A COMPARATIVE ANALYSIS OF VARIOUS OPTIMIZATION TECHNIQUES FOR MPPT IN RENEWABLE ENERGY SYSTEM WITH NONLINEAR LOAD VARIATION

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Abstract

Electrical energy is the most widely used forms of energy worldwide. Solar is the important energy resource and abundantly available in nature. The world’s production of electrical power from the solar has been increasing at a fast rate during the last two decades. The Maximum Power Point Tracking (MPPT) plays significant role in the PV systems to get peak power under any irradiance levels. Conventional techniques such as Perturb & Observe (P&O) and Incremental Conductance (InC) has been applied so far for tracking of maximum solar power. But in the recent years, many computational techniques also been used for MPPT in the literature. Therefore, this work demonstrates the application of the more recent computational techniques like Antlion Optimizer (ALO) and FireFly Algorithm (FFA) for MPPT under nonlinear load variations. A comparative study of these techniques ALO, FFA along with InC method is also presented. The results reveals that ALO optimizer gives optimal peak power from PV systems than the other two methods under above said conditions.

Keywords:*MPPT, ALO, Ants, Antlions, Elite, Ant fitness, Antlions fitness.*

INTRODUCTION

Day by day, the demand for electricity increases rapidly. Extent of non-renewable energy sources produces the demand for renewable energy sources. Renewable energy stands as a hope for the future generation. There are different renewable energy which is being given to the humans for making their life standard. Suitable and abundant source is solar energy because of its feasibility and scalability and free of maintenance [1]. The PV system has been marketed in many countries because of eco-friendly nature [2]. But the high installation price has been a factor to implement of this technology.

The below diagram embraces PV module, DC to DC converter, Inverter, and grid as indicated in Fig. 1. MPPT plays a major role in this system to match impedance of input source and load [3] [4]. Many solar cells linked in series, we called it as PV module. The equivalent circuit of PV cell shows in

Fig. 2.

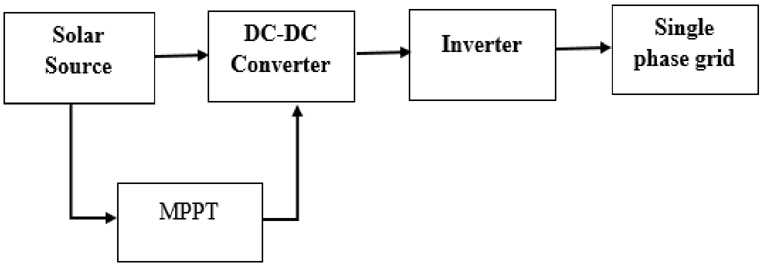


Figure. 1. Block diagram of PV system

For small system battery is required and for extent arrangement inverter is connected to the grid.

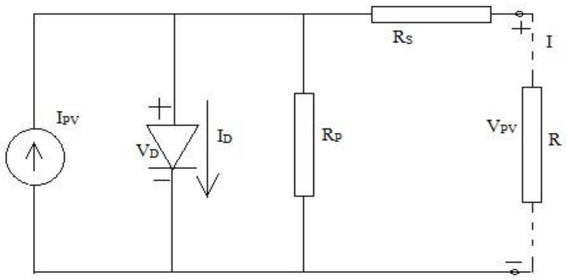


Figure. 2. Equivalent circuit of Solar PV Cell

Where $\mathbf{V_{PV}}$ and $\mathbf{I_{PV}}$ are the voltage and current of the PV cell, $\mathbf{R_S}$ is the series impedance, $\mathbf{R_P}$ is a parallel resistance respectively. The output current is determined by

$$I = I_{PV} - I_O[exp\,(V+IR_S)/\,aV_T) - 1] - (V + IR_S)/R_P \quad \textbf{(1)}$$

The Maximum Power Point can b k e determined by panel temperature and irradiance condition. To extract maximum available power from PV system, the operating point must be tracked accurately in all-weather by using MPPT algorithm. And, we can increase the life span of the PV system using MPPT algorithm.

II. MAXIMUM POWER POINT TRACKING (MPPT) TECHNIQUES:

There are different MPPT techniques available for extracting maximum power from solar. Some of the important techniques are discussed below.

- Perturb & observe
- Incremental conductance

2.1 Perturb & observe method:

Compared to other techniques P&O has advantage like low implementation cost. This is a stranded algorithm to find MPP.But P&O technique suffers with one disadvantage, its keep on changing operating point, according to the sun irradiance. Thus, it never reaches the actual MPP [5].

