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Cuckoo Search Optimization Algorithm Based MPPT Technique for Photovoltaic Systems Under Partial Shading Condition

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Abstract:
The main aim of this research work is to provide maximum power point tracking (MPPT) design for photovoltaic systems using the Cuckoo Search algorithm technique. Due to the fact that the power to voltage characteristics of partially shadowed solar arrays create several peaks, a strong optimization strategy is desperately capture the peak of these arrays rather than just local ones. The required optimization method must detect the global peak with rapid convergence and accuracy. The P-V and I-V curves show multiple Local Maximums (LM) and a Global Maximum (GM) when partial shading (PS) is present. Through the Maximum Power Point Tapping process, the Cuckoo Search algorithm dynamically switches between the exploratory and exploitative phases, resulting in exceptional dynamic reaction and high convergence speed. Several simulations were run in the Matlab/Simulink system for various shading patterns to assess the practicality of the suggested method. The simulation results demonstrate the accuracy of the proposed approach for controlling the energy output at solar panels. Experiments show that the proposed method can reliably track global peaks and handle partial shading with optimal efficacy.

Keywords **—Maximum power point tracking (MPPT), Photovoltaic (PV), Partial shading (PS).**

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I. INTRODUCTION

Photovoltaic (PV) technology is the most promising renewable energy technology. Photovoltaic systems can be configured in three different ways: freestanding, grid-connected, and hybrid. Photovoltaic (PV) gadgets are mostly solar powered devices. The weather has a significant impact on PV system production. Depending on the building and cloud colour, different outcomes could occur. The DC-DC converter's duty cycle is changed in order to aspire to the MPP. The MPPT is required to maximize the performance of PV systems in order to achieve this goal. diverse weather conditions cause diverse behaviors from PV systems. The general features of PV generators vary and depend on a number of variables, particularly the meteorological circumstances, such as solar radiation and ambient temperature as well as the ageing of the PV cells, PS, and uneven lighting. When PV modules are exposed to constant sunshine, a single point of MPP results in a unimodal P-V characteristic. Some weakly lit cells become reverse bias and transform into receiving elements when a portion or the entire module is illuminated unevenly. These cells may be destroyed as a result of this "hot spot phenomenon. The general characteristics of PV generators differ and are dependent on several factors, especially the weather, which includes solar radiation, ambient temperature, aging of PV cells and PS, and uneven lighting. A uni-modal P-V characteristic is produced by a single point of MPP when PV modules are exposed to continuous sunshine. When part or all of the module is unevenly lighted, certain weakly lit cells become reverse biased and become receiving elements. This "heat spot phenomenon" could lead to the destruction of these cells. Solar modules are designed with switching devices that safeguard the cells that turn passive in order to address this issue. Partial shadowing modifies and simply becomes multimodal since bypass diodes are integrated onto solar panels. Several peaks, including a few local maximum power points (LMPPs) and one global maximum power point (GMPP), develop when the P-V characteristic is present. The number of peaks is always influenced by the sun's distribution throughout the solar power system, the quantity of parasitic components built into each photovoltaic module, and the presence or absence of shadows. The primary goal of the paper is to increase the PV system's performance under various conditions by utilizing an mppt controller and the cuckoo search optimization technique. The applicability of the recommended technique is verified by experiments and statistical studies that compare it to earlier meta-heuristic MPPT strategies. We can address CPS with 100% GM tracking capabilities and up to 99.7% power conversion efficiency using the recommended approach.

II. PV CELL CHARACTERISTICS

solar panels. Several peaks, including a few local maximum power points (LMPPs) In a PV characteristic Three key elements that make up : the maximum power point, the short circuit current, and the open circuit voltage. At the maximum power points, a photovoltaic cell can yield its maximum power. PV equivalent circuit is shown in figure1.

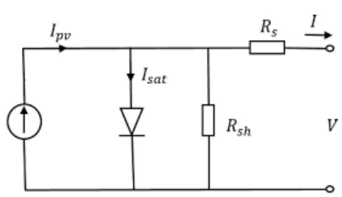

Fig.1 **PV equivalent circuit**

The basic equation of semiconductors that mathematically describes the photovoltaic cell I-V characteristic is: $I = I_{pv} - I_0\left(\exp\left(\frac{V+R_sI}{V_t\alpha}\right) - 1\right) - \frac{V+R_sI}{R_s}$

T- temperature of the p-n junction in Kelvin, and a is the diode ideality constant.

