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Numerical Simulation and Performance Assessment of Improved Cuckoo Search based Maximum Power Point Tracking System for Solar Photovoltaic System Under Partial Shading Condition

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Abstract— The Government of India has set itself the ambitious target of meeting the country's rapidly rising demand, which is mainly met by coal and oil. Government has targeted to produce 40 percent of total energy generation through renewable energy by 2030. New Delhi works hard to produce 175 GW (GW) of renewable energy by 2022 with prevailing solar power, with a goal of 100GW, and wind power. Increasing environmental concerns, declining fuel supplies, and increased energy requirements have directed our focus towards an aspirational future based entirely on energy supply technologies for renewable sources and non-polluting sources. Power generation via photovoltaic (PV), due to their benefits such as ease of available, low cost, negligible environmental pollution and lower maintenance tariff, is increasingly becoming popular in comparison with other renewable resources. In this paper, three different maximum power point tracking techniques are used to create a solar pv system (MPPT). Modeling and simulation using MATLAB Simulink software is performed to verify the effectiveness of the proposed system. Maximum point tracking system based on cuckoo search algorithm has shown promising results in the complex operating condition.The model is examined in two partial shading patterns. By providing different input radiation values for all four serial-connection modules, we have generated partial shading conditions via the PV Array Block. The panel output is provided by the optimization block and is supplied to the boost converter from its duty cycle output. The results show that the optimization of cuckoo search algorithm gives better results than the algorithm for perturbing, observing, and incremental behavior, provided partial shading is possible.

Keywords:- *Photovoltaic (PV), Cuckoo Search, Matrix laboratory (MATLAB)), Particle Swarm Optimization (PSO), Mega Watt Peak (MWp), Soft Computing Techniques, Maximum Power Point Tracker (MPPT), Global Maximum Power Point (GMPP)*

I. INTRODUCTION

In photovoltaic power conversion into solar cells, two major breakthroughs have been made. To begin with, light assimilation results in the formation of an electron-hole pair. The electron and the hole are isolated by the gadget's structure. The electrons go to the negative terminal, while the holes go to the positive terminal. The power is provided based on the distribution of holes and electrons. The perfect terminal voltage and current are set using photovoltaic solar picture displays that are combined similarly, arranged, or mixed. The arrangement string configuration allows for a higher voltage level, but current evaluations are constrained by the individual photovoltaic cell value.[11]

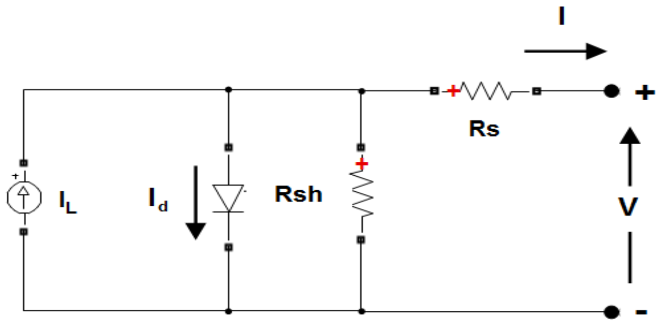

Fig. 1: Diode Modelling of Solar Cell

Figure 1.1 depicts the solar cell modelling diode. The solar cell diode model is used to calculate the I-V and P-V characteristics of solar cells. The controlling equations for the diode model are discussed, taking into account the Rs and Rp effects:

$$I = I_{sc} - I_{01}\left[e^{q\left(\frac{V+I.R_s}{kT}\right)} - 1\right] - I_{02}\left[e^{q\left(\frac{V+I.R_s}{kT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right) \qquad (1.1)$$

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_s}{nkT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right) \qquad (1.2)$$

where n is known as the "ideality factor," and the value of the ideality factor is usually determined by the solar cell manufacturing technology. A solar cell is a semi-conductor that converts sunlight into electricity. Solar cells, for example, will produce electricity using electromagnetic power if the photons' power is high enough to discern electron matches. A single or multi-crystal solar cell produces an electric flux voltage of 0.5 volts. (Solar irradiance is electromagnetic radiation emitted by the sun. The voltage of the solar cell's N/P obstacle layer causes this. The sum

