ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

Mathematical Modeling of photovoltaic cells Using Matlab/Simulink and MPPT Techniques

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ABSTRACT: This model is developed basic circuit equation of pv cells includes the effect of solar irradiation, operating temperature and shunt resistance, ideality factor are changing. In this paper based on the mathematical modelling because it is more efficient than physical modelling and it's described through an equivalent circuit includes a photocurrent source a diode and series and shunt resistance. And our analysis MPPT technique in photovoltaic system this technique are used to increase the efficiency of pv system.

KEYWORDS: pv cells/pv modules/pv array, characteristics of pv cell, MPPT technique, Matlab/Simulink.

I. INTRODUCTION

Solar energy is the most important renewable energy as compared to non renewable energy like that coal, wood, natural gases, etc. Because solar energy is a clean, pollution free and inexhaustible and no potential damage to the environment, and it's free and available to the at fairly equal manner. A photovoltaic system converts solar energy (sunlight) into electricity. In which devices use the pv cells are combined to inform of panels or module and the combine of modules of the array and panel or modules can be grouped to form of large photovoltaic cells in the photovoltaic array describe a photovoltaic panel connected in series and / or parallel or a group of panels [7]. A pv cells is a basic unit the generates the voltages in the range of 0.5 to 0.8 volts and it's depends on cells technology [6]. The monocryslalline pv cells/module has the best efficiency among all commercially available technology. The main application of pv system is in standalone (street lighting, domestic, military and space, etc.) and grid connected (hybrid system) [8]. This model based on mathematical equations and equivalent circuits likes photocurrent sources, a diode, a series resister and shunt resistor. The performance of pv array system depends on its output voltage, current and power of pv array vary as functions of solar irradiation level temperature and load current.

The main purpose of this paper presents a brief introduction to its functioning and behaviour of pv device and its basic equations and it's followed by the mathematical modelling and simulation of pv array and MPPT technique of the main purpose of this paper. And in the unique point P-V and I-V characteristics which photovoltaic system operates at maximum efficiency. So this point called maximum power point (MPP). The maximum power point trackers (MPPT) are used to maintain the MPP. So it's minimized the overall cost and maximizes the array efficiency. MPPT typically regulates the terminal voltage of the panel and the MPPT control to extract maximum power from the pv array becomes indispensable in the pv generation system.

II. PRINCIPLE AND OPRERATION OF PV CELL

An array/module of pv cell converts solar energy into a usable amount of DC (direct current) energy. The panels of solar made of semiconductor. Material and silicon being the most abundant (very large) used semiconductor [1].

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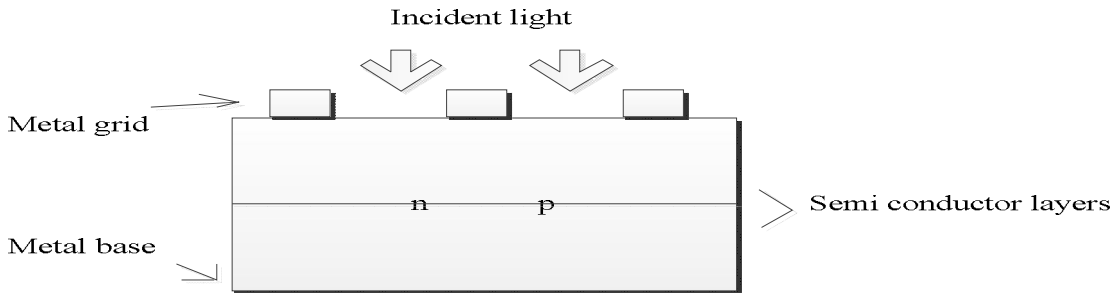

Fig:- physical structure of pv cell

The p-n junction exposed to light, photons with energy greater than the gap of energy are absorbed, causing the emergence of electron-hole pairs. There carriers are separated under the influence of electric fields within the junction. Creating a current that is proportional to incidence of solar irradiation [3]. Being exposed to the sunlight, photons with energy of the semiconductor creates some electrons-hole pair proportional to the incident irradiation [4]. The light generated current is acted as a constant current source supplying the current to either the junction or a useful load depending on the junction characteristics and the value of the external load resistance. This phenomenon depends on the semiconductor material and on the wavelength of the incident light. The rate of generation of electric carries depends on the flux of incident light and the capacity of absorption of semiconductor. The capacity of absorption depends mainly on the semiconductor band gap, on the reflectance of the cell surface (that depends on the shape and treatment of the surface). The value of series resistance is very low, but the value of parallel resistance is infinity.

III. CHARACTERISTICS OF PV CELL

The I-V and P-V characteristics of pv/solar cell are shown in figure.
The fundamental parameters rated to pv cells are short circuit (Isc), open circuit voltage (Voc), maximum power point (MPP), the efficiency of pv cell and fill factor.

