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# Implementation of Maximum Power Point Tracking Algorithms for Photovoltaic Systems

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## ABSTRACT

This paper proposes a New Particle swarm algorithm for improving the Optimization and performance of Maximum Power Point Tracking in PV System. The PSO technique has been applied for multi-junction solar cell system. The solar panels are made up of different type materials and give constant output from Boost converter. The main aim of PSO algorithm is to find out duty cycle to the Boost converter to maintain constant output voltage irrespective of power produced by solar panels. This proposed Particle Swarm Optimization (PSO) is also used to minimizing active power loss, voltage deviation and voltage stability index. A detailed simulation of the proposed method has been simulated in Matlab/Simulink. The simulation result shows that this design can be effectively realized in practical applications.
**Keywords :** Maximum Power Point Tracking (MPPT); Particle Swarm Optimization (PSO); Boost Converter.

## I. INTRODUCTION

Photovoltaic (PV) energy is accepted as a popular source of non-conventional energy due to a number of benefits, particularly low operational cost and less pollution. Throughout the world, photovoltaic power generation is becoming increasingly popular due to a combination of factors: low maintenance, minimal wear and tear of components due to the absence of moving parts, lack of audible noise, absence of fuel cost, and pollution-free operation after installation. Small-scale PV installations are very popular as lighting and water pumping solutions in developing countries, remote villages, and small rural and urban communities. These systems are also commonly used in developed countries that have a considerable amount of solar irradiation.

Energy has enhanced interest in electrical applications, from the time when it is premeditated as a significantly unrestrained and mostly accessible energy supply. Among several renewable energy schemes, PV power generation structures are projected to play a consequential part as an unpolluted power electric source since PV panels are suggested to install in roof-tops of house and porticos of buildings. The potency obtained from the PV panel is mainly dependent on atmospheric conditions like temperature and Irradiation. Ergo the efficiency of the solar cell is 20% is relatively very low. To amend the efficiency and reliability of the PV system several tracking systems are cited in the literature. Thus, to acquire consummate benefit of the solar energy it is vital to determine the peak point of the PV system.

The PV array has a only operating peak that can afford maximum power to the load. This peak is titled as the Maximum Power Point (MPP). This peak point has a nonlinear variation with irradiation and temperature. Hence to run the PV system at its MPP, the PV system has to use feature Maximum Power Point Tracking (MPPT) controller. MPPT control with DC/DC boost converter will grant the PV array to engender the maximum available puissance, irrespective of the atmospheric conditions. Single junction solar cells utilize an element of the solar band depending upon apex of the band-gap of the particles utilized. On the contrary, multi junction (MJ) solar cells [1]-[2] formulated to find energy from a superior energy band of the solar group. Depending upon way of the links, two main forms of kineticism subsist: lateral multi-junction (LMJ) solar cells and vertical multi-junction (VMJ) solar cells.

A VMJ solar cell can get high open circuit voltage and competencies accede with conventional single junction solar cells. As well, VMJ cells has the potential to get more efficiency by utilizing most recent material placements, concentrator methods and verbally express of the art manufacture technologies, while the usefulness of LMJ solar cell is generally dependent on expert diffraction process. Solar cells in a multi-junction configuration are annexed in series to shape a string, and multiple strings [4] are tied in parallel [3] to compose a panel. LMJ solar cells are capable to combine to turn out a thoroughly synchronized system to procure gain of the multi-junction portion. The outputs from the solar cells oscillate with irradiation, temperature and the load associated to it. So, maximum power point tracking (MPPT) is proximately an essentiality component of a capable solar cell system.

MPPT are divided into three major groups. First group is called as conventional group namely Perturb and Observe and Incremental Conductance method. The draw backs of this group are its sluggish tracking faculty, steady state fluctuation at Maximum power point (MPP) and reduced competence. To overcome these drawbacks soft computing techniques are evolved. The techniques [7] that are included in this category are the Evolutionary Algorithms (EA), Fuzzy logic controller (FLC) and Artificial Neural Network (ANN). These groups have some shortcomings because of a few details like it requires periodic training and it utilizes adscititious recollection will become arduous to implement in bio inspired methods The third group appeared under the type of Evolutionary computing, Particle swarm optimization (PSO), Bacterial foraging algorithm, Ant colony optimization (ACO) and Genetic Algorithm (GA) are the techniques included under this category. Particle Swarm Optimization (PSO) predicated MPPT technique has been discussed in this paper where the obligation signal of four boost converters are modified on a customary substructure with a one MPPT controller to track the ecumenical maximum power point of the system.