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of electrons thumped into the conduction band determines the current or amperage of the solar cell. This current is linked to the measurement of solar radiation by the sun. The current of a solar cell can be increased by increasing the solar cell's surface area or by increasing the solar cell's measurement of solar radiation. A solar battery is made up of solar cells. As solar cells are combined, the current stays the same, but the voltage increases at the same time.

Solar cells are connected to form a "module" that supplies current and voltage to the system (and therefore power). To frame a 12-volt module, for example, 24 solar cells must be attached in a scheme. A photovoltaic module is also known as a solar cell array. Power is proportional to current voltage. When the sun shines at a rate of 1000 watts/meter^2 and the temperature is 25 degrees Celsius, the power level of a photovoltaic module is commonly referred to as the module's power output. This is an approximation of average sunshine in the middle of a clear summer day. A 15 percent effective 1m2 square module will thus produce 150 Watts in the early afternoon. A photovoltaic (PV) exhibit is a set of power-generating photovoltaic modules. A PV display can be made up of only one module, with output ranging from a few watts to several megawatts, depending on the number and output of the modules. The "heap" is powered by direct current produced by a photovoltaic display. From charging a battery to powering a matching system in a minicomputer to powering a structure or city, batteries are used in a variety of applications. An inverter that adjusts the immediate current in the current should be associated with a PV cluster when it is linked to the utility network. The majority of inverters have a 90% efficiency rating. The advanced inverters generate extremely clean electricity at a constant voltage. Clean power denotes a spinning current that is nearly free of mutilation or harmonics, similar to a sinus wave. Solar panels today are just 30-40 percent electrical. Radiation from the sun. Via maximum power point control, the aim is to improve the operational efficiency of solar photovoltaic systems. The source impedance and load impedance can be adjusted by changing the duty cycle of the corresponding boost converter, allowing for complete power transfer monitoring from the photovoltaic system.[18]

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II. MAXIMUM POWER POINT TRACKING

The standard solar photovoltaic models with one and dual diodes are seen. The single diode model is less complex, but the dual diode model is more advanced in order to increase solar PV modelling performance. Double diode displays, on the other hand, have a more complicated and mathematical charge in parameter extraction. In electrical equivalent circuits for the solar photovoltaic system shown in figure 1.1. The performance equation for a single diode model is as follows.

$$I = I_{PV} - I_0\left[exp\left(\frac{V+IR_S}{nV_T}\right) - 1\right] - \left(\frac{V+IR_S}{R_{sh}}\right) \quad 2.1$$

Where,

I_{PV} output current PV module, A
I_0 diode saturation current, A
I_D Diode Current, A
I_{Sh} Shunt Current, A
R_S Series Resistance, Ω
R_{Sh} Shunt Resistance
V_T Thermal Voltage,V
V output voltage of PV array, V
I output current of PV array, A
N_S No.of series cell connected
N_P No. of Parallel cells connected
K Boltzmann constant (1.3806503 x10^{-23} J/K).
q electron charge(1.60217646 x 10-19 C)
T Temp., ° C.
n fill Factor (ideal=1)

Thermal relation is provided

$$V_T = KT / q. \quad 2.2$$

The diode current expression is indicated

$$I_D = I_0\left(e^{qVd/nKT} - 1\right) \quad 2.3$$

The current load expression is given

$$I = I_{PV} - I_d - I_{sh} \quad 2.4$$

Shunt current is given by Shunt

$$I_{sh} = \left(\frac{V+IR_S}{R_{sh}}\right) \quad 2.5$$

The current phase equation is calculated by

$$I_{PV} = I - I_0\left[\exp\left(\frac{V_{ph}+R_{sh}I_{sh}}{n}\right) - 1\right] \quad 2.6$$

The current equation is given by the reverse saturation

$$I_0 = n_pI_{ph} - n_pI_{rs}\left[exp\left(\frac{KV}{n_s}\right) - 1\right] \quad 2.7$$

I-V characteristics represent a relationship between current and voltage in the Solar Cell under various irradiation and temperature conditions. This curve evaluates the parameters and behaviour of certain solar cells.

