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Maximum power point tracking for PV array based on ant colony optimization under uniform and non-uniform irradiance

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Abstract— **Photovoltaic method of power generation is essentially important as they provide an alternative method of power generation. The solar array have a nonlinear voltage current characteristics where maximum power is reached .When the solar panel is partially shaded it is difficult to track the global maximum power from local peak. So there will be a need of maximum power point tracker to track maximum power. This project defines a simulation circuit in MATLAB/SIMULINK for tracking maximum power from solar panel under varying atmospheric condition and partially shaded conditions. A boost converter is used which will minimize the ripple content and it will provide duty cycle to the maximum power point tracker to track maximum power. The maximum power varies with respect to temperature and solar radiation. MPPT algorithm is used to track the maximum power and thereby improving the efficiency of the system. By manipulating the duty cycle of the boost converter the system implements Ant Colony optimization based MPPT algorithm. The Ant Colony optimization is a randomly searching algorithm which generates duty cycle randomly to reach maximum power in shortest way. The simulation was performed under various solar radiations and their waveforms are obtained for particle swarm optimization and ant colony optimization based maximum power point tracking algorithm.**

Index Terms— **Ant Colony Optimization (ACO), Boost converter, Duty cycle, MPPT algorithm, Particle Swarm Optimization (PSO) ,Solar Panel.**

I. INTRODUCTION

Recently, renewable energy sources have attracted a great attention in research fields due to the fact that they provide the solution to the power demand problem without creating any pollution. Out of renewable energy sources solar energy based power production is most suitable in India as it lies nearer to the equatorial region and can get solar power mostly throughout the year.

As the day progresses, the direction of sun gets changed so, that the solar radiation level and the temperature changes resulting in change in PV module output. When a PV array is connected directly to a load, the system's operating point will be at the intersection of the I-V curve of the PV array and load. In this method, the PV array usually be oversized to ensure that the load's power requirements can be supplied - expensive system. To overcome this problem MPPT can be used to maintain the PV array's operating point at the MPP.

There are various MPPT algorithm available namely perturb and observe algorithm [4], incremental conductance algorithm [2], voltage based peak power tracking, current based peak power tracking etc. These methods vary in complexity, required convergence speed, sensors, cost, range of effectiveness, implementation hardware, popularity, etc. [3]. These algorithm changes the duty cycle of the dc/dc converter to maximize the power output of the module and make it operate in the peak power point of the module. To track the global maxima Ant Colony optimization (ACO) based MPPT algorithm is used. With this MPPT control scheme only one pair of current and voltage sensors are required which simplifies the PV system and reduces the system cost.

The output of the solar panel is literally small and has to be boosted i.e., increased in voltage by means of boost converter. A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage [1]. It is a class of the switching-mode power supply (SMPS) containing at least two semiconductor switches a diode and a transistor and at least one energy storage element.

II. BLOCK CONFIGURATION

From the below block diagram it can be seen that the output of solar panel is given to the MPPT. The MPPT algorithm processes the voltage and current so that it produces a duty cycle that can be giving to the dc-dc boost converter so that the load can be provided with the maximum power that can be tapped from the source.

Even when the solar panel is partially shaded the Ant Colony Optimization based MPPT algorithm tracks the maximum power as efficiently as like the normal condition. When comparing with all optimization Ant colony

Optimization has fast convergence speed, which is independent of the initial conditions and no requirement of knowledge about the characteristic of PV array. The Ant Colony algorithm randomly sends the duty cycle and then it checks the power whichever duty cycle tracks the maximum power the Ant Colony algorithm sends it which is shown in the Fig.1. Since the efficiency of the solar panel has been restricted to about 20-30% MPPT is essential in all solar PV application areas.