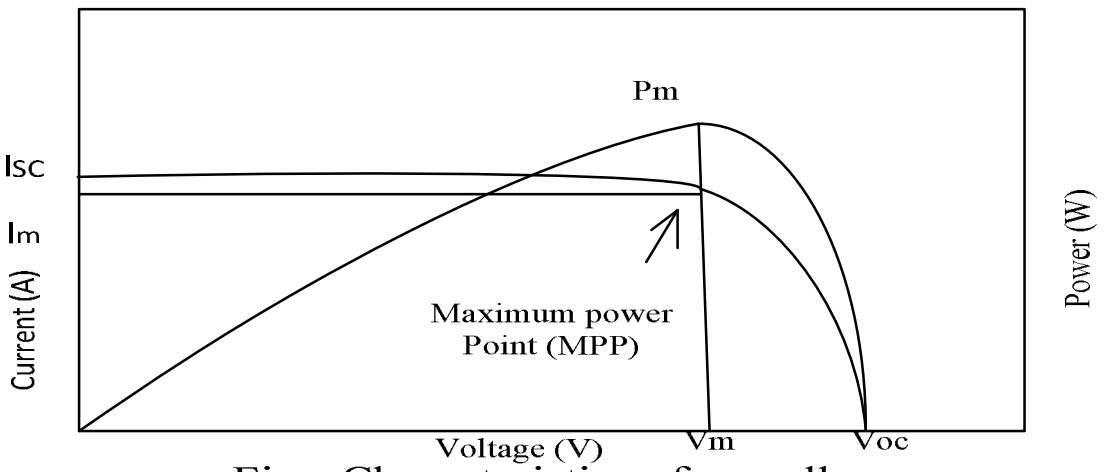

Fig:- Characteristics of pv cell

That may be increase or decrease output power due to all parameters used in pv cell like irradiation, temperature, series resistance, parallel resistance, ideality factor, saturation current etc.

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IV. MATHEMATICAL MODELING OF PV CELL

The equivalent circuit diagram of pv cell is shown below in figure. It includes a current source (I_{ph}), diode (D), a series resistance (R_s), and shunt resistance (R_{sh})[2].

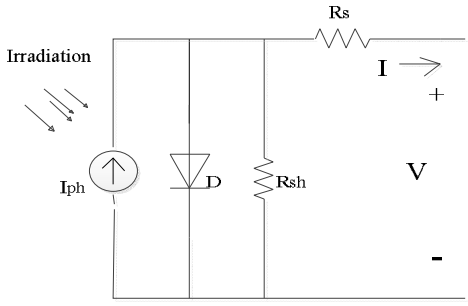

Fig:- Circuit diagram of pv cell

The equivalent circuit based model is mainly used for the MPPT technologies. In mathematical equations in pv cell/module used following nomenclature.
Vpv is the output voltage, V
Ipv is output current, A
Tn is the reference temperature
T is the operating temperature in Kelvin
Is=Io is the saturation current (A)
Isc is the short circuit current
Io_R is the cell reverse saturation current at a reference temperature
Iph is the light generated current or photon current
A=B is the ideality factor
K is the Boltzmann constant ($1.3805*10^{-23}$ J/K)
q is electron charge ($1.6*10^{-19}$ C)
Rs is the series resistance
Rsh is the shunt resistance
Ns is the number of cells connected in series
Np is the number of cells connected in parallel
Eg is the band gap energy (1.1 eV)
Ki is a cell's short circuit temperature coefficient
G is the irradiance (W/m^2)
The voltage, current (V-I) characteristic equation of pv/solar cell is given by-

$$I = Iph - Io\left(\exp\frac{q.(V+IRs)}{N.K.T} - 1\right) - \frac{(V+IRs)}{Rsh} \quad (1)$$

Where photon current is-

$$Iph = (Isc + Ki\,(T-Tn))\frac{G}{100} \quad (2)$$

The cell's saturation current varies with cell temperature, which is-

$$Is_{(T)} = Is\left(\frac{T}{Tn}\right)^3 * \exp\left[\frac{Eg}{Vt}\left(\frac{T}{Tn} - 1\right)\right] \quad (3)$$

Vt is called thermal voltage-

$$Vt = {}^{K.T}/_{q} \quad (4)$$

The current output of pv module is-

$$Ipv = Np*Iph - Np*Io\left[\exp\left\{\frac{q*(Vpv+I.Rs)}{Ns.A.K.T}\right\} - 1\right] \quad (5)$$

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V. MAXIMUM POWER POINT TRACKING

MPPT is an algorithm that included in charge controllers used for extracting maximum available power from pv cell/module under certain conditions. This voltage at which pv cells/module can provide maximum power is called maximum power point (or peak power voltage)[11]. The output power depends on it radiation, temperature and it's parameters and product of voltage and current.