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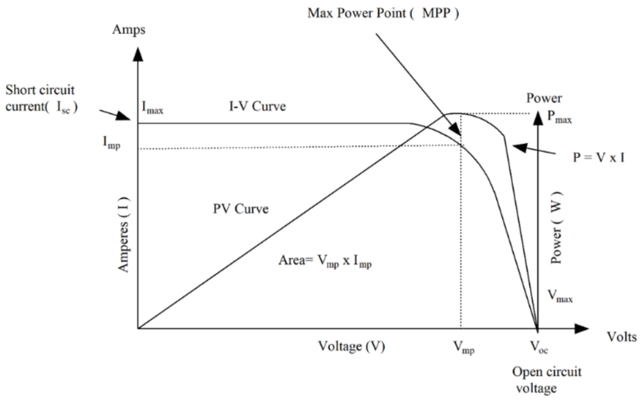

Figure. 2.1 I-V Curve of Solar Cell Characteristics

The graph above depicts a standard solar PV cell that operates at a standard test condition (STC). The charcteristic curve demonstrate the relation of voltage and current which in turn is the result of solar cell power generation. The solar cells are open-circuited and not connected to a load, ensuring that the current is zero and the cell voltage is at its maximum. When the voltage transverse solar cell is zero, the current through the solar cell is known as short circuit (Isc).[16]

$P_{max} = V_{oc} \times I_{SC}$ 2.8

$P_{mpp} = V_{mp} \times I_{mp}$ 2.9

Where,

V_{oc} Open Voltage Circuit

I_{sc} Short circuit current

P_{max} Max Power

V_{mp} High voltage at the point of service

Effect Optimum current at operational condition.

P_{mpp} Highest power at the operational condition.

Maximum power point monitoring methods are used to obtain the maximum value of power in a solar system, allowing the most reliable and maximum amount of power to be sent from the source to the load. We know that solar radiation and temperature fluctuate during the day, so an algorithm that can monitor the MPP is needed. These can have a major impact on the PV system's performance. It is also claimed that if the system's operating point is not closer to MPP, a large amount of losses would occur. The "Maximum Power Point" is the voltage point at which the power value is at its highest. This point, however, varies with solar irradiance and temperature, and the key challenge is determining the optimum voltage and current points for maximum power under varying atmospheric conditions. The majority of MPPT methodologies depend on PV characteristics such as duty cycle management and the use of a look-up table.[15]

III. PARTIAL SHADING CONDITION

Research shows that the methods offered by the MPPT method of tracking points are imperfect and fail to track specific MPP points Implement MPPT [(Maximum Power Point Tracking)] in a shading-condition, there is the algorithm problem, the cost and the failure problem. In order to avoid the difficulties caused by spoofing attack, several methods such as tracking and authentication are performed in the past of each research. This figure illustrates that the system that has been addressed is just like a partial shaded system.

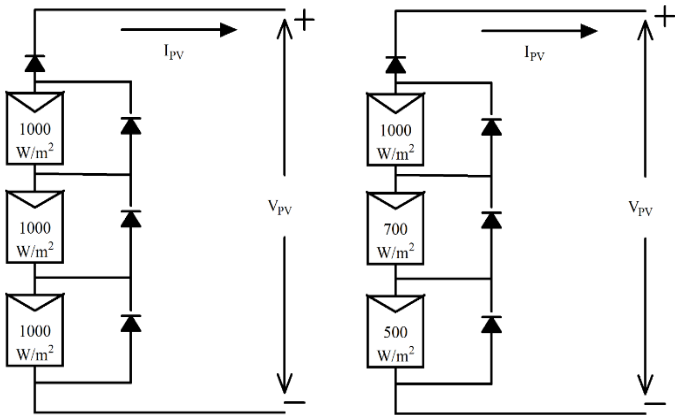

Fig 3.1 Comparative Irradiance Representation of Normal System and Partial Shaded System

