21. 06V
Short cct current	Isc	3.74
Total No. of cells in series	N_s	36
Total No. of cells in parallel	N_p	1

4.1 Stage A:

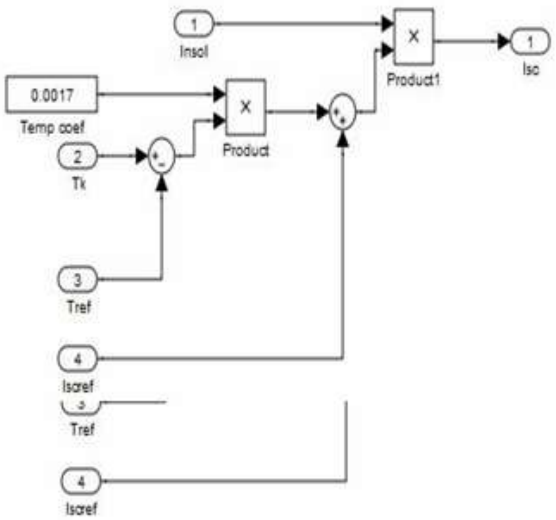


Figure-3. This model calculates the short circuit current I_{sc} at given operating temperature.

4.2 Stage B:

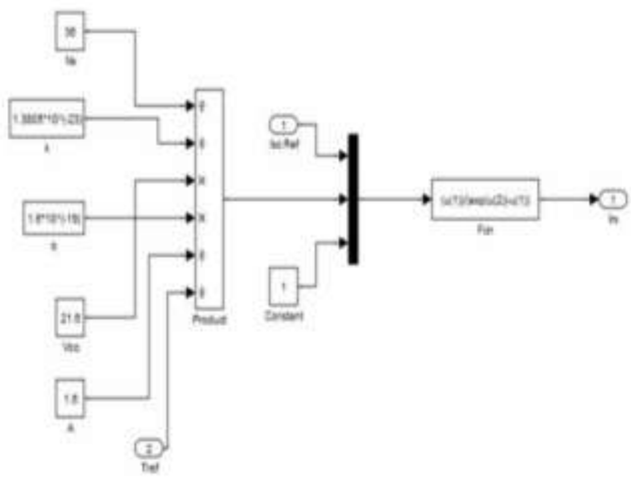


Figure-4. This model calculates the reverse saturation current through the diode using equation 6.

4.3 Stage C:

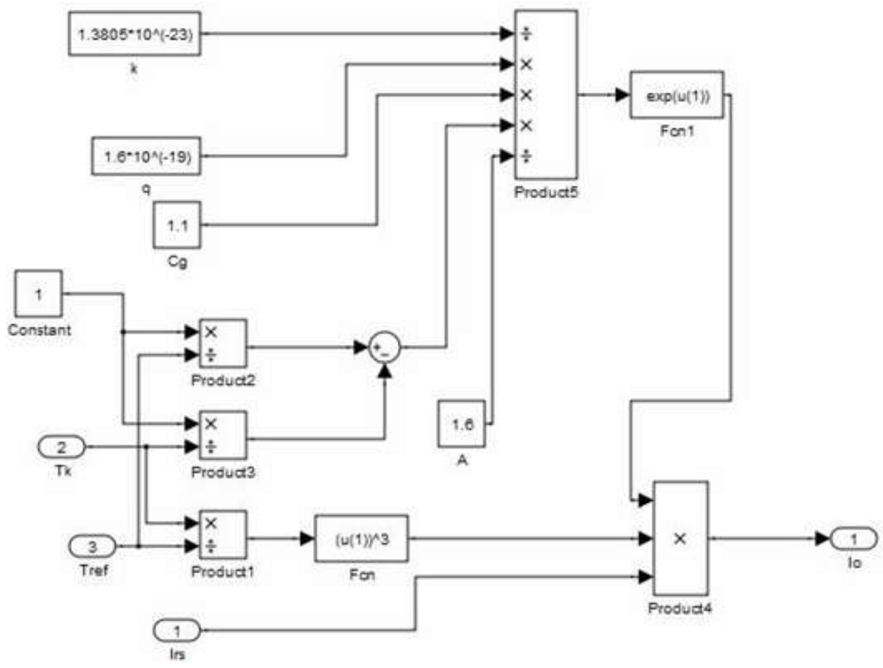


Figure-5. This model takes reverse saturation current, module reference temperature and the module operating temperature as input and calculates module saturation current.

4.4 Stage D:

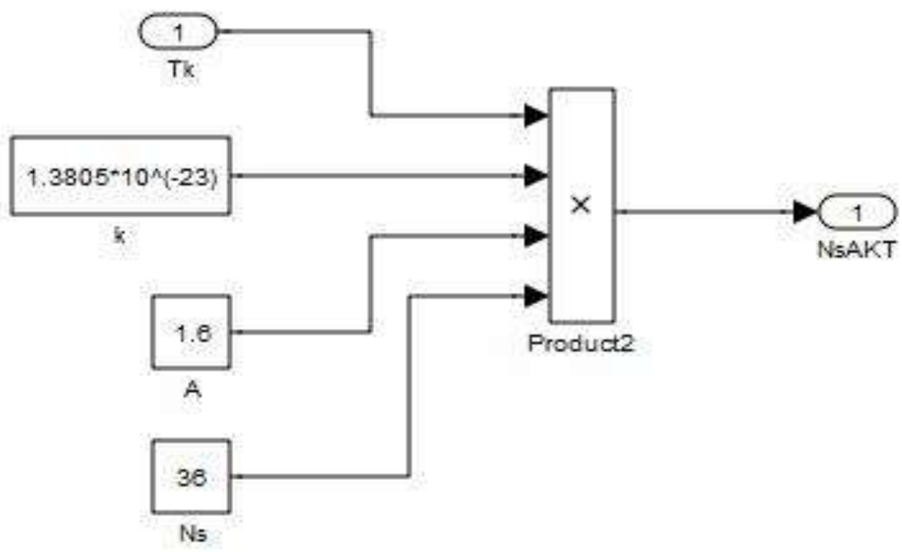


Figure-6. This model takes operating temperature in Kelvin and calculates the product NsAkT

