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Design of Energy Efficient Low Cost Solar Concentrators using BFO Algorithm

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Abstract: The main problem involved in utilization of solar energy is low efficiency of photovoltaic conversion and high cost. The objectives of the paper are to increase the efficiency of photovoltaic cells and to reduce the cost of the photovoltaic module. A novel method is presented in this paper to increase the efficiency of photovoltaic modules and reduce the cost by the use of specially designed solar concentrators .The efficiency of photovoltaic module is increased by covering an angle of nearly 180° so that the sun's radiation converges throughout the day from all angles on to a fixed flat plate module. The cost is reduced by use of cheaper glass for module and covering a wider area for the radiation. The above objectives are achieved by the use of a special arrangement of three lenses for the concentrators. A dynamic rapid method for tracking the maximum power angle of solar cell arrays known as Bacteria Foraging Optimization (BFO) algorithm has been used. Experimental analysis is presented for the comparison of different positions of the sun for maximum power alignment.

Keywords: Concentrators, Convex Lenses, Focal Length, Radius of Curvature, Refractive Index, Solar Panel, Bacterial Foraging Optimization algorithm, maximum power point.

I. Introduction

An ideal tracker would allow the PV cell to accurately point towards the sun, compensating for both changes in the altitude angle and longitudinal angle of the sun [2]. The reported solutions for MPPT in PV systems are based on different criteria. Some of them estimate the power-voltage or power- current characteristics minimizing the cost of the estimation [3]. Conventionally, standalone PV systems have been used in rural and remote areas where normal electricity supply may not be readily accessible. In modern urban cities with many compactly built high-rise blocks, the concept of building integrated photo-voltaic (BIPV) would be an appropriate alternative form to receive solar energy. However, the energy transfer mechanism is strongly influenced by the illumination condition such as the angle of incidence of the sunlight which varies along the day. All such phenomena can be interpreted as transient or permanent perturbations affecting and reducing the efficiency of the energy production phase. In many part of the world, the basic solar data for the surfaces of interest are not always readily obtainable. It is also impracticable to measure the solar radiation for every tilt angle to deduce the peak value. Traditionally, solar radiation on an inclined surface is modeled using horizontal data. Alternatively, the solar radiation of an inclined plane can be computed by integrating the radiance distribution of the sky seen by the plane.

BFO algorithm yields fast and parameter insensitive MPPT of PV systems. BFO is a new algorithm which has simple implementation to track the maximum power point of photovoltaic array or a solar panel. Nowadays Bacteria Foraging technique is gaining importance in the optimization problems. Because,

- Biology provides highly automated, robust and effective organism
- Search strategy of bacteria is salutary (like common fish) in nature
- Bacteria can sense, decide and act so adopts social foraging (foraging in groups).

The design of solar concentrators covers an angle of about 180° in a semicircular shape. This provide an option of keeping the module fixed at a particular flat position and avoid the rotation of the module in order to face the sun to absorb more sun rays and increase the efficiency

II. Modelling of BFO

Since selection behavior of bacteria tends to eliminate animals with poor foraging strategies and favor the propagation of genes of those animals that have successful foraging strategies, they can be applied to have optimal solution through methods for locating, handling and ingesting food. After many generations, a foraging animal takes actions to maximize the energy obtained per unit time spent foraging. That is, poor foraging strategies are either eliminated or shaped into good ones. Optimization models are also valid for social foraging where groups of animals communicate to cooperatively forage, in the face of constraints presented by its own physiology such as, sensing and cognitive capabilities and environment [7]. This activity of foraging inspired the researchers to utilize it as a novel optimization tool. The E. Coli bacteria present in our intestines also practice a foraging strategy. The control system of these bacteria governing their foraging process can be sub divided into four sections, which are chemo taxis, swarming, reproduction and elimination and dispersal [8].

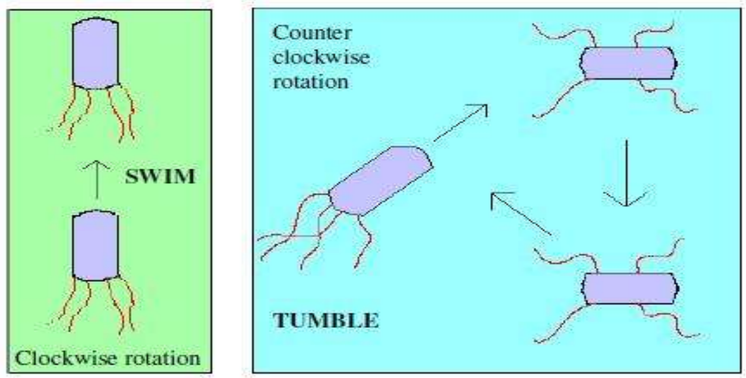


Fig. 1: Swim and tumble of a bacterium

A. Chemotaxis

This process simulates the environment of an E. Coli cell through swimming and tumbling via flagella as shown in Fig. 1. Biologically an E. Coli bacterium can move in two different ways. It can swim for a period of time in the same direction or it may tumble and alternate between these two modes of operation for the entire lifetime [9].