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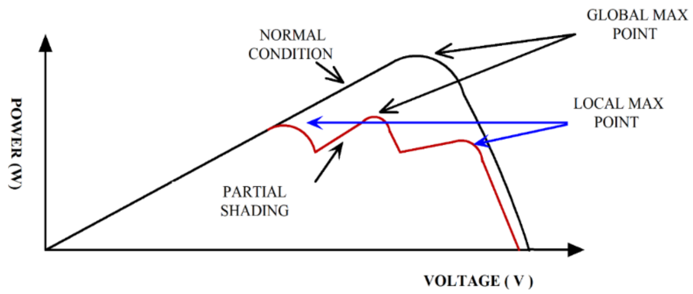

Fig 3.2 Characteristics of PV Module under partial shading condition

When it comes to partial shading, cuckoo search optimization is the most common technique due to its effectiveness and faster tracking speed. It efficiently handles the optimum voltage, making it easier to find the highest power point. Various parameters are predetermined before the process begins in this method. Then, in order to monitor the maximum power point, we must select a vector voltage (V_1 to $V_{d,}$ where'd' is module) that is controlled by the device. In this case, the output voltage is compared to the real voltage. This algorithm's code is written in the MATLAB software.
We discovered a function 'F' in the flowchart that does not remain constant and varies with the weather, so the condition function is re-initialized repeatedly to obtain the new maximum power point.
A PV array is connected to a DC/DC boost converter; with the duty cycle controlled using the cuckoo search optimization technique. We divided two PV modules into four groups in our system, each of which contains 18 cells connected in series with the bypass diode. Some of the four classes get partial shading, while others get half and full shading. The converter, which consists of a MOSFET switch, inductor, capacitors, and load resistance, passes the voltage obtained from the PV array.

IV. PROPOSED METHODOLOGY

Cuckoos are fascinating birds, due to their beautiful sounds, and their aggressive reproduction strategy. There are some types of cuckoo birds like *ani* and *guira*. These types lay their eggs in communal nests and these may remove others' eggs to increase the hatching probability of their own eggs [16]. Brood parasitism is the 785ehavior of some cuckoo birds, *Tapera* are intelligent birds that imitates the host birds in shape and colour, that may led to increase reproduction probability. It is surprising and magnificence to look at the timing of the process of laying eggs for Tapera. Firstly, cuckoos female select a group of host species with similar nest sites and egg characteristics to their own, then choosing the best from these nests. Host birds could be fooled and accept foreign eggs but if these eggs discovered, they are dumped outside the nest or the nest completely destroyed and go to new area to build a new nest. Usually there are three kinds of brood parasitism namely intraspecific, cooperative and nest takeover [17].Cuckoo birds start in looking for the best nest, but this step has an important role in cuckoo's reproduct ion method. The process of searching the nest is the same as the process of searching food, the walks and directions are chosen and modelled on certain mathematical functions, *le'vy* flight is one of the most common models.A recent study by Reynolds and Frey shows that the fruit flies or Drosophila melanogaster, explore their landscape using a series of straight flight paths punctuated by sudden 900 turn leading to a *le'vy* flight style [18]. This behavior is used in making optimization for different problems [19]. *Le'vy* flight is a random walk in which the step lengths have a probability distribution and steps are defined in terms of the step lengths. In CS, the step length is drawn from le'vy distribution according to power law [20], i.e.
Le'vy $\sim u = t^{-\lambda}$ *where* $(1 < \lambda \leq 3)$
Here the steps essentially form a random walk process with a power-law step-length distribution with a heavy tail [21]. *Le'vy* flight in two-dimensional plan is shown in Fig 4.1