2.2 Incremental Conductance method:

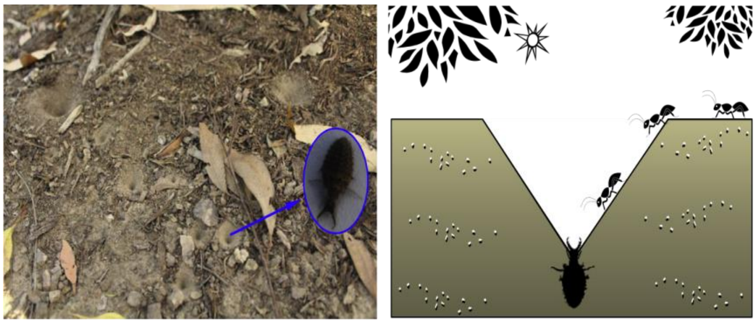
The drawback (i.e., oscillations around operating point) of P&O can be eliminated by InC method. The basic InC method used a fixed step size for operating panel voltage. From the figure, zero point shows the MPP and positive MPP on the left side and negative MPP on the right side[6]. Using bigger size will speed up tracking but may also cause oscillations around MPP. In this technique, for tracking new MPP, $\mathbf{V_{ref}}$may increase or decreases.

In both P&O and InC schemes, time involved to track the MPP depends on the size of the increment of the reference voltage ($\mathbf{V_{ref}}$). In order to increase tracking speed, the large step size is required. But in these techniques, the system will not operate exactly at the MPP and it will oscillate around the MPP. It will contribute to poor efficiency. This can be worked by altering the size, but this algorithm requires complex and costly control circuit.

III. PROPOSED ALGORITHMS

3.1 Antlion Optimizer (ALO):

Antlion optimizer (ALO) is a recent metaheuristic algorithm, introduced by Seyedali Mirjalili in 2015 [9] that replicates the hunting scheme of antlions in catching ants. This strikes five steps in hunting ants namely, the casual way of walking of ants, constructing deceptions, frame of ants in deceptions, gathering ants, and reconstruction deceptions. Antlion is a net-winged insect. The life cycle consists two stages, namely, larvae and adult. The total lifespan is 3 years. Antlions undergo transformation in a Cocoon to become an adult. They are mostly hunting process occur in larvae period and remaining for reproduction.



(a) (b)

Figure. 3. Trapping Strategy of antlion

A no of cone-shaped pits digging in sand with different sizes indicated in Fig. 3 (a). After that it will hide under the trap and waiting for insects shown illustrated in Fig. 3 (b). The edge of the pit is very sharp, ants have easily fallen into the bottom of the trap. Once the Antlion feels that a prey is in the trap, it proves to get it.

Even, after making it at the bottom end of the pit, ants are trying to get away from the ambush, it will not caught directly. In this case, antlions intelligently throw sands towards to edge of the cone. After seeing the ant consumes its body. Antlions throw the leftovers outside the pit and prepare the trap for the next search.

The detailed steps taken in this algorithm are as follows:

- *Initialization:* An initial population of ants as $X_A = (x_1, x_2, x_3 \ldots x_N)$ and antlions as $X_{AL} = (x_1, x_2, x_3 \ldots x_n)$ is engendered inside the bounds of the parameters. Where N is the population size. The range of upper and lower bounds of the parameter is 0.1 to 0.9. Evaluate the fitness of ants and antlions by using objective function. Identify the best Antlion and assume it as an elite.

- *Constructing deceptions:* Select an antlion for every ant by Roulette wheel selection based on the fitness of antlions to build the trap for ants. The Roulette wheel selection is as follows:

- *Casual way of walking of ants:* The movement of ants is stochastic in nature while searching for food. The random walk of ants is mathematically formulated as

$X(t)$ = [0, $cumsum$ (2$r(t_1)$−1), $cumsum$ (2$r(t_2)$−1) ,… ,

$cumsum$ (2(t_n−1)] ⟶ **(2)**

Where cum sum - Cumulative sum, n- Maximum number of iteration, t- Step of random walk, and r (t) -stochastic function, which is defined as

(t) = { 1 if d> 0.5

0 if and< 0.5 ⟶ **(3)**

Where Rand is the randomly generated number between the interval [0, 1]. The random walk of ants is normalized usingequation (6) to uphold the position of ants within the search distance.

$$X_i^t = \frac{(X_i^t - a_i) \times (d_i - C_i^t)}{(X_i^t - a_i)} + C_i \quad \textbf{(4)} \longrightarrow$$

Where a is the minimum of random walk, b is the maximum of a random walk, c is the lower bound variable and d is the upper bound variable. The random walk is normalized. Random walk of ant around an Antlion R_A selected by Roulette wheel and random walk of ant around an Antlion R_E is performed and normalized.