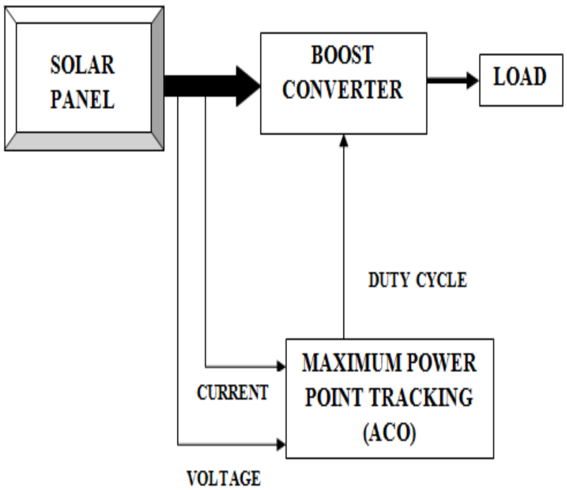

Fig.1 Block Diagram of Maximum Power Tracking

Under partially shaded condition the power of the solar panel is much reduced because of the presence of many local maxima's. So for the purpose of tracking the global maxima Ant Colony Optimization based maximum power point tracking is used.

A. *Solar Panel*

A PV cell is the building block of a solar panel. Photovoltaic (PV) cells are made up of at least 2 semi-conductor layers. One layer contains a positive charge, the other a negative charge. A photovoltaic module is formed by connecting many solar cells in series and parallel. Solar cells produce the direct current electricity from sun light which can be used to recharge a battery or to power the equipment. The first practical application of photovoltaic was to power the orbiting satellites and other spacecraft but today the majority of photovoltaic modules are used for grid connected power generation. Considering a single solar cell, it can be modeled by utilizing two resistors, one diode and current source [5]. This model is known as a single diode model of solar cell which is shown in the Fig.2.

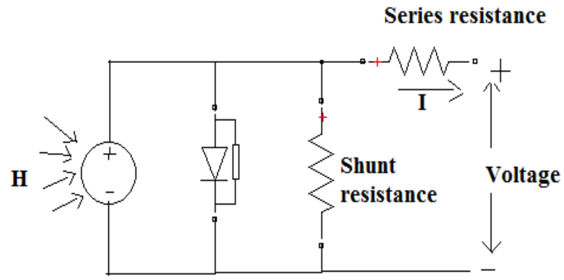

Fig.2 Single Diode Model of the PV Cell

$$I = N_P I_{PH} - N_P I_S \left[\exp\left(\frac{q\left(\frac{V}{N_S} + \frac{I R_S}{N_P}\right)}{AKT} \right) - 1 \right] - \left(\frac{V\left(\frac{N_P}{N_S}\right) + I R_S}{R_{Sh}} \right) \quad (1)$$

Where N_s and N_p are the number of series and number of parallel cells.

When the solar panel is partially shaded [8] the power produced in the sun shaded areas would be more than the shaded areas so that the power produced in the unshaded areas would be of higher potential and the power produced in the shaded areas would be of lower potential so that the charge gets accumulated in the shaded areas resulting in increase of temperature in shaded areas resulting an effect known as hotspot [11]. To avoid hotspot feedback diode and bye pass diodes are used to disconnect those shaded cells [14].

B. *Boost Converter*

Boost converter is used to step up the voltage where the input is given from the solar panel. It will boost the input voltage as per that of the load requirement. When the switch is closed, current flows through the inductor in clockwise direction and the energy gets stored as shown in the Fig.3. Polarity of the left side of the inductor is positive. When the switch is opened, impedance is higher so the current gets reduced. Therefore, change or reduction in current will be opposed by the inductor. Thus the polarity will be reversed then the left side of inductor will be negative now. As a result shows that the two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

