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Enhanced Performance of Solar Concentrators using Soft Computing Techniques

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A B S T R A C T

The objective of this paper is to increase the effeciency of photovoltaic cell and to reduce the cost of the photovoltaic module. The efficiency of photovoltic module is increased by covering an angle of nearing 180 degree and the cost is reduced by use of cheaper glass materials.The amount of current produced by a solar cell / panel depends on various factors due to which the state variables of a cell keep changing. The various state variables in question mainfest different behaviours as time and place changes and emprical formula of a solar cell does not suffice. In absence of such emprical formula, one has to relay on estimation in order to predict the behaviour of a solar cell. In this paper behaviour of state of solar cell has been done by kalman filter.Dynamic rapid method for tracking the maximum power angle of solar cell arrays known as Bacteria Foraging Optimisation (BFO) algoritham has been used. Experimental analysis is presented for the comparision of different positions of the sun for maximum power alignment.

INTRODUCTION

The number of photons striking the surface of the photovoltaic module can be increased by using solar concentrators made of lenses by using the refractive property of the lenses .Also, the design of solar concentrators covers an angle of about 180° in a semicircular shape. This provides 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. Kalman estimator has been found to be more accurate than least squares estimation (Thesis (Ph. D.), 2011). Each estimator is optimal for a particular perspective. Our goal is to estimate and predict the state variables of a solar cell in which the noise generated by a photovoltaic cell and the noise of the senor used for current measurement are random in nature. Ours is a time dependent system and best represented by state estimation technique. 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 group**s).**

II. Solar Concentrator Design:

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.

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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 (Ibrahim Zeid, 1996; "Alternative fuels", 2006).

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

Variation of the focal point (f) depends on refractive index of the lenses (μ) and radius of curvature of the lenses (R)

Table 1: Is obtained using equation (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.

2.1. Angle Calculation:

In this design, the angle at which the side lenses are to be placed with respect to the horizontal lens holds a key in order to utilize the module with maximum efficiency (Chetan Singh Solanki,). The placement of the module mainly depends on R, μ and f.

i.e. θ varies depending on the variations in R and μ, but it mainly depends on f. The variation of θ with respect to f is given by

$\theta = (70° + Y10°) + 47.5°$ (2)

Where Y=0, 1, 2, ---- and f = 2R + YR.

The value of Y is selected depending on the variation of f with respect to μ as given in table-1.

The focal point also varies depending on the variations in radius of curvature of the lens at

Constant refractive index and hence variation of angle takes place.

Here R is taken as R=2.5X Where X=1, 4/5, 3/5, 2/5.

For a length of 5X of the lens, so that the related values can be easily calculated for various lengths of the module by making it multiples of 5.

For the values other than this R goes in to decimal values for which the calculations are difficult.

The variation of θ with respect to R can be formulated as

$\theta = 90° + (47.5°X)$ for f=4R

$\theta = 80° + (47.5°X)$ for f=3R (3)

Hence the overall variation of θ depending on the variations of f and R can combinely be formulated as

f = 2R+YR

$\theta = (70° + Y10°) + (47.5°X)$ (4)

For $\mu > 1.5$, f becomes less than 2R. For these values Plano convex lenses will not converge the radiation on to the module surface fully because of the narrowing of the path of the converged rays.

2.2. Module Length:

The module length is inversely proportional to the focal distance of the lenses that are being selected [19]. Hence the module can be selected based on the values of radius of curvature and refractive index of the lenses.

III. State Estimator Design:

Kalman filter is a linear estimator and hence an assumption is made regarding the linearity of solar cells fig.-1 shows the algorithm of a Kalmanfilter.

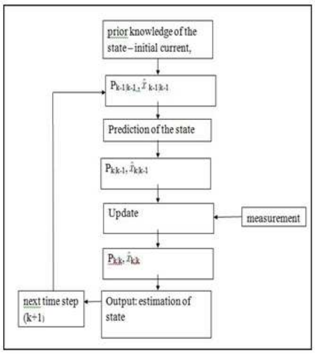

Fig. 1: Kalman filter Algorithm3.1. Mathematical Interpretation of Algorithm.

