International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174 Volume 7, Number 7 (2014), pp. 735-742

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Mathematical Modelling and Simulation of PV Penal

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Abstract

This paper proposes a mathematical modelling and simulation of photovoltaic penal. The photovoltaic penal is simulated with MATLAB Simulator. The mathematical modelling of PV penal model gives variation in PV cell behaviour under different environmental conditions. This paper outlines the working of PV model & PV penal.

Keywords: Matlab, Simulation, PV, Solar Cell Model, V_{mpp}, I_{mpp}

Introduction

Demand and supply of the energy are vital factors in the economic growth. The global demand of energy is increasing day by day with the economic growth. The lack of sufficient energy supply can affect the overall economic growth. World's energy consumption in 1995 was 385 exa-joules. In 2007 consumption of the energy had grown to 531 exa-joules. By the year 2015 world's energy demand is projected to be around 593 exa-joules. Projected availability with current rate of consumption of oil is around 40.2 years, gas is around 53.8 years, and coal is around 205 years. To cope up with the future energy demand it is necessary to develop the clean, secure, sustainable and affordable energy sources. [1]

About 1% to 3% of the solar energy falling on the earth's surface gets converted into wind energy. Solar to Wind energy conversion is 50 to 100 times greater than the Solar to Biomass energy conversion through photosynthesis.

Solar energy is one of the most important renewable sources of energy. The power from the sun intercepted by the earth is about 180000 giga-watts. Hence lot of research and development is being carried out to harvest the solar energy. Various technologies have been developed for different applications such as solar thermal, solar photovoltaic etc. Solar energy intercepted by earth is thousand times greater than the current power requirement and consumption from all the sources. India has high solar insolation. It is an ideal place for using solar power.

India receives solar energy of about 5 to 7 kWh/m^2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant. With the government's initiative over the last two decades a sizeable research and technology base, a growing manufacturing capability and a countrywide infrastructure for the distribution and after-sales service of solar energy products has been established.

Structure of a Solar Cell

A typical solar cell is a multi-layered unit consisting of a *Cover*-a clear glass or plastic layer that provides outer protection from the Elements. *Transparent Adhesive*-holds the glass to the rest of the solar cell. *Anti-reflective Coating*-this substance is designed to prevent the light that strikes the cell from bouncing off so that the maximum energy is absorbed into the cell. *Front Contact*-transmits the electric current. *N-Type Semiconductor Layer*-This is a thin layer of silicon which has been mixed (Process if called doping) with phosphorous to make it a better conductor. *P-Type Semiconductor Layer*-This is a thin layer of silicon which has been mixed or doped with boron to make it a better conductor. Back Contact-transmits the electric current.

N-Layer-is often formed from silicon and a small amount of Phosphorus. Phosphorus gives the layer an excess of electrons and therefore has a negative Character. The n-layer is not a charged layer-it has an equal number of protons and electrons-but some of the electrons are not held tightly to the atoms and are free to move. *P-Layer*-is formed from silicon and Boron and gives the layer a positive Character because it has a tendency to attract electrons. The p-layer is not a charged layer and it has an equal number of protons and electrons. *P-N Junction*-when the two layers are placed together, the free electrons from the n-layer are attracted to the p-layer. At the moment of contact between the two wafers, free electrons from the n-layer flow into the p-layer for a split second, then form a barrier to prevent more electrons from moving from one layer to the other. This contact point and barrier is called the p-n junction.

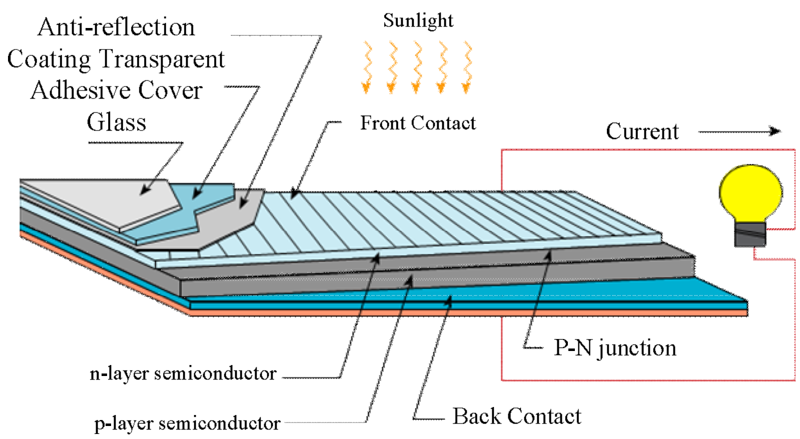

Figure 1.2 Structure of a Solar Cell

Once the layers have been joined, there is a negative charge in the p-layer and a positive charge in the n-layer section of the junction. This imbalance in the charge of the two layers at the p-n junction produces an electric field between the p-layer and the n-layer.

