# An Improved Cuckoo Search Algorithm for Maximum Power Point Tracking of Solar Panel under Partial Shading Condition

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**Abstract -** The performance of PV system is strongly affected by partial shading conditions. Under partial shading condition the power-voltage characteristics of PV system presents multiple local maxima power point and one global maxima power point. The conventional MPPT algorithms are not able to track the global maximum power point under partial shading condition which results in loss in efficiency. Therefore new methodologies for MPPT tracking must be devised which can differentiate local and global maximum power peaks. Impact of shading patterns on different PV array configuration such as series, series-parallel, TCT can also be checked for improving the performance of PV system. In this paper Cuckoo Search based MPPT algorithm is proposed to track the global maximum power point under partial shading condition with different PV configuration. The performance improvement of PV system with cuckoo search based MPPT algorithm is presented through simulated results under MATLAB environment to extract maximum power from the PV system exposed to dynamic conditions.

## I. INTRODUCTION

Environmental concerns regarding global warming, deterioration of environment, energy sources and energy deficit have boosted the application of renewable energy sources for generation of power. The use of renewable system has been further increased due to advancement in power electronic field. Solar energy is the prominent source of renewable energy where potential of research is available. Solar energy is widely available and it can be converted into direct electrical energy by photovoltaic (PV) effect [1]. The PV technology is static, noiseless and free of moving parts which reduces operation and maintenance cost of system. Despite of environmental friendly technology, PV technology faces challenges like low conversion efficiency and further reduction in efficiency due to partial shading. Under partial shading condition, PV arrays are subjected to different irradiance level due to moving clouds and shadows of nearby obstacles which has significant impact on its power output and energy yield. This causes multiple peaks in Power-Voltage (P-V) characteristics with one global maximum power point and multiple local maximum power points and tracking of this global maximum power point is difficult., Under uniform condition, conventional MPPT algorithms such as perturb and observe (P&O), incremental conduction (INC), hill climbing works efficiently. But under partial shading conditions, these algorithms may track local maximum point which may result in decreasing the output power of PV panel [2-4].

To tackle these problems, soft computing supported MPPTs algorithms based on soft computing are recommended such as genetic algorithm, particle swarm optimization (PSO), artificial neural network (ANN), artificial bee colony, firefly algorithm, and cuckoo search (CS) [5-10]. Although these algorithms are searching the MPPT globally, these algorithms are complicated and take more time than traditional algorithms [11-12]. Hence an enhanced Cuckoo Search algorithm with variable step size is proposed in this study which tracks the MPP rapidly.

## II. PV CELL MODELLING AND PV ARRAY CONFIGURATION

Solar cells are the basic building block of PV arrays. PV cells with similar characteristics are connected and encapsulated to form the PV modules which, in turn are the basic building blocks of solar arrays. Solar cells are connected in series and parallel to obtain desired voltage and current respectively for the solar panel. In ideal solar cell series and parallel resistance are not present but in practical case series and shunt resistance are included due to ohmic resistances and leakage current as shown in Fig. 1. Major contributors to the series resistance are the bulk resistance of semiconductor material, the metallic contacts, and interconnections. Series resistance has significant effect on the PV power output. The shunt resistance is due to p-n junction non-idealities and impurities near the junction.

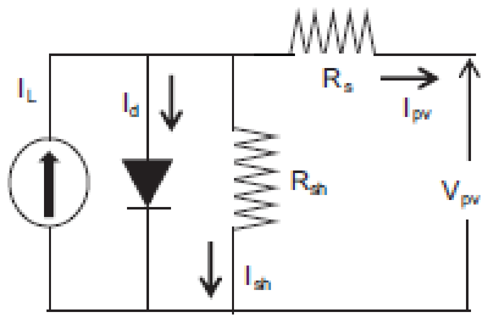


Fig. 1 Equivalent circuit of solar cell

Mathematical Modeling of PV Cell

Energy balance equations for solar cell are given below, solar cell behaves as a diode and if external supply is connected then diode current will flow in external circuit which is given as[17-19]

$$I_d = I_0\left\{\exp\left(\frac{qv_d}{nkT}\right)-1\right\} \quad (1)$$

where

$I_d$- Diode current

$I_0$- Reverse saturation current of a diode

$V_d$-Voltage across diode

$K$ - Boltzmann's constant ($1.38\text{x}10^{-23}$J/K)

$n$- Diode ideality factor (typically between 1 and 2)