PV cell current is

$$I_{pv} = \left(I_{pv,n} + K_1(T - T_n)\right)\frac{G}{G_n}$$

Saturation current is ,

$$I_0 = \frac{\left(I_{SC} + K_1(T - T_n)\right)}{\exp\left(V_{oc} + \frac{K_v(T-T_n)}{aV_t}\right) - 1}$$

Thermal voltage is ,

$$V_t = \frac{N_sKT}{q}$$

The practical photovoltaic device has two resistances: Rp, which is parallel and has a stronger influence in the current source zone of operation, and Rs, which is series and has a stronger influence when the device works in the voltage source region. The device's several structural resistances add up to the Rs resistance.

III CUCKOO SEARCH OPTIMIZATION ALGORITHM

Because of their aggressive breeding strategy and lovely noises, cuckoos are interesting birds. Cuckoo birds come in various varieties, such as ani and guira. In order to improve the likelihood that their own eggs will hatch, some species, which deposit their eggs in communal nests, may remove the eggs of other species. Some people exhibit the behavior of brood parasitism.

Cuckoo birds, also known as Tapera, are clever birds that mimic the shape and colour of their hosts, potentially increasing the likelihood of successful reproduction. Examining the timing of Tapera's egg-laying process is astounding and remarkable. The female cuckoo first chooses a group of host species that have nest sites and egg qualities similar to their own, then she selects the best nest from these nests.Although host birds can be tricked into accepting foreign eggs, if these eggs are found, they are either thrown outside the nest or the nest is entirely destroyed, and the birds move on to a new location to construct a new nest. Typically, brood parasitism comes in three flavors: intraspecific, cooperative, and nest takeover.Cuckoo birds begin their search for the ideal nest, but this process is crucial to their mode of reproduction. Le'vy flying is one of the most popular models.

The process of exploring the nest is similar to the process of hunting for food; the walks and directions are selected and based on specific mathematical factors.This characteristic is employed in the optimization of several issues. Le'vy flight is a random walk where steps are described in terms of the step lengths and the step lengths have a probability distribution. According to power law , the step length in CS is derived from the le'vy distribution, where Le'vy ~ u = t–λ, where (1 < λ ≤ 3).

There are certain distinctions between hill climbing and computer science with regard to the MPPT Algorithm, but there are also some similarities.

a)Like in PSO and GA, CS is population-dependent, but it also employs elitism and/or selection in a manner akin to harmony search.

b)There is a chance that every big stride, inaddition to the step length, contains a substantial tail, which makes randomization more effective.

c)CS can be expanded to the type of Metapopulation Algorithm because it has less tunable parameters than GA or PSO.

Yang and Deb have employed three idealized rules for computer science. These guidelines are:

1.Every cuckoo deposits one egg at a time into a nest that is selected at random.

2.The next generation will inherit the best nest with the highest caliber of eggs.

3. There is a set number of nests available, and the host bird finds the cuckoo's egg with a probability of Pa, where Pa ∈ [0, 1].

In the event that the host bird finds out about the cuckoo's eggs, it may decide to depart the nest or destroy the eggs, but in the worst case scenario, a new nest is likely to be created with a probability of Pa. In its most basic version, the last assumption can be roughly represented by the fraction Pa, and new nests (with fresh random solutions) take the place of the n original nests. The following basic representation is employed in its simplest form; each egg stands for a solution, and a cuckoo egg for a novel solution. A straightforward method is used in this work, with only one egg in each nest.

The process of creating a new solution X(t+1) for a cuckoo i involves a levy flight.

Xi(t+1) = Xi(t) + α ⊕ Le'vy flight (λ)

In most circumstances, it is assumed that α=1, where α > 0, is the step size related to the optimization problem's scales . The current position is the first term in equation, and the transition probability is the second. The symbol ⊗ denotes an entry-wise multiplication, akin to those employed in PSO.

While there are certain differences, such as the following, between hill climbing and computer science in terms of the MPPT Algorithm, there are also some similarities.

1. CS uses a similar kind of elitism and/or selection to harmony search, but it is dependent on the population as in both PSO and GA.

2. Any big step may include a hefty tail in addition to the step length, which would makerandomization more effective.

3. Because CS has less fine-tuned parameters than GA or PSO, it can be modified to include the kind of metapopulation algorithm.The flowchart of Cuckoo search optimization is shown below.