## II. MODELLING OF THE PV SYSTEM

The schematic diagram of a single-phase grid-connected PV system, which is the main focus of this paper, is shown in Fig.1, the PV system consists of a PV array, a dc-link capacitor and single phase inverter and a filter.

A model of photovoltaic cell is shown in Fig.2. From the circuit it can be seen that the current produced by the solar cell is equal to that produced by the current source minus that which flows through the shunt resistor.

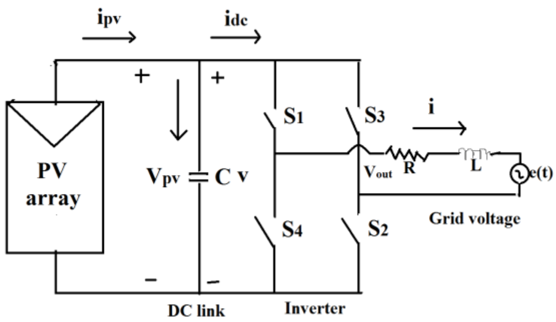


**Figure 1.** Equivalent circuit diagram of single-phase grid-connected PV system

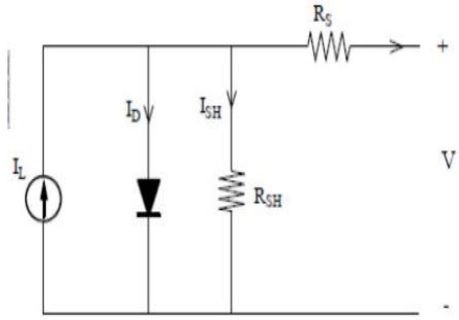


**Figure 2.**Equivalent circuit of a solar cell

Using the equivalent circuit of a solar cell (Fig:2) and the pertinent equations, the non-linear (I-V) characteristics of a solar cells is given by the following equation:

$$I = Iph - Io\left[\exp\left(\frac{V+IRsh}{Vt}\right) - 1\right] - \left[\frac{V+IRs}{Rp}\right] \quad (1)$$

Where '**I**' is the PV array output current (A), '**V**' is the PV array output voltage (V). From equation (1) V is given by

$$V = \left(\frac{NsK}{q}\right) \quad (2)$$

Where Ns is the number of series cell, K is the Boltzmann's constant in J/K, q is the electric charge.

The photocurrent $I_{ph}$ depends on the solar radiation and the cell temperature as stated in the following.

$$I_{ph}=\left(Iscr + Ki(T - Tr)\right) * \left(\frac{G}{Gn}\right) \quad (3)$$

Where Iscr is the PV array short circuit current at reference temperature and radiation (A), $K_i$ is the short circuit current temperature coefficient (A/K) and G is the solar radiation (mW/cm^2). The Fig.3 below gives the characteristics I-V and P-V curve for fixed level of solar irradiation and temperature.

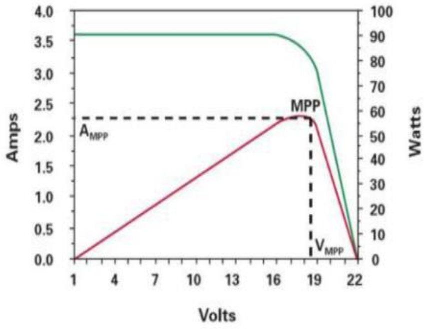


**Figure 3.**PV array characteristics curve

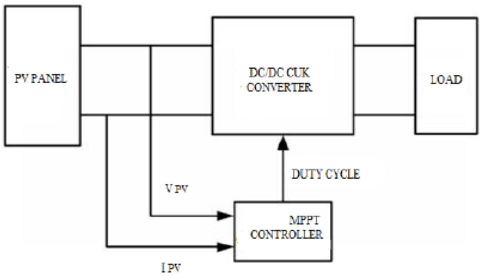


**Figure 4.**Block diagram of Solar system with MPPT controller

**Perturb and Observation Method (P&O):**

P&O method is the most frequently used algorithm to track the maximum power due to its simple structure and fewer required parameters. This method finds the maximum power point of PV modules by means of iteratively perturbing, observing and comparing the power generated by the PV modules. It is widely applied to the maximum power point tracker of the photovoltaic system for its features of simplicity and convenience.

