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Comparison of Artificial Bee Colony Algorithm with other Algorithms used for Tracking of Maximum Power Point of Photovoltaic Arrays

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Abstract. Maximum power point tracker (MPPT) is one of the key components of a solar electricity generation systems. It is used to extract the maximum power produced by an array of Photovoltaic cells. In this paper Artificial Bee Colony algorithm is analysed and implemented for tracking the maximum power point of Photovoltaic arrays. Furthermore the results obtained from ABC algorithm are compared with that of Perturb and Observe method, Fuzzy Logic Control and Genetic Algorithms.

Key words:

Artificial Bee Colony algorithm, Photovoltaic arrays, Maximum Power Point Tracking.

1. Introduction

An increase in the use of solar electric energy has been observed in recent years. The reason of this focus on photovoltaic is due of their simple structure, noiseless operations and little maintenance. More over these systems can be designed from very small power generating systems to very large Mega-Watt systems. The main drawbacks of Photovoltaic systems include lower efficiency and a high capital cost. Currently the efficiency of photovoltaic systems is in the range of 9-17%. In addition to that, characteristics of photovoltaic are non-linear and mainly depend on the environmental conditions. To overcome the issues of high installation costs the efficiency of these systems has to be increased. One of the main techniques to increase PV energy harvesting is by keeping the photovoltaic to extract power at its maximum point. In Fig. 1 P-V and I-V typical characteristic diagrams of Photovoltaic systems are shown. These characteristics are mainly dependent on the environmental conditions and the maximum power point coordinates change with the temperature and solar irradiance. In the last time, in literature are proposed different intelligent algorithms for seeking of the maximum power point [1-5]. In this work the Artificial Bee Colony algorithm used for maximum power point tracking is analysed and compared with other algorithms used for the same purpose: Perturb and Observe algorithm, Genetic Algorithm and Fuzzy Logic algorithm.

2. Artificial Bee Colony algorithm

The artificial bee colony algorithm (ABC) was introduced by Karaboga in 2005 [6] and a modified version was introduced in by Akay and Karaboga in 2010 [7]. In a bee swarm there is a very efficient natural task management mechanism that actively changes by the condition of the surroundings. Foraging behaviour is one of the very important parts of bee swarms. It is guided by the factors such as task management, division of labour, grouping of bees according to their statuses and the quantity and quality of the available food. The two main management criteria for the foraging are recruitment for exploring food sources and the abandonment after their depletion.

Naturally there are three groups of bees in a swarm and they differ with each other due to the tasks handled by them. Scouts bees have the job of founding new food sources; they do their job by randomly exploring the area either by internal motivation or by some external clue. Employed bees exploit the already discovered food source until the food source is depleted. Onlooker bees wait in the hives and they select a food source after getting motivated by watching dances performed by the employed bees in the dancing area. Dancing area can be considered as the main information sharing area of the bee hives. In this area the employed bees return with the nectar and perform different types of dances, while at the same time the onlooker bees watch these dances. Different types of dances are performed for example round, tremble and waggle dance. The type of dance and its intensity provides a measure of the feasibility of the food source [8].

The three groups of bees in a hive, as explained before, perform specialized task for maximizing the amount of nectar. In the algorithm, half of the bees are always employed bees while half of them are onlooker bees. Every food source is exploited by a single employed bee, which means for every employed bee there is one food source available. All the food sources are considered as viable solutions for a particular problem, which means, there are as many solutions as there are employed bees. The steps taken by the algorithm is explained below:

1) In the beginning the population is initialised in the range encompassing the pre-defined upper limit and the lower. All the employed bees are allocated a position in the search space, bearing a particular solution. The initialisation is performed by using the following equation:

$$x_{ij} = x_j^{\min} + rand(0;1)(x_j^{\max} - x_j^{\min}), \quad (1)$$

Where i=1,2,3 …, SN and j=1,2,3 …, D. SN is the population of the colony and D is the number of parameters to be optimised by the algorithm. After the initialisation, changes are brought in these positions until the maximum number of cycles is reached or some error criteria are met. 2) As explained earlier, each food source is associated with one employed bee, after the initialisation each employed bee is allotted a food source. After this allotment the bee makes changes the position of the food source depending on local information and explores surrounding food source. Once it finds a source it evaluates its quality. The neighbouring food sources are defined by the following equation.

