Grasshopper Optimizer Based MPPT Technique for the PV System

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Abstract—**In light of the rising load, distributed power generation is becoming more practical and valuable. The photovoltaic system is the primary focus of this kind of electricity generation. Research on ways to increase the efficiency of solar power plants has increased in recent years. To begin with, this study demonstrates how to maximise the output of a solar power plant by using a DC-DC boost converter to extract additional power. An improved maximum power point tracking technique based on a grasshopper optimiser has been suggested in this study. The simulation analysis results are shown, which deals with comparison research. Based on the simulation results, it can be concluded that the proposed grasshopper optimisation algorithm-based maximum power point tracking technique offers improved efficiency and robust control over current methods.**

Keywords—Grasshopper optimisation algorithm, Maximum power point tracker, Photovoltaic, Power converter.

I. Introduction

Since renewable energy sources are more environmentally friendly than conventional power generation, they substantially impact local economies [1]. Jobs, earnings, and gross output are all affected by socio-economic factors. Constructing a new power plant has far-reaching social and economic ramifications for the province's economic future. Electricity may be generated with little or no impact on the environment, thanks to the usage of locally sourced renewable energy sources [2]. Ecological and health advantages are also related to renewable energy's rapid expansion.

Solar photovoltaics (PV) are leading the pack in renewable energy sources because they are abundant and more uniformly dispersed in the natural world than any other renewable energy [3]. Because PV systems do not produce noise or chemical pollutants, they are commonly regarded to have favourable environmental consequences when operating. The insolation and temperature of the sun affect the amount of energy a PV device can produce. Due to environmental circumstances, the quantity of energy generated by PV systems fluctuates. As a result of the PV system's P-V curve having many maximum points, estimating its maximum power point (MPP) is tricky [4]. The modelling of an efficient PV system relies heavily on MPP control. This increases the need for maximum power point tracking (MPPT) for the PV system to work at its best [5]. A software algorithm searches for MPP based on PV modules' measured characteristics (voltage, current, and power).

MPPT methods for using PV systems have been extensively discussed in scientific research works. Several distinct methods have been implemented, including changes to existing methods [6]. Several scientists and programmers have successfully monitored the MPP of a PV module. These solutions vary in complexity, precision, speed, MPP variations, and the sensors necessary to switch on the equipment. There are various ways to maximise the transmission of PV energy to diverse loads in the literature. There are two ways to address this issue: one is to pick the suitable PV module characteristics, and the other is to alter the array configuration, i.e., switching between serial and parallel modules in order to meet the MPP.

MPPT algorithms, perturbation and observation (P&O), and incremental conductance (INC) algorithms are the most widely utilised [7], [8]. The P&O and INC processes are simple and effective. Because of delayed convergences, volatility in output power via the MPP and changing weather conditions might cause malfunctions, and these processes are not ideal. The MPP tracking rate is still lower when oscillation is reduced by utilising a modest disturbance step size.

There is no way to ensure convergence to genuine MPPs using typical MPPT algorithms, which presume an MPP on the PV curve. They frequently become trapped at a local high because they cannot discern between an actual global peak and a fake peak. Fuzzy and neural network models are often used in PV applications to minimise nonlinearity. However, finding a solution to the worldwide MPPT issue is not easy. The multi-start technique is typically utilised with deterministic local search methods; a final global optimum is not sure to be reached when applied for this purpose. However, stochastic search strategies hold more promise in this aspect due to their greater efficiency in scouring the whole search space and then localising on the most exciting places. Metaheuristic properties of nature-inspired optimisation algorithms make them well-suited for handling these kinds of issues as a version of stochastic search.

It has been shown that artificial intelligence techniques, such as evolutionary algorithms, grasshopper optimisation algorithm (GOA) [9], fuzzy systems, neural networks, and intelligent hybrid algorithms, have been successful because they can find solutions that are close to the optimal global solution.

GOA-based stochastic optimisation methods such as hybrid grasshopper optimisation and binary grasshopper optimisation algorithms have recently been introduced in the context of various recent investigations.

Nature's steady process of development is continuously reshaping the environment. Humans have derived several technological ideas from nature, which serves as a significant source of creative inspiration. The researchers were motivated to address the optimisation challenge of the grasshopper's life cycle. Seyedali Mirijalili came up with the GOA in 2017 as an example of a challenge inspired by nature [9].

