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NATURE INSPIRED ALGORITHM BASED HYBRID MPPT FOR SOLAR PHOTOVOLTAIC SYSTEMS

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Abstract

To maximize the solar Photovoltaic (PV) system's output under dynamic weather conditions, Maximum Power Point Tracking (MPPT) controllers are incorporated in solar PV systems. However, the occurrence of multiple peaks due to partial shading adds complexity to the tracking process. Even though conventional techniques are widely used for MPPT, conventional methods exhibit limited performance due to fixed step size. Hence, a new hybrid MPPT algorithm is proposed which combines Bumble Bee Mating Optimization (BBMO) and Shuffled Frog Leaping Algorithm (SFLA) to reach the Global Maximum Power Point (GMPP). BBMO is a nature-inspired optimization algorithm that simulates the behavior of the bumble bees. SFLA is a population based cooperative search metaphor inspired by natural memetics. Optimization process in SFLA and BBMO method performs global and local search respectively and they are the tool for its success in Maximum Power Point Tracking. Further, performance is estimated via simulation, and the results are compared to prove the effectiveness of proposed hybrid MPPT algorithm. The results of simulations show that the proposed controller track Global Maximum Power Point with reduced steady-state oscillations.

Keywords: Solar Photovoltaic Systems, Maximum Power Point Tracking, Shuffled Frog Leaping Algorithm, Bumble Bee Mating Optimization, hybrid MPPT

1.Introduction

The government all over the country emphasizes the electricity production from renewable energy sources namely solar energy, biomass energy, ocean energy, wind energy, fuels cells and hydrogen energy. Solar energy is found to be one of the abundantly available energy in the world which could be used for power production. The limitation with the solar Photovoltaic (PV) system is to obtain the maximum power from the PV array during changing atmospheric conditions, that is, during change in solar irradiations and temperature and during partial shading conditions, that is, when the irradiation falling on all the PV panels in a PV array is different due to shading of trees or buildings on particular part of PV array or due to bird droppings or due to clouds. To incorporate Maximum Power Point Tracking (MPPT) in solar PV system, a DC-DC boost converter is required, and the maximum power point is reached by varying the duty cycle of DC-DC boost converter.
Conventional MPPT algorithms such as Perturb and Observe (P&O) [1], Incremental Conductance (IC) [2], and Hill Climbing (HC) [3], were not able to find the Global Maximum Power Point (GMPP) since the Power-Voltage P-V characteristics of PV array have many peaks, and also, have steady-state oscillations near the

maximum power point. The Artificial Neural Network (ANN) based MPPT [4] and Fuzzy Logic Control (FLC) based MPPT algorithm [5] have been proposed to find the GMPP of PV array, but they involve high cost for computation though able to find the global maximum.

Nature inspired algorithms such as Particle Swarm Optimization (PSO) based MPPT [6], Artificial Bee Colony (ABC) based MPPT [7], Ant Colony Optimization (ACO) based MPPT [8], Bumble Bee Mating Optimization (BBMO) based MPPT [9], Shuffled Frog Leaping Algorithm (SFLA) based MPPT [10] have been developed in the literature in the aim of finding the global maximum under partial shading conditions and suddenly changing irradiation conditions. Research focus is always on finding the best optimization technique by combining two algorithms to increase the reliability and to have better chance of finding GMPP. Hence, this paper proposes a hybrid algorithm that combines Bumble Bee Mating Optimization (BBMO) and Shuffled Frog Leaping Algorithm (SFLA) to find the global maximum to increase the tracking efficiency with less convergence time.
The paper is organized as follows. Section 2 describes the BBMO based MPPT, SFLA based MPPT, and the proposed hybrid MPPT. Section 3 explains the simulation results and the conclusion is described in section 4.

2.Bumble Bee Mating Optimization (BBMO) based MPPT, Shuffled Frog Leaping Algorithm (SFLA) based MPPT and Proposed Hybrid MPPT Algorithm

2.1 BBMO based MPPT

Bumble Bee Mating Optimization is a population based nature inspired algorithm developed based on the mating behavior of bumble bees. In the bumble bees colony, there are three kinds of bees namely, the female bee workers, the male bee drones, and the queen. When BBMO is applied for MPPT, the bees represent the duty cycles, δ, and the fitness function is PV power. PV is calculated from the PV voltage, V_{PV}, and PV current, I_{PV}. The best bee which is the solution of BBMO represent the best duty cycle corresponding to Maximum Power Point. The pseudo code algorithm for BBMO is as follows.

