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MODELING AND DESIGN OF PHOTOVOLATIC SOLAR ANNEL

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ABSTRACT

Haque MD, Islam MM, Hossain MM, Sultana N (2014) Modeling and design of photovolatic solar panel. *Ins. Engg. Tech.* 4(1), 12-17.

This paper describe the basic working principle of PV module as well as PV array. This model is based on mathematical equations and is described through an equivalent circuit including a photo current source, a diode, a series resistor and a shunt resistor. The developed model allows the prediction of PV cell behaviour under different physical and environmental parameters. Matlab coding has been done to find the maximum power output, Pm, and voltage at maximum power output, Vm, of solar module. The annual energy yield of 60W PV module has been estimated. The model can also be used to extract the physical parameters for a given solar PV cell as a function of temperature and solar radiation. Effect of two environmental parameters of temperature and irradiance variations could be observed from simulated characteristics.

Key words: *photovoltaic pannel, photo current, environmental parameters, solar radiation*

INTRODUCTION

Photovoltaic technology in reality goes back over 160 years. The basic science was first came upon in 1839 but the pace of advancement really hastened in two major drives in the 20thcentury. Bell Laboratories, discovered silicon had photoelectric attributes and quickly developed Si solar cells, achieving 6% efficiency and former satellites were the elemental use for these first solar cells. To spur acceptance, Germany and then Japan initiated appreciable subsidy programs and now those markets exist largely without grants. In 2007, California leads the US with a similar 10-years program recently, the massive consumption and exhaustion of fossil fuel resulted in enormous interest to utilize renewable sources of energy such as solar energy. Photovoltaic power is an established technology and has recently experienced rapid growth over the last ten years (Tsai 2010). A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated. PVs offer several advantages such as: high reliability, low maintenance cost, no environmental pollution, and absence of noise (Petrone *et al*. 2008).

MATERIALS AND METHODS

A photovoltaic system is a system which uses one or more solar panels to convert solar energy into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output (Padmanabhan Balaji 2008).

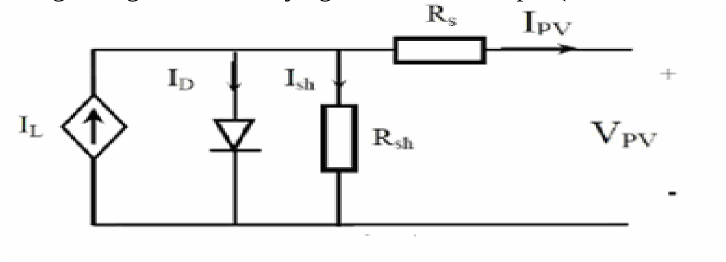

Fig. 1. Electrical Equivalent circuit of Photovolatic Solar cell

PV cells are made of semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current - that is, electricity. This electricity can then be used to power a load (Katsuaki 2008). The power produced by a single PV cell is not enough for general use. So by connecting many single PV cell in series (for high voltage requirement) and in parallel (for high current requirement) can get us the desired power. Generally a series connection is chosen this set of arrangement is known as a module. Generally commercial modules consist of 36 or 72 cells. The p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics and these are not necessary. Reverse currents waste power and can also lead to overheating of shaded cells. Solar cells become less efficient at higher temperatures and installers try to provide good ventilation behind solar panels (Soto *et al.* 2006).

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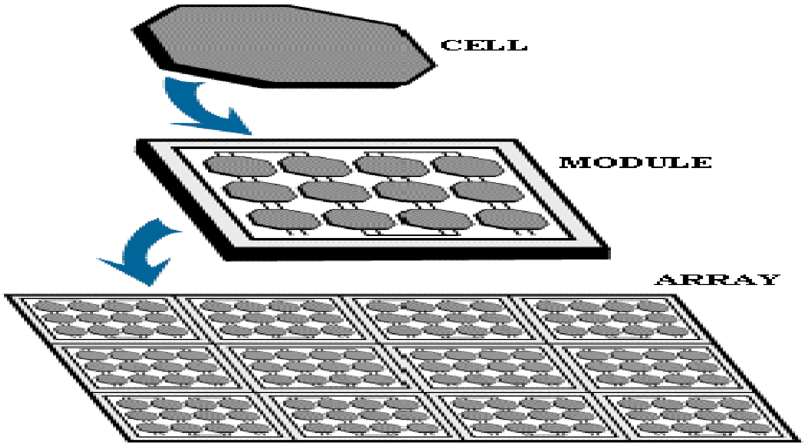