According to the structure of MPPT system shown in Fig.5 the required parameters of the power-feedback type MPPT algorithms are only the voltage and current of PV modules shown in Fig.6 is the relationship between the terminal voltage and output power generated by a PV module. It can be observed that regardless of the magnitude of sun irradiance and terminal voltage of PV modules, the maximum power point is obtained while condition *dP/dV* = 0 is accomplished. The slope (*dP/dV*) of the power can be calculated by the consecutive output voltages and output currents, and can be expressed as follows,

$$\frac{dP}{dV}(n) = \frac{P(n)-P(n-1)}{V(n)-V(n-1)} \quad (6)$$

Where P(n) = V(n)I(n)

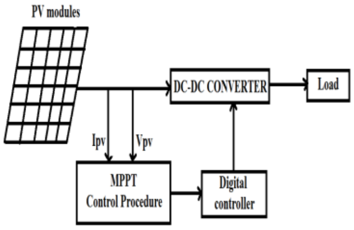


**Figure 5.**A structure of PV system with MPPT function

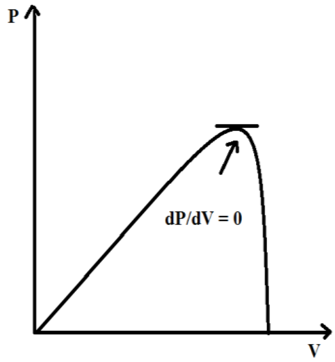


**Figure 6.**P-V characteristic of a PV module

P&O method may result in top level efficiency; provide that a proper predictive and adaptive hill climbing strategy is adopted. The fig.7 shows flowchart for P&O method.

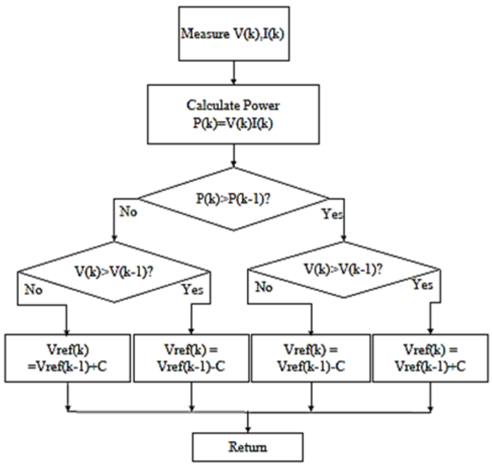


**Figure 7.**P&O method flow chart

## III. PARTICLE SWARM OPTIMIZATION TECHNIQUE

PSO is a swarm intelligence optimization algorithm, first suggested by Kennedy and Eberhart in 1995, and it has been emerging rapidly in recent years. It is represented according to the actions of bird flocks. Simple realization and fast convergence are some of its merits, and it is well applied to locate the global best possible solution in a nonlinear, discontinuous, non-differentiable curve [6]. In this algorithm [9], a number of particles are employed in an n-dimensional space. Each particle holds its position $y_i$ (scattered randomly) and velocity $a_i$ ($a_i$= 0 in initiation). The position of a particle is controlled by its best position until now $p_{besti}$, and the best position of all particles so far, position and velocity of particles is revised by using the subsequent equation:

$$a_i^{t+1} = sa_i^t + z_1\text{rand}()(pbest_i^t - y_i^t) + z_2\text{rand}()(\text{gbest}_i^t - y_i^t) \quad (7)$$

And

$$y_i^{t+1} = y_i^t + v_i^{t+1} \quad (8)$$

where, $a_i^{t+1}$ is the particle velocity. $y_i^{t+1}$ is the current position of a particle. $y_i^t$ is previous particle position. $y_i^{t+1}$ is new particle position. s is weight factor. $z_1$, $z_2$ is learning coefficients, usually lies between 1 to 2. rand() is the variable generated randomly. $pbest^t_i$ is the Pbest. $gbest^t_i$ is the Gbest.

PSO algorithm flowchart of the proposed PV system is illustrated in Fig 8.

1) Fix the velocity and position limit when the parameters and particles are initialized.
2) For each particle the velocity and the position are initialized randomly.
3) For each particle the value of P best has been calculated.
4) G best value has been set when the best value of the particle has been reached.
5) The value of the velocity and the position has been updated automatically based on the G best.
6) repeat the steps 3 and 4 until the optimal solution is attained.
7) The optimized value has been determined at the last iteration based on G best.