- *Trapping of ants:* Trapping of ants is formulated mathematically as,

$$C_i^t = Antlion_i^t + C^t d_i^t = Antlion_i^t + d^t \quad \textbf{(5)} \longrightarrow$$

Where, i is the index of the selected ant and j is the index of antlion.

- *Sliding of ants towards Antlion: when an ant tries to take away from the trap, Antlion throws sand on the boundary of the trap to slide the ant towards the ambush.* This sliding mechanism is formulated as,

$$C^t = \frac{C^t}{I} \qquad d^t = \frac{d^t}{I} \quad \textbf{(6)} \longrightarrow$$

Where I = 10^w t/T, t is the current iteration, T is the maximum iterations, w is the constant that depends on iteration and it is defined as:

w = 2 when t > 0.1T

w = 3 when t > 0.5T

w = 4 when t > 0.75T

w = 5 when t > 0.9T

w = 6 when t > 0.95T **(7)** ⟶

- *Catching prey and re-constructing pit:* the fitness of the new position of the ant is evaluated. If the ant suits fitter than its equivalent antlion, ant is caught by antlion and then the antlion re-constructs the trap for the next hunt.

$$Antlion_i^t = Ant_i^t \, if \; f\left(Ant_i^t\right) > f\left(Antlion_i^t\right) \quad \textbf{(8)} \quad \longrightarrow$$

This process is given off from catching prey and re-constructing the pit in the position where there is a better chance of catching ants for the next iteration.

- *Elitism:* The position of the best antlion (elite) is maintained in the process of optimization by elitism. The below equation depicts elitism.

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \quad \textbf{(9)}$$

- Update elite if an Antlion becomes fitter than elite.
- Stop if termination criteria are achieved or else proceed to step 3 to begin the next iteration.

