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# PSIM and MATLAB based simulation of PV array for enhance the performance by using MPPT algorithm

Ashish Kumar Singhal<sup>1</sup> and Rakesh Narvey<sup>2</sup>

<sup>1</sup>Madhav institute of technology and science, Gwalior, India

<sup>2</sup>EED, M.I.T.S, Gwalior, India.

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## ABSTRACT

In this Paper a new Max. Power point tracking algorithm is used for PV array. The algorithm which is based on the mathematical calculation based MATLAB used to detect the max. Power point. Software (PSIM, MATLAB) dedicated to the simulation of the photovoltaic system can realize the extensive and precise analysis, but they are generally do not allow the modify the algorithm. Software includes the models of the solar panels, battery and investor, solar radiation.

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## Introduction

Renewable energy resources will be an increasingly important part of power generation in the new millennium. Besides assisting in the reduction of the emission of greenhouse gases, they add the much-needed flexibility to the energy resource mix by decreasing the dependence on fossil fuels. In other hand, deregulation of the electric utility industry is providing an opportunity for higher penetration and use of distributed resources (DR). Distributed resources are generation sources that can be located at or near loads. PV systems are ideally suited for distributed resource applications. Photovoltaic (PV) systems produce DC electricity when sunlight shines on the PV array, without any emissions. The DC power is converted to AC power with an inverter and can be used to power local loads or fed back to the utility. PV systems consist of a PV generator (cell, module, array), energy storage devices (such as batteries), AC and DC consumers and elements for power conditioning. This article refers about a model for modeling and simulation of PV module based on Shockley diode equation and the result on the basis of PSIM & Matlab software. PV generation systems have two major problems which are related to low conversion efficiency of about 9 to 12 % especially in low radiation conditions and that the amount of electric power generated by PV arrays varies continuously with weather conditions. Therefore, considerable research is being carried out to increase the efficiency of the energy produced from PV systems.

For any PV system, one option for increasing its output power is by tracking the maximum power point (MPP) of the PV system. The solar cell current-voltage (I-V) characteristic is nonlinear and varies with irradiation and temperature. However, there is a unique point on the I-V and a power-voltage (P-V) curve, called as the MPP, in which at this point the PV system is said to operate at maximum efficiency and produces its maximum power output. The location of the MPP is not known

but can be traced by using MPPT methods to maintain the PV array's operating point at its MPP.

## PV Generator

A photovoltaic PV generator is the whole assembly of solar cells, connections, protective parts, supports etc. In the present modeling, the focus is only on cell/module/array. Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor (usually silicon). In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode. When solar energy (photons) hits the solar cell, with energy greater than band gap energy of the semiconductor, electrons are knocked loose from the atoms in the material, creating electron-hole pairs. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. When the cell is short circuited, this current flows in the external circuit; when open circuited, this current is shunted internally by the intrinsic p-n junction diode. The characteristics of this diode therefore set the open circuit voltage characteristics of the cell.

## Modelling the Solar Cell

Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent  $I_{ph}$ ). During darkness, the solar cell is not an active device; it works as a diode

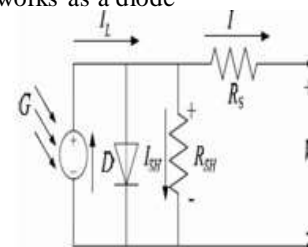


Fig 1:- Equivalent circuit of PV panel

Tele:

E-mail addresses: [rakeshnarvey@yahoo.com](mailto:rakeshnarvey@yahoo.com), [ashishee@gmail.com](mailto:ashishee@gmail.com)

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### MATLAB Model Of The Pv Module

The Solarex MSX60 PV module was chosen for modeling, due is well-suited to traditional applications of photo voltaics. The MSX 60 module provides 60 watt of nominal maximum power, and has 36 series connected polycrystalline silicon cells. The key specifications are shown in Table 1.

The model of the PV module was implemented using a Matlab program. The model parameters are evaluated during execution using the equations listed on the previous section. The program, calculate the current  $I$ , using typical electrical parameter of the module (ISC, VOC), and the variables Voltage, Irradiation ( $G$ ), and Temperature ( $T$ ).