For the PV array panel to generate the maximum amount of electricity, this article describes and evaluates the GOA. Improved algorithmic convergence speed benefits the GOA technique, especially when searching for a good spot. Compared to other approaches, the GOA method often yields a final solution that is more closely aligned with the optimal than any other method now available.

II. Problem Formulation

A direct connection of a boost converter to the PV array is recommended for MPPT algorithm implementation. Both industrial and home PV arrays often employ DC-DC conversion as a boost converter. Due to low voltages at PV terminals, a converter may still harvest power from the cell arrays and deliver energy to the battery or load even when solar intensity is low. Fig. 1 shows a typical converter architecture for the test system utilised in this work. According to the scientific literature [10], the boost converter's theory and principles are well-known. The boost converter's output voltage rises as the duty cycle decreases.

The alleged MPPT approach aims to discover the optimum duty cycle of the DC-DC converter that can produce the current and the voltage from the PV panel at various solar radiation and ambient temperature. As a result, the duty cycle is the variable in the suggested MPPT controller's solution. In this way, the suggested MPPT controller based on GOA has the following objective,

$$Max \quad P = V \times I \tag{1}$$

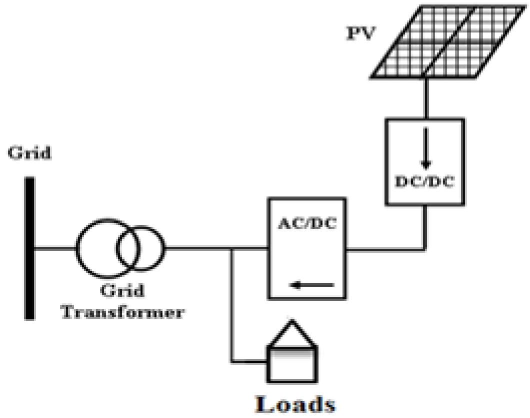

Fig. 1 Test system

III. GRASSHOPPER OPTIMISATION ALGORITHM

A deterministic technique and a stochastic approach are two types of optimisation strategies. Using the gradient of the objective function (maximum power), deterministic algorithms seek a minimal point in the search space (where maximisation is the goal). When using these methods, the effectiveness is dependent on a number of variables, including beginning solution, downhill direction accuracy, internet search methodology, and stopping criteria. If the function is merely a fashion, the answer is generally a local minimal point that may be global minima.

Stochastic approaches like GOA, which do not need gradient computation, are more likely to locate the global solution than deterministic methods like quadratic programming. Deterministic approaches need a smaller number of evaluations of fitness functions to reach the optimal result than deterministic methods [9].

Search, optimisation, machine learning, and design challenges may all benefit from the GOA. Simulation of evolution is used in the technique to find answers to complicated issues. As a population of individuals, each representing a possible solution to a particular issue, the GOA is built on this population. The GOA employs a number of fitness-based selection processes. GOA's basics and potential are summarised here. For example, (i) the GOA's speed of convergence and (ii) its simplicity in implementation are two possible benefits.

GOA is used to understand and implement the MPPT in this article. The grasshopper's social behaviour serves as a visual representation of GOA. In both nymph and adult stages, the grasshopper hunts for its prey. The grasshopper travels to find its meal, investigates the prey, and then finally takes advantage of the prey. The GOA approach is based on investigating and using grasshopper behaviour as a model activity. This grasshopper inquiry model is used in GOA to increase the convergence rate. There are a variety of ways to make an optimal solution using GOA. GOA levels investigations and exploitation. GOA addresses several of the most significant prospective issues in science and industry.

It is possible to represent GOA in the form of [9].

$$X_i = S_i + G_i + A_i \tag{2}$$

where X_i is the position of the i^{th} grasshopper, S_i is the social interaction, G_i is the gravity force, and A_i is the wind advection.