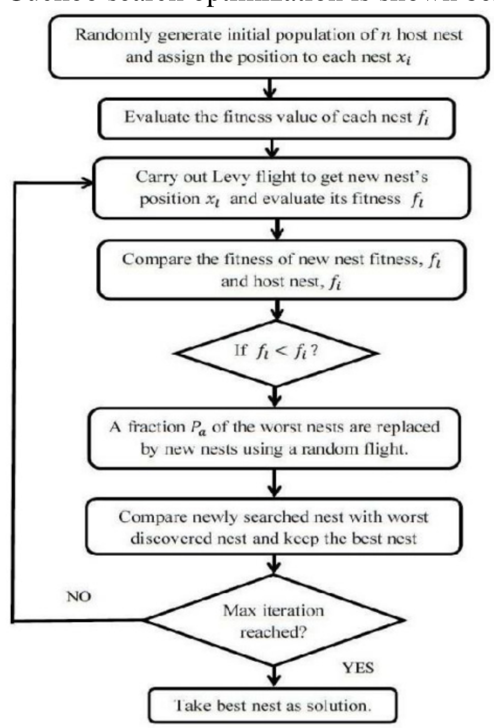

Fig.2Flowchart of CSO

It is necessary to choose the right search variables in order to use CS for designing MPPT. The samples come first; in this instance, they are defined as the PV voltage values, or Vi (i = 1, 2...n). The definition of the total number of samples is n.

The step size, indicated by an, comes in second. The PV power value at MPP is the fitness function is,

J = f(V)

since J depends on the PV voltage. The power is initially set as the starting fitness value and the generated values are the output to the PV modules. The best example available at the moment is the maximum power that a voltage can produce. The Lévy flight is then executed.

The overall flow of the optimization is MATLAB is used to implement the algorithm. First, initializations are made for all constants and variables, including voltage, current, power, number of samples. Using the voltage's current value With current, one can compute power. The voltage V_i^t and fitness J_i^t arrays, respectively, hold the new voltage and power values. Additionally, a check is done to see if the samples have already reached convergence or not before the beginning of each iteration. The samples will combine to form the same value and the corresponding power if they have converged to MPP.

All of the associated sample power levels are measured and stored in the J_i^tarray if the samples do not converge. The sample with the highest power is determined to be the best sample by analysing the array. All subsequent samples are therefore compelled to converge on this optimal value. The Lévy flight, as detailed by, is used to calculate the step sizes. As a result, fresh samples are discovered. The relevant powers of these fresh samples are then determined by measuring the PV panel. However, in the event that any sample yields a lower power, that specific sample is eliminated and a fresh sample is created. Until every sample converges to the MPP, the optimum point, this iteration is carried out.

IV RESULTS AND DISCUSSIONS

A solar PV system is first simulated and modelled. The detail of the EMVEE DIAMOND PV module is utilized. CSA-based Simulink model of the entire system. The waveform indicates that the power from the PV Module oscillations are kept to a minimum while tracking at maximum value. The MPPT algorithm is integrated into the system as an embedded function and is implemented as code. The MPPT algorithm determines the optimal voltage, or the voltage at which maximum power is produced, based on the voltage and current sensed from the panel. Therefore, the proposed research project is designed to function in either decreased shade or partial shade environments. Series connectors are used to arrange the four PV modules. The PV array layout is connected by a DC-DC boost converter, and it is controlled and optimized via MPPT. PID controllers are employed in the optimization and controlling methods, respectively. The maximum power point is observed via the MPPT, which is connected to the PID controller and EPSO.

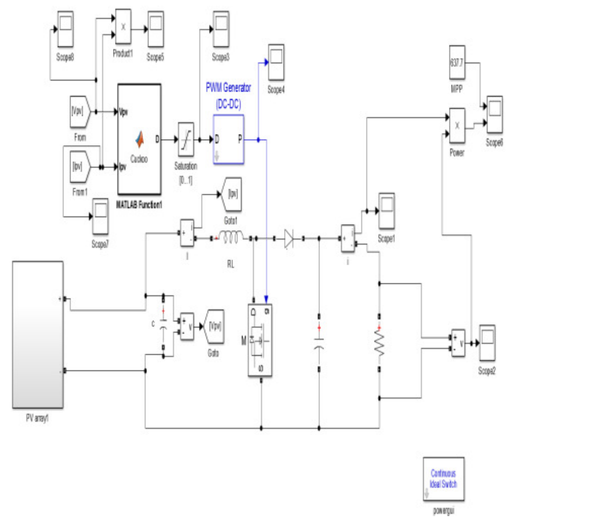

Fig.3 Simulation diagram of Cuckoo search optimization

The simulation diagram of cuckoo search optimization algorithm is shown in the above figure.

