Numerical Simulation and Comparative Assessment of Improved Cuckoo Search and PSO based MPPT System for Solar Photovoltaic System Under Partial Shading Condition

Ashish Raj[1], Manoj Gupta[2]
[1]PhD Scholar, Department of Electrical and Electronics Engineering, Poornima University, Jaipur, Rajasthan, India
[2]Professor, Department of Electrical and Electronics Engineering, Poornima University, Jaipur, Rajasthan, India
ashish.raj@poornima.edu.in[1], manojg@poornima.edu.in[2]

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Abstract— The Indian government has set an ambitious goal of satisfying the country's fast expanding demand, which is currently fulfilled primarily by coal and oil. By 2030, the government wants renewable energy to account for 40% of total energy generation. New Delhi is working hard to develop 175 GW (GW) of renewable energy by 2022, with an aim of 100 GW of solar power and 100 GW of wind power. Increasing environmental concerns, dwindling fuel supplies, and rising energy demands have shifted our focus to an idealistic future based solely on renewable and non-polluting energy supply technology. Photovoltaic (PV) power generation is becoming more popular in contrast to other renewable energy sources due to advantages such as ease of access, low cost, less environmental contamination, and lower maintenance costs. In this paper, different maximum power point tracking strategies based on particle swarm optimization and improved cuckoo search based optimization are employed to develop a solar PV system (MPPT). To validate the effectiveness of the proposed system, modelling and simulation using the MATLAB Simulink software are carried out. In the complex operating environment, a maximum point tracking system based on the cuckoo search algorithm has demonstrated promising results. Two partial shade patterns are used to analyse the model. We created partial shading conditions using the PV Array Block by giving distinct input radiation values for all four serial-connection modules. The optimization block generates the panel output, which is fed to the boost converter via its duty cycle output. The results reveal that if partial shading is possible, the optimization of the cuckoo search method produces better results than the methodology for perturbing, watching, and incremental behavior.

***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]

When photons from the sun reach a PV cell, they are absorbed, causing electrons in the cell's atoms to travel to the cell's holes[Ashley, 1992]. This is the process of changing the physical location of electrons and holes in order to generate electricity. Fahrenbruch and Bube (2012) cite electricity as one example. To put it another way, the photovoltaic effect is the name given to the physical process of converting sunlight into energy. via the photovoltaic cell A single PV cell can produce between 0.5 and 0.8 volts, or 2 volts. watts of power and can't power a wristwatch or a pocket calculator They require a minimum of 1 to 2 volts in either case. The power output, on the other hand, can vary. By connecting numerous PV cells to make a module, the total amount of energy produced can be increased. This may be the case. Solar panels, which are larger units, are used to generate electricity. A large number of panels are linked together. Arrays are a type of data structure. Solar cells are another name for photovoltaic cells [Nguyen]. [Lehman, 2006] and Lehman, 2006]. Two critical processes are involved in converting solar energy into photovoltaic cells [Razykov et al., 2011].. The absorption of light is first caused by a pair of electron-holes. The electron and hole are then separated by the semiconductor chip's structure. The electrons are separated into negative and positive terminals, whereas the holes are separated into positive and negative terminals. The hole spins as the devices remain stationary. As a result, an electron quits its hole and enters the empty location of another hole, and potential electrons do the same. The solar cell then turns into a conductor, absorbing electricity from the silicon wafer [Baeg et al., 2013]. However, the dopants, which are impure atoms, are required for the solar cell to function. The most frequent dopants utilised in PV cells are boron and phosphorus. When doped with Phosphorous, the Silicon Solar Cell becomes a negative type (n-type), however when doped with Boron Positive (p-type), the cell stays a negative type.

