Implementation of MPPT Algorithm Using Firefly Technique for Solar Photovoltaic Systems

Bhavana Prasad B .M[1] A. Chitra[2]
[2]Assistant Professor
[1,2]Department of Electrical Engineering
[1,2]AMC Bangalore

Abstract— This paper presents a new firefly technique based Maximum Power Point Tracking (MPPT) algorithm for solar panel. The Solar panel can produce maximum power at a particular operating point called Maximum Power Point (MPP).To produce maximum power and to get maximum efficiency, the entire photovoltaic panel must operate at this particular point. Maximum power point of PV panel keeps on changing with changing environmental conditions such as solar irradiance and cell temperature. Thus to extract maximum available power from a PV module, MPPT algorithms are implemented. The solar panel is modelled and analysed in MATLAB/SIMULINK. In this paper, Incremental Conductance approach & firefly algorithms based MPPT has been developed and comparative studies between them shows more sophisticated approach of obtaining maximum power is also being analysed. Simulation results also shows the effectiveness of the firefly based technique to produce a more stable power.

Key words: Maximum Power Point Tracking (MPPT), Photovoltaic (PV) System, Incremental conductance (IncCond), firefly (FF)

I. INTRODUCTION

Solar Photovoltaic (PV) system converts sunlight into electricity with no pollution, no maintenance and no depletion of natural resources. The output power induced in a PV module depends on solar insolation and temperature of the solar cells[1]. In order to get maximum power from the solar panels, they have to operate at their maximum power point despite the changes in the environmental conditions. To operate the PV array at its maximum power point, the PV system can implement a maximum-power point tracking (MPPT) controller[1]. MPPT algorithms are necessary because PV arrays have a non-linear voltage-current characteristic. The electric characteristics of the PV cell depend mainly on the irradiance received by the cell, and the cell temperature. In order to determine the characteristics of the PV module, the Power vs. Voltage (P-V) and Current vs. Voltage (I-V) curves must be constructed. Three parameters, namely, OpenCircuit voltage (Voc), Short circuit current (Isc), and Maximum Power Point (Vmp, Imp), given by the manufacturer of the PV module, are used for the prediction of the PV characteristics of solar PV module[2]. The Typical P-V and I–V characteristics of a PV cell are shown in Fig-1. There is a unique Maximum Power Point (MPP) on the P–V curve, at which the PV cell generates the maximum power. This point is known as the maximum power point (Vmpp, Impp).

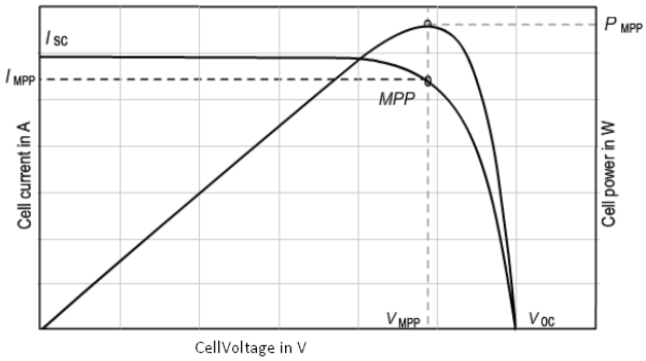

Fig. 1: P-V And I-V Curve Of Solar PV Cell

II. MPPT METHODS

In the past years numerous MPP tracking methods have been proposed. They differ in many aspects such as complexity, accuracy, sensors required, cost or efficiency, and speed. Based on the control variable it uses, each method can be categorized. There are different MPPT techniques such as Perturb and Observe, Hill climbing method, Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Firefly approach, Fuzzy Control, and Neural Network Control, etc[3],. Among all those Firefly algorithm have shown reasonably stable power output at the grid.

A. *Perturb & Observe Method:*

Perturb and observe is the simplest method. In this we use only one sensor that is either voltage sensor or current sensor, to sense the PV array voltage or current and so the cost of implementation is less. In this method the sign of last perturbation and last increment in power are used to decide what the next perturbation should be. If there is an increase in the power, the perturbation should be kept in the same direction and if the power decreases, then the perturbation should be in the opposite direction [2]. The process is repeated until the MPP is reached. Then the operating point oscillates around the MPP. Also this method does not take account of the rapid change of insolation level and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP [4]. To avoid this problem we can use incremental conductance method.