In an ideal cell  $R_s = R_{sh} = 0$ , which is a relatively common assumption. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photocurrent,  $I_L$  and the normal diode current  $I_0$ :

$$I = I_L - I_0 \left( e^{\frac{q(V+IR_s)}{nkT}} - 1 \right) \quad (1)$$

The model included temperature dependence of the photo-current  $I_L$  and the saturation current of the diode  $I_0$ .

$$I_L = I_L(T_1) + K_0 (T - T_1) \quad (2)$$

$$I_L(T_1) = I_{SC} (T_{1,NOM}) \frac{G}{G_{NOM}} \quad (3)$$

$$K_0 = \frac{I_{SC}(T_2) - I_{SC}(T_1)}{(T_2 - T_1)} \quad (4)$$

$$I_0 = I_0(T_1) * \left( \frac{T}{T_1} \right)^{\frac{n}{2}} e^{\frac{qV_g(T_1)}{nk \left( \frac{1}{T} - \frac{1}{T_1} \right)}} \quad (5)$$

$$I_0(T_1) = \frac{I_{SC}(T_1)}{\left( e^{\frac{qV_{oc}(T_1)}{nkT_1}} - 1 \right)} \quad (6)$$

A series resistance  $R_s$  was included; with represents the resistance inside each cell in the connection between cells.

$$R_s = -\frac{dV}{dI_{voc}} - \frac{1}{X_V} \quad (7)$$

$$X_V = I_0(T_1) \frac{q}{nkT_1} e^{\frac{qV_{oc}(T_1)}{nkT_1}} - \frac{1}{X_V} \quad (8)$$

The shunt resistance  $R_{sh}$  is neglected. A single shunt diode was used with the diode quality factor set to achieve the best curve match. This model is a simplified version of the two diode model presented by Gow and Manning. The circuit diagram for the solar cell is shown in Figure 1.

### Current-Voltage I-V Curve for a solar Cell

A typical I-V characteristic of the solar cell for a certain ambient irradiation  $G$  and a certain fixed cell temperature  $T$ , is shown in Fig 2.

For a resistive load, the load characteristic is a straight line with slope  $I/V=1/R$ . It should be pointed out that the power delivered to the load depends on the value of the resistance only.

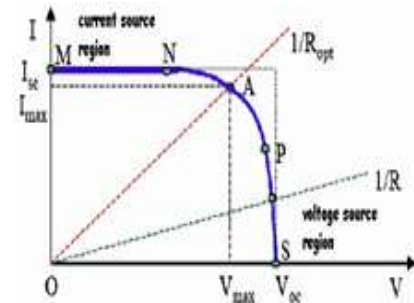


Fig 2. A typical current-voltage I-V curve for a solar cell.

However, if the load  $R$  is small, the cell operates in the region  $M-N$  of the curve (Fig 2), where the cell behave as a constant current source, almost equal to the short circuit current. On the other hand, if the load  $R$  is large, the cell operates on the regions  $P-S$  of the curve, the cell behaves more as a constant voltage source, almost equal to the open-circuit voltage.

A real solar cell can be characterized by the following fundamental parameters, which are also sketched in Fig. 2.

- **Short circuit current:**  $I_{sh} = I_{ph}$ . It is the greatest value of the current generated by a cell. It is produce by the short circuit conditions:  $V = 0$ .

- **Open circuit voltage** correspond to the voltage drop across the diode (p-n junction), when it is transverse by the photocurrent  $I_{ph}$  (namely  $I_L = I_{ph}$ ), namely when the generated currents is  $I = 0$ . It reflects the voltage of the cell in the night and it can be mathematically expressed as:

$$V_{oc} = \frac{nkT}{q} \ln \left( \frac{I_L}{I_0} \right) = V_t \ln \left( \frac{I_L}{I_0} \right) \quad (9)$$

Where

$$V_t = \frac{mkT}{q}$$

is known as thermal voltage and  $T$  is the absolute cell temperature.

- **Maximum power point** is the operating point  $A(V_{max}, I_{max})$  in Fig 2, at which the power dissipated in the resistive load is maximum:

$$P_{max} = V_{max} I_{max}$$

- **Maximum efficiency** is the ratio between the maximum power and the incident light power.

$$\eta = \frac{P_{max}}{P_{in}} = \frac{V_{max} I_{max}}{AG_a} \quad (10)$$

Where  $G_a$  is the ambient irradiation and  $A$  is the cell area.