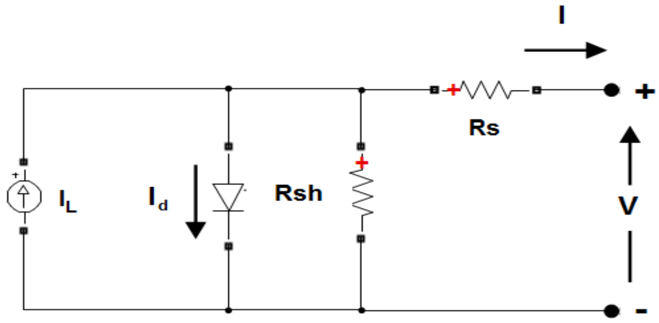

Fig. 1.1: Diode Modelling of Solar Cell

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:

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

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

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 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 joined to form a "module" that provides the system with current and voltage (and therefore power). A design of 24 solar cells, for example, is required to frame a 12-volt module. A solar cell array is another name for a photovoltaic module. The current voltage is proportional to the power. The power level of a photovoltaic module is often referred to as the module's power output when the sun shines at a rate of 1000 watts/meter2 and the temperature is 25 degrees Celsius. This is an approximate representation of average sunshine on a clear summer day. In the early afternoon, a 15% effective 1m2 square module will produce 150 Watts. A photovoltaic (PV) display is a collection of solar modules that generate electricity. Depending on the number and output of the modules, a PV display can be made up of just one module, with output ranging from a few watts to many megawatts. A photovoltaic display generates direct current, which powers the "heap." Batteries are used in a number of purposes, from charging a battery to powering a matching system in a minicomputer to powering a structure or city. When a PV cluster is connected to the utility network, it should have an inverter that modifies the instantaneous current in the current. The majority of inverters are rated at 90% efficiency. At a constant voltage, the modern inverters produce highly clean electricity. A spinning current that is largely free of mutilation or harmonics, comparable to a sinus wave, is referred to as clean power. Solar panels are just 30-40% electrical nowadays. The sun's radiation. The goal of maximum power point control is to boost the efficiency of solar photovoltaic systems. The duty cycle of the associated boost converter can be changed to modify the source and load impedances, allowing for complete power transfer monitoring from the photovoltaic system. [18].

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.

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

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

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

The diode current expression is indicated

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

The current load expression is given

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

Shunt current is given by Shunt

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

The current phase equation is calculated by

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

The current equation is given by the reverse saturation

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

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.

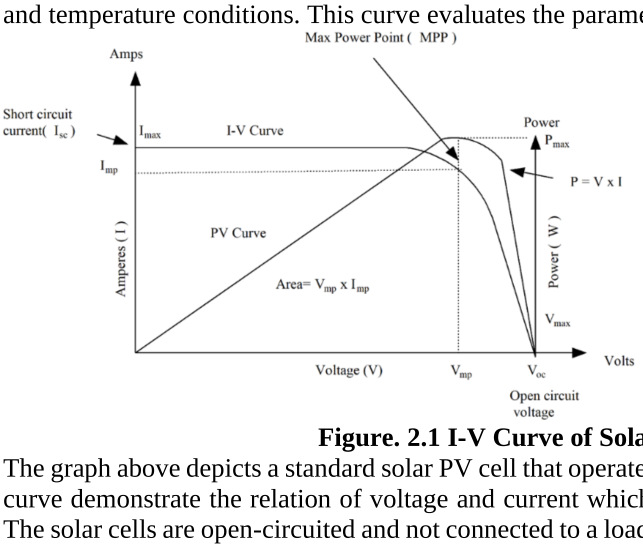

Figure. 2.1 I-V Curve of Solar Cell Characteristics

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 in solar systems to determine the maximum value of power, allowing the most dependable and maximum quantity of power to be transmitted from the source to the load. We know that sun radiation and temperature change throughout the day, thus a monitoring algorithm for the MPP is required. These can have a significant impact on the performance of the PV system. It is also suggested that if the operating point of the system is not closer to MPP, significant losses will occur. The voltage point at which the power value is at its peak is known as the "Maximum Power Point." This point, however, varies with solar irradiance and temperature, therefore establishing the best voltage and current points for maximum power under changeable atmospheric circumstances is a major difficulty. PV characteristics such as duty cycle management and the usage of a look-up table are used in the majority of MPPT approaches. [2]

III. PARTIAL SHADING CONDITION

According to research, the MPPT technique of recording points is flawed, as it fails to track individual MPP points. There is an algorithm difficulty, a cost problem, and a failure problem when using MPPT [(Maximum Power Point Tracking)] in a shading-condition. Several approaches such as tracking and authentication are conducted in the past of each investigation to avoid the challenges posed by spoofing attacks. This diagram shows that the system under consideration is similar to a partially shaded system..