B. *Incremental Conductance:*

Incremental conductance method uses two sensors, that is voltage and current sensors to sense the output voltage and current of the PV array. Algorithm works by comparing the ratio of derivative of conductance with the instantaneous conductance [5]. When this instantaneous conductance equals the conductance of the solar then MPP is reached. The basic equations of this method are as follows

$$\frac{dI}{dV} = -\frac{I}{V} \quad ,at\ MPP \qquad (1)$$

$$\frac{dI}{dV} > -\frac{I}{V} \quad ,left\ of\ MPP \qquad (2)$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad ,right\ of\ MPP \qquad (3)$$

Where I and V are the PV array current and voltage respectively. The left-hand side of the equations represents the IncCond of the PV module, and the right-hand side represents the instantaneous conductance. From (1)–(3), it is obvious that when the ratio of change in the output conductance is equal to the negative output conductance, the solar array will operate at the MPP. In other words, by comparing the conductance at each sampling time, the MPPT will track the maximum power of the PV module. Here we are sensing both the voltage and current simultaneously. Hence the error due to change in insolation is eliminated. However the complexity and the cost of implementation increases. The drawbacks of these techniques are mainly two. The first and main one is that they can easily lose track of the MPP if the solar insolation level changes rapidly. The other one is the oscillations of the voltage and current around the MPP in the steady state. This is due to the fact that the control is discrete and the voltage and current are not constantly at the MPP but oscillating around it.

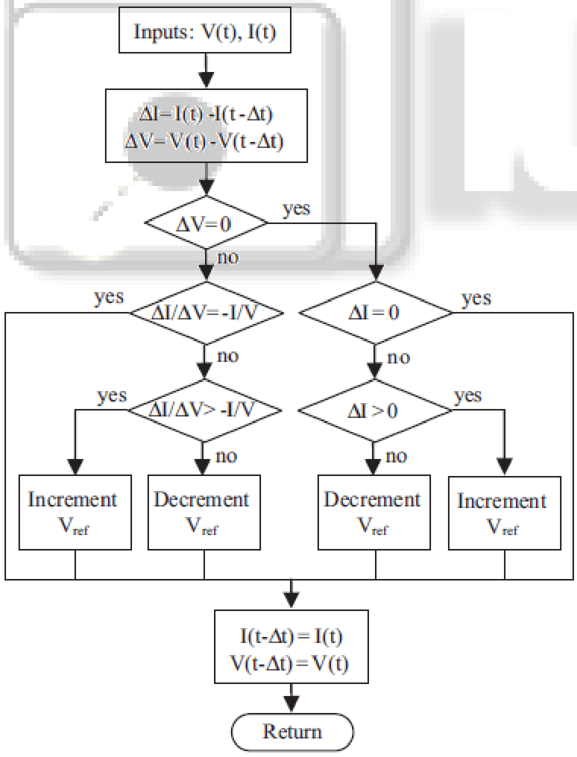

Fig. 2: IncCond Algorithm

The maximum output power, PMPP=VMPPIMPP, is obtained by differentiating the PV output power with respect to voltage and setting the result to zero[6]. The MPP can thus be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance(I/V) as shownin the flowchart given in Fig.2. Vref is the reference voltage at which the PV array is forced to operate. AttheMPP, Vref equals to VMPP. Once the MPP is reached, the operation of the Varray is main tainedat this pointunlessa change incurrent, I, occurs as a resul to fa change in atmospher ic conditions leading to avariation in MPP. The algorithm,then,tracks the MPP by applying decrement sorincrements to Vref. The size of the increment or decrement determine show fast the MPP is tracked. Fast tracking can be achieved by applying larger increments, but the system may not operate exactly at the MPP and oscillations around the MPP may result. That is, use of the Inc Cond method involves at rade-off between speed of convergence and the like li hood of appearance of oscillations around the MPP.

III. PROPOSED METHOD

In this paper, a modified firefly method is proposed**.** Firefly algorithm [14]-[15] is a new meta-heuristic algorithm inspired by a flashing of fireflies, for optimizationproblemsby the movement of lightning bugs known asfireflies. The fundamental flashes of such fireflies are toattract mating partners and to attract potential prey. Thefollowing assumptions are, all fireflies are unisex. Onefirefly can be attracted to other firefly regardless of sex[7].The attraction between two fireflies is proportional torelative brightness. If there is no brighter one in the fireflycolony, it moves towards brighter colony. Formaximization problems, the brightness can be simplyproportional to the value of functions. Firefly algorithm issuperior to other methods in terms of tracking speed,convergence to track GMPP and possesses good trackingefficiency. The efficiency can be calculated by taking theratio between output power and maximum power of thePV array under steady state conditions. The advantages ofthese methods, such as simple computational steps, fasterconvergence and implemented in low cost microcontroller.