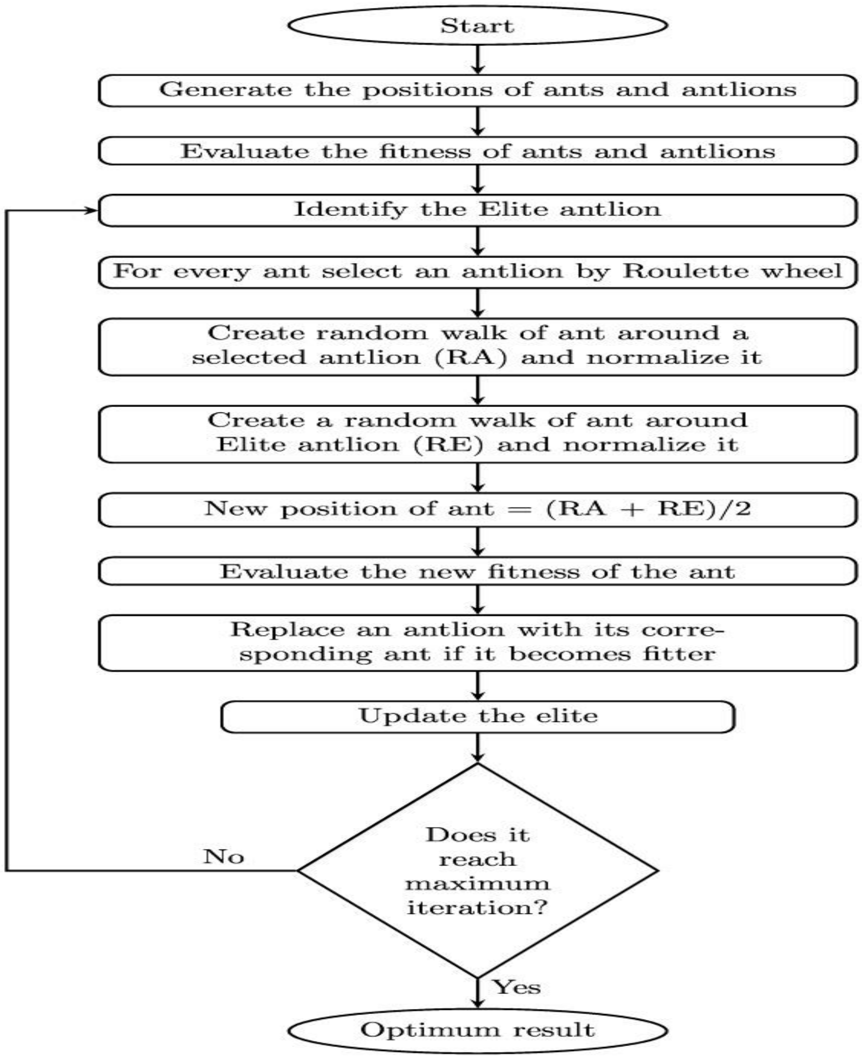


Figure. 4. Flow Chart for ALO

The stepwise algorithm discussed above is shown in fig.4

Pseudo Code for ALO:

Initialize the first population of ants and antlions randomly

Calculate the fitness of ants and antlions

Find the best antlions and asuume it as the elite(determined optimum)

While the end criterion is not satisfied

for every ant

Select an antlion using roulette wheel

Update c and d

Create a random walk and normalize it

Update the position of ant

end for

Calculate the fitness of all ants

Repalce an antlion with its corresponding ant it if becomes fitter

Update elite if an antlion becomes fitter than the elite

End while

Return elite

3.2 Firefly Algorithm (FFA):

The FA is a new metaheuristic algorithm is proposed by Yang in 2010 [9], [10]. The Motivation of this algorithm is flashing of fire beetles. The following presumptions are made for this algorithm

- All fireflies are same gender. so that fireflies are attracted to each other regardless their gender.
- Any two fireflies' attractiveness is proportional to relative brightness. Brighter one will attract all lesser one.
- The landscape of the objective function affects the brightness of the firefly.

Brightness is the objective function in maximization problem. Let suppose $X_j$is the i firefly& X_j is the j firefly respectively, and the distance between X_j&X_j fireflies is r_{ij}, by giving equation

$r_{ij} = |X_i - X_j|$**(10)**

β is the degree of attractiveness , it is the function of distance between two fireflies and is given by

$\beta(r) = \beta_0 e^{-\gamma^2}$**(11)**

where γ is the absorption coefficient and controls the light intensity, n = 2 and β_o is initial attractiveness and is chosen as 1.

Presuming that the lesser firefly *i* moves towards the brighter firefly *j*,*i* the fireflynew positionis made by

$X_i^{t+1} = X_i^t + \beta_0 e^{-\gamma^2} ij(X_j^t - X_i^t) + \propto_1 (rand - 0.5)$**(12)**

Where α is the random movement factor and Rand is a random number.

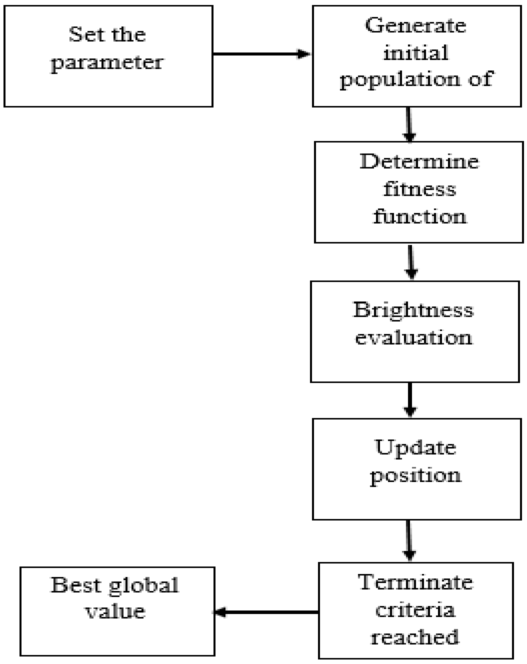


Figure. 5. Flow Chart for ALO

Pseudo Code for FFA:

Objective function f(x), $x=(x_{1,\ldots\ldots}x_d)^T$

Generate initial population of fireflies x_i (i=1,2….,n)

Light intencity I_i at x_i is determined by $f(x_i)$

Define light absorption coefficient γ

While (t< maxeneration)

for i=1:n all n fireflies

for j=1:n all n fireflies (inner loop)

if (I_i< I_j), move firefly I towards j; **end if**

Vary attractiveness with distance r via exp [-γr]

Evaluate new solutions and update light intencity

end for j

end for i

rank the firefly and find the current global best **g**

end while

Postprocess results and visualization

IV. SIMULATION RESULTS AND DISCUSSIONS:

The Simulink model of MPPT using ALO is shown in fig. 6 and also shown subsystems for DC-DC converter, inverter and nonlinear load in fig.7, 8, 9. The simulation circuit includes a 150 MH inductor and 22 µF capacitors for Buck-Boost converter stage, 5 MH inductor and a 90 µF capacitor for Boost converter stage, 0.5 MH inductor for Buck converter stage. Electrical parameters of the PV cell considered in given table 1. Fig.10 shows the maximum power extracted without MPPT, Fig.11, 12 shows the maximum power tracking with InC, FFA & ALO. The maximum power obtained for ALO, FFA and InC methods found to be 1582, 1565 & 1571 respectively.