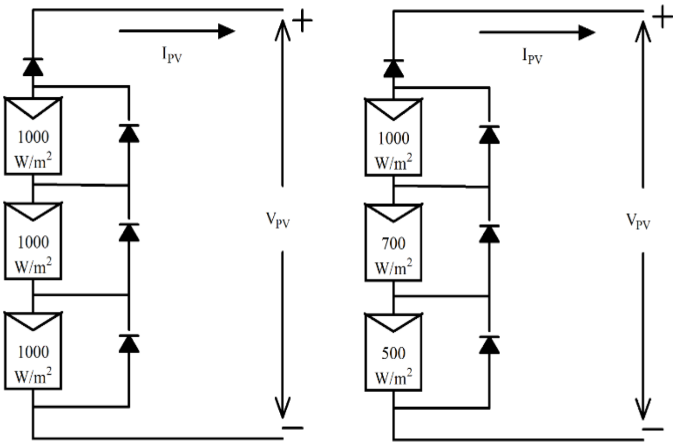

Fig 3.1 Comparative Irradiance Representation of Normal System and Partial Shaded System

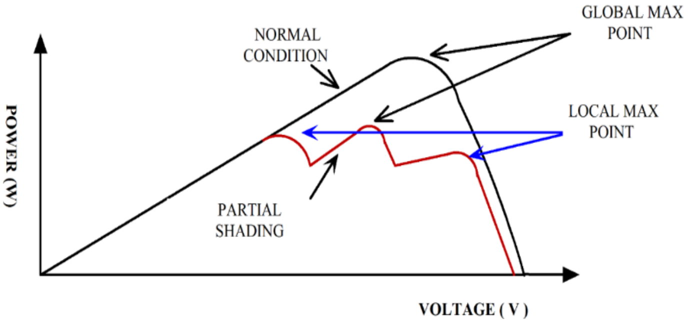

Fig 3.2 Characteristics of PV Module under partial shading condition

Cuckoo search optimization is the most used partial shading approach because to its efficacy and better tracking speed. It efficiently manages the ideal voltage, making finding the highest power point easier. In this procedure, certain parameters are predetermined before the procedure begins. Then, in order to monitor the maximum power point, we must choose a device-controlled vector voltage (V1 to Vd, where 'd' is module). The output voltage is compared to the real voltage in this scenario. The code for this algorithm is provided in the MATLAB software.
The condition function is re-initialized continuously to acquire the new maximum power point because we uncovered a function "F" in the flowchart that does not remain constant and varies with the weather.
The duty cycle of a PV array is adjusted using the cuckoo search optimization methodology, which is coupled to a DC/DC boost converter. In our setup, we divided two PV modules into four groups, each with 18 cells connected in series with the bypass diode. Partial shading is applied to some of the four classes, while half and full shading is applied to others. The voltage obtained from the PV array is sent through the converter, which comprises of a MOSFET switch, inductor, capacitors, and load resistance.