$$t_{ij} = x_{ij} + \varphi_{ij}(x_{ij} - x_{kj}), \quad (2)$$

The food source t_i in the neighbourhood of x_i is found by changing one parameter of x_i. In the above equation j is a random integer in the range of [1, D] while and k = {1,2,3 …, SN} is a randomly chosen index that is different than i. and φ_{ij} is a randomly distributed number in the domain [-1, +1]. It can be seen from equation (2) that as the difference between x_{ij} and x_{jk} decreases an optimal value is reached. When these two values become equal, there are no more changes in the position. After finding t_i a fitness value is assigned to each t_i by the following equations:

$$fitness_i = \begin{cases} 1 = (1 + fi) & if\ fi \succ 0 \\ 1 + abs(fi) & if\ fi \prec 0, \end{cases} \quad (3)$$

Where, fi is the cost value of the solution t_i. Following that a greedy selection is applied to the values obtained for x_i and t_i, a better value between the two is selected according to their fitness.

3) When all the employed bees have completed their searches and the first cycle is completed, the information regarding the quantity of the nectar (solution) is shared with the onlooker bees in the dancing area. An onlooker bee makes a probability on the quality of nectar (by the fitness values). In the ABC algorithm a roulette wheel scheme is used for such probabilistic values as shown in the equation below:

$$P_i = \frac{fitness_i}{\sum_{i=1}^{SN} fitness_i}, \quad (4)$$

4) In such a probabilistic selection scheme, as the fitness of solutions increases, the number of onlookers attracted towards them also increases. This is the positive feedback feature of ABC. When one complete search cycle is complete, the algorithm searches for the exhausted food sources by checking the counters and comparing it with a pre-set value called the "limit". If the values are the same the food source is abandoned and a new food source is searched by the scout bees and replaced with the abandoned source. This is the negative feedback feature of ABC.
5) The above three steps are repeated and the possible solution sets are optimized till the criteria of the maximum number of cycles is met or the pre-defined error value is reached.

By following the above steps a global minima is achieved by the algorithm.

3. The objective function

Swarm intelligence algorithm like Particle Swarm Optimization, ABC algorithm etc or evolution algorithms like Genetic algorithms works on minimizing an objective function. But, when we consider seeking a maximum power point in PV arrays the scenario changes. The problem becomes a maximization problem. There are two solutions for solving this problem, the first is to bring a change in the whole algorithm and change it to seek for maximization, or to bring a change in the objective function. For MPPT, the power was chosen as the objective function which is shown in the equation below:

$$f_{\min}(I,V) = -\left\{ I_{ph} - I_{Dsat}\left\{ \exp\left[\frac{q(V+IR_s)}{am.k.T}\right] - 1 \right\} - \frac{V+IR_s}{R_p} \right\} \cdot V, \quad (4)$$

The above equation is the equation for the output power of the PV cells. The minus in the beginning of the equation changes all the produced values of power into negative values. The parameters I and V are varied over the range defined in the ABC algorithm and the solutions are fed into the algorithm and minimization process begins. In the MATLAB m-file equation (4) was written as:

```
ObjVal = (Ipv – Io*(exp((x2+x1*Rs)/Vt/Ns/a)-1)-
(x2+x1*Rs)/Rp*x2;
```
(5)

where x1 is the current and x2 is the voltage.

4. Results and analysis

For tracking the maximum power point, the artificial bee colony algorithm was implemented in MATLAB. For testing the algorithm, the Kyocera KC200GT PV panel was modelled in MATLAB. The specifications for this PV panel are given in the Table I.

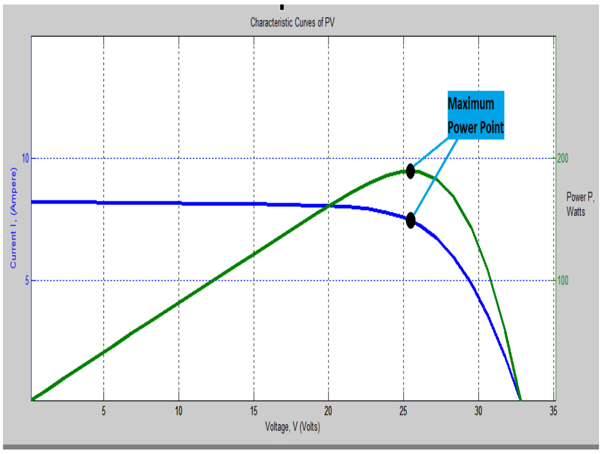

Fig. 1. Photovoltaic panel I-V and P-V characteristic curves; maximum power point is shown on these curves.