When PV cell is exposed to solar radiation the output current from the PV cell can be found using the equation

$$I = I_L - I_d \quad (2)$$

where$I_L$ is light generated current and is given as

$$I_L = G\left[I_{sc}\left\{1+a*\left(T-T_{ref}\right)\right\}\right] \quad (3)$$

where

$G$- Solar irradiance (W/m$^2$)

$I_{sc}$ - Short circuit current of the PV cell

$A$- Short circuit current temperature coefficient (%/C)

$I_{sc}$-Maximum current at zero voltage and it is directly proportional to solar irradiance

Characteristic equation of PV cell is given as

$$I = I_L - I_0\left\{\exp\left(\frac{q(v+IR_s)}{nkT}\right)-1\right\}-\frac{v+IR_s}{R_{sh}} \quad (4)$$

$R_s$-Series resistance

$R_{sh}$- Parallel resistance

$T$ -Absolute temperature

$q$ -*Electric* charge ($1.69\text{x}10^{-19}$C)

PV efficiency is not affected by variation in $R_{sh}$ and it is considered as infinity and therefore current through parallel resistance $I_{sh}$ is negligible and therefore ignored in the present model.

In current study 4X4 series connected PV array arrangement is considered as shown in Fig. 2. MAX60 solar cell is used for simulation purpose and specifications are shown in Table I.

Table I. Solar array datasheet parameters

| Parameter | Value |
|---|---|
| Open circuit voltage (Voc) | 21.1V |
| Short circuit current(Isc) | 3.8A |
| Maximum power | 59.5≅60W |
| Voltage at MPP | 17.1V |
| Current at MPP | 3.5A |
| No of cells in series | 36 |

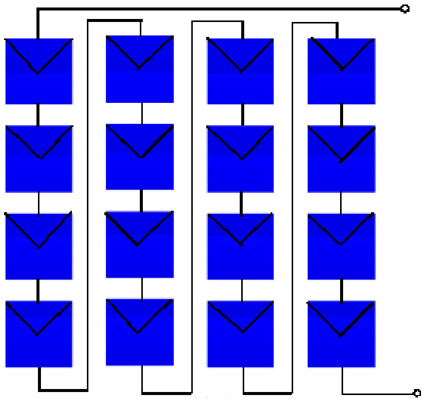

Fig. 2. 4X4 PV Cells Series Configuration

Proposed system for energy harvesting consisting of MPPT charge controller to interface PV panel with load is shown in Fig. 3. MPPT controller is designed with boost converter to achieve maximum power under partial shading conditions.

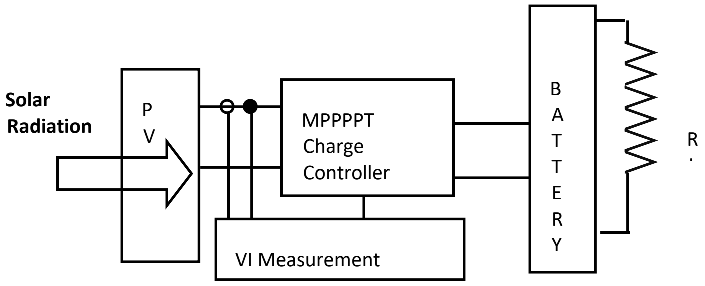


Fig. 3 Proposed system for energy harvesting under partial shading conditions

## III. MATHEMATICAL MODELLING OF PROPOSED SYSTEM

PV array is operating around an open circuit voltage before connecting to the load. When PV is connected to the load it doesn't operate at open circuit voltage and voltage drops to a new point and this voltage depends upon the impedance of the load. Output voltage also depends upon temperature and solar insolation. Fig.3 shows the block diagram of MPPT system with converter. MPPT algorithm works on two loops, the first loop includes MPPT algorithm to compute the MPP and second loop contains proportional-integral(PI) controller to maintain the MPP voltage.

Cuckoo Search (CS) is a intelligent optimization algorithm which is inspired by nature. The obligate brood parasitism of some cuckoo species lay their eggs in the nests of host birds of other species. Some host birds takes the action against this behaviour by discovering the foreign eggs and they will throw these alien eggs away or they will discard its nest and make a new nest at other place. Some cuckoo species have evolved in such a way that female parasitic cuckoos are often very specialized in the mimicry in colors and pattern of the eggs of a few chosen host species. Cuckoo search idealized such breeding behavior, and thus can be applied for various optimization problems.

For MPPT, large numbers of algorithms with significant researches are available and successfully implemented [23-25]. Cuckoo Search Optimization method is selected for present work with added feature of variable step size for rapid tracking of MPP.