IV.CUCKOO SEARCH OPTIMIZATION BASED MPPT

Because of their wonderful noises and aggressive reproduction technique, cuckoos are interesting birds. Cuckoos come in a variety of shapes and sizes, including ani and guira. These species deposit their eggs in communal nests and may remove other people's eggs to boost the chances of their own eggs hatching [16]. Brood parasitism is the behaviour of some cuckoo birds, Tapera, which are intelligent birds that copy the host birds in shape and colour, possibly increasing the chances of reproduction. Looking at the timing of Tapera's egg-laying process is both startling and magnificent. Cuckoo females first choose a group of host species that have similar nest locations and egg features to their own, then choose the best from among these nests. Host birds may be duped into accepting foreign eggs, but if these eggs are discovered, they are tossed outside the nest or the nest is completely destroyed, and the host bird moves to a new location to start a new nest. Brood parasitism can be classified into three types: intraspecific, cooperative, and nest takeover [17]. Cuckoos begin their search for the best nest, but this phase is critical to the cuckoo's reproduction technique. The process of seeking for a nest is similar to that of looking for food; the walks and directions are chosen and modelled on mathematical functions, with Levy flight being one of the most prevalent. According to a recent study by Reynolds and Frey, fruit flies, or Drosophila melanogaster, explore their surroundings by flying in a sequence of straight lines punctuated by unexpected 900 turns, resulting in a le'vy flight style [18]. This tendency is employed in the optimization of a variety of issues [19]. Le'vy flight is a random walk with a probability distribution for step lengths and steps described in terms of step lengths. The step length in CS is calculated using the Le'vy distribution according to the 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

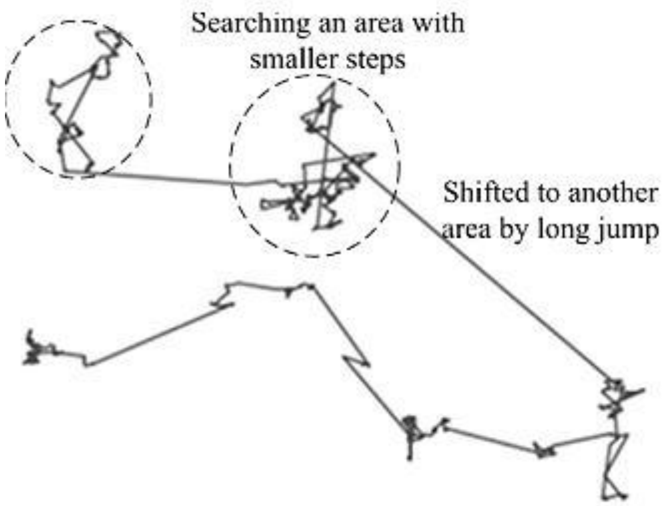

Fig. 4.1 Description of Search Algorithm

Yang and Deb have employed three idealised rules for CS in their work. [21.] These are the rules: Each cuckoo lays one egg at a time in a nest that is chosen at random. The best nest with the best eggs will be passed down to the following generation. The number of accessible nests is fixed, and the host bird discovers the cuckoo's egg with a probability of Pa, where Pa is between 0 and 1. If the cuckoos' eggs are discovered by the host birds, the host bird can depart its nest, destroy the cuckoos' eggs, or a new nest will be established with probability Pa. The last assumption can be approximated by the fraction Pa, and the n nests are replaced by new nests in the simplest form (with new random solutions). The following simple representation is employed in a simplified form: each egg symbolises a solution, and a cuckoo egg symbolises a new solution. A simple technique is adopted in this work, with each nest containing only one egg. Pseudocode can be used to describe CS[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 $\alpha > 0$, denotes the step size connected to the optimization problem's scales; in most cases, 0 is assumed [20]. The present position is the first term in Equation (3), whereas the transition probability is the second term. The term "product" refers to an entry-by-entry multiplication, like to those seen in PSO. The length of a random step is calculated using equation (2). In certain large-scale randomization, the MPPT Algorithm is comparable to CS and Hill climbing, although there are notable distinctions, such as. CS, like PSO and GA, is based on the population, but it employs elitism and/or selection in a manner similar to harmony search. The possibility for any huge step, in addition to the step length, has a hefty tail, resulting in a more efficient randomization process. Because CS has fewer adjusted parameters than GA or PSO, it can be used to create a Meta-population Algorithm. Pa=VaIa is the formula for calculating the fitness value of power. Then, as [13] suggests, pick the best current, select a.random nest, and generate a new solution via random walk.