B. Swarming

When a group of E. Coli bacteria is placed in the semi-solid agar having a single nutrient chemo-effector (sensor), they move from the centre to outwards direction in a moving ring of bacteria by following the nutrient gradient produced by the group by consuming the nutrient. Furthermore, the bacteria release attractant aspartate if high levels of succinate are used as the nutrient, which lead the bacteria to concentrate into groups and hence move as concentric patterns of groups with high bacterial density. The spatial order depend both the outward movement of the ring and the local releases of the attractant, which functions as an attraction signal between bacteria to gather into a swarm [8].

C. Reproduction

The total fitness of each bacterium is calculated as the sum of the step fitness during its life. All bacteria are sorted in reverse order according to their fitness. In the reproduction step, only the first-half of population survive and surviving bacterium splits into two identical ones, which can occupy the same positions in the environment at first step. Thus, the population of bacteria keeps constant in each chemotaxis process [10].

D. Dispersion and Elimination

As mentioned in the above, foraging can be modelled as an optimization process which sometimes operates in swarms and relevance of these areas to optimization. Foraging behavior of bacteria can be found using for instance, dynamic programming. Search and optimal foraging decision-making of animals can be used to engineering. Selection behavior or bacteria forage as individuals and others forage as groups. While to perform social foraging an animal needs communication capabilities, it can gain advantages in that it exploit essentially the sensing capabilities of the group, the group can gang-up on large prey, individuals can obtain protection from predators while in a group, and in a certain sense the group can forage with a type of collective intelligence. This paper describes the optimal parameter selection of maximum power point of photovoltaic or solar panel using bacteria foraging [7].

III. DESIGN ASPECTS

The general requirements of the lenses are as follows The lenses should be of rectangular shape with its length dependent on the focal length of the lens itself, the distance at which the module is to be placed and the length of the module on which the rays have to be focused.The breadth of the lens should be equal to the breadth of the photovoltaic module used.According to lens maker's formula for Plano convex lens [11], [12].

$$1/f = (\mu - 1)(1/R) \qquad (1)$$

Variation of the focal point (f) depends on refractive index of the lenses (μ) and radius of curvature of the lenses (R) These variations shown in the table-1 are obtained using equation (1).

Table-1

μ	1.5	1.33	1.25	---	1.10	---	1	<1
f	2R	3R	4R	---	10R	---	∞	-kR

When the refractive index of a glass is 1, the focal distance will be infinity and when it is less than 1, then the focal length will be negative. For a lens of same refractive index the focal distance can be varied by varying the radius of curvature of the lens and vice versa.

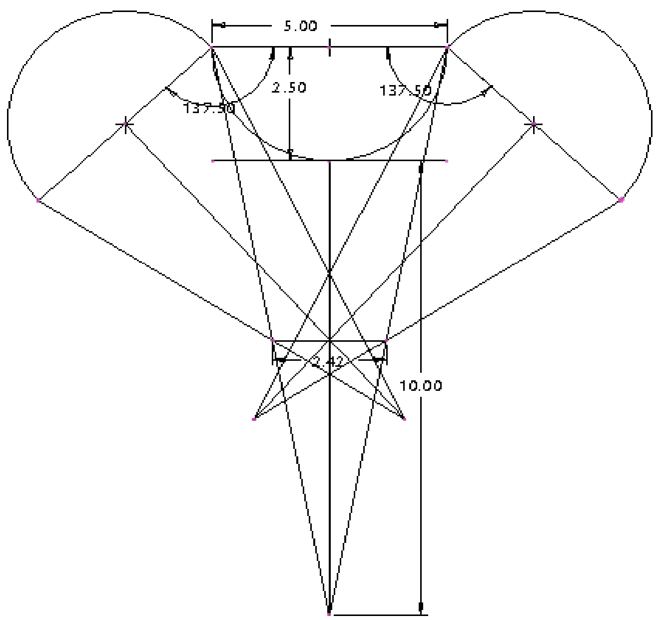


Fig. 2 Experimental setup of solar power optimization using CAD Design

IV. METHODOLOGY

In this paper, the work presents the prediction of solar radiation for various inclined angles and orientations on the surface of earth using the measurement of current and voltage characteristics of various latitude and longitudinal angles on the hemi sphere surface (for just imagine as an earth equator). A number of different points are to be taken on the hemi sphere surface. Then voltages and current are measured with the help of solar panel and multi-meters to acquire accurate readings with respect to the time and the position of sun's radiations.