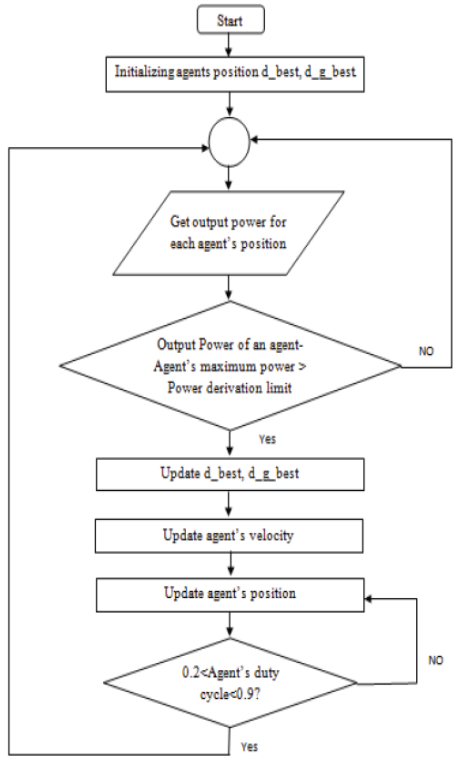


**Figure 8.**PSO method flow chart

The minimum and maximum values of parameters used in each iteration for changing the velocity and updating the position of particle for PSO [5] algorithm is shown in Table. I.

**Table I.**PSO Parameters

| S.No | Parameters | Value |
|---|---|---|
| 1 | No of particles | 20 |
| 2 | Min duty cycle | 0.01 |
| 3 | Max duty cycle | 0.9 |
| 4 | Sampling time | 0.1s |
| 5 | Max iteration | 30 |
| 6 | wmax | 1 |
| 7 | wmin | 0.3 |
| 8 | C1 min | 0.1 |
| 9 | C1 max | 1.05 |
| 10 | C2 min | 0.1 |
| 11 | C2 max | 1.05 |

The proposed system consists of four PV modules and requires four MPPT trackers. To reduce the cost and computation time only one MPPT tracker is used in this method. The PSO algorithm is applied to update the duty cycle of DC-DC Converters by tracking the global maximum point with continually update the position and velocity.

Boost converters are connected in series to share a common load as shown in Fig.9. In this system the purpose of PSO is to generate duty cycles dc (1), dc (2), dc (3) and dc (4) individually to each Boost converter to give determined output.

## IV. SIMULATION RESULTS

The model consists of a DC-DC Boost converter operated with switching frequency of 5 KHz. According to the specifications of the converter it can operate with voltage ranges from 0 to 200V at each input of the converters. In the proposed system solar panels with different materials are used. Here four panels is made up of four different materials like GaInAsp, GaInp, GaInAs, GaAs and it is connected to seperate Boost converter.

The simulation results of the PV system using PSO optimization technique along with other MPPT techniques has been shown in Fig.12. Simulation results depicts that PSO based MPPT algorithm can rapidly and precisely determine the maximum power of each modules and the system accomplished a accurate sense of the maximum power output. Irrespective of the irradiation the proposed PSO tracks the maximum point and it gives corresponding duty cycle to the converters which are not possible by other MPPT techniques.

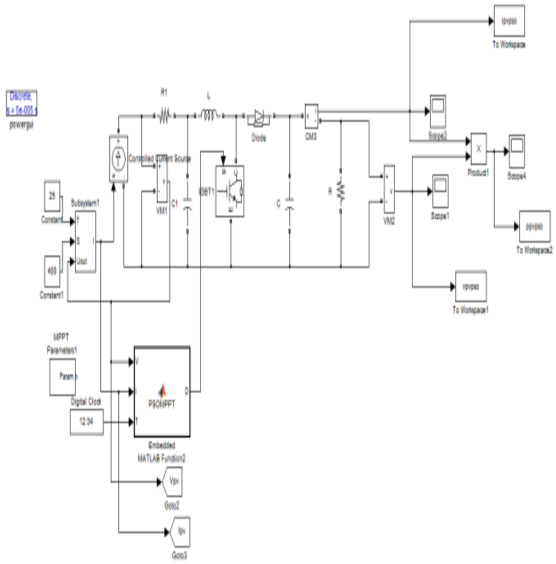

**Figure 9.** Schematic diagram of proposed system with PSO Algorithm