Modelling And Simulation of Photovoltaic Module and MPPT algorithm

Shubhangi R. Raut

Electrical Engineering Department
Ramdeobaba College of Engineering and Management, Nagpur, India

***Abstract*— This paper presents the modelling of photovoltaic cell/ module based on mathematical equations and its simulation in MATLAB/SIMULINK. The I-V characteristic and P-V characteristics are obtained for different isolation and constant temperature. For extracting maximum power from solar, maximum power point tracker i.e., MPPT algorithm had been proposed.**

***IndexTerms*— PV cell/module/array, MPPT, MATLAB/SIMULINK**

I. INTRODUCTION

A photovoltaic (PV) system directly convert solar energy into electrical energy by the photovoltaic effect. Resources for conventional energy decreasing day by day stirring up worries among many. As sun is a clean source of energy, PV energy gained significant attention rapidly nowadays. Environmental issues and concern on global warming are other incentives that favor the development of photovoltaic power.

Grid connected photovoltaic system is establishing everywhere. Nowadays interconnection system is used in India as well as thegrid to grid interconnection system with other countries for continuous supply of solar energy so that we can get the power at night also. Therefore designing of economical and efficient photovoltaic system is necessary. With the use of newest power control mechanismcalled the maximum power point tracking (MPPT) algorithm has led to the increase in the efficiency of operation of the solar module and thus is effective in the field of utilization of renewable resources of energy.

II. PV CELL/ MODULE/ ARRAY

PV cell is basically semiconductor diode. This semiconductor diode has a p-n junction which is exposed to light. When illuminated by sunlight it generates electrical power. PV cell are made up of various semiconductor materials, but mono-crystalline and poly-crystalline silicon are mainly used for commercial use.

The power produced by a single PV cell is not enough for general use. So by connecting many single PV cell in series and parallel according to voltage and current requirement can get us the desired power. Generally a series connection is chosen, this set of arrangement is known as a module. Commercial module consist of 36 or 72 cells.

Interconnection of modules is known as a photovoltaic array (PV system)which in turn is made up of many PV cells in series and parallel. This photovoltaic hierarchy is shown in figure below.

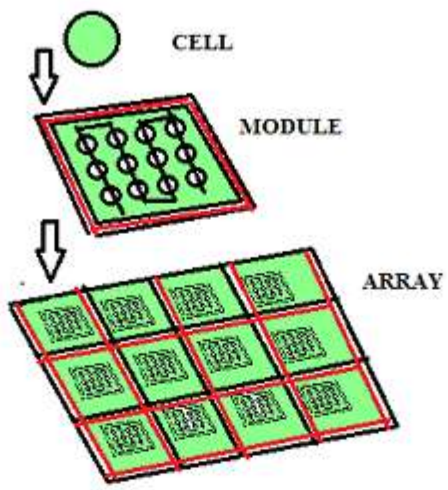


Fig. 1 - Photovoltaic Hierarchy

III. MODELLING OF PV CELL

A solar cell is the building block of a solar panel. A photovoltaic module is formed by connecting many solar cells in series and parallel. Theuse of equivalent electric circuits makes it possible to model characteristics of a PV cell. For modelling, it is necessary to analyze the influence of different factors on the photovoltaic cell. Considering only a single solar cell; it can be modeled by utilizing a current source, a diode and two resistors. This method is known as single diode model of solar cell. It is the most simple and the most used model for PV cell and it is given in figure below.

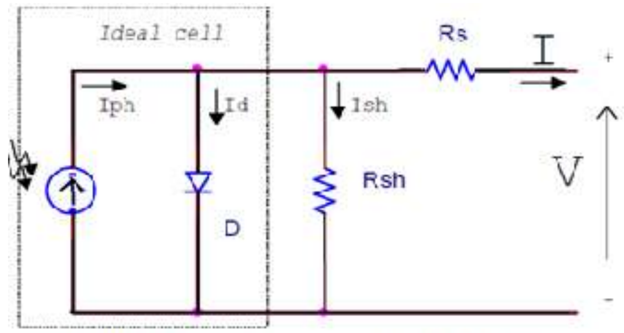


Fig. 2- Single diode model of PV cell

In this model we consider a current source (I) along with a diode and series resistance (Rs). The shunt resistance (Rsh) in parallel is very high, has a negligible effect and can be neglected.