$Vi\ (t+1) = Vi\ (t) + \alpha \oplus$ L´evy **(λ)**

The method employed is a simple random walk, which is less efficient than levy flights. For problems with different scales, a vector should be added to the step size, with step size=0.05, [13]. Following the generation of new solutions, the fitness values are examined again, and the best current is chosen. Iterations are carried out until all nests have reached their full power. The following is the fictitious code:

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

Two behaviours are used to describe the CSA for simplicity: breeding behaviour and Levy flight. Cuckoos lay their eggs in communal nests, however they always remove the eggs of others to improve the chances of their own eggs hatching. When a host cuckoo discovers an alien egg, it either throws it away or abandons the present nest and builds a new one elsewhere. Poorer alternatives are abandoned in each step of the previous breeding behaviour as new solutions are developed. Many birds fly between nests to find the best nest, and their flight path is effectively a random walk that is indicative of Levy flights with step lengths taken from the Levy distribution. The isolated system proposed operates at any operational point at first. For maximum power tracking, the ideal chopping ratio n or duty cycle D is modified as environmental circumstances vary.

V. PSO BASED MPPT

This approach is swarming with fish and birds and stimulated socially by other biological training practices. PSO offers a population-based study program, the individual's status over time being partly modified. The particles travel in multi-dimensional search spaces in the PSO-based method. Each particle adapts its position to its own knowledge and experience, using the best location and the best location it finds. Each particle during its flight. In some cases, the best solution can be found for measuring each particle in an optimal position by adding speed. Three variables, inertia, perception and culture are influenced by particle velocity. The inertial part simulation of a flying bird's inertial behaviour. The cognitive aspect imitates the best location of birds and the best social memory that imitates the memory of feline birds. Multidimensional space for searches to travel across the room before the best solution is found. This speed will use the current speed and measure the agent's distance to Pbest and Gbest accordingly.

$$V_i^{k+1} = W \times V_i^k + C_1 \times r_1 \times \left(Pbest_i^k - X_i^k\right) + C_2 \times r_2 \times \left(Gbest^k - X_i^k\right) \quad (4.1)$$

Where, V_i^k The speed of individual i when iterating k, X_i^k Individual i is in the position of iteration k, W inertial weight C1 , C2 acceleration factor, $Pbest_i^k$ The best position of individual i in iteration k, $Gbest^k$ Group's best position until iteration k r1 , r2 Random number between 0 and 1. Accelerate during this speed update the coefficients C1, C2 and the inertia weight W are Predefined and r1, r2 are randomly generated uniformly The number is in the range [0, 1].

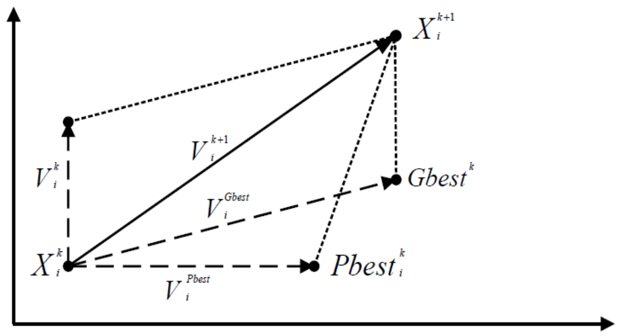

Figure 5.1 PSO Optimization system

The modified velocity equation (6) is given by:

$$V_i^{K+1} = K.\left(W.V_i^k + C_1 G_d()\left(Pbest_i^k - X_i^k\right) + C_2 C_d()\left(Gbest^k - X_i^k\right)\right)$$