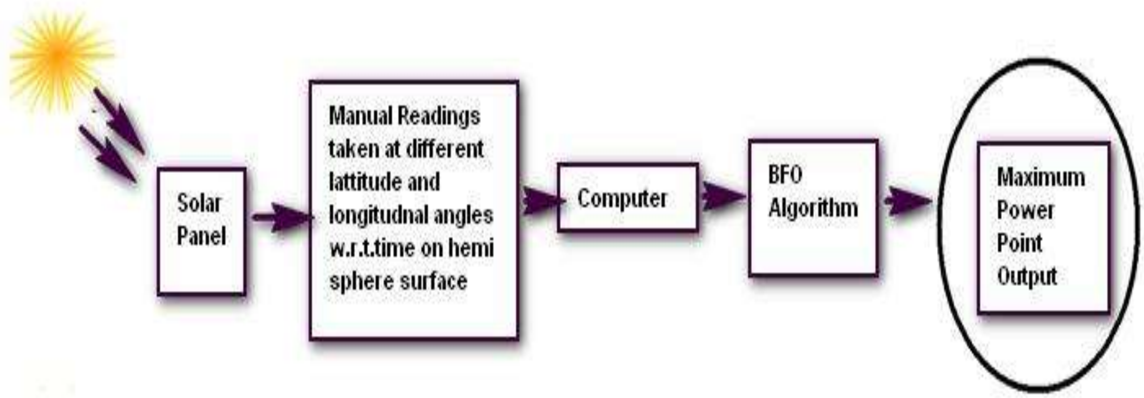


Fig. 3: Experimental setup of solar power optimization using BFO algorithm

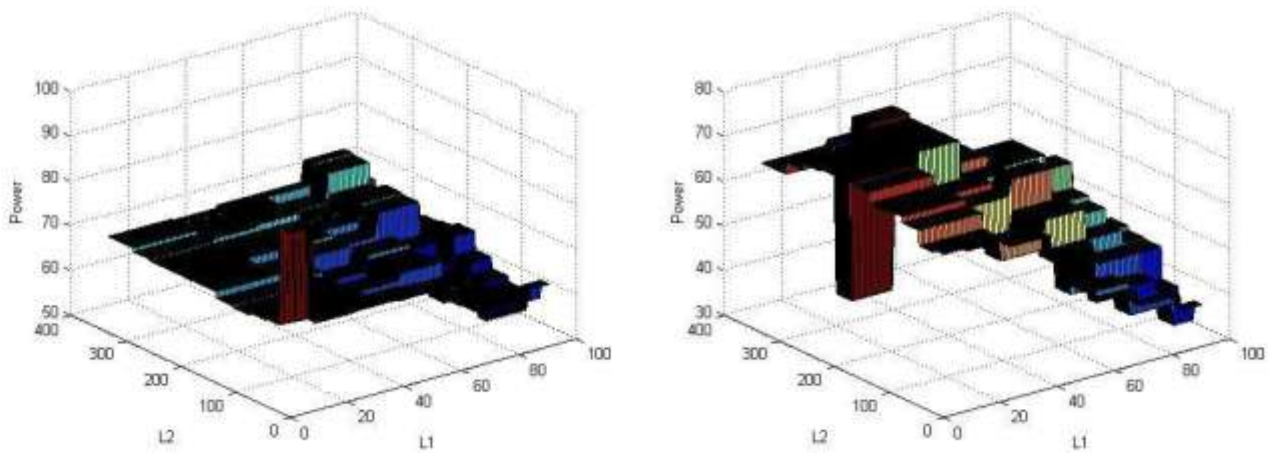
V. RESULT AND DISCUSSION

Solar radiation power data was recorded in terms of current and voltages. In order to calculate the maximum power from the collected data, BFO algorithm was used. Table I, shows estimation of minimum number of bacteria for finding maximum power and hence its location. Readings were taken during afternoon and evening time. It is observed that different numbers of bacteria are required get power estimated at different time of intervals.

Table I: Results of solar power optimization using BFO algorithm

No. of bacteria	Estimated power	Inclined axis angles(L1)	Horizontal axis angles (L2)
	Afternoon		
6	77.0430	76°	310°
10	72.6800	46°	280°
14	72.3600	76°	220°
18	73.7080	76°	250°
22	74.7080	76°	250°
26	77.3840	76°	340°
30	92.9440	0°	0°
	Evening		
6	73.3060	15°	150°
10	76.6000	30°	210°
14	76.6000	30°	210°
18	77.5320	30°	270°
22	78.5320	30°	270°

For example, as per Table I, the six number of bacteria get 76.043 (mW) estimated power at 75° vertical axis and 300° horizontal axis angles in afternoon time, but get 72.3060 (mW) estimated power at 15° vertical axis and 150° horizontal axis angles in evening time. It is also observed that however number of bacteria increases, the estimated power also increases respectively with different vertical and horizontal angles to track maximum power point. Thus atleast more than 30 bacteria must be used to find maximum point. Fig. 3 shows 3D-graphical presentation of the results of solar power optimization using BFO algorithm at different time of interval w.r.t. vertical angle (L1) and horizontal angle (L2). During afternoon and evening time with bacteria size 30 and 22 respectively.



(a) (b)

Fig. 4: Solar power optimization using BFO algorithm during (a) afternoon (b) evening time

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