4.5 Stage E:

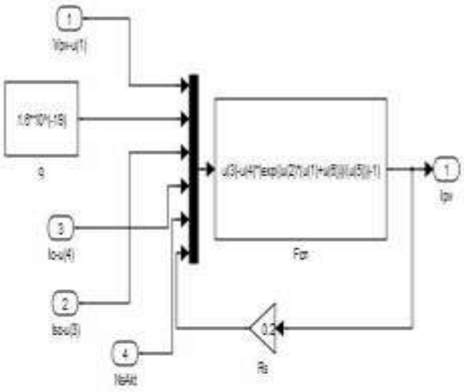


Figure-7. This model executes the function given by equation 8.

4.6 Stage F:

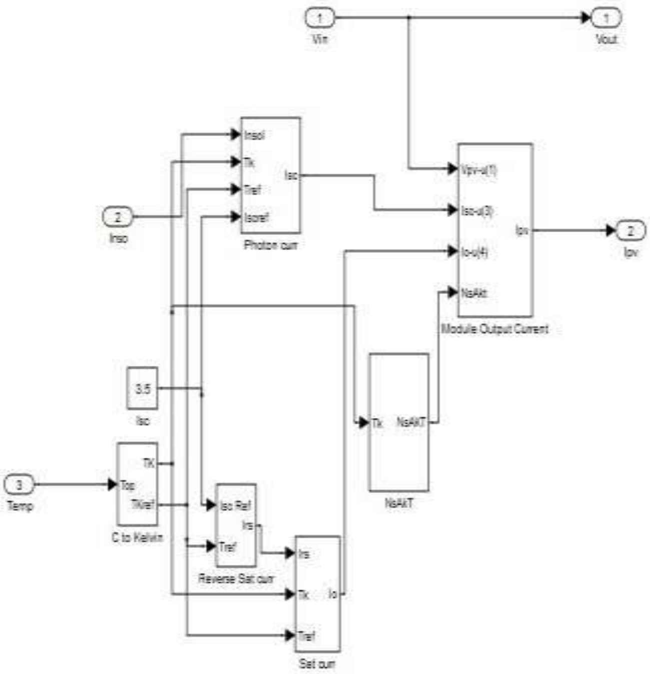


Figure-8. This model contains all the six model interconnected together

This model shows the whole modeling of photovoltaic cell. Equations of saturation current, reverse saturation current, photon current are interconnected and got equation of photovoltaic current.

4.7 Stage G:

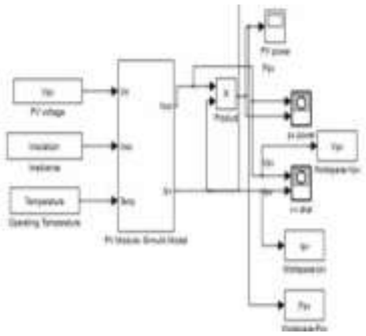


Figure-9. This is the final model which takes irradiation, operating temperature and Module voltage as input and gives the output current I_{pv}, and output voltage V_{pv} .

5. THE SIMULATION RESULTS

The model of the PV module was implemented using a Matlab Simulink model. The model parameters are evaluated during execution using the equations listed as in the previous section. The PV module chosen for this simulation is MXS60, which provides 60W nominal maximum power and has 36 series connected cells (Pandiarajan N. *et al*., 2011; Aissa Chouder, 2011). The parameter specification of the module is as shown in Table-1. The model was built in stages as indicated above starting from stage A to the final model. The subsystem contains all the mathematical equations of every stage model block.

I-V output characteristics of PV module with varying irradiance at the constant temperatures. It is depicted that the PV output current varies drastically with insulation conditions and there is an optimum operating point such that the PV system delivers its maximum possible power to the load. The optimum operating points changes with the solar insulation, temperature and load conditions.

P-V out characteristics of the PV module with varying irradiance at the constant temperatures (Pandiarajan N. *et al*., 2011; Altas I.H. and Sharaf A.M., 2007; Yushaizad Yusof, 2004). From the graphs when the irradiance increases, the current and voltage output also increases. This result shows the net increase in power output with an increase in irradiance at the constant temperatures. Furthermore, it is well known that for a certain PV panel, the voltage-power characteristics are fixed for each insolation without intersection, as shown in Figure-11. Hence, for any given PV voltage and power, the corresponding insolation can be estimated (Nema S. *et al*., 2010).

The I-V and P-V characteristics under constant irradiance with varying temperature are presented in Figure 12 and 13, respectively. When the operating temperature increases, the current output increases marginally but the voltage output decreases drastically, which result in net reduction in power output with a rise in temperature.

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