Algorithm 1

Step 1: Parameters definition
Maximum number of queens, iterations, and matings to be defined
Step 2: Initialization Phase
Bumble bees initial population to be generated
Each bumble bee's fitness value is to be calculated
The bee which has the best fitness value is selected as the queen
The rest of the bees are selected as the drones
The drones are arranged in accordance to the fitness value
The queens then select the drones for mating
The genotypes of drones are stored to spermatheca of queen
Step 3: Main Phase
do while till maximum number of iterations
Apply crossover operator to create the broods
Calculate each brood's fitness value
The broods are arranged in accordance to the fitness value
The best broods are selected as the new queens
The rest of the broods are selected as the workers
The new queens are fed by the workers and old queens
A percentage of drones is formed using mutation of genotypes of old queens
The rest drones are formed using mutation of the genotypes of workers
The fitness value of all drones are calculated
The direction of movement of the drones is calculated which is away from the hive
Arrange the drones in accordance to the fitness value
do while till the maximum defined number of matings for every new queen
The drones are selected for mating done by every new queen
The genotypes of drones are stored to spermatheca of every new queen
end do

The new queens survive for the upcoming iteration
All the other workers and drones in the population die
end do
return The best queen is found

2.2 SFLA based MPPT

Shuffled Frog Leaping Algorithm (SFLA) is a nature inspired algorithm which is based on the social behavior of frogs. In this algorithm, the frogs form the population, and they are divided into groups called memeplexes. Each memeplexes will be performing the local search. The memeplexes are evolved by the influence of best frog which is carried on to other frogs in the same memeplex. After required iterations, then ideas from each memeplexes are passed on to the other memeplex using shuffling phenomenon and this is process is carried out till convergence is reached. The pseudo code algorithm for SFLA is as follows:

Algorithm 2

Step 1: Memeplexes number, number of frogs in each memeplex, iterations number, and total algorithm iteration number are set.
Step 2:
Begin
Random population with P number of frog individuals is generated and m memeplexes is obtained by dividing the population, P.
In each memeplex group, find the worst individual and the best individual.
The worst individual position is improved using the frog position changing equation and new position equation.
Repeating it for a defined iterations number.
Step 3: The memeplexes that are evolved are combined.
The population P is sorted in accordance to the fitness value.
End if termination condition is reached.
End

When SFLA is used for MPPT, the frogs represent duty cycle and the fitness value is the PV power measured as the product of PV voltage, V_{PV}, and PV current, I_{PV}, for that particular duty cycle.

2.3 Proposed Hybrid MPPT

The proposed hybrid MPPT combines SFLA and BBMO for global maximum power point tracking. The SFLA based MPPT is first implemented to explore the global maximum area, and once, the evolved memeplexes are obtained, then BBMO based MPPT is applied to do the local search in the global maximum area, which helps to find the global maximum in a PV solar system under varying irradiation conditions and partially shading conditions. The best duty cycle corresponding to global maximum power point is obtained as a result of hybrid MPPT. The pseudo code algorithm for proposed hybrid MPPT is as follows.

Algorithm 3

Begin
Step 1: Follow algorithm 2 up to step 2 till memeplexes are evolved after defined number of iterations finding the global maximum area.
Step 2: Follow algorithm 1 to find the local maximum in the global maximum area to find the best duty cycle.
Step 3: Return the best duty cycle corresponding to global maximum power point
E**nd**

3.Results and Discussion

The application of hybrid MPPT for solar PV system is simulated using MATLAB Simulink platform. The block diagram of the PV system with hybrid MPPT is shown in Figure 1, which is consisting of PV array, which is connection of PV modules in series and parallel connection, DC-DC boost converter, hybrid MPPT

controller and DC load. The PV array considered in this work has one parallel string and one series string. Under uniform irradiation condition of 1000 W/m^2, the output power, output voltage, and output current for BBMO MPPT, SFLA MPPT and hybrid MPPT is compared. The comparison is represented in Figure 2. From the figure, it is clear that output power, output voltage, and output current is highest for hybrid MPPT leading to low power loss and high efficiency. At 1 second, partial shading condition occurs, and comparison of output power and output voltage under partial shading condition for BBMO, SFLA and hybrid MPPTs is shown in Figure 3 and Figure 4 respectively.