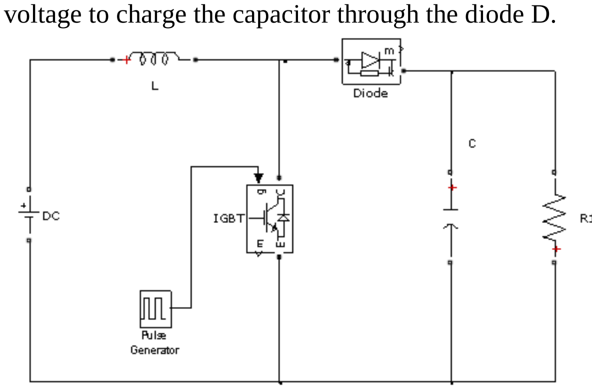

Fig.3 Circuit Diagram of Boost Converter

The input and output voltage relationship is controlled by the switch duty cycle, D as shown in the Fig.4, according to the equation below

$$V_{out} = \frac{1}{1-D} V_{in} \qquad (2)$$

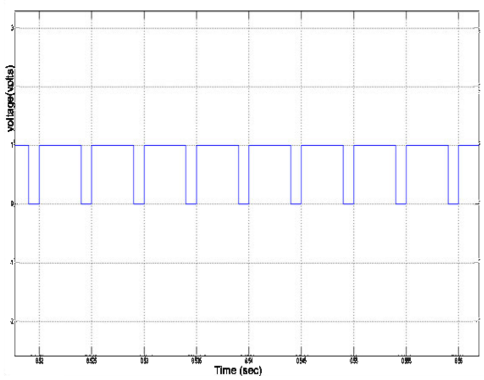

Fig.4 Switching Pulse of Boost Converter

With an input voltage of 90V, and with the inductance of 20mH, capacitor values of 220uF and resistance of 20 Ω then the output voltage obtained from the boost converter is 580V.

III. ANT COLONY OPTIMIZATION ALGORITHM

There are various MPPT algorithm are available to track maximum power from the solar panel namely Particle Swarm Optimization, Ant Colony Optimization, etc. The concept of particle swarm optimisation is that the particles are placed randomly at initial position and these particles are allowed to search for a better fitness value in search space [7]. The key point in particle swarm optimisation is that it seaches randomly and analyses an objective function. PSO is proposed in this research to optimize the power generation for the PV system under various operating conditions such as different isolation levels and cell temperatures. It models that a group of animals like birds and fish, search for the location of food [9]. Some search points that are called “agents” and each agent stores the best position which it searched in past: pbest, the most excellent one of pbests is assumed to be gbest and it is shared as information on the agent group. Distance between present position of pbest and gbest decide the next trace direction and speed.

Particle swarm optimization algorithms are the method easily suffers from the partial optimism, which causes less at the regulation of its speed and the direction [12]. The Particle Swarm Optimization method cannot work out the problems of scattering and optimization and for non-coordinate system such as, solution to the energy field and the moving rules of the particles in the energy field. Finding the best value for the parameters is not an easy task and it may differ from one to another problem [13]. It can be concluded that the Particle Swarm Optimization performance is problem-dependent.

The ACO is used to track maximum power than PSO. ACO is a technique for optimization that was introduced in the early days [6]. The inspiring source of ant colony optimization is the foraging behavior of real ant colonies. ACO is a technique for solving problems which can be expressed as finding good paths through graphs. Ant colony is swarm of ants. Each ant tries to find a route between its nest and a food source as shown in the Fig.5.

Other ants follow one of the paths at random, also laying pheromone trails. Since the ants on the shortest path lay trails faster, this path gets reinforced with more pheromone and it n appealing for future ants [10]. The ants become increasingly likely to follow the shortest path since it is constantly reinforced with a larger amount of pheromones. The pheromone trails of the longer paths evaporate. when one ant finds a good path from a colony to the food source, other ants are more likely to follow the same path and positive feedback eventually leads to all the ants' following a single path.