Fig. 2. Block diagram of Photovolatic solar module

Characteristics of PV cell:

In a PV characteristic there are basically three important points *viz.* open circuit voltage (Vo), short circuit current (Io) and maximum power point. The maximum power that can be extracted from a PV cell are at the maximum power points. Usually manufacturers provide these parameters in their datasheets for a particular PV cell or module (Jafari *et al.* 2011).

Numerical Analysis:

Band gap energy- of the solar cell material
Eg = Ego-(alpha*T*T)/(T+beta)*q ....(5.1)
Photocurrent-Iph = [(Iscr+ki(TTrefk))](s/100) ....(5.2)
Saturation current-The saturation current of the solar photovoltaic cell can be expressed as Irs
Irs = Irr(T/Trefk)3exp(q.Eg(1/Trefk-1/T)/(K.A)) ....(5.3)
Output current-The output current of the solar photovoltaic cell can be expressed as Io
Io = Np*Iph ± Np*Irs*(exp(q/(k*T*A)*Vo./Ns)-1) ....(5.4)
Power-The output power of the solar photovoltaic cell can be expressed as Po and it is the product of output voltage and current.
Po = Vo*Io...(5.5)
Solar radiation- $S(t) = S_{\max}\left[\exp^{-(t-t_c)/2\sigma^2}\right]$
Maximum power Pmax = Vmax*Imax = V oc.I sc.FF........................(5.6)
The ideality constant varies depends on PV technology. Ideality constant of different PV technology is presented bellow:

Technology	Insolation A
Si mono	1.2
Si poly	1.3
A si H	1.8
A si H Tandem	3.3
A si H triple	5
cdte	1.5
CIS	1.5
AsGa	1.3

Energy Efficiency of Solar Panel:

The most general formulation of the energy equation for an open system under steady state assumption, using the first law of thermodynamics can be written

$$E_{in} = E_{out}$$

$$EX_{in} - E_{out} = E_{loss}$$

The equation is a general equation for the energy balance Ex_{out} is the maximum amount of energy that can be obtained from a system whose supplying energy is Ex_{in} the smaller the energy consumed, the smaller the energy loss. A solar cell's energy conversion efficiency is the percentage of power converted (from absorbed light to electrical energy) and collected, when a solar cell is connected to an electrical circuit. Energy efficiency of the solar PV can be defined as the ratio of power output to energy input of the solar PV. The output power and energy efficiency of the PV system, however, fluctuates depending on solar radiance and surface temperature. The energy conversion efficiency $PV(\eta_{energy})$ of solar cell (Messenger and Ventre, 2000). Energy is calculated from the following equation

$$\eta_{energy} = \frac{V_{oc} I_{sc} FF}{AG}$$

The current-voltage characteristics of the electric circuit of solar cell can be described by the following simplified equation

$$I = I_1 - I_0 \exp^{\left[\frac{q(V - IR_s)}{AKT}\right]}$$

The electric power output of PV is

$$P_{ol} = VI$$

Moreover, the maximum output power is given by

$$P_{\max} = V_{oc} I_{sc} FF = V_{mp} I_{mp}$$

The solar energy absorbed by the PV modules is converted to electric energy and thermal energy, which is dissipated, by convection, conductive, and radiation. The rate of the heat transfer process depends on the design of the PV system. To achieve the efficiency of a PV module its operating temperature TC must be determined which is for simplicity could be assumed homogenous on the plate and it is depends on the ambient conditions. The higher surface temperature could cause reduction in PV efficiency. Therefore, the cells may be cooled artificially by passing air or water on the backside of the module especially in the hot region (Hua and Shen, 2008).