If the PV cell is placed in the sun, radiant energy strikes the electrons in the p-n junction and energizes them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-layer and are repelled by the negative charge in the p-layer.

A wire can be attached from the p-layer to the n-layer to form a circuit. As the free electrons are pushed into the n-layer by the radiant energy, they repel each other. The wire provides a path for the electrons to flow away from each other. This flow of electrons is an electric current that we can observe.

The electron flow provides the current, and the cell's electric field causes a voltage. With both current and voltage, power is developed, which is the product of the two.

45% of the cost of a solar cell is for the silicon wafers and about 35% is for the other components. With increasing numbers of photovoltaic cells being sold around the world and with ongoing research to make them more efficient, the price of PV cells has gone down about 4% per year for the last 15 years.

PV Panel Model

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array.

Typically a solar cell can be modelled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n top junction and parallel resistance is due to the leakage current.

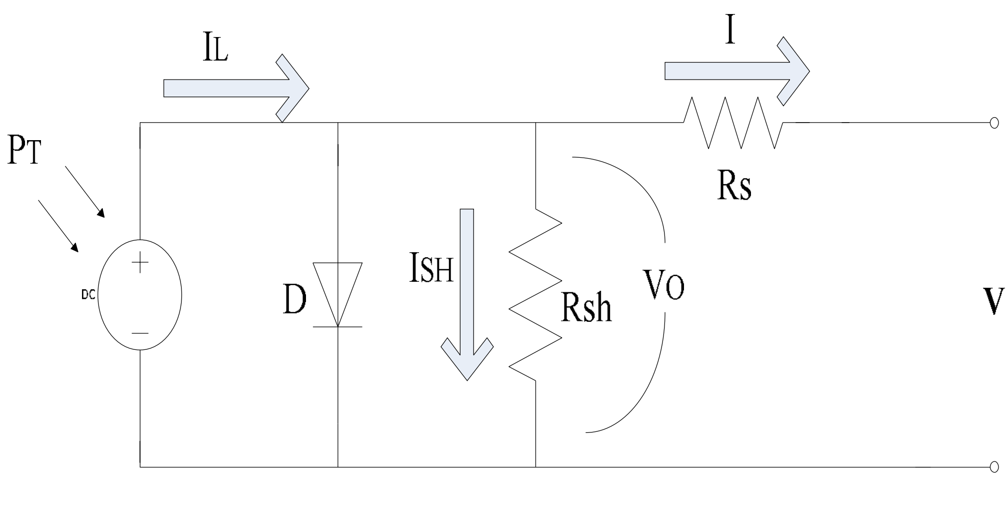

Figure 1-3: Single diode model of a PV cell

In this model we consider a current source (I_L) along with a diode and series resistance (Rs). The shunt resistance (R_{SH}) in parallel is very high and has a negligible effect. Hence it is neglected.

The output current from the photovoltaic array is

$$I = I_L - I_d - \frac{V_0}{R_{sh}} \quad (1)$$

Where,

$$V = V_0 - R_s I \quad (2)$$

The basic equation for the ideal case of the elementary PV cell does not represent the *I–V* characteristic of a practical PV array, actually Practical arrays are composed of several connected PV cells and the observation of the characteristics at the terminals of the PV Array is expressed by considering one the parameter called "I" which is given by:

$$I = I_l - I_d \left[\exp\left(\frac{q(V + R_s I)}{nktN_s}\right)\right] - 1 \quad (3)$$

In the above mentioned equation, the parameter I_L and I_0 are expressed as:

$$I_l = I_{L(T_r)}(1 + \alpha_{I_{se}}(T - T_r)) \quad (4)$$

$$I_o = I_{0(T_r)} \left(\frac{T}{T_r}\right) \exp\left[\frac{qV_g}{nk}\left(\frac{1}{T} - \frac{1}{T_r}\right)\right] \quad (5)$$

Where $I_{L(T_r)}$ *is* :

$$I_{L(T_r)} = G\left(\frac{I_{sc(T_{r,nom})}}{G_e}\right) \quad (6)$$

Where $I_{0(T_r)}$ is a reverse saturation current.

$$I_{0(T_r)} = \frac{I_{sc(T_r)}}{\exp\left(\frac{q(V_{oc(T_r)})}{nkT_r N_s}\right) - 1} \quad (7)$$

Where,

$$\alpha_{I_{sc}} = \frac{dI_{sc}}{dT} \quad (8)$$

Here,

I_L: light or photo current.

