ISSN: 2454-9940

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

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INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 17, Issue.2 June 2023

Efficient Solar Harvesting: Boosting Photovoltaic Performance with Boa-Based MPPT

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Article Info

Received: 09-03-2023 *Revised: 10 -04-2023* *Accepted: 22-05-2023*

Abstract

Due to factors like dust, trees, and tallbuildings in the vicinity, partial shading conditions (PSC) often affect the performance of photovoltaic (PV) systems, reducing their power output. PSC can lead to the presence of both a global maximum power point (GMPP) and several local maximum power points (LMPP), making the task of maximum power point tracking (MPPT) challenging. To addressthis issue, soft computing techniques such as gray wolf optimization (GWO), particle swarm optimization (PSO), and Gravitational Search Algorithm (GSA) have been used. However, there is still room for improvement in the performance of MPPT trackers.

This paper focuses on enhancing the tracking speed by incorporating Biogeography-Based Optimization Algorithm (BOA) into the MPPT of PV systems operating under PSC. This approach presents a promising alternative in real-time applications for improving the performance of PV systems dealing with variable PSC, thanks to its fast-tracking speed. The PV system, comprising a PV array, boost converter, and load, is modeled and simulated using MATLAB/Simulink. The output is then fed to an inverter for small power applications.

INDEX TERMS: photovoltaic (PV), Maximum power point tracking (MPPT), gray wolf optimization (GWO), Gravitational Search Algorithm (GSA), partial shading conditions (PSC).

1. Introduction

PV panels in an array may receive different intensity of the sunlight. When the panels in a PV array receive the same level of solar radiation, P-V characteristics of the system shows only one MPP. On the other hand, in case of a shading condition, the P-V curve at the output of the system has more than one MPPs. One of these points is called the global MPP (GMPP) and others are called local MPPs (LMPP). In the case of shading, the conventional MPPT algorithms for PV systems have failed because of the existence of LMPP. At this point, there is a need for an MPPT algorithm that can reach GMPP without sticking on LMPP. In order to meet this, need a lot of researches have been made during recent years about mitigation of the impact of partial shading conditions (PSC) on PV systems.

The proposed algorithm compared with PSO and Differential Evolution in order to test its performance. The authors stated that the proposed algorithm showed better performance than the other two algorithms. and it presented an improved PSO algorithm to track MPP of PV systems under PSC and validated the proposed algorithm by experimentally on 110 W PV system. configuration to enhance the performance of the PV system under PSC. The idea is based on the fact that the physical location of PV modules under PSC affects the performance of the system. The system consists of two main components; PV and DC-DC Boost Converter. In this section, these systems will be discussed in detail. Figure 1 shows the block diagram of the system. The PV system generating power depending on environmental parameters such as solar radiation and temperature.

The generated power is transferred to a DC load via DC-DC boost converter. The input voltage and current values of the Boost converter are measured to be used in the MPPT controller. The duty cycle of the gate signal of the MOSFET in the Boost converter is controlled by the MPPT controller to keep the system operate at the MPP. The duty cycle signal is converted to a PWM signal by PWM generator for inverter is not easy as it depends on the technology available, it may require

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
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better components, which can increase drastically the cost of the installation. Instead, improving the tracking of the maximum power point (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generationand consequently a reduction in its price.

The remainder of the paper is organized as follows: Photovoltaic System described in section II, followed by the Algorithms in section III, In Section IV discusses some Simulation Examples V describes the simulation results and section VI ends with some concluding remarks.

II. PHOTOVOLTAIC SYSTEM

The modeling of the Photovoltaic system is done with MATLAB SIMULINK. The system consists of a photovoltaic panel, boost converter, a resistive load and Butterfly optimizer and a single-phase inverter.

OPERATING PRINCIPLE

Solar cells are the basic components of photovoltaic panels. Most are made from silicon even though other materials are also used.

Solar cells take advantage of the photoelectric effect: the ability of some semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are separated conveniently to create an electrical current by an appropriate design of the structure of the solar cell, as will be explained in brief below. For further details, the reader can consult references [4] and [10].