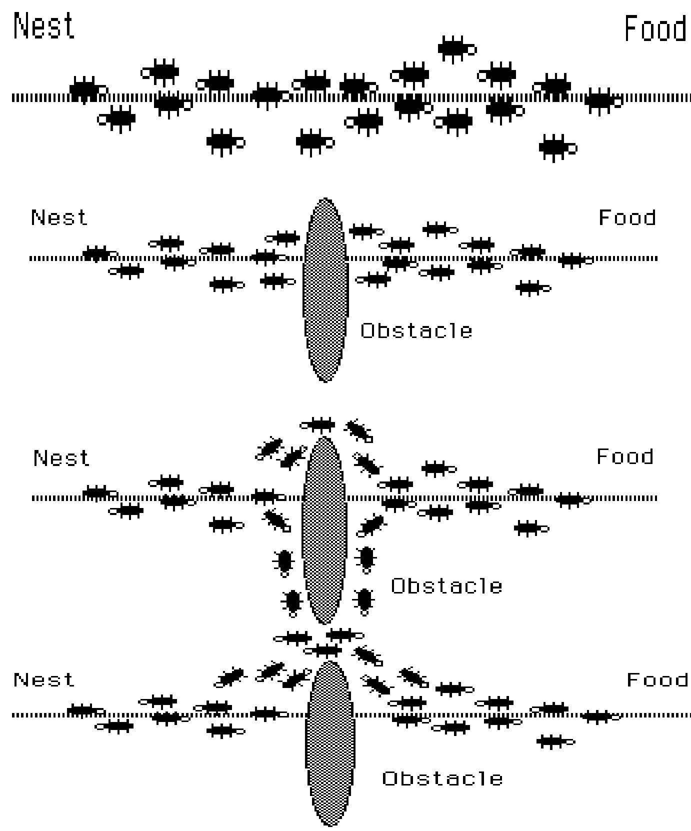

Fig.5 Behavior of Ant

In Ant Colony Optimization algorithm, in two ways target can be achieved one is with single ant and single colony and other is with multi ant with multi colony. For maximum power point tracking multi ant multi colony system is used. In multi ant multi colony system first ant and food are placed randomly and iteration will start with ant searching for a food. If ant found the food iteration will check whether all the ant reach their food place or not if even one ant is left in half way that distance will be calculated. Suppose all the ant reach the food then the various distance is calculated and among that shortest path can be identified. Based on that remaining ant will follow and that will be taken the optimum solution. First ant will search the target randomly here the target is duty cycle ,once if one ant found the target in shortest way remaining ant will follow the same way with the help of indirect communication of pheromone as shown in the Fig.6.

Duty cycle is taken from 0 to 1 and distance will be taken from 0 to 200 here 0 is minimum and 200 is maximum and distance will be normalized to the duty cycle (i.e.) if the distance is minimum then duty cycle will be consider as 0 and if the distance is maximum then duty cycle will be consider as 1 like that for each distance duty cycle will be normalized in equ.3.