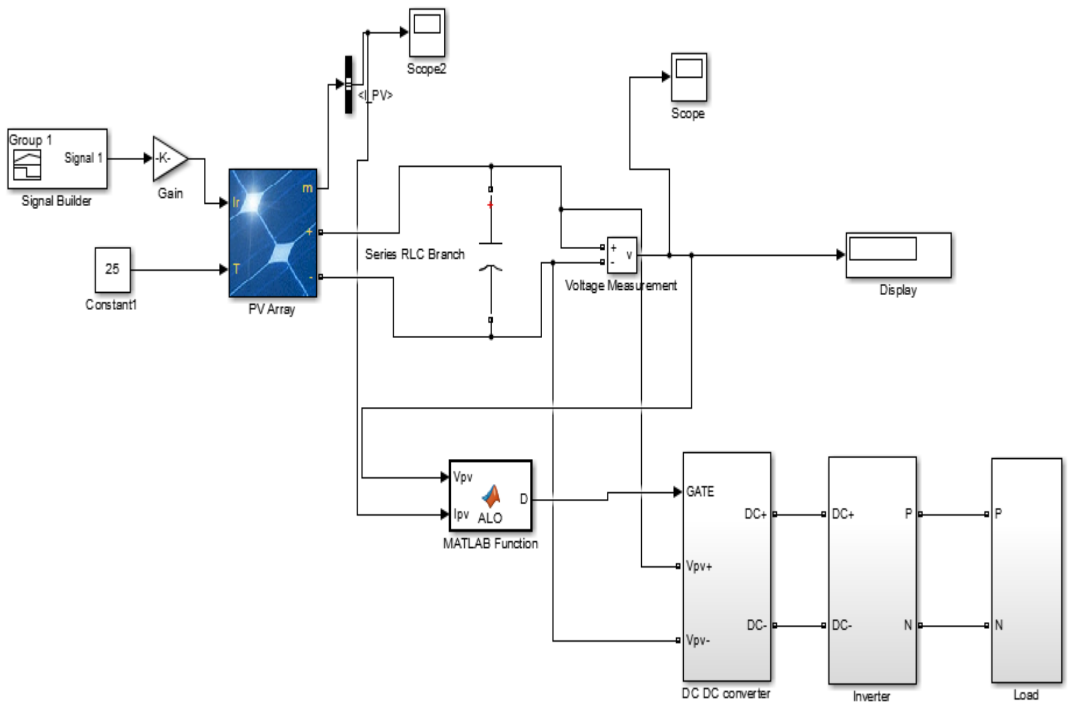


Figure. 6. Simulink Model of MPPT system using ALO

Table 4.1: Electrical parameters of PV cell:

PARAMETERS	VALUES
Maximum power	P_{MAX} =100 W_P
Voltage at MPP	V_{MPP} =17.8 V
Current at MPP	I_{MPP} =5.62 A
Open circuit voltage	V_{OC} =21.8 V
Short circuit current	I_{SC} = 6.2 A
Temperature coefficient of I_{SC}	α=2.46×10^{-3} A/ °C