$$K = \frac{2}{\left|2-\varphi-\sqrt{\varphi^2 - 4\varphi}\right|}$$

Where $\varphi = C_1 + C_2, \varphi > 4$

The convergence characteristic of the system can be controlled byφ. Contraction factor method (CFA) φ must be greater than 4.0 to guarantee stability. But as φ Increase Factor K is reduced, diversification is reduced, Produces a slower reaction. Usually when Using shrinkage factors, φSet to 4.1 (ie C_1, C_2 = Therefore, the constant multiplier K is 0.729.QPSO, proposed and developed by Sun et al., is the expansion of PSO in the field of quantum computing. The concept of qubits and revolving doors is here to introduce the improvement of demographic characteristics Diversity. Qubit and angle Represents the state of the particle rather than the position and the particle velocity completed in the basic PSO. Thereby, QPSO has powerful search capabilities and powerful search capabilities Fast convergence feature. The basic difference between a qubit and a classical bit is the latter can stay at the same time Superposition of two different quantum states,

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

In the above equation, α and β are complex numbers that satisfy the equation

$$|\alpha|^2 + |\beta|^2 = 1$$

This superposition state can also expressed as

$$|\psi\rangle = \sin\theta|0\rangle + \cos\theta\,|1\rangle$$

Where the phase of the qubit is represented by θ. the relation among α,β and θ. The relation among α,β and θ can be defined as the position of the particle in QPSO can be described as

$$\theta = \arctan(\beta/\alpha) \qquad x_{id} = p_{id} \pm \frac{L}{2}\ln\left(\frac{1}{u}\right)$$

Where x_{id} is the position of the ith particle and p_{id} is local attractor of particle i is located between pbest and gbest and u is a uniformly distributed random number in the range [0,1]. The value of L can be used following equation

$$L = 2\alpha|x_{id} - p_{id}|$$

Where α is the only parameter of QPSO, which can be calculated using the following equation

$$\alpha = (1 - 0.5).\frac{t_{max} - t}{t_{max}} + 0.5$$

And the local attractor p can be represented as below

$p = \varphi . pbest + (1 - \varphi). gbest$

Where φ corresponds to a random number that is uniformly distributed. β is a [0, 1] range. · The QPSO flow chart is shown in Figure 5.1 . The first step is to initialize the dimensions and maximum number of iterations with algorithm parameters such as population size, particles. The second step is to determine each particle's fitness and record pbest and gbest.

- The function 'F" changes due to changed weather conditions Thus, when the following condition is possible, the condition function is restarted to find the new maximum power point.
- In MATLAB program, modeling and simulation is performed.
- It includes a DC/DC boost converter PV array for which PSO optimization is used.
- In this case, two PV modules, which consist of 18 series cells connected to the circumvention diode, are divided in four groups.
- Three out of four groups don't have any sort of partial shading, but one group gets half of the radiation, while the other three groups have partial shading.