Normalization 0-1 formula,

$$X_{i,0to1} = \frac{X_i - X_{min}}{X_{max} - X_{min}} \qquad (3)$$

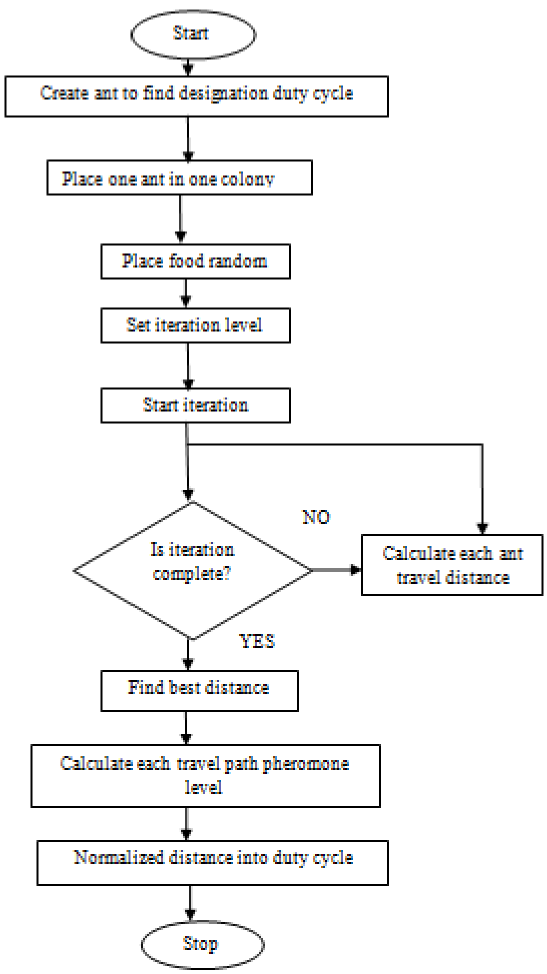

Fig.6 Flow chart of ACO

IV. SIMULATION RESULT

The results of the various MPPT algorithm blocks were simulated by using the MATLAB/Simulink. The solar panel is modeled in Simulink with the basic equations of the solar panel whose voltage and current are sensed and given as the input to the Ant Colony optimization based maximum power point tracking algorithm. The coding for Ant Colony optimization based maximum power point tracking is done in interpreted MATLAB function which sends the duty cycle and checks the power.

From the Fig.7 the output of solar panel is obtained as 90 V and that will be boosted to 580 W which is shown in the Fig.8 for normal perturb and observe algorithm.

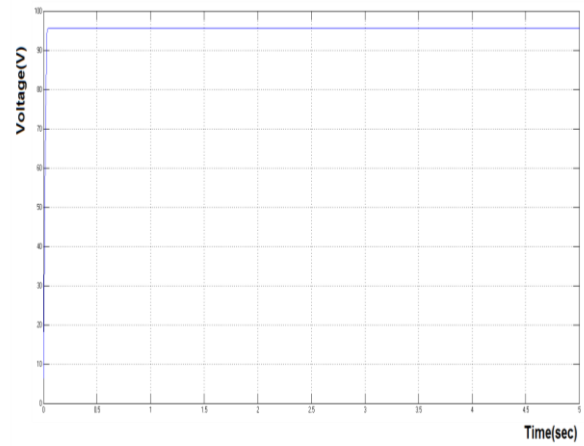

Fig.7 Output Voltage of the Solar Panel

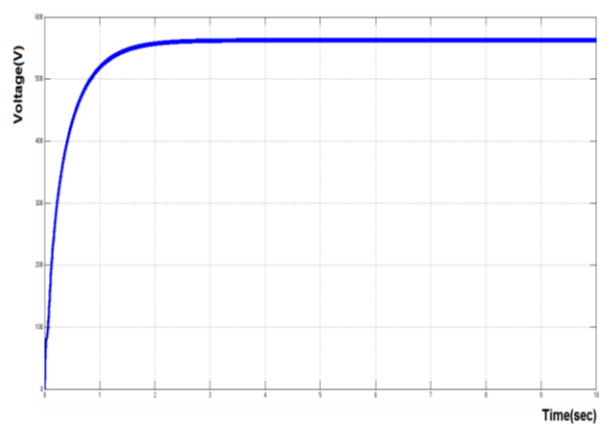

Fig.8 Output Voltage of Boost Converter

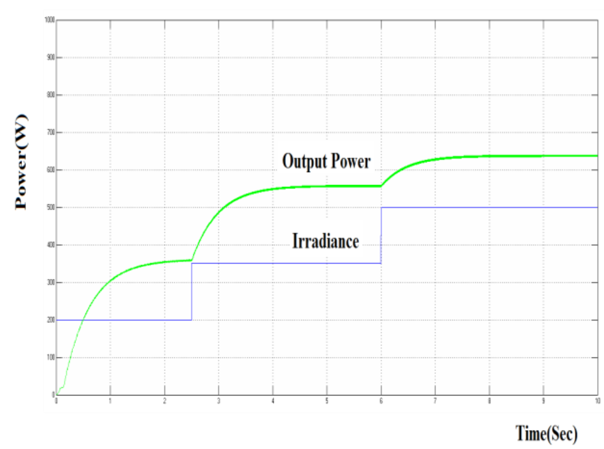

Fig.9 Output Power of PSO

From fig.9 maximum output power tracked by particle swarm optimization is 630W whereas input from solar panel is 90V.