Table I. Specifications of KYOCERA KC200GT panel

Variable	Value
Maximum Power, *Pmax*	200 Watts (+10% / -5%)
Maximum Power Voltage, *Vmpp*	26.3 V
Maximum Power Current, *Impp*	7.61 A
Open Circuit Voltage, *Voc*	32.9 V
Short Circuit Current, Isc	8.21 A
Temperature Coefficient, KVoc	-1.23×10^{-1} V/^{0}C
Temperature Coefficient, KIsc	3.18×10^{-3} A/^{0}C

The results of output power maximum searched by the Artificial Bee Colony algorithm are given in Table II. The irradiance G and the temperature T were set at 1000 W/m^2 and 25^{0}C, respectively. The simulation was performed 10times to check the reliability of the algorithm.

Table II. ABC algorithm results for 1000 W/m^2 and 25^{0}C

Run Number	**Output Value of P_{max}**
1	206.087
2	195.189
3	189.110
4	205.008
5	199.028
6	205.008
7	203.606
8	204.848
9	205.008
10	200.675

In the above sample of outputs the best value is 206.087, the worst value is 189.11 and the average of the above data is 201.36 which has an error of 0.0068%. The average time for one run was 0.2 seconds.

Along with Artificial Bee Colony algorithm, Perturb and Observe Algorithm, Genetic Algorithm and Fuzzy Logic Algorithm were applied for the same PV panel. A comparison of Artificial Bee Colony algorithm with Perturb and Observe algorithm, Genetic Algorithms and Fuzzy Logic algorithm is shown in Table III.

Table III. P_{max} given by different algorithms

Irradiation	ABC	P&O	GA	FL
(W/m^2)	W	W	W	W
1000	206.08	200.10	205.00	199.00
800	163.61	160.40	161.17	157.10
600	118.63	119.30	118.46	91.09
400	71.51	45.55	75.42	41.31
200	33.56	36.70	31.09	10.92

It is worth mentioning here that for Perturb and Observe algorithm a time of 4.5 seconds was used, while for other algorithms on the average 0.3 seconds was used. The data from the Table III can be better visualized in graphic form. In Figure 2 the power correlation graph of the used algorithms is shown. It can be seen that ABC algorithm performs better that other algorithms.

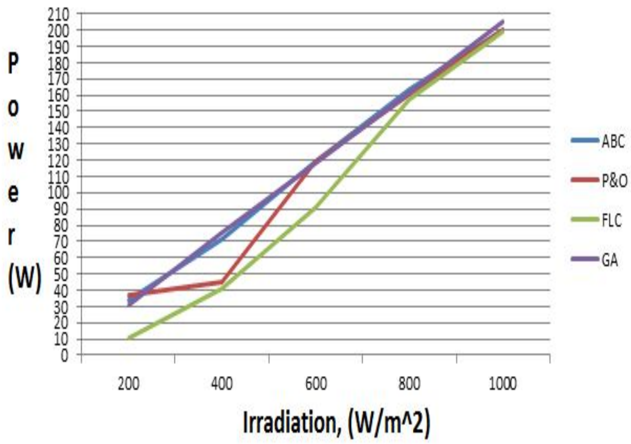

Fig. 2. Power correlation graph comparing performances of ABC, P&O, GA and FL algorithms in seeking MPP at different irradiations.

5. Conclusion

The Artificial Bee Colony algorithm can be considered as one of the main competitive algorithms for the maximum point tracking of the Photovoltaic arrays. In comparison with Perturb & Observe and Fuzzy Logic algorithms, ABC Perturb & Observe and Fuzzy Logic algorithms, ABC algorithm give better results. It gives similar or superior results in comparison with Genetic algorithm.

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