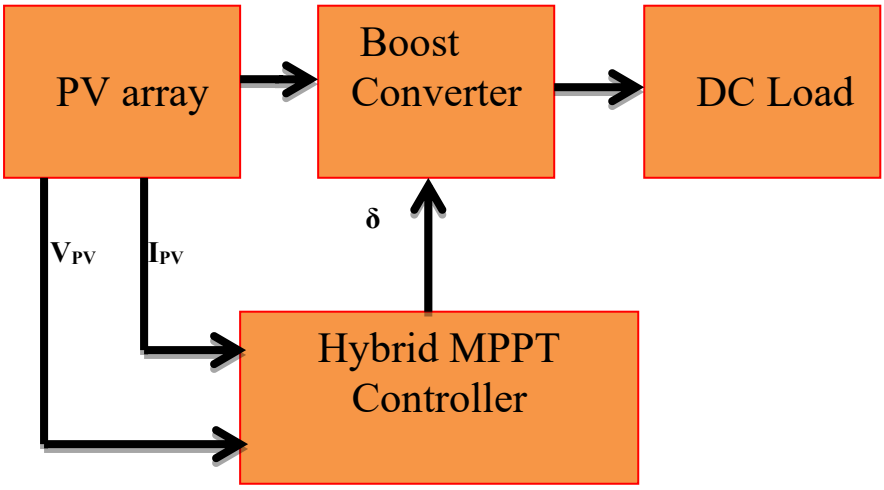
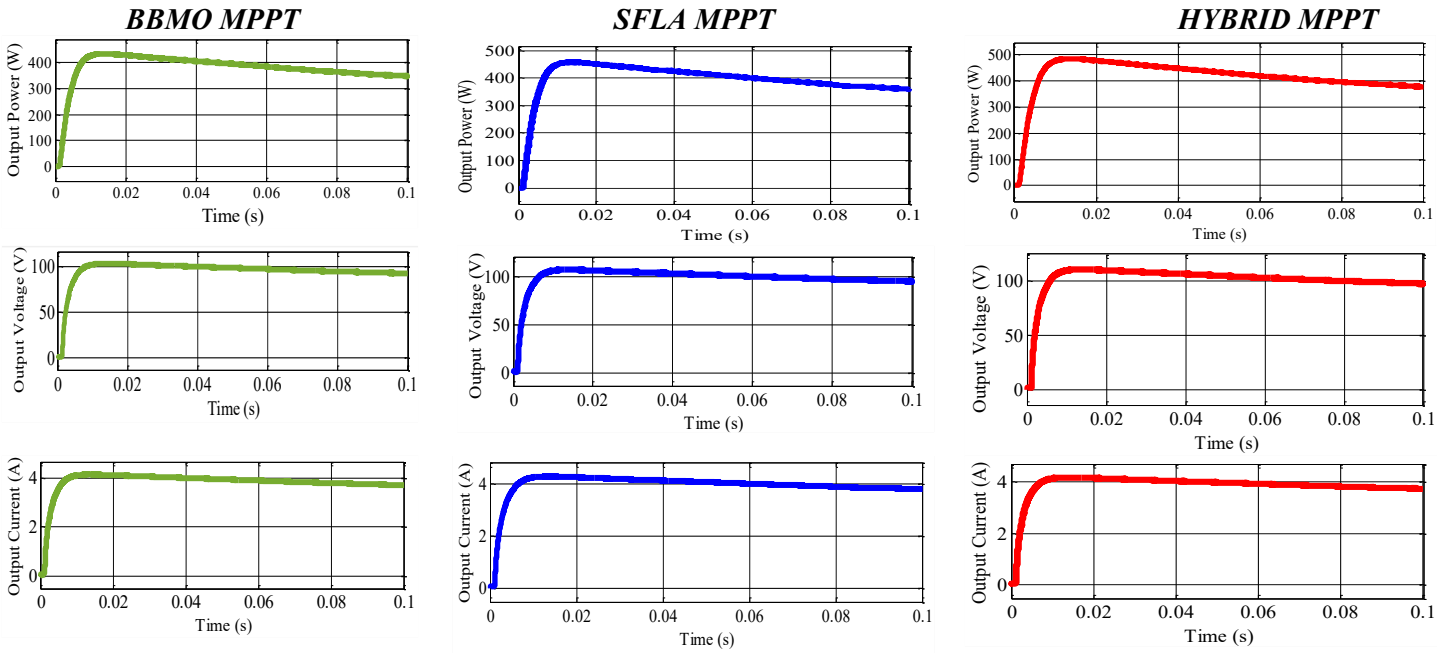


Figure 1 Block diagram of PV system with hybrid MPPT



(a) (b) (c)

Figure 2 Uniform radiation condition - (a) Output power, output voltage, output current for BBMO MPPT (b) Output power, output voltage, output current for SFLA MPPT (c) Output power, output voltage, output current for hybrid MPPT