- **Fill factor** is the ratio of the maximum power that can be delivered to the load and he product of  $I_{sc}$  and  $V_{oc}$ :

$$FF = \frac{P_{max}}{V_{oc} I_{sc}} = \frac{I_{max} V_{max}}{V_{oc} I_{sc}} \quad (11)$$

The fill factor is a measure of the real I-V characteristic. Its valued is higher than 0.7 for good cells. The fill factor diminishes as the cell temperature is increased. A program that simulates the V-I characteristics curves of solar panel on Matlab based

For Rad=[200,400,600,xm]/1000; ( $X_m$ , maximum radiation for the day  $n$ )

Va=[0:0.5:21.5];

Working voltage

k = 1.38e-23;

Boltzman constant

q = 1.60e-19;

Electron Charge

A = 1.85; (Diode quality coefficient:=2 for Crystalline Silicon, <2 for Amorphous Silicon)

Vg = 1.12; (Diode Voltage =1.12eV for Crystalline Silicon,

<1.75 for Amorphous Silicon)

$N_s = 36$ ; (Number of cells connected in series)

$T_1 = 273 + 25$ ; (Working temperature)

$V_{oc\_T1} = 21.06/N_s$ ; (Open circuit voltage per cell to  $T_1$ )

$I_{sc\_T1} = 3$  (Current of short circuit per cell to  $T_1$ )

$T_2 = 273 + 75$ ; (Working temperature 2)

$V_{oc\_T2} = 17.05/N_s$ ; (Open circuit voltage per cell to  $T_2$ )

$I_{sc\_T2} = 3.92$ ; (Current of short circuit per cell to  $T_2$ )

$T_{ak} = 273 + T_{ac}$ ; (Working temperature)

Where, ( $T_{ac} = T_1$ )

$K_o = (I_{sc\_T2} - I_{sc\_T1}) / (T_2 - T_1)$

1 sun = 1000 W/m<sup>2</sup>

$I_{L\_T1} = I_{sc\_T1} * \text{sun}$ ;

$I_L = I_{L\_T1} + K_o * (T_{ak} - T_1)$ ;

$I_{0\_T1} = I_{sc\_T1} / (\exp(q * V_{oc\_T1} / (n * k * T_1)) - 1)$ ;

$I_0 = I_{0\_T1} * (T_{ak} / T_1)^{(3/n)} * \exp(-q * V_g / (n * k) * ((1/T_{ak}) - (1/T_1)))$ ;

$X_v = I_{0\_T1} * q / (n * k * T_{ac}) * \exp(q * V_{oc\_T1} / (n * k * T_{ac}))$ ;

$X_v = \text{NaN}$ ;

$dV/dI_{Voc} = -1.15 / N_s / 2$ ;

$R_s = dV/dI_{Voc} - (1/X_v) = \text{NaN}$

$V_{t\_Ta} = A * k * T_{ak} / q$ ;

$I_a = \text{zero}(\text{size}(V_c))$ ; (Apply Newton Raphson method)

$I_a = I_a - (I_L - I_a - I_0 * (\exp((V_c + I_a * R_s) / V_{t\_Ta}) - 1)) / (-I_0 * (\exp((V_c + I_a * R_s) / V_{t\_Ta}) - 1)) * R_s / V_{t\_Ta}$

End

### Simulation result based on Matlab

In this method the evaluation of parasitic capacitance is obtained by accounting the average ripple in the power array generated by switching frequency. The limitation of this algorithm is that, the parasitic capacitances are small in quantity and accountable for only very large dimension PV array.