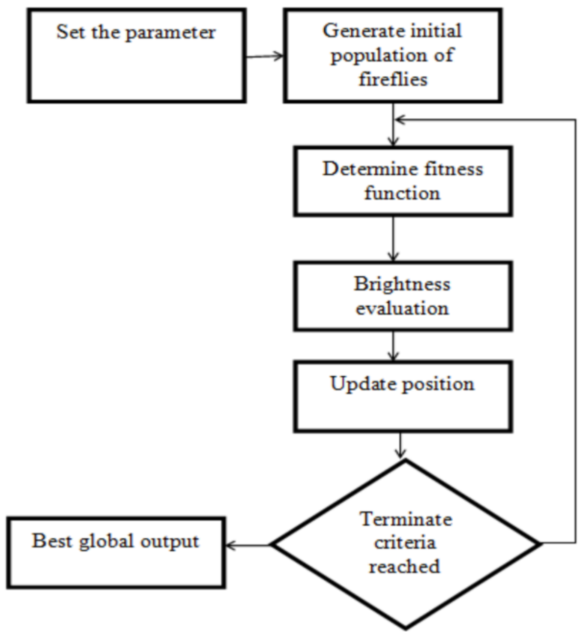

Fig. 3: Flowchart For Firefly Algorithm

IV. DESIGN CONSIDERATIONS

A model of PV module with moderate complexity that includes the temperature independence of the photocurrent source, the saturation current of the diode, and a series resistance is considered based on the Shockley diode equation. Being illuminated with radiation of sunlight, PV cellconverts part of the photovoltaic potential directly into electricity with both I-V and P-V output characteristics.

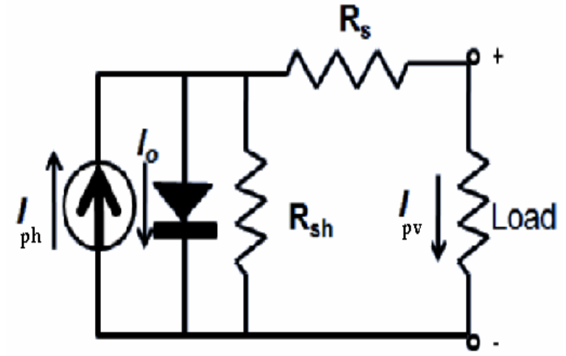

Fig. 4: PV Cell Modelled As Diode Circuit

The current source Iph represents the cell photocurrent. Rsh and Rs are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of Rsh is very large and that of Rs is very small, hence they may be neglected to simplify the analysis[6].

The photovoltaic panel can be modeled mathematically asgiven in equations (1)- (4)

Module photo-current:

$$I_{ph} = [I_{SCr} + K_i(T - 298)] * \lambda / 1000 \qquad (1)$$

Module reverse saturation current - I_{rs}:

$$I_{rs} = I_{SCr} / [\exp(qV_{OC} / N_s kAT) - 1] \qquad (2)$$

The module saturation current I_0 varies with the cell temperature, which is given by

$$I_0 = I_{rs}[\frac{T}{T_r}]^3 \exp[\frac{q * E_{g0}}{Bk}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}] \qquad (3)$$

The current output of PV module is

$$I_{PV} = N_P * I_{ph} - N_P * I_0[\exp\left\{\frac{q * (V_{PV} + I_{PV} R_s)}{N_S AkT}\right\} - 1] \qquad (4)$$

Where $V_{pv} = V_{oc}$, $N_p = 1$ and $N_s = 36$

V. SIMULINK MODELLING

Being illuminated with radiation of sunlight, PV cellconverts part of the photovoltaic potential directly intoelectricity with both I-V and P-V output characteristics[7]. Using the equations, Simulink modelling is done using firefly algorithm. Fig-5 shows the Simulink model using firefly algorithm