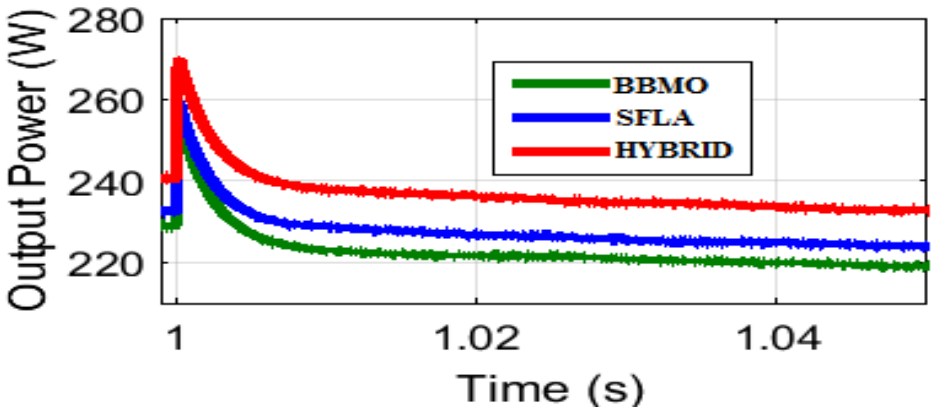


Figure 3 Comparison of output power for BBMO, SFLA and hybrid MPPT under partial shading conditions

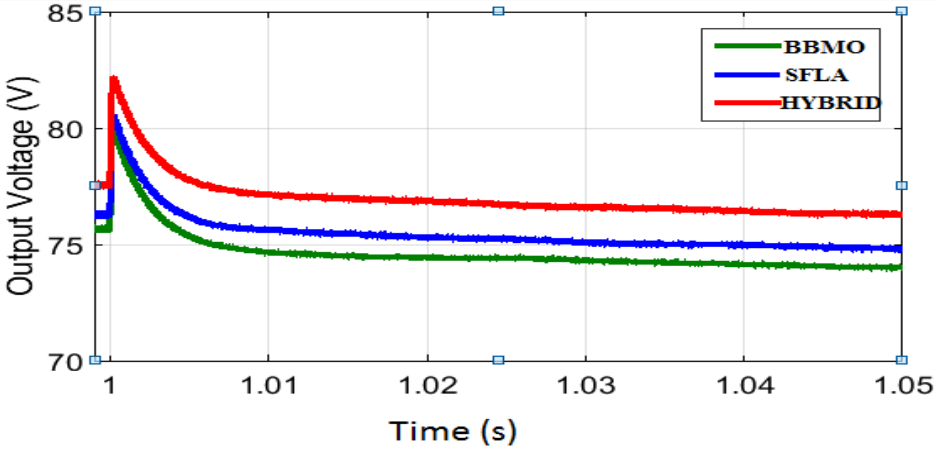


Figure 4 Comparison of output voltage for BBMO, SFLA and hybrid MPPT under partial shading conditions

It is clear from the Figure 3 and Figure 4 that hybrid MPPT results in maximum voltage and maximum power compared to BBMO and SFLA based MPPT. Table 1 gives the comparison of performance of BBMO MPPT, SFLA MPPT and hybrid MPPT. From Table 1, it is clear that the convergence time for reaching the global maximum point of SFLA based MPPT is lesser than BBMO based MPPT ensuring better performance. Though, hybrid MPPT has same convergence time same as that of SFLA based MPPT, but results in high output power, output voltage, and output current ensuring best performance among three types of MPPT methods.

Table 1 Comparison of performances of BBMO MPPT, SFLA MPPT and Hybrid MPPT

CONDITION	PARAMETER	BBMO MPPT	SFLA MPPT	HYBRID MPPT
Uniform irradiation condition	Output voltage (v)	75	76	78
	Output current (a)	3.14	3.23	3.33
	Output power (w)	235.5	245.48	259.74
	Convergence Time (s)	0.071	0.065	0.065
Partial shading condition	Output voltage (v)	73	74	76
	Output current (a)	2.7	2.8	2.9
	Output power (w)	197.1	207.2	220.4
	Convergence Time (s)	0.072	0.066	0.066

4. Conclusion

In this paper, a hybrid of Nature Inspired Algorithms, Bumble Bee Mating Optimization and Shuffled Frog Leaping Algorithm based MPPT is proposed to track the Global Maximum Power Point in PV Array. Simulation results of SFLA and BBMO is generated along with the hybrid output. The results of the performance parameters at uniform irradiation and partial shaded conditions are observed. Based on the results, SFLA is better than BBMO in tracking the maximum power with less convergence time. However, hybrid MPPT algorithm using SFLA and BBMO results in much more power with the same convergence time as that of SFLA MPPT concluding this hybrid algorithm as an effective MPPT algorithm for solar PV applications.

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