The measurement vector z is represented by,

$Z = Xtrue(k+1) + \sigma_{meas}$ *random noise (5)

where Xtrue is the assumed value

$P1 = \varphi * P * \varphi'$ (6)

$S = M*P1*M' + R$ (7)

Kalman gain is found by the following equation

$K = P1*M'*inv(S)$ (8)

$P = P1 - K*M*P1$ (9)

If Kalman gain shows a high value, more weight is given to the measurement, and if Kalman gain is low, then an emphasis is given on model prediction.

Xk is the state estimation of the latest state and Xk_prev is the state estimation of the previous state.

$Xk=\varphi*Xk\_prev+K*(Z-M*\varphi *Xk\_prev)$ (10)

A single step of iteration is executed when we run the simulation based on equation 5 to equation 9 which calculates and buffers only the (k -1)-th value of Q, R, K and P. Subsequently as more and more measurement data (along with random measurement error) is received, the error between the estimated value and sensor data (measurement) reduces on employing Kalman filter algorithm as stated above.

IV. Modeling 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. 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.

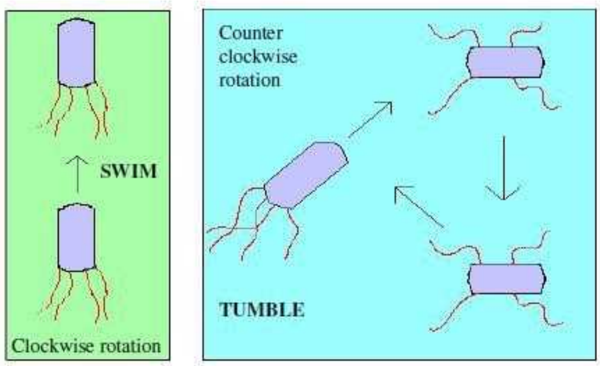

Fig. 2: Swim and tumble of a bacterium.

4.1. Chemotaxis:

This process simulates the environment of an E. Coli cell through swimming and tumbling via flagella as shown in Fig. 2. 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 (Das, S., 2009).

4.2. 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 (Guney, K., S. Basbug, 2008).

4.3. 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 .

4.4. 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 (Kim, D.H., J.H. Cho, 2004). 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 II, 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 2: Results of solar power optimization using BFO algorithm.

No. of	Estimated power	Inclined	Horizontal
bacteria		axis	axis angles
	Afternoon	Angles (L1)	(L2)
	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	
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 II, 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 evenin g time with bacteria size 30 and 22 respectively.

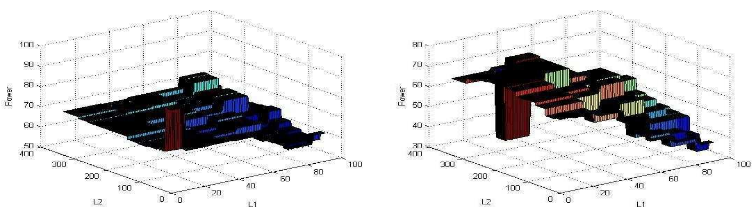

Fig. 3: Solar power optimization using BFO during (a) Afternoon (b).

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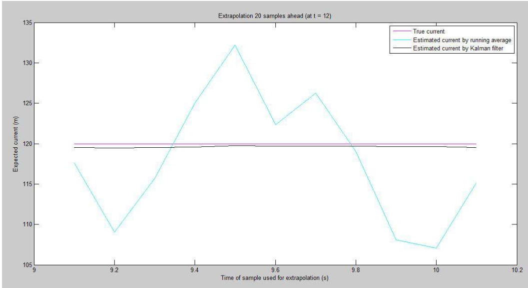

Fig. 4: Prediction of power by Kalman Filter & BFO.

V. Conclusion:

Kalman filter can estimate as well as predict a linear system very closely, but the plant model has to be accurate. To estimate and predict with higher precision more emphasis should be given on plant model than the sensor model. Kalman filter can be termed as second generation estimator as compared to its first generation counterpart like moving average filter. It is not necessary to know the initial state of the system and hence Kalman filter can be used in the problem of filtering, smoothing and prediction. 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

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