Social interaction, gravitational force result, and wind advection are included in the (2) [9]. The Grasshopper movement ensures that all of the aforementioned views are taken care of. Grasshoppers are used as a starting point for the discussion of social interactions.

$$S_i = \sum_{\substack{j=1 \\ j \neq i}}^{N} s\left(d_{ij}\right) \hat{d}_{ij} \tag{3}$$

where S is the social forces, $\hat{d}_{ij}$ is the distance between the ith and jth grasshopper.
The following is an expression for the social forces s(r),

$$s(r) = f_i e^{\frac{-r}{l}} - e^{-r} \qquad (4)$$

where l = attractive length scale and f = attraction intensity.
Attractive and repulsive forces that grasshoppers exert on each other when they move together or apart are becoming more critical in swarming behaviour. The comfort zone, attraction area, and repulsion region seem to be controlled by the parameters l and f.
The S function will clearly delineate the region between the repulsion zone, the comfort zone, and the attraction zone. With distances greater than ten, this S function produces a closer to zero value. The equation may be used to approximate the gravitational force (Gi) (5),

$$G_i = -g\hat{e}_g \qquad (5)$$

where $\hat{e}_g$ is the unity vector towards the earth's centre and g is the gravitational constant.
The wind advection (Ai) may be calculated as follows,

$$A_i = u\hat{e}_w \qquad (6)$$

where u = constant drift, $\hat{e}_w$ = unity vector in the wind direction.

$$X_i = \sum_{\substack{j=1 \\ j\neq i}}^{N} s(|x_j - x_i|)\frac{x_j - x_i}{d_{ij}} - g\hat{e}_g + u\hat{e}_w \qquad (7)$$

The concept cannot be used directly since either the grasshoppers reach their comfort zone rapidly or the swarm does not proceed toward the preset spot. In order to address the optimisation issue, a different version of this phrase is recommended.

$$X_i^d = c\left(\sum_{\substack{j=1 \\ j\neq i}}^{N} c\frac{ub_d - lb_d}{2} s(|x_j^d - x_i^d|)\frac{x_j - x_i}{di_j}\right) + \hat{T}_d \qquad (8)$$

where u_{bd} = upper limit in the Dth dimension, l_{bd} = lower limit in the Dth dimension, c is the decreasing coefficient to shrink the comfort zone, repulsion zone and attraction zone, and $s(r) = f_i e^{\frac{-r}{l}} - e^{-r}, \hat{T}_d$ is the value of the Dth dimension in the target.
As the number of iterations increases, the coefficient c reduces the comfort zone's size, and it may be calculated using equation (9),

$$c = c_{max} - l\frac{c_{max} - c_{min}}{L} \qquad (9)$$

where c_{max} = coefficient c maximum limit, c_{min} = coefficient c minimum limit, l = current iteration, L = maximum iteration count.
In GOA, it is widely understood that optimising for the best performance is the primary goal. This is the most motivating aim for all search-related solutions that may be saved for GOA. This has been completed with the hope of obtaining a more accurate and better goal as an outcome. It can clearly see how successful the GOA approach is in determining optimal global solutions in a given search space from the preceding discussions.

IV. Results and Discussion

This study sets the step-up boost converter's switching frequency is set at 5 kHz in this study. Additionally, the converter parameter influences the PV production system's static behaviour; hence, the exact DC-DC converter structure and settings are used to compare the proposed GOA-based MPPT control with conventional P&O MPPP controls. Computer simulations in the MATLAB Simulink framework are used to investigate and verify the proposed GOA-based MPPT and P&O algorithms. There is a 10-second for the whole simulation considered. The voltage response characteristics of the PV side and load side are presented in Table 1. Comparisons of average power retrieved from the array and the average power used by the load are shown in Table 2 for the proposed GOA-based MPPT and conventional P&O approaches.

The grid power, PV power, DC link voltage, and PV voltage are shown in Fig. 2 in response to sunlight intensity variations. The voltage of the load and PV sides is shown in Table 1 with their rising and settling times. It can be seen in Table 1 that the P&O MPPT approach takes longer to settle with 0.381 s. With a settling time of 0.360 s, the GOA-based MPPT algorithm described in Table 1 swiftly settles. Table 1 shows that the load side voltage of the P&O MPPT approach takes longer to settle than the GOA algorithm-based MPPT, which settles swiftly at 0.429 s.

Table 1 Steady-State Response

	Method	**Voltage**	**Rise time (s)**	**Settling time (s)**
Steady state response	P&O MPPT	PV side voltage	0.092	0.381
	GOA based MPPT		0.095	0.360
	P&O MPPT	Load side	0.143	0.452
	GOA based MPPT		0.138	0.429