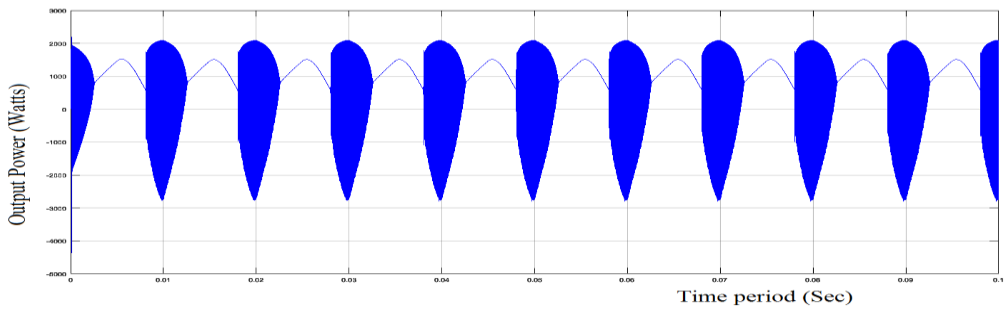


Figure.7

Tracking curve Without MPPT

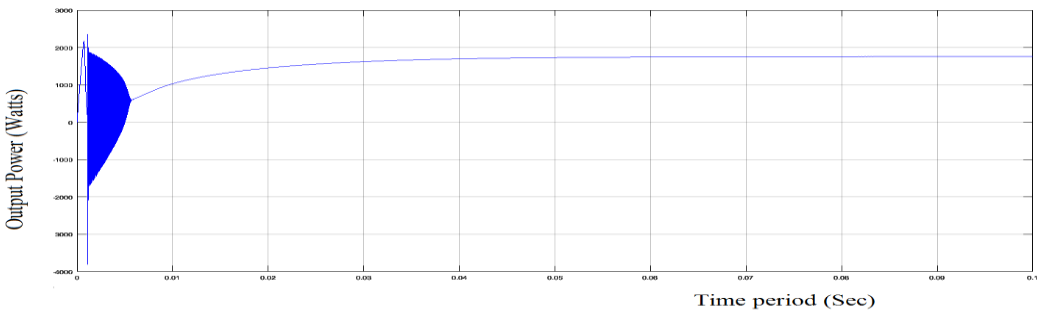


Figure.8 Tracking curve for IC

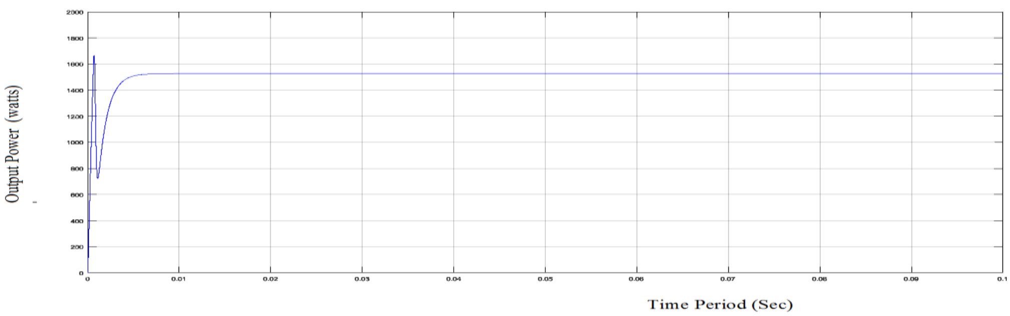


Figure.9 Tracking Curve for FFA

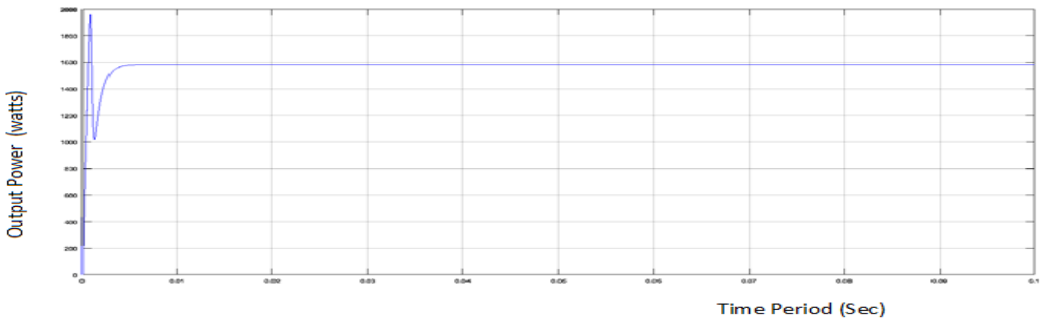


Figure.10 Tracking Curve for ALO

V. CONCLUSION:

The simulation of PV system is carried out using MATLAB/SIMULINK. Initially, the simulation was run without using MPPT and we obtained the load side power as 1456Watts under standard test conditions with notable oscillations around MPP. Then, the simulation was run with the MPPT mode using Antlion optimizer, Firefly Algorithms and InC as well, under the same standard test conditions. It is observed that the PV panel could able to generate approximately 1582 Watts for ALO, 1565 for FFA and 1571 for InC. From the obtained results, it is understood that ALO provides optimal peak power than the other two methods. Thus, the effectiveness of ALO method is proven.

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