PERTURB AND OBSERVE (P&O) METHOD:-

P&O is mostly used algorithm for MPPT. And it operated by the periodically perturbing (increasing or decreasing). It involves introducing perturbation in power operating voltage. In this algorithm if the power has increased, it keeps same direction (increase voltage) otherwise, changes its direction (decrease voltage). This process is repeated at each MPP tracking step until the MPP is reached. After reaching the MPP, the algorithm naturally oscillates around its correct value. It means power decreases then continue vary the voltage or current in the reverse direction.

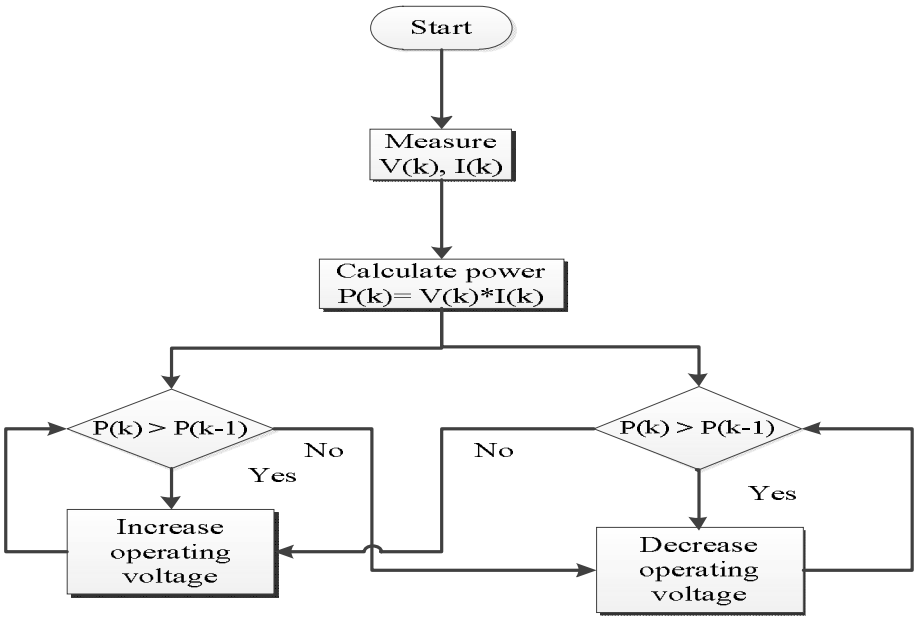

Fig:- Flow chart for P&O method

INCREMENTAL CONDUCTANCE METHOD:-

The P&O method is not sufficient for all condition of the MPP, and it fail under continues changing environment condition. So overcome this condition we use incremental conductance method. In this method used to derivative of the current with respect to the voltage to reach the maximum power point (MPP). This maximum power should be equal to $\mathbf{di/dv = -i/v}$. The variation in the voltage towards biggest or smallest value it also be affected the power value. If power increase then should continue in the same direction. If power decrease then should be reverse direction.

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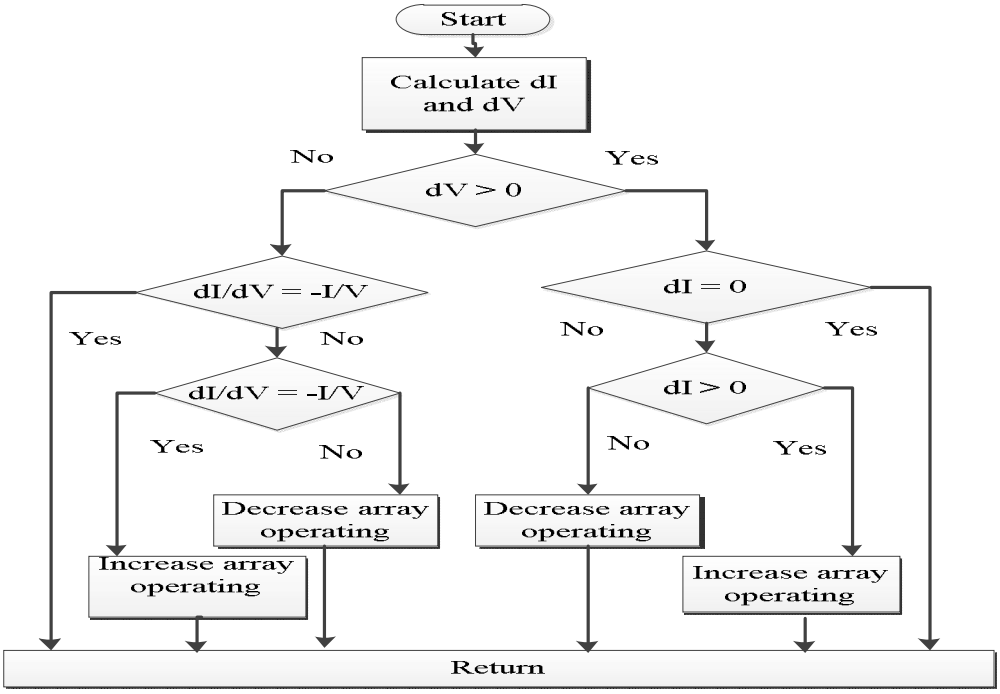