By applying Kirchhoff's current law in above circuit, the output current from the photovoltaic array is

$$\mathrm{I} = \mathrm{Iph(photon\ current)} - \mathrm{Id(diode\ current)} - \mathrm{Ish(current\ in\ parallel\ branch)} (1)$$

$$Iph = [\mathrm{Isc} + \mathrm{Ki}\ (\mathrm{T} - \mathrm{Tr})\ \gamma](2)$$

$$Id = Is\,.(exp^{\frac{V+Rs*I}{AKT}} - 1)\ (3)$$

And $\mathrm{Vt} = \frac{\mathrm{KT}}{\mathrm{q}}$ (4)

On the other hand, the cell saturation current varies with the cell temperature, which is described as

$$\mathrm{Is(t)} = \mathrm{Irs}\left(\frac{\mathrm{T}}{\mathrm{Tr}}\right)^3 \exp\left[\frac{\mathrm{qEg}\left(\frac{1}{\mathrm{Tr}}-\frac{1}{\mathrm{T}}\right)}{\mathrm{KA}}\right] (5)$$

Where
Isc = short circuit current
Ki = temperature coefficient having value 0.0017 A/°C
T = working temperature
Tr = reference temperature
γ = solar radiation W/m^2
Vt = terminal voltage
K = Boltzmann's constant having value 1.38*10^-13 J/K
q = electron charge having value 1.6* 10^ -19 C
Eg = band gap energy of semiconductor which is approximately 1.2eV
A = diode ideality factor whose value always lie between 1 to 5

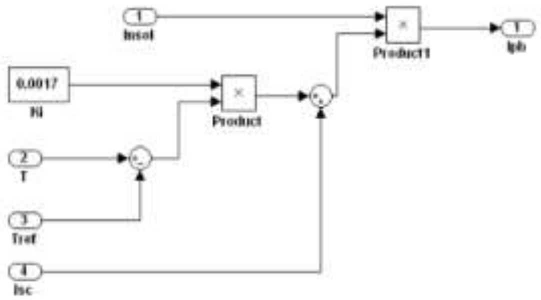
Since normally Iph >> Is and is ignoring the small diode and ground leakage current under zero short circuit current. Isc is approximately equal to the photocurrent Iph i.e., Iph = Isc .On the other hand, the Voc parameter is obtained by assuming the output current is zero. Given PV open circuit voltage Voc at reference temperature and ignoring the shunt leakage current, the reverse saturation current at reference temperature can be approximately obtained as

$$\mathrm{Irs} = \frac{\mathrm{Isc}}{\left[\exp\left(\frac{\mathrm{q*Voc}}{\mathrm{KTA}}\right)-1\right]}(6)$$

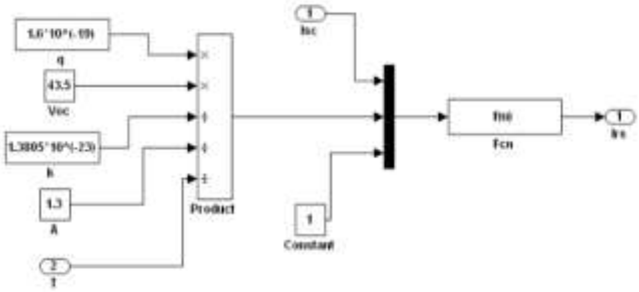
Where
Irs = diode reverse saturation current
Voc = open circuit voltage
And current in shunt branch is given as