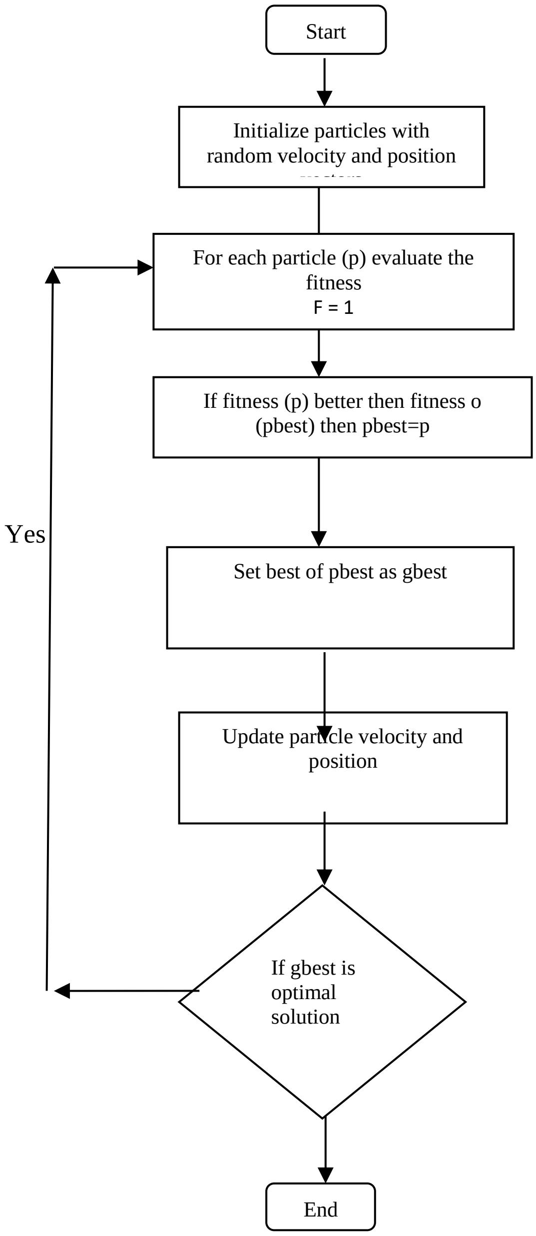

Fig 5.2 Flow Chart of Methodology

Table 1 Parameters use in PSO Algorithm

Parameters	Values
Number of Particles	10
Number of Dimensions	1 or 2
Maximum Velocity	2.70
Number of Iterations	80
Position step size	0.15
ω_{max}	0.9
ω_{min}	0.4
r1 r2	[0,1]

The simulation of photovoltaic systems by the process of optimizing particulate swarm and provides a contrast between the method suggested in [19] and [11] with the two methods of use.Now the solar photovoltaic array produces a power converter via the device. Different parameters are related to this boost converter are:

• MOSFET

• 130mH inductive (L)

• 20micro farad capacitor (C1) •

• 700 micro farad capacitor (C2) •

• 350ohm (R) load resistor

These parameters are connected across the system to reduce the fluctuation of the system. After applying the input parameters. Output of the system is obtained. In output actual voltage is compare with optimal voltage obtained from PSO (particle Swarm optimization) method system. After that the solar PV system is work on optimal voltage to achieve the maximum power point.

VI.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.
- 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 6.1 (Partial Shading Scenario- Test Case-1)

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

Table 6.1 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 6.2 (Partial Shading Scenario- Test Case-2)

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

Table 6.2 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.

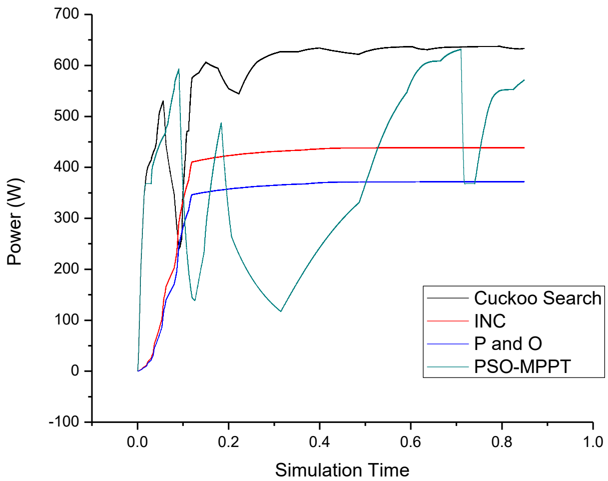

Fig.5.1 Comparative Assessment of MPPT Techniques (tTest Case-1)

Under partial shading, Figure 6.1 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.

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.

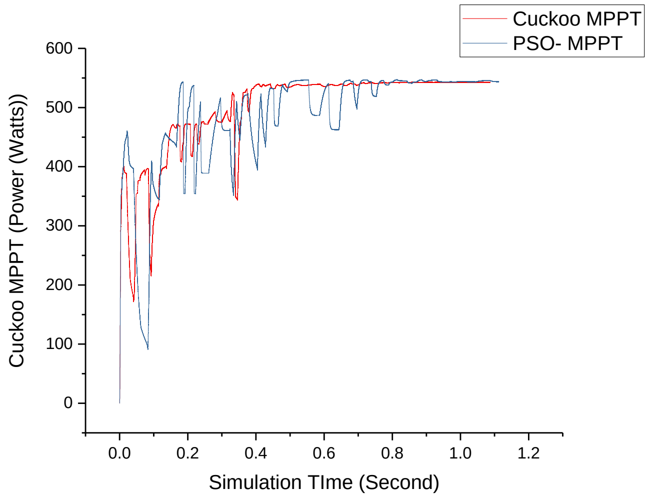

Fig.6.2 Comparative Assessment of MPPT Techniques (Test Case-2)