In nature, cuckoo's search for a suitable nest of a host bird is similar to the search for food, which occurs in a random or a quasi-random form. CS is based on three idealized rules:

1. Each cuckoo lays one egg at a time, and dumps its egg in a randomly chosen nest;
2. The best nests with high quality of eggs will carry over to the next generation;
3. The number of available hosts nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $P_a$€(0,1). In this case, the host bird can throw the egg away/abandon the nest, and build a completely new nest.

In addition, Yang and Deb discovered that the random-walk style search is better performed by Lévy flights rather than simple random walk.

The following strategy is formed based on above three rules

$$x_i^{(t+1)} = x_i^t + \propto \oplus Levy(\lambda) \quad (5)$$

where $x_i^t$ refers to samples/eggs, $i$ is the sample number, and t is the number of iterations. The product $\oplus$ indicates entry-wise multiplication, where

$$\alpha = \alpha_0 (x_{cgb} - x_i^{t-1}) \quad (6)$$

A simplified scheme of levy distribution is presented as

$$Levy(\lambda) \approx \frac{u}{(|v|)^{1/\beta}}, \quad (7)$$

where β=1.5 , $\propto_0$ is the levy multiplying coefficient (chosen by designer), whereas $u$ and $v$ are determined from the normal distribution curves, namely

$$u \approx N(0, \sigma_u^2) \quad (8)$$

$$v \approx N(0, \sigma_v^2) \quad (9)$$

If Γ denotes integral gamma function, then the variables $u$ and $v$ are defined as

$$\sigma_u = \left( \frac{\Gamma(1+\beta) \times \sin(\pi \times \beta / 2)}{\Gamma\left(\frac{1+\beta}{2}\right) \times \beta \times (2)^{\left(\frac{\beta-1}{2}\right)}} \right)^{1/\beta} . \quad (10)$$

$$\sigma_v = 1 \quad (11)$$

As per the Levy distribution, the step consists of many small steps and few large steps and long-distance jumps. The random step may obviously produce extremely small steps or large steps depending upon the power generated.

## IV. SIMULATION RESULTS

A series connected 800W stand-alone PV system is tested for various shading scenarios. A standalone PV system consists of MPPT controller, PV array and a resistive load. The developed MATLAB module is shown in Fig. 4.

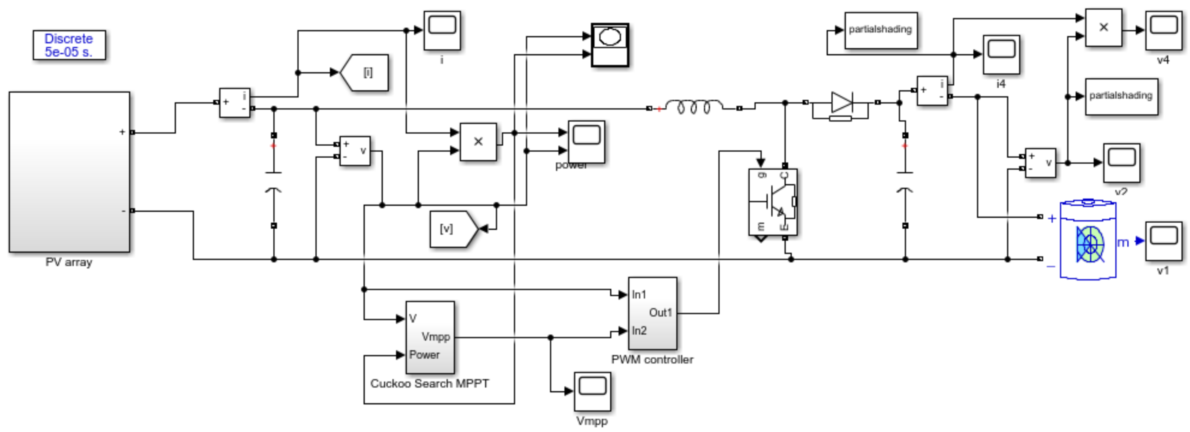


Fig. 4 Simulation model of proposed system

The developed simulation model in MATLAB/Simulink environment is shown in Fig. 4 The results of simulation are shown in Fig.5-7. The considered shading scenarios has been tested with proposed algorithm Fig. 5 shows current vs voltage plot under partial shading condition. Fig. 6 shows the variation of power under partial shading condition. The nonlinear P–V characteristic exhibits multiple peaks. These multiple peaks contain many LMPPs and single GMPP. It can be observed form Fig. 6 that maximum power of 630W is generated for given shading condition. Fig. 7 shows the performance of developed MPP algorithm under partially shaded condition.