$$\mathrm{Ish} = \frac{(\mathrm{V+I*Rs})}{\mathrm{Rsh}}\ (7)$$

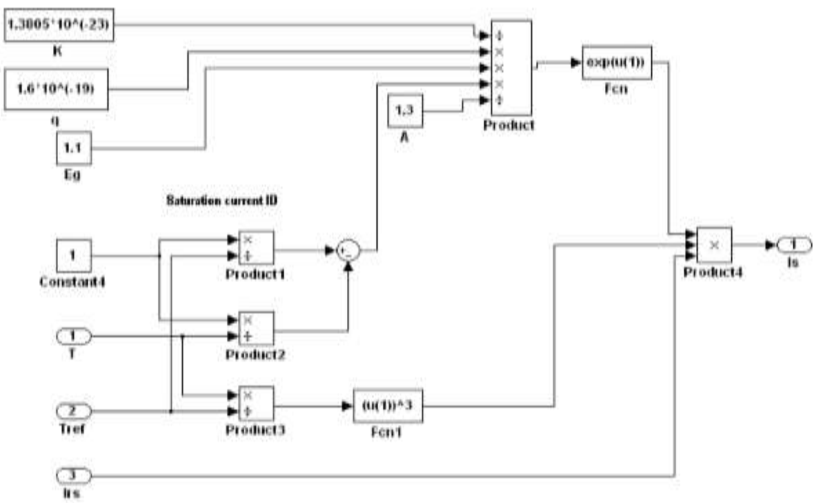
IV. MATLAB MODEL OF PV MODULE ACCORDING TO EQUATIONS



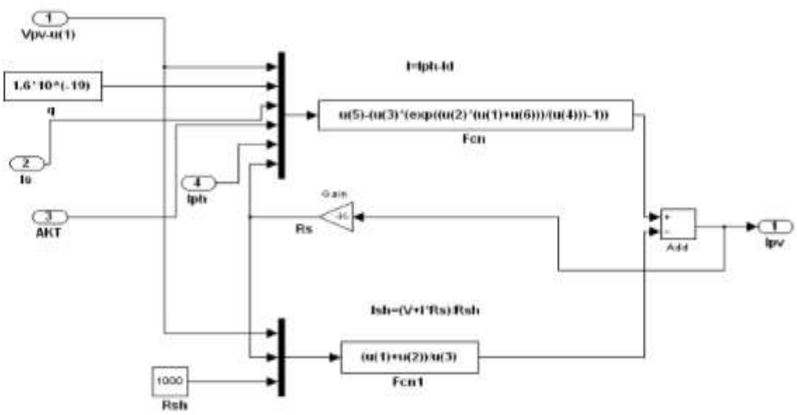
$$\text{Irs} = \frac{\text{Isc}}{\left[\exp\left(\frac{q*\text{Voc}}{\text{KTA}}\right) - 1\right]}$$

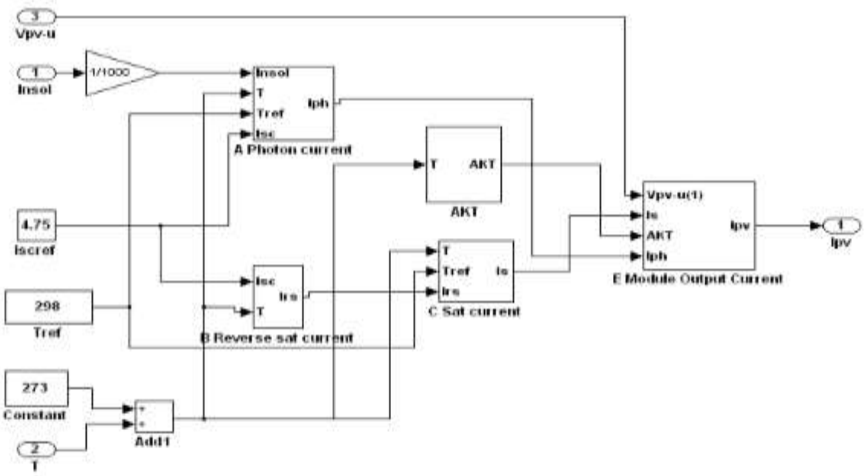


$$\text{Is(t)} = \text{Irs}\left(\frac{\text{T}}{\text{Tr}}\right)^3 \exp\left[\frac{\text{qEg}\left(\frac{1}{\text{Tr}} - \frac{1}{\text{T}}\right)}{\text{KA}}\right]$$