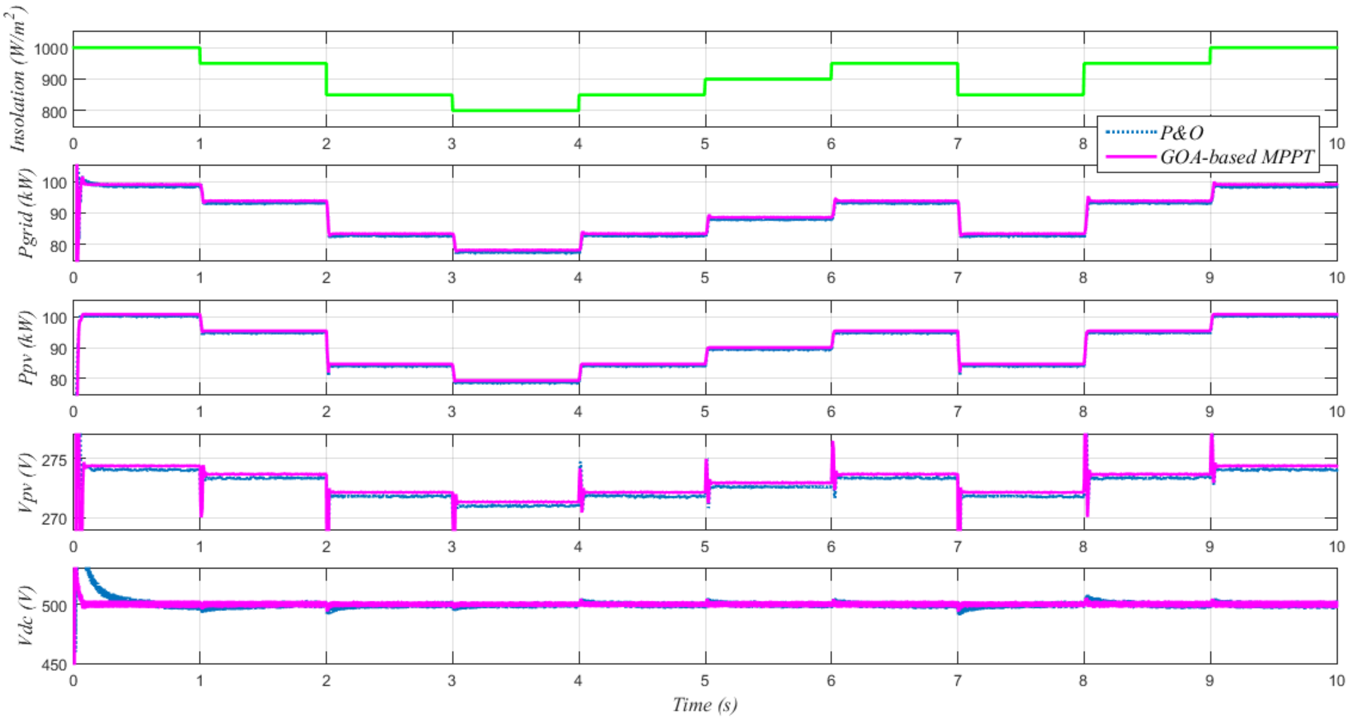

Fig. 1 Simulation waveforms under time-varying solar insolation

The ultimate purpose of MPPT is to extract the highest amount of power from a PV panel. Thus, each approach's power collected from the PV panel must be compared to discover which method is extracting the most power from the panel. As a result, in this simulation research, the waveforms generated by the two different MPPT algorithms are being compared side by side. The GOA-based MPPT yields the highest average power of 90.874 kW in the time period from 0 s to 10 s, whereas the P&O MPPT method only yields 85.071 kW. Fig. 1 shows that the putative GOA-based MPPT approach exports the maximum power to the load under time-varying solar insolation. The P&O technique exports less power than the GOA-based MPPT technique. To put it another way, the suggested GOA-based MPPT approach can deliver more power to the loads than existing MPPT systems.

V. Conclusion

Using a novel quick and precise MPPT termed the GOA-based MPPT approach, the performance of the PV array has been evaluated and found to be satisfactory. As an MPPT controller for a solar system, the GOA-based technique has shown to be promising. The ability of the GOA algorithm to prevent the local maximum MPOP due to nonlinear effects in the PV generating system has been shown. GOA-based MPPT is more efficient and more tightly controlled than other MPPT technologies. Under time-varying solar insolation, the GOA-based MPPT controller extracts an average power of 90.874 kW.

In contrast, the P&O MPPT technique extracts less power. It was shown that the GOA-based MPPT approach outperformed the P&O MPPT technique in simulated results. Improved voltage response characteristics and a decreased settling time were attributed to the alleged GOA-based MPPT controller's performance.

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