A solar cell is basically a p-n junction which is made from two different layers of silicon doped with a small quantity of impurity atoms:in the case of the n-layer, atoms with one morevalence electron, called donors, and in the caseof the p-layer, with one less valence electron, known as acceptors. When the two layers are joined together, near the interface the free electrons of the n-layer are diffused in the p- side, leaving behind an area positively chargedby the donors. Similarly, the free holes in the p-layer are diffused in the n-side, leaving behind a region negatively charged by the acceptors. This creates an electrical field between the two sides that is a potential barrier to further flow. This electric field pulls the electrons and holes in opposite directions so the current can flow in one way only: electronscan move from the p-side to the n-side and the holes in the opposite direction. A diagram of the p-n junction showing the effect of the mentioned electric field is illustrated in below figure.

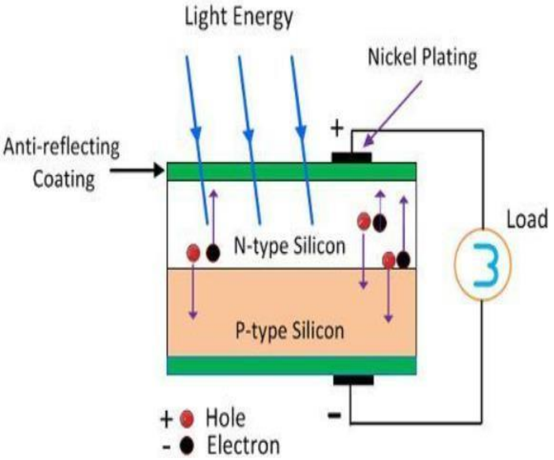

Fig.1: Solar cell

Metallic contacts are added at both sides to collect the electrons and holes so the current can flow. In the case of the n-layer, which is facing the solar irradiance, the contacts are several metallic strips, as they must allow thelight to pass to the solar cell, called fingers.

MPPT Controller

- Maximum power point tracking (MPPT) is a technique used to maximize energy extraction.
- Maximum power point tracking (MPPT) is an algorithmimplemented in photovoltaic (PV) inverters to continuously adjust the impedance seen by the solar array to keep the PV system operating at, or close to, the peak power point of the PV panel under varying conditions.
- Output of boost converter is compared with previous power of the module. Duty cycle is adjusted to

ISSN2454-9940
www.ijsem.org
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track the Max Power Point. It continuous until the power of the PV reaches the max.

- The condition at which Max poweris transferred to the load is
  $R_L = R_{solar\ cell}$

III. ALGORITHM
FIREFLY ALGORITHM

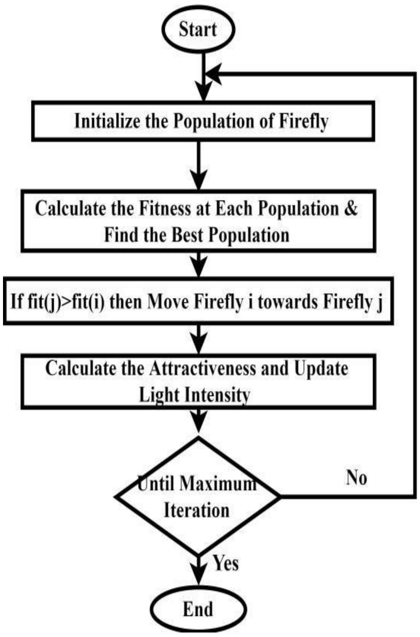

Fig.2: Flow-chat of Firefly algorithm

Fireflies are winged beetles or insects that produce light and blinking at night. The light has no infrared or an ultraviolet frequency which is chemically produced from the lower abdomen is called bioluminescence. They use the flashlight specially to attract mates or prey. The flashlight also used as a protective warning mechanism to remind the fireflies about the potential predators. Firefly algorithm formulated by Yang is a metaheuristic algorithm that is inspired by the flashing behavior of fireflies and the phenomenon of bioluminescent communication. formulated the Firefly Algorithm with the following assumptions:

1) A firefly will be attracted to each other regardless of their sex because they are unisexual.