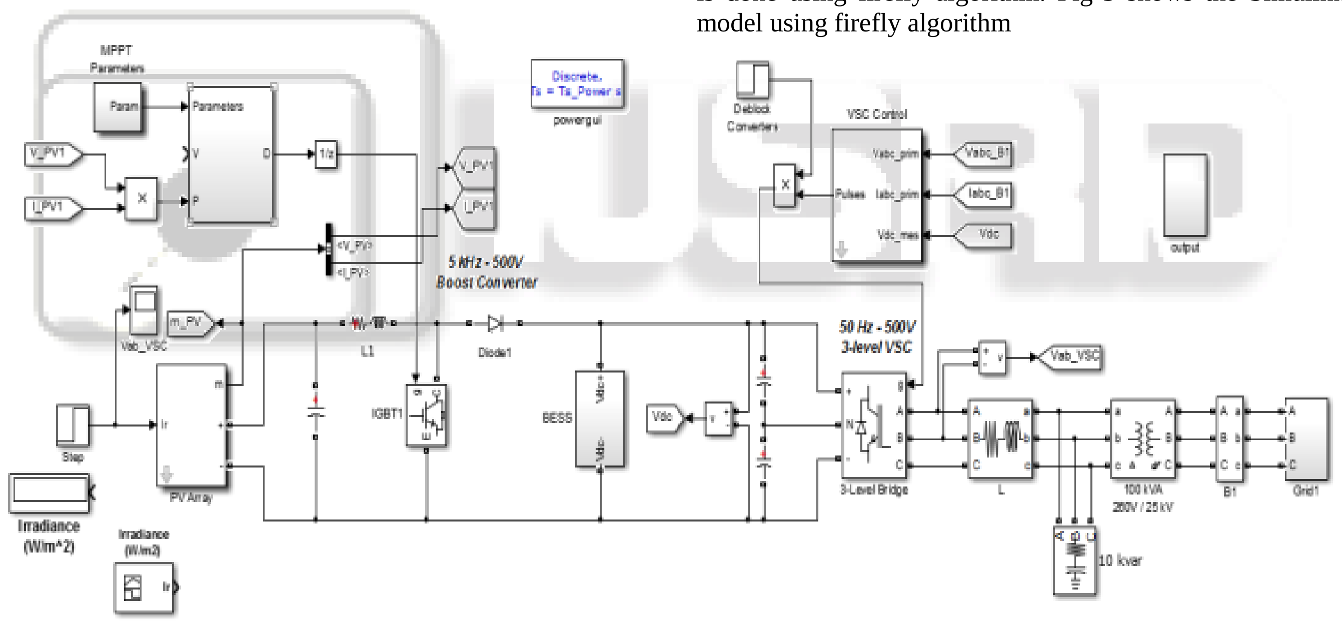

Fig. 5: Firefly Algorithm

The model is run by Mex support compiler & the waveforms shown in Fig-5 clearly visualises the output voltage supplied to the grid.

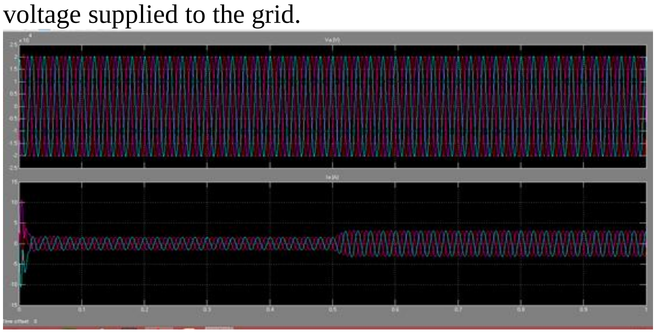

Fig. 6: Voltage Measurements

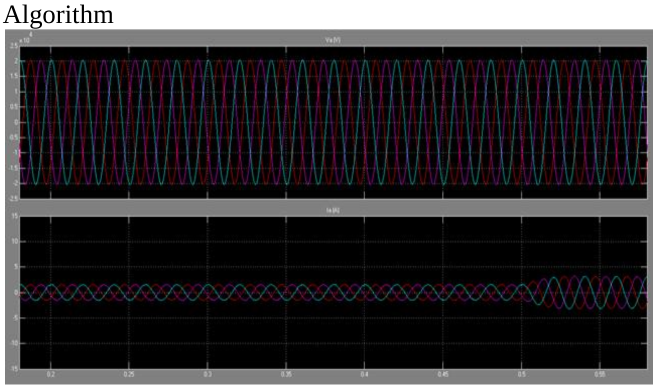

Fig. 7: Current Measurements

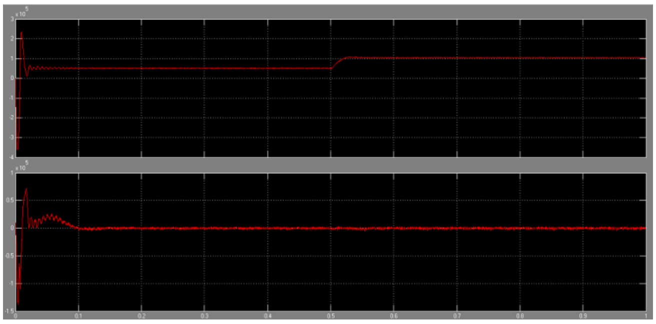

Fig. 8: Real & Reactive Power

VI. CONCLUSION

A general approach on modelling photovoltaic modules is presented. The proposed MPPtracking computational method is based on a DC/DC converter control with an firefly algorithm. The theoretical evaluations of the MPPT advantages, based on the proposedmodel, suggest that the power gain, obtained by MPP tracking, is higher than 27%.We developed, simulated and evaluated two MPPT algorithms, based on presented model and a comparative analysis is being carried out.The proposed algorithms are independent of the used solar panel type, which could be considered a "black box".

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