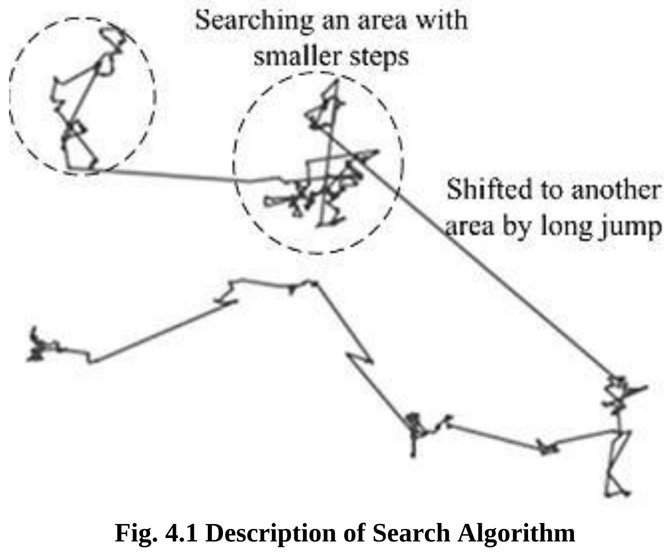

Fig. 4.1 Description of Search Algorithm

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There are three idealized rules used for CS have been used by Yang and Deb. [21]. These rules are: Each cuckoo lays one egg at a time and places it in a randomly chosen nest. The best nest with high quality of eggs will carry over to the next generation. The number of available nests is fixed and the egg laid by a cuckoo is discovered by the host bird with a probability of Pa, where Pa $\in [0, 1]$. If the host birds are discovered the cuckoo's eggs, the host bird can abandon its nest or destroy cuckoos' eggs or in this case a new nest will be generated with probability *P*a. In simple form, the last assumption can be approximated by the fraction *P*a and the n nests are replaced by new nests (with new random solutions). In a simple form the following simple representation is used, each egg represents a solution and a cuckoo egg represents a new solution. In this this work, a simple approach is used where each nest has only a single egg. CS can be summarized as pseudo code. [11]
When generating a new solutions X(t+1) for a cuckoo i a levy flight is performed
$Xi(t+1) = Xi(t) + \alpha \oplus$ *le'vy* flight (λ)
Where $\alpha > 0$, is the step size related to the scales of the optimization problem, in most cases it is assumed that α=1, [20]. Equation (3) consists of two terms, the first term is the current location and the second term is the transition probability. The product $\oplus$ means an entry wise multiplication, which is similar to those used in PSO. The random step length is drawn from equation (2).For MPPT Algorithm there is a similarity between CS and Hill climbing in some large scale randomization, but there are some differences such as. CS depends on the population as in both PSO and GA, but it uses some sort of elitism and/or selection similar to that used in harmony search. The possibility for any large step in addition to the step length has weighty tail that led to the process of randomization is more efficient.CS has less tuned parameters compared to GA or PSO, so that CS can thus be extended to the type of Meta-population Algorithm. The fitness value of power is calculated as in $Pa=Va\times Ia$ .Then find the best current, choose a .random nest and generate a new solution by random walk as [13]
$Vi\ (t+1) = Vi\ (t) + \alpha \oplus$ L´evy (**λ**)
A simplified scheme of a random walk is used which is less efficient than levy flights. In addition to the step size should be a vector for problems with different scales, with step size=0.05, [13]. After new solutions are generated, values of the fitness are tested again and best current is selected. Iterations are performed until all nests reach at the maximum power point. Psuedo code is as follows-