2) Attractiveness is proportional to their brightness whereas the less bright firefly will be attracted to the brighter firefly. However, the attractiveness decreased when the distance of the two fireflies increased.

3) If the brightness of both fireflies is the same, the fireflies will move randomly. The generations of new solutions are by random walk and attraction of the fireflies. The brightness of the fireflies should be associated with the objective function of the related problem. Their attractiveness makes them capable to subdivide themselves into smaller groups and each subgroup swarm around the local models.

MAXIMUM POWER POINT TRACKING BUTTERFLY-ALGORITHMS

To date, numerous maximum power point tracking algorithms have been proposed, with various trade-offs between performance (tracking speed, accuracy) and complexity (need for sensors, mathematical modeling, computation burden, etc.).

IV. SIMULATION Results

Simulink

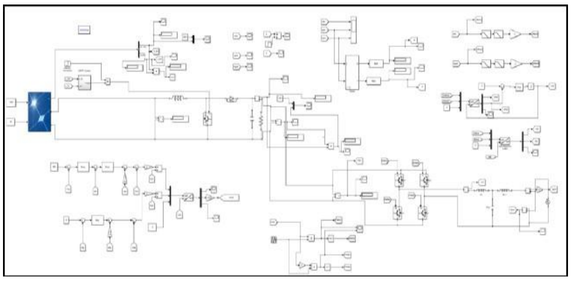

Fig.3: Simulink model of the System with Inverter

Simulation Results –

Output Power = 248.1W

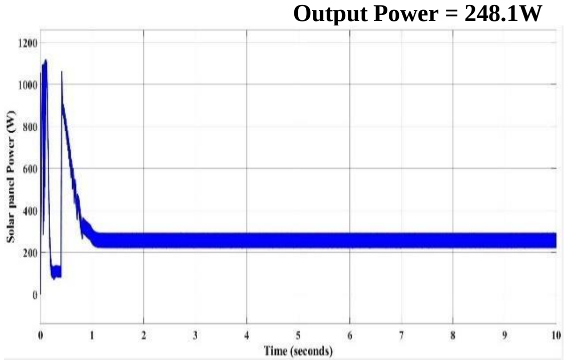

Fig.4: Solar panel output with BOA

Output Power = 241 W

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 17, Issue.2 June 2023

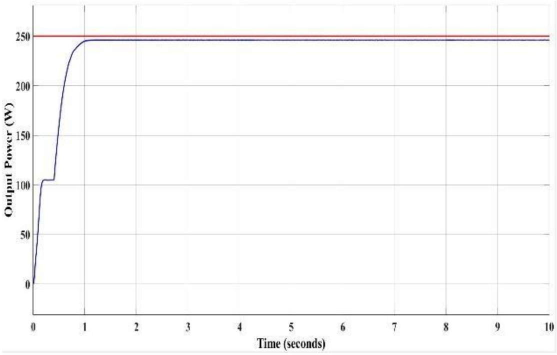

Fig.5: PV system with BOA MPPT unit

Output Power = 240 W

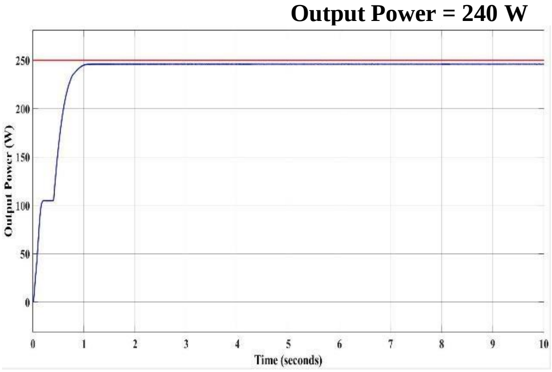

Fig.6: System with FFA MPPT

Output Power = 101.2 W

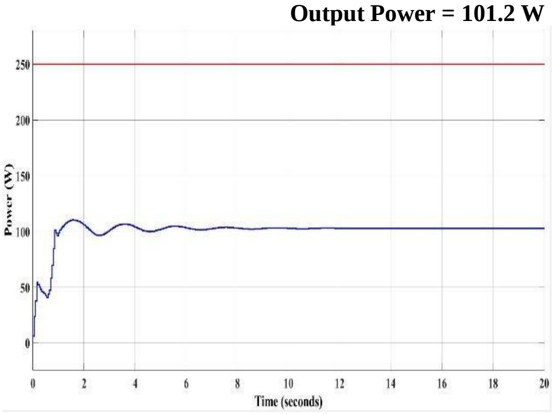

Fig.7: Tracking of maximum power with BOA

Output Power = 246 W

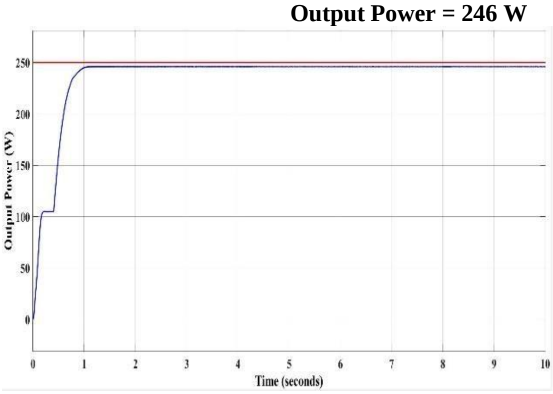

Fig.8: Tracking of maximum power without BOA