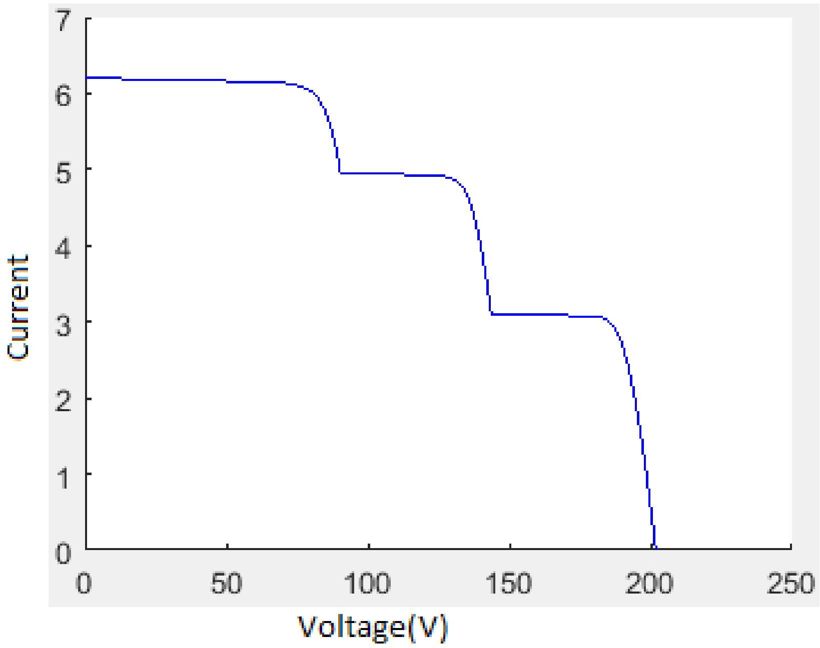


Fig. 5. I-V characteristics of PV array under partial shading condition

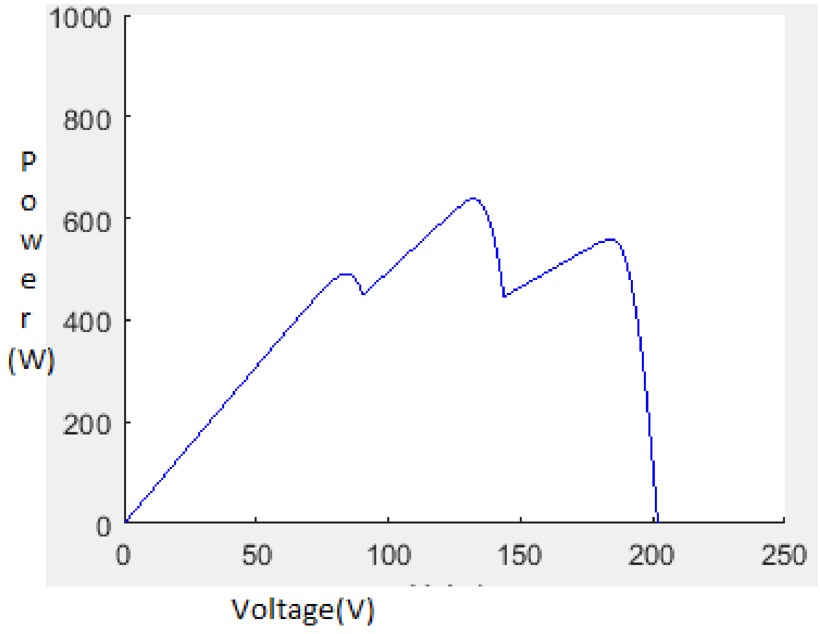


Fig 6. P-V characteristics of PV array under partial shading condition

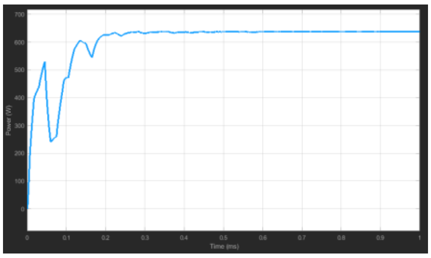

Fig. 7. Maximum Power Tracked by developed Improved Cuckoo Search Algorithm

## V. CONCLUSION

In the present paper an improved cuckoo search algorithm is implemented to track maximum power point under partial shading condition. The presented algorithm has been tested for various shading scenarios. The PV simulation model is scanned for various voltage levels for capturing maximum power point. The developed improved CS algorithm is compared with the captured maximum power and voltage points. The simulation results shows that proposed MPPT algorithm tracks the maximum power efficiently and rapidly under all the shading scenarios.

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