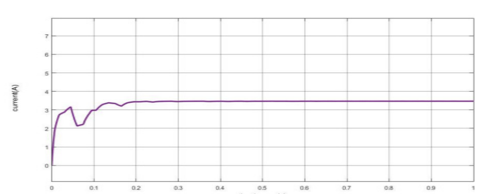

Fig.4characteristics curve of PV array

In the figure.4 it represent the characteristics cure of PV array that drawn between the time and current. Current and voltage plays an important role in the MPPT algorithm ,where they are used to determine whether the power is increased or decreased.

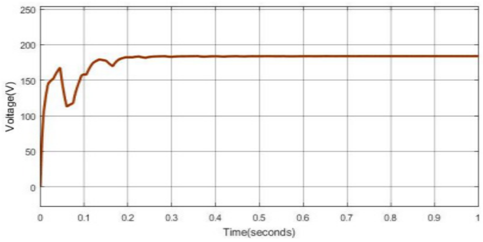

Fig.5 Characteristics curve of time and voltage

In the above figure 5 it represents characteristics curve of time and voltage. After the voltage reaches its highest value, it begins to flow steadily. Matlab/Simulink is used to do time domain simulation for the photovoltaic system MPPT under four shading patterns. The outcomes will be contrasted with FLC and traditional P&O techniques to demonstrate the superiority of the suggested adaptive fuzzy logic controller approach (ALFC). For every shade pattern, the tracking efficiency, tracking speed, and steady-state performance of three MPPT algorithms are examined. For the current work, four shading patterns that incorporate various shading effects were considered. The first, second, and third peaks of the global MPP are thought to be occupied by the shading patterns.

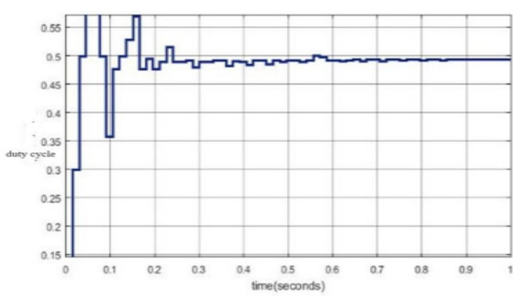

Fig.6 Characteristics curve of duty cycle

The above shows the duty cycle of the solar MPP array where it gives the on and off conditions. Because power in the duty cycle needs to be increased in the CSO algorithm, the duty cycle is the most significant one in the MPPT algorithm. Because CS naturally looks for a global peak, it is suited to handle partial shading. A partial shading scenario is built up in simulation to demonstrate this capability.

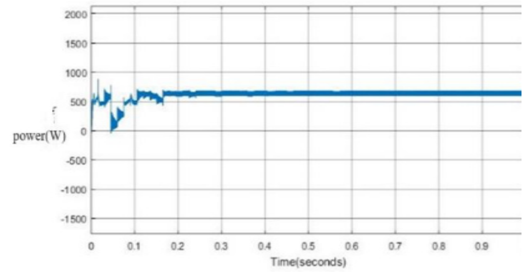

Fig.7 Characteristics curve of power

The above figure shows the characteristics curve of the Power obtained.Because power in the duty cycle needs to be increased in the CSO algorithm, the duty cycle is the most significant one in the MPPT algorithm. Because CS naturally looks for a global peak, it is suited to handle partial shading. A partial shading scenario is built up in simulation to demonstrate this capability.

V CONCLUSION

The MPPT algorithm is presented in this study using the Cuckoo search algorithm, which is based on the reduced form of the Levy flying distribution and the natural behaviour of the cuckoo. The results demonstrate that cuckoo can effectively track the MPP. It is verified by contrasting the outcomes with those from other techniques, such as artificial neural networks and incremental conductance. When compared to artificial networks and incremental conductance, Cuckoo search yielded highest power. Additionally, in the cuckoo search strategy, there are no more fluctuations and it increases the efficiency.

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