Active Power = 9 W

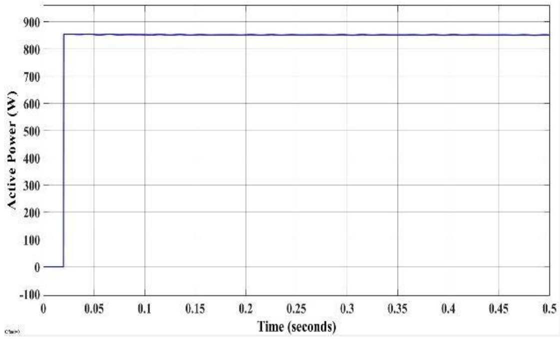

Fig.9: Simulation results active power

Reactive Power = 1.07 VAR

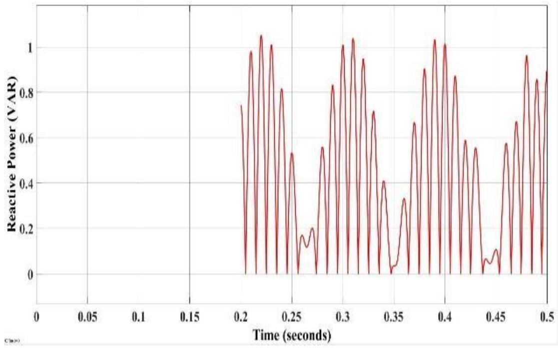

Fig.10: Simulation results reactive power

V. Conclusion

This study employs the Butterfly Optimization Algorithm (BOA) to address the global optimization problem faced by partially shaded PV arrays, which exhibit both local peaks and a global peak on their power- voltage curve. The implementation of BOA as an MPPT algorithm is particularly suitable for applications dealing with variable Partial Shading Conditions (PSC) due to its high accuracy and fast-tracking speed.

The PV system, comprising a PV array, boost converter, and load, is simulated in MATLAB/Simulink, with BOA integrated into the MPPT controller of the boost converter. The results suggest that the modified Perturb and Observe (P&O) algorithm is the most effective, offering a dynamic MPPT efficiency comparable to that of the modified Incremental Conductance (In Cond) algorithm but with simpler implementation.

While these conclusions are based on simulations and literature findings, experimental validation is necessary to confirm their applicability. A comparative analysis is conducted among the various

Maximum Power Point Tracking (MPPT) algorithms, considering three different insolation scenarios. The results indicate that BOA demonstrates high accuracy and the fastest convergence speed among the three algorithms. Overall, the study finds that, for the three insolation scenarios examined, all three algorithms exhibit similar levels of accuracy.

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