1. Begin
 (Parameter Initialization- no of clusters, no of host nests)
2. Consider NH host nests containing 1 egg (solution) each
3. For each solution of host i
4. Initialize x_i to contain k randomly selected cluster centroids (corresponding to k clusters), as $x_i = (m_{i,1},\ldots,m_{i,j},\ldots m_{i,k})$ where $m_{i,k}$ represents the kth cluster centroid vector of ith cluster centroid vector of i^{th} host.
 End for loop
5. For **t** iterations
6. For each solution of host i of the population
7. For each data document z_p
8. Calculate distance $d(z_p,m_{j,k})$ from all cluster centroids $C_{i,k}$ by using Euclidean Distance eq-2
9. Assign z_p to $C_{i,k}$ by
 $d(z_p,m_{j,k}) = \min_{k=1\ldots k} \{ d(z_p,m_{j,k}) \}$
 End for loop in step 7
10. Calculate fitness function $f(x_i)$ for each host nest i by Eq-(9)
11. End for loop in step 6
12. Replace all worse nests by **new Cuckoo eggs**
13. A fraction pa of worse nests are abandoned and new ones are built randomly
14. Keep the best solutions (or nests with quality solutions)
15. Find the current best solution
End for loop in step 5
16. Consider the clustering solution represented by the best solution
17. End

For simplicity in describing the CSA, two behaviours are utilized: breeding behaviour and Levy flight. Cuckoos lay their eggs in communal nests, but they always remove others' eggs, to increase the hatching probability of their own eggs. But a host cuckoo throws an alien egg away or discards the current nest and build another nest elsewhere, as it discovers the alien egg. In each step of the previous breeding behaviour, poorer solutions are abandoned, as the new solutions are generated. The flight path of many birds between nests to reach the best nest is effectively a random walk that is representative of Levy flights with step lengths drawn from the Levy distribution. The propo0sed isolated system initially operates at any operating point. When the environmental conditions change, the optimum chopping ratio n or duty cycle D is adjusted for maximum power tracking.[14]

V. RESULTS

For Simulation the following condition are implemented.

- Modelling and simulation is done in MATLAB software.
- It contain PV array having DC/DC boost converter for which the duty cycle is managed by CS optimization.
- Here, two PV modules are divided into four groups which consist of 18 cells in series connected with bypass diode.

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- From four groups, three has no any type of partial shading means full irradiation are coming but on one group receive half radiation than other three that is one group is partial shaded.

Different MPPT techniques were simulated for qualitative and quantitative comparison of the MPPT techniques in the given condition. Following MPPT algorithms were implemented in the given simulation-

- Perturb and Observe Method
- Incremental conductance Method
- Adaptive Neuro Fuzzy Inference System (ANFIS) System
- Particle Swarm Optimization
- Cuckoo search Algorithm

Table 5.1 (Partial Shading Scenario- Test Case-1)

Module	**Irradiations (W/m^2)**	**Temperature (ºC)**
1	500	25
2	800	25
3	1000	25
4	1000	25

Table 5.1 depicts a partial shading scenario for test case-1. In this scenario, the device receives a constant temperature input while radiation is applied in ascending order to different modules linked in sequence.

Table 5.2 (Partial Shading Scenario- Test Case-2)

Module	**Irradiations (W/m^2)**	**Temperature (ºC)**
1	500	26
2	800	28
3	600	27
4	700	27.5

Table 5.2 depicts a partial shading scenario for test case 2. In this scenario, the device receives variable temperature feedback when radiation is applied in a random order to different modules linked in sequence.