Energy Efficiency of Solar Cell:

Energy analysis includes a consideration of energy quality or capability, which permits evaluation of the most effective, not just most efficient, use of energy potential. For the steady-state flow process during a finite time interval, the overall energy balance of the solar PV can be written as follows.

Energy Input = Energy Output + Energy Loss + Irreversibility

This degradation in the quality of energy is called energy loss (availability loss). The energy loss is also called irreversibility. The solar radiation emitted by the solar cells translated by two ways electrical and thermal. The electrical energy is utilized as electrical energy. The thermal energy is dissipated to the ambient as a heat loss, it becomes energy destruction Energy efficiency of the photovoltaic module is also defined as the ratio of total output energy to total input energy [16, 18, 19]. An energy efficiency of the solar PV can be defined as the ratio of the energy gained by the solar PV (energy output) to the energy of the solar radiation (Pandiarajan and Ranganath, 2011).

$$\eta_{ex} = \frac{E_x output}{E_x input}$$

Inlet energy of a PV system includes only solar radiation intensity energy

$$E_x in = AG\left[1 - \frac{4}{3}\left(\frac{T_a}{T_s}\right) + \frac{1}{3}\left(\frac{T_a}{T_s}\right)^4\right]$$

The energy output of the photovoltaic system can be calculated Outlet energy for a PV system includes thermal Energy and Electrical Energy

$$E_{out} = E_x thermal + E_x electrical$$

Energy of the thermal Energy

$$E_x thermal = Q\left[1 - \frac{T_a}{T_m}\right]$$

Where $Q = UA(T_m - T_a)$

Overall heat loss coefficient of a PV module includes convection and radiation losses

$$U = h_{conv} + h_{rad}$$

Convective heat transfer coefficient

$$h_{conv} = 2.8 + 3v_w$$

Radiative heat transfer coefficient between PV array & surroundings

$$h_{rad} = \varepsilon\sigma(T_{sky} + T_m)(T_{sky}{}^2 + T_m{}^2)$$

Effective temperature of the sky

$$T_{sky} = T_a - 6$$

Temperature of the module can be calculated on the base of NOCT value

$$T_m = T_a + (NOCT - 20).\frac{G}{800}$$

Electrical Energy in the output electrical power of PV module

$$E_X electrical = V_{oc} I_{sc} FF$$ (Sudhakar *et al.* 2012)

RESULTS AND DISCUSSION

The simulation results of photo-volatic solar module are shown below at different temperatures and solar radiation.

Different Temperature:

Therefore solar cells give their full performance on cold and sunny days rather on hot and sunny weather. Nowadays Solar panels are made of non-silicon cells as they are temperature insensitive. Thus the temperature remains close to room temperature.

It is observed from the simulation results of the photovoltaic module at different temperatures. With the increase of the temperature of the solar cell short circuit current of the P-V module increases while the maximum power of the solar module decreases. These results thus indicate the nonlinear nature of solar module.

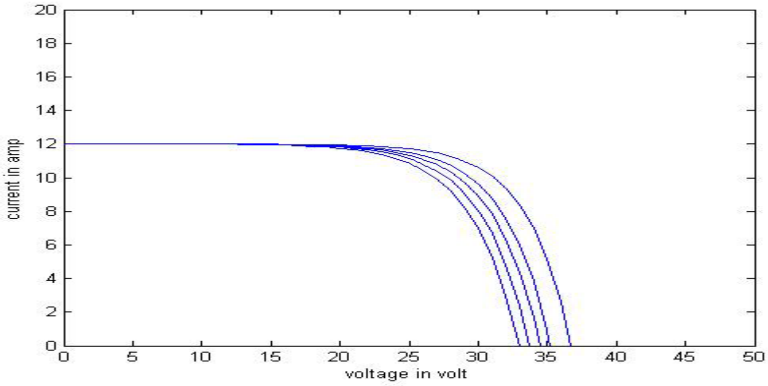

Fig. V-I characteristics of Solar module at different temperatures

Voltage and current of solar panel significantly decrease with increasing panel temperature. Like other semiconductor devices solar cell are sensitive to temperature. Increase in temperature reduce the band gap of semiconductor. Thereby effecting most of the semiconductor material parameters. The decrease in the band gap of a semiconductor with increasing temperature can be viewed as increasing the energy of the electrons in the material. Lower energy is therefore needed to break the bond. In the bond model of a semiconductor band gap, reduction in the bond energy also reduces the band gap. Therefore increasing the temperature reduces the band gap.