Io: reverse saturation current of the diode.

Is, *Vs:* output current and voltage of the photovoltaic generator respectively.

q: charge on electron.

K: Boltzmann's constant.

Rs: series resistance.

n: Ideality factor for P-N junction.

Simulation and Results

All model parameters can be determined by examining the manufacturer's specification of the PV products. The important parameters used for the penal electrical performance is the open circuit voltage (V_{oc}) and short circuit current (I_{sc}).

Table 1:-Solar array KC200GT Specifications (1000 W/m^2, 25^o C)

Parameters	Specifications	Parameters	Specifications
	7.61 A		0.00032 V/K
	26.3 V		54
	200.143 W		9.2825* A
	8.21 A		1.3
	32.9 V		415.405
	-0.1230 V/K		0.221

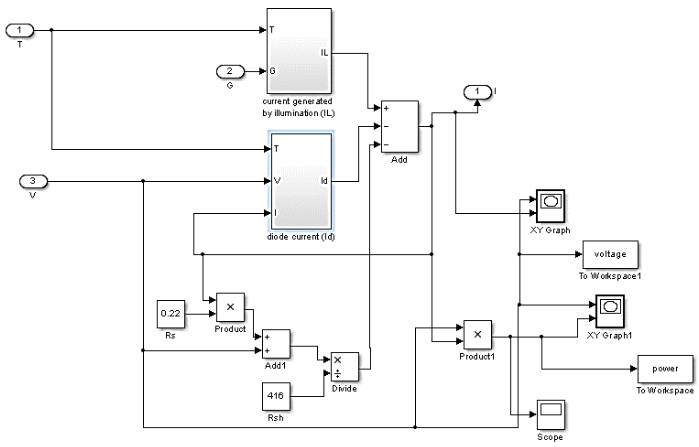

Figure 1-4: PV panel model

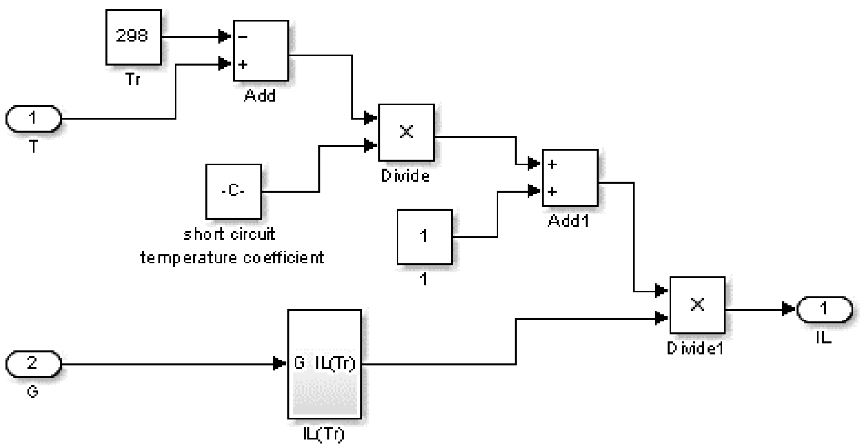

Figure1-5: Subsystem of Current generated by illumination (I_L)

Here figure 1-5 shows the subsystem of current generated by illumination (I_L) from main system of the PV panel.

Here figure 1-6 shows the subsystem of diode current (I_d) from main system of the PV panel.