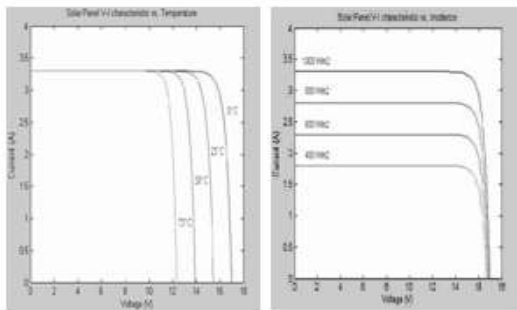
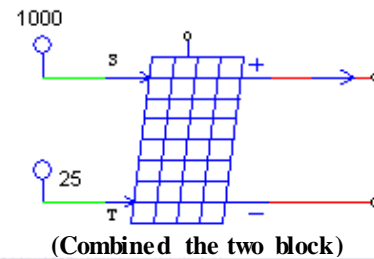
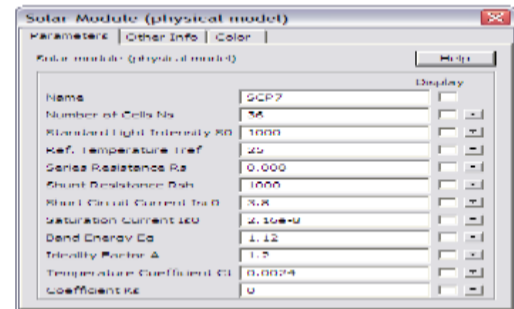
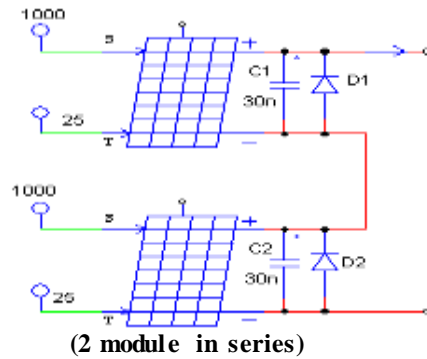
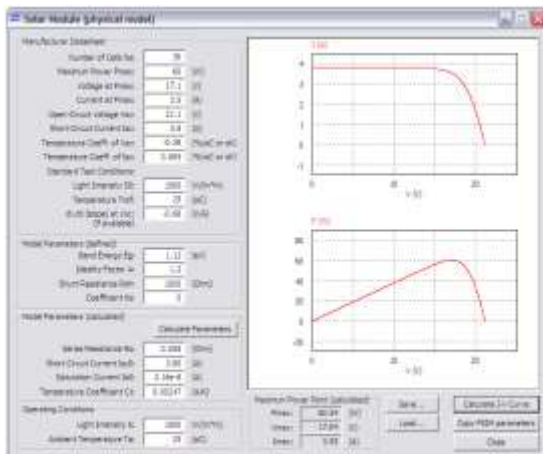


Fig.3: Variation of Solar Panel V-I characteristics with varying Irradiance, Temperature

### Simulation with PSIM software



### Conclusion

An accurate PV module electrical model is presented and demonstrated in Matlab for a typical 60W solar panel. Given solar insulation and temperature, the model calculates the current for a given voltage. The results from the Matlab model show excellent correspondence to manufacturer's published curves. Finally the model development was used to show the effect of: insulation, temperature, ideality factor and series resistances

This paper is the first step to develop a complete solar Photovoltaic power electronic conversion system in simulation. The final objective is develops a general model to simulate the electrical behavior of the PV systems in a grid-connected application.

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Table 1

Typical Electrical characteristic of MSX 60 PV model		
Parameter	Variables	Value
		MSX 60
Maximum power	$P_m$	60 Watt.
Maximum Voltage	$V_m$	17.1 volt
Maximum Current	$I_m$	3.5 Amp
Short Circuit Current	$I_{sc}$	3.8 Amp
Open Circuit Voltage	$V_{oc}$	21.1 volt
Temperature coefficient of Short circuit voltage		$(0.0065 \pm 0.015) \% / ^\circ C$
Temperature coefficient of Open circuit voltage		$-(80 \pm 10) mV / ^\circ C$
Temperature coefficient of power NOCT <sup>2</sup>	$P_m$	$-(0.5 \pm 0.005) \% / ^\circ C$

**Notes:**

(1) The data are based on measurements made in a solar simulator at Standard Test Conditions (STC), which are:

- Illumination of  $1 \text{ kW/m}^2$  (1 sun) at spectral distribution of AM 1.5;
- Cell temperature of  $25^\circ\text{C}$  or as otherwise specified (on curves).

(2) Under most climatic conditions, the cells in a module operate hotter than the ambient temperature. NOCT (Nominal Operating Cell Temperature) is an indicator of this temperature differential, and is the cell temperature

under Standard Operating Conditions: ambient temperature of  $20^\circ\text{C}$ , solar irradiation of  $0.8 \text{ kW/m}^2$ , and wind speed of  $1 \text{ m/s}$ .