Solar cells vary under temperature changes. The change in temperature will affect the power output from the cells. The voltage is highly dependent on the temperature and an increase in temperature will decrease the voltage.

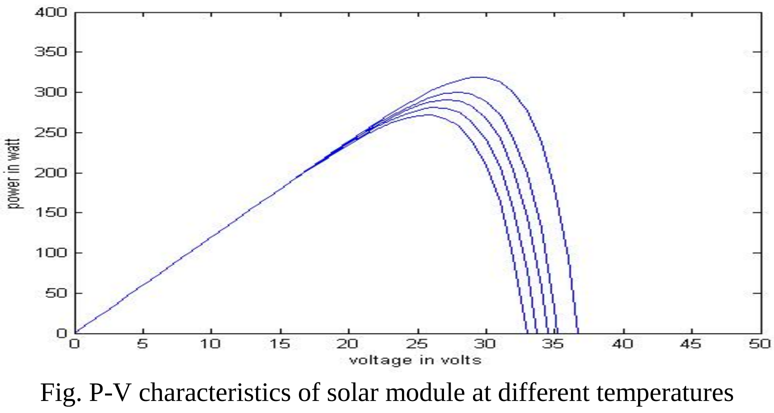

Fig. P-V characteristics of solar module at different temperatures

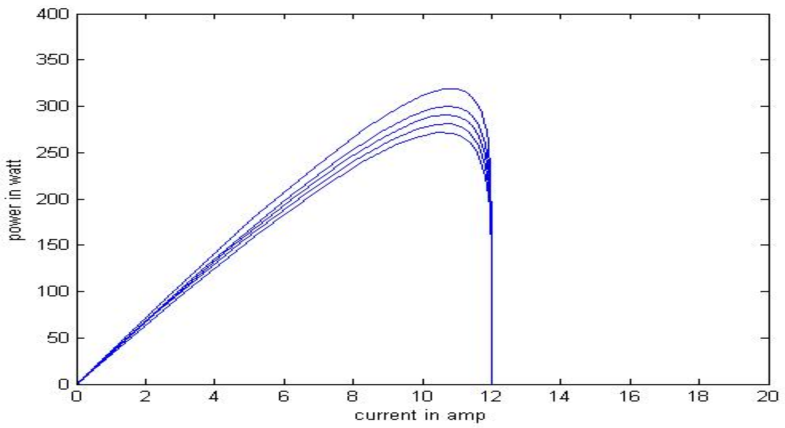

Fig. P-I characteristics of solar module at different temperatures

Different Solar radiations:

The simulation results of I-V, P-V and P-I characteristics of solar module at different solar radiations are shown below. It is very clear that with the increase of the solar radiation the generation of the current increases and maximum power output increases. On the other hand, voltage is also staying constant and it is not changing so much as like as current.

As the solar insolation keeps on changing throughtout the day similarily I-V and P-V characteristics varies. With the increasing solar irradiance both the open circuit voltage and the short circuit current increases and hence the maximum power point varies.

A non-uniform distribution of irradiance affects mainly the voltage range between the short-circuit current and the maximum power point (MPP). As the level of non-uniformity increases, the characteristic loses its typical curvature and behaves linearly between the MPP and the short-circuit current. With increasing the measurements of the short-circuit current and hence the fill factor (FF) yield false results. The short-circuit current is underrated and the fill factor consequently overrated. The open circuit voltage remains unaffected by the non-uniformity of the light.