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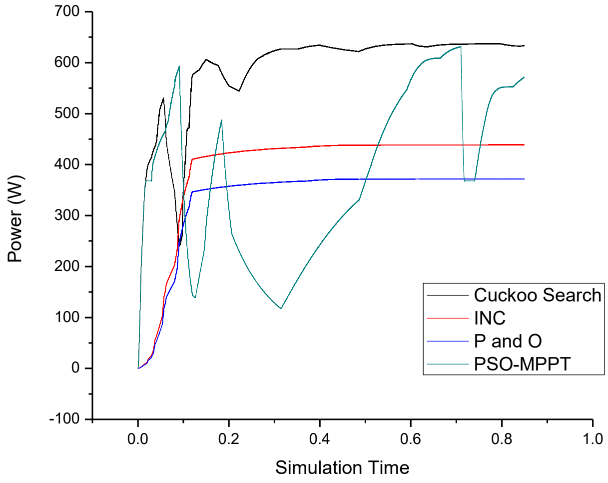

Fig.5.1 Comparative Assessment of MPPT Techniques

Under partial shading, Figure 5.1 shows a comparison of traditional techniques such as perturb and observe and incremental conductance approach with soft computing-based techniques such as cuckoo search algorithm and particle swarm optimization. The output of the cuckoo search algorithm is observed to monitor the maximum power after the transient response within the first 0.275 seconds. In particle swarm optimization, there are several iterations before reaching a steady state answer. It can be shown that traditional algorithms struggle to achieve full power tracking in the partial shading condition from the initial state. Before reaching the final height, i.e. the global maximum power point, it converges. 1.75 seconds were needed to reach the steady state. During the particle swarm optimization method, the number of search iterations is 33-35 iterations. It can be shown that there are many ups and downs before reaching steady state error, implying that particle swarm optimization was capable of monitoring the maximum power point under variable irradiance and variable temperature conditions. Using the improved cuckoo search algorithm, the disadvantage of particle swarm optimization was eliminated.

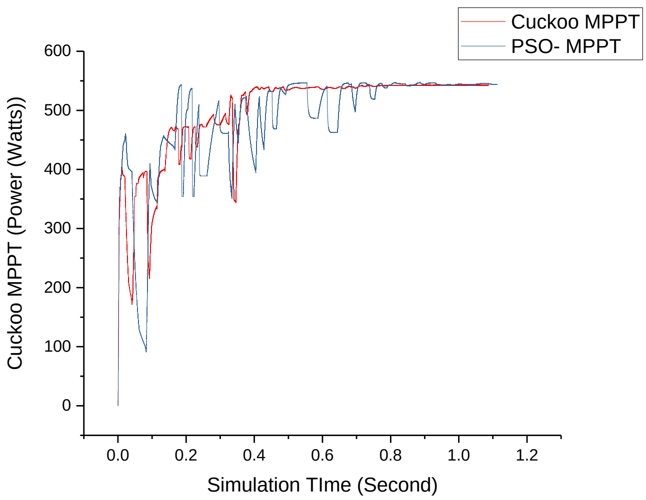

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Fig.5.2 Comparative Assessment of MPPT Techniques (Test Case-2)

Under partial shading conditions, the figure of merits compares traditional techniques such as perturb and observe and incremental conductance approach with soft computing related techniques such as cuckoo search algorithm and particle swarm optimization. When compared to other techniques in partial shading and variable irradiance conditions, the performance of the cuckoo search algorithm in tracking the maximum power after transient response is precise, accurate, and quick. For an accurate evaluation of the proposed system's accuracy and precision, the technique's efficacy is further evaluated on several variable test systems and related conditions. We evaluated the proposed system's efficacy and accuracy both qualitatively and quantitatively.

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VI. CONCLUSION

In this research In this study, a soft computer-based charge controller based on cuckoo search optimization was developed to efficiently monitor the maximum power points of I V characteristics of PV systems under variable irradiance and complex operating conditions, as well as to manage soft computer-based control controls with boost configuration and duty cycles based on improved particulate swarm optimization. In high-energy applications, the charging controller is connected to PV modules and the battery in the storage unit, as well as the inverter. According to the findings of this study, the operating performance of solar photovoltaic systems can be improved by using an efficient power converter with a soft computer-based MPPT controller system. It improves the performance of solar photovoltaic systems by incorporating an efficient charge controller based on an intelligent maximum energy monitoring system.

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