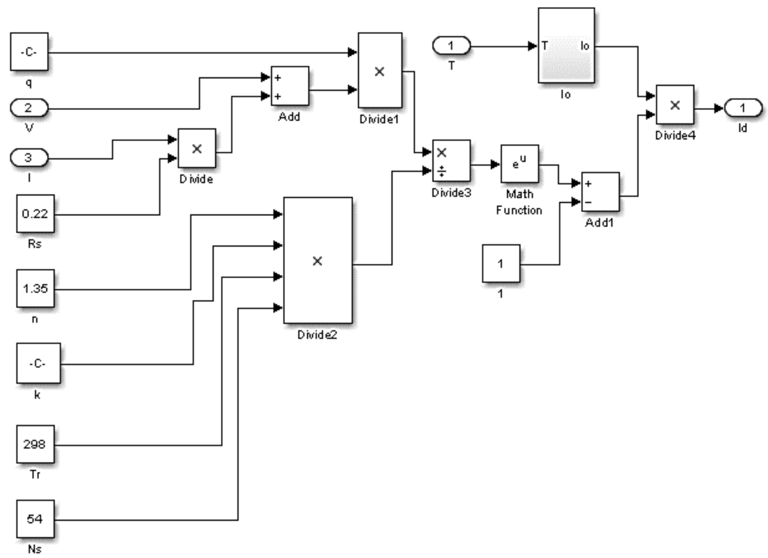

Figure 1-6:-Subsystem of Diode current (I_d)

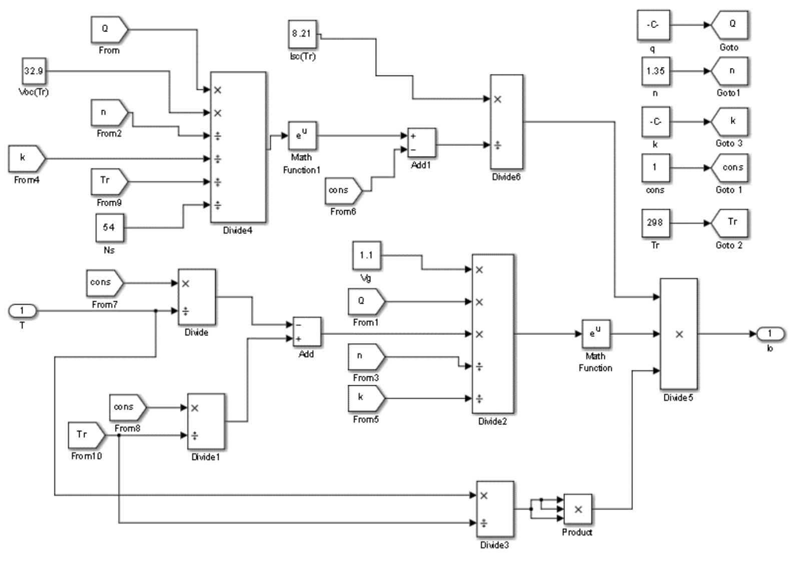

Figure 1-7:-Subsystem of Saturation current

Here figure 1-7 shows the subsystem of Saturation current from main system of the PV panel.

Simulation Results of the PV

a) I-V curve

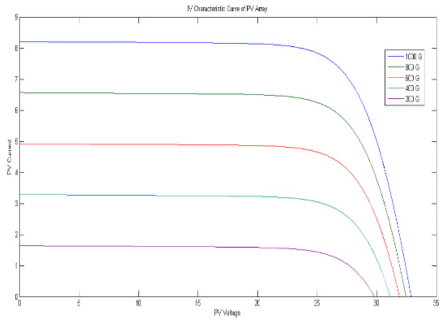

Figure 1-8: I-V curve.

b) P-V curve

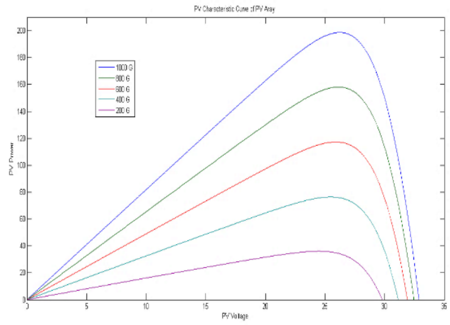

Figure 1-9: P-V curve.

Conclusion

Analysis of the development of a method for the mathematical modelling of the PV penal is done in the paper. The objective of the method is to satisfy the mathematical I-V equation with the experimental remarkable points of the I-V curve of the practical penal. The method obtains the parameters of the I-V equation by using following nominal information like open circuit voltage, short-circuit current, maximum output power, voltage and current at the MPP, current/temperature and voltage temperature coefficients from the array datasheet.This paper provides the necessary information to easily develop a single-diode PV penal model for analysing and simulating a PV penal.

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