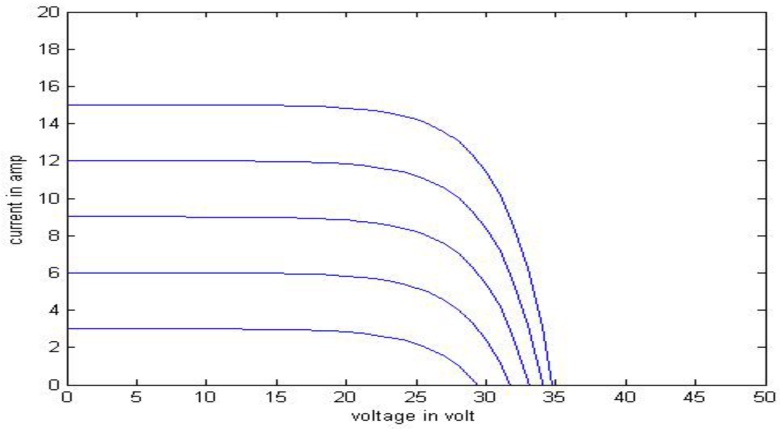

Fig. I-V characteristic of solar module at different solar radiation

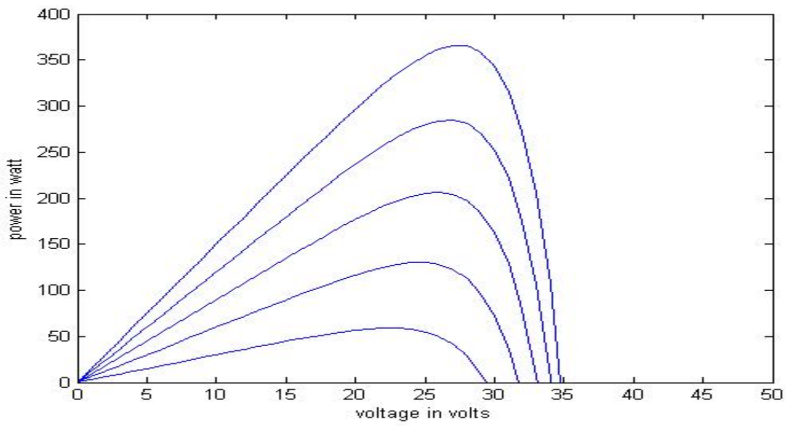

Fig. P-V characteristics of solar module at different radiation

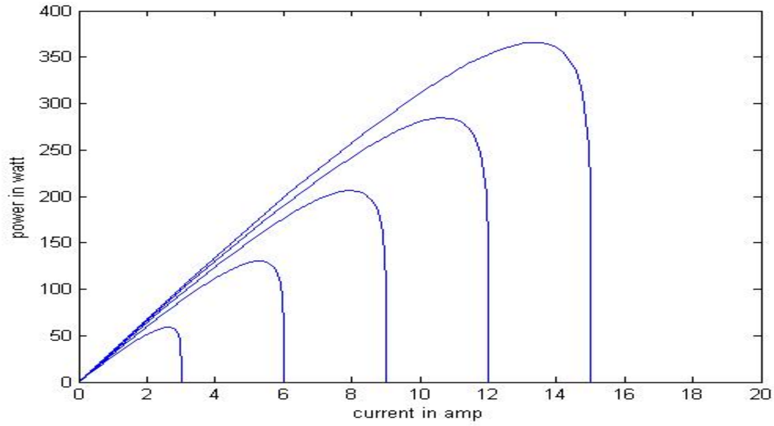

Fig. P-I characteristic of solar module at different radiation

CONCLUSION

In conclusion, the modeling of SiNW FETs is done. The model development was divided into two sections. The first section is devoted to the modeling of SiNW FETs assuming ballistic transport. The model is based on Natori's theory of ballistic MOSFETs and is extended to include 2D electrostatic effects. The simulation results found from the developed model were compared with that of the numerical simulation results. The numerical simulation results were found from the NanoHub, using the software, NW. The comparison results give a good agreement which shows the accuracy of the developed model.

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