Fig:- Flow chart of Incremental conductance method

VI. SIMULINK PV MODEL

The blocks of the model are developed using MATLAB/Simulink based on mathematical equations [5]. The photovoltaic model and circuits that can be used in simulation of power conversion for its applications and shows the different conditions related to physical and environmental to estimate the electrical behaviour of the pv cell [9].
The simulation model of photo current (Iph) as shown in below-

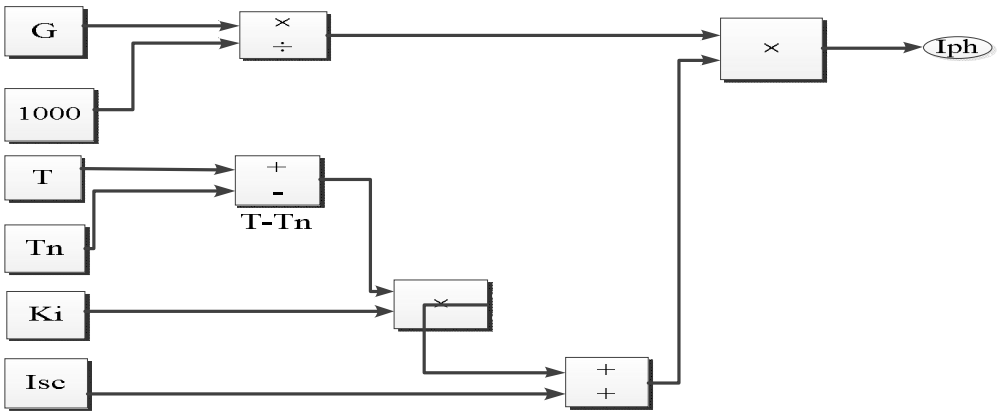

Fig :- Simulation model of calculation of Iph

And the Simulation model of reverse saturation current (Is) is-

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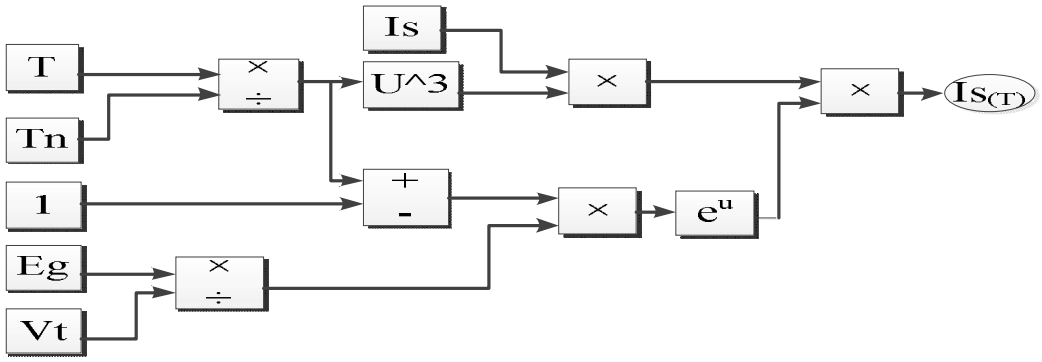

Fig:- Simulink model of Reverse saturation current

VII. CONCLUSION

A pv model based on the mathematical equation of solar cell is developed using MATLAB/Simulink model. In pv array works only part of the I-V characteristic near the working point maximum voltage and current. The photovoltaic system works most of time with maximum efficiency. The behaviour of the pv cell in electrical changes in the varies parameters like resistance, sun irradiation, temperature, and parameter of the diode are value considered as input and the I-V and P-V characteristics are considered to output. Increasing temperature yields decreasing power and voltage and increasing sun irradiation the current and voltage and also power will be increased. Parallel resistance, no significant effect or (little effect) on the I-V and P-V curve if change of resistance has a very low effect on power. So removing it to have a simple model, and increasing the series resistance results in the decreasing the power, increasing the diode ideality factor power is increased, while and increasing the amount of reverse saturation current power will reduce. In the paper two techniques (P&O, incremental conductance method) used to maximize the output power. By analysing the current with the help of mathematical model it has very convenient justified, required parameters by changing the value.

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