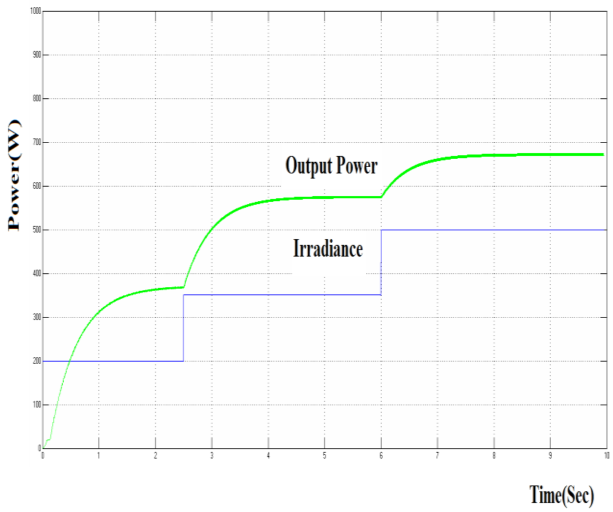

Fig.10 Output Power of ACO

The concept of Ant Colony optimization based maximum power point tracking algorithm is that it sends the duty cycle randomly and analyses the power, whichever duty cycle tracks the maximum power the Ant Colony optimization sends it continuously and fine tunes it to get the maximum power. The duty cycle which is sent by the Ant Colony optimization based MPPT algorithm is given to the switches of boost converter and the final power from ACO is 670 W as shown in the Fig.10.

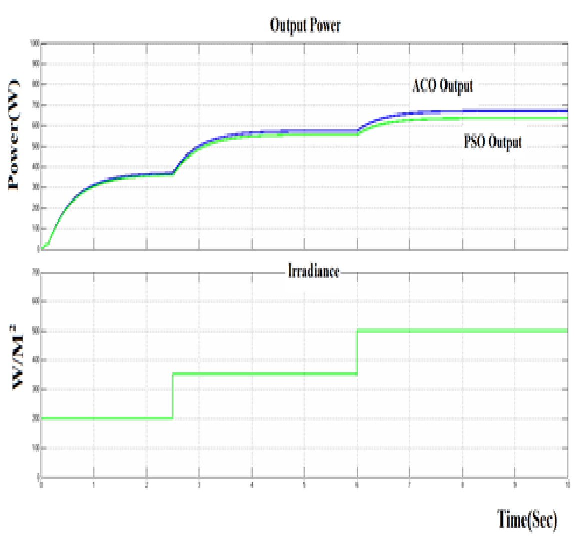

Fig.11 Comparison of PSO and ACO

The results shows in Table.1 that the power tracked by PSO algorithm is 630W and the power tracked by ACO algorithm is 670W which shows that PSO algorithm gets trapped in local maxima whereas ACO algorithm tracks global maxima as shown in the Fig.11.

Table.1 Comparison table of PSO and ACO

S.NO	MPPT ALGORITHM	INPUT VOLTAGE	OUTPUT POWER
1.	Particle Swarm Optimization Algorithm	90 V	630 W
2.	Ant Colony Optimization Algorithm	90 V	670 W

V. CONCLUSION

The simulation results of solar panel, boost converter are presented. The output Voltage and output power of the PV panel are obtained. All simulations are performed in MATLAB/Simulink modeling and simulation platform. The power tracked by the various maximum power points tracking algorithm namely Ant Colony Optimization based MPPT and particle swarm optimization based MPPT are presented. These MPPT algorithms are tested under standard testing condition and the results shows that Ant Colony Optimization based MPPT tracks more power.

Under partially shading condition there will be multiple peaks in P-V curve which makes MPPT complex and the results shows that Particle Swarm Optimization based Maximum Power Point tracking algorithm will track global peak and track a power of 630W but Ant Colony Optimization based Maximum Power Point tracking algorithm tracks the global maxima and track a power of 670W.

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