The tracking of the algorithms from the initial state of 0.0 seconds can be observed. It takes 1,75 seconds to reach the constant condition. Although 33-35 iterations have been used during the process of searching by optimizing the particle swarm. It can be observed that before the achievement of a constant state mistake the maximum power point monitoring can be tracked by the particle swarm optimization under variable irradiance conditions. The research work has shown and supplied the value and requirement of a new soft calculation methodology which is quicker and more reliable in the monitoring of maximum power and in consolidating its steady state.

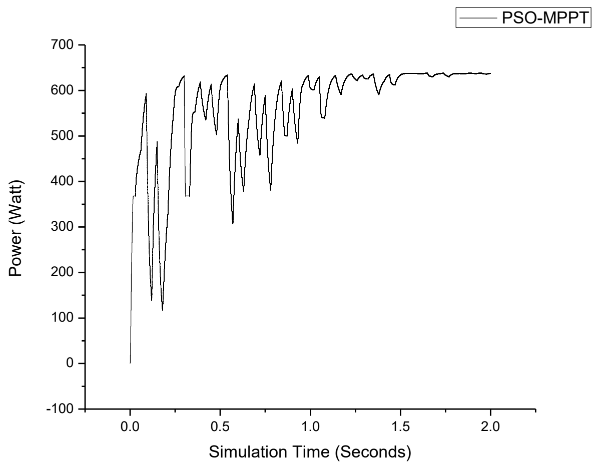

Fig .6.3 Implementation of PSO-MPPT for Partial Shading

Table 3: Comparative Assessment of MPPT Methods in Partial Shading Condition

Method	**Peak Power Tracked**	**Reaction Time**	**Stability Time**
P and O Method	348 Watts	0.173 Seconds	0.173 Second
INC Method	413 Watts	0.175 Seconds	0.175 Second
Improved PSO Method	627 Watts	0.0012 Seconds	**1.59 Seconds**
Improved Cuckoo Search Method	627 Watts	0.0011 Seconds	**0.30 Seconds**

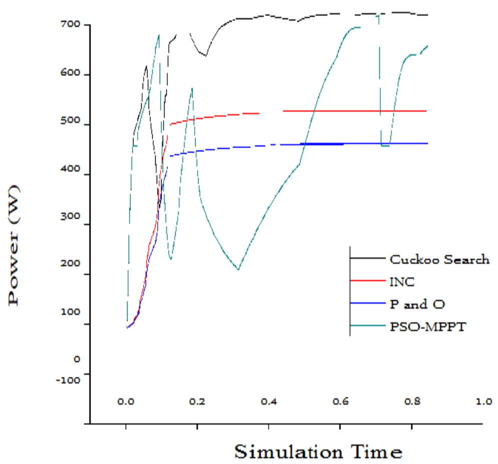

Fig.6.4 Comparative Performance of Cuckoo Search MPPT for Partial Shading (Only one panel shaded)

VII. CONCLUSION

In this study, A soft computer-based charge controller based on cuckoo search optimization was developed in this study to effectively 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. The charging controller is connected to PV modules, the battery in the storage unit, and the inverter in high-energy applications. According to the findings of this study, utilising an efficient power converter with a soft computer-based MPPT controller system can increase the operating performance of solar PV systems. By combining an efficient charge controller based on an intelligent maximum energy monitoring system, it increases the performance of solar photovoltaic systems.

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