$$\text{I} = \text{Iph} - \text{Id} - \text{Ish}$$



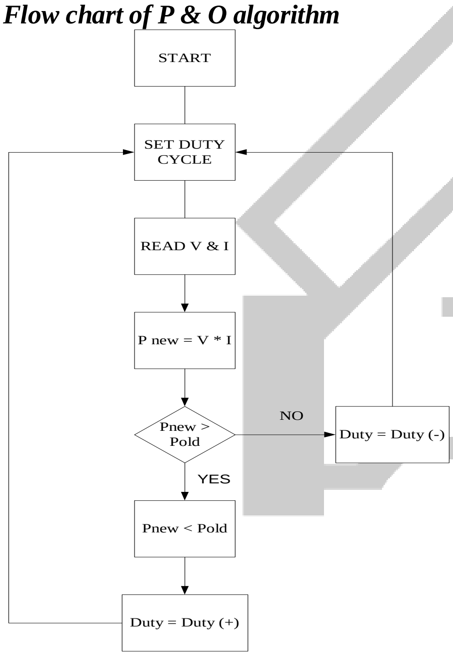


V. MAXIMUM POWER POINT TRACKER (MPPT) ALGORITHM

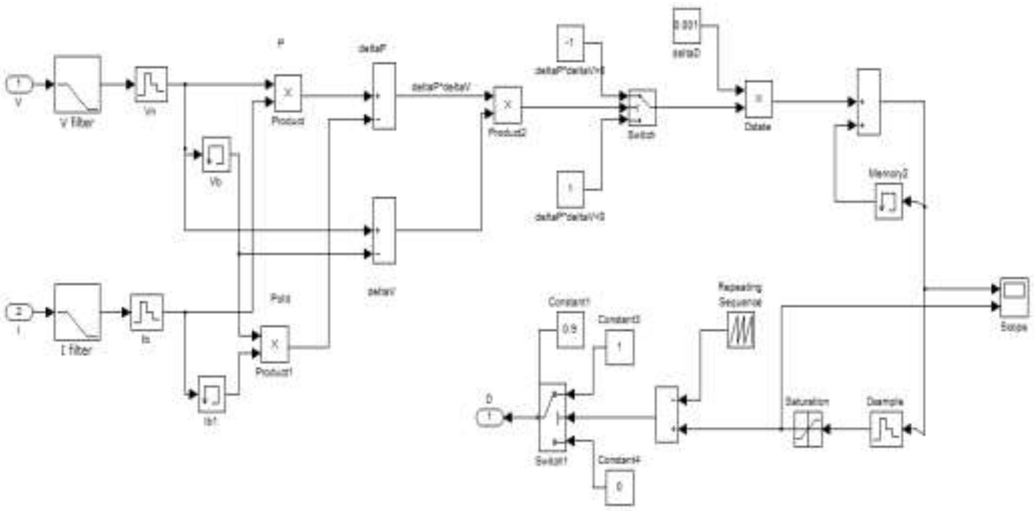
The MPPT algorithm embedded in charge controller takes voltage and current feedback from the panel and adjust the control signals to operate the panel at its peak power. There are various algorithm to track the maximum power and operate the PV module on that point to extract the maximum power but here perturb and observe (P&O) method is used as it is most commonly used algorithm because of its ease of implementation.

Perturb & Observe (P&O) method

Flow chart of P & O algorithm

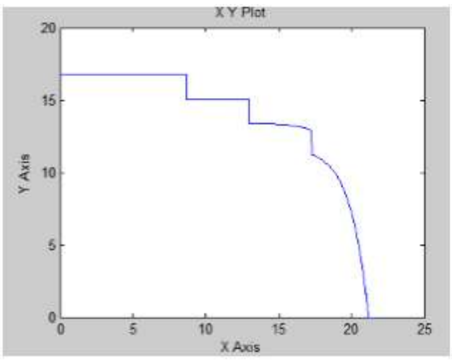


Matlab model of P & O algorithm

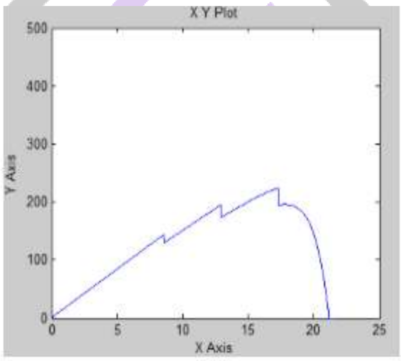


VI. SIMULATION RESULTS

PV characteristic for varying irradiations of single module



I-V characteristic



P-V characteristic

VII. CONCLUSION

The P-V and I-V curve of a solar cell are highly dependent on the solar irradiation values. The solar irradiation as a result of the environmental changes keeps on fluctuating. Higher the solar radiation, higher would be the solar input to the solar cell and hence power magnitude would increase for same voltage value. With increase in solar irradiations the open circuit voltage increases due to the fact that, when more sunlight incident on solar cell, the electrons are supplied with higher excitation energy thereby increasing the electron mobility and thus more power is generated. On the contrary the temperature increases around the solar cell has a negative impact on power generation capability. Increase in temperature causes increase in the band gap of a material and thus more energy is required to cross this barrier. Thus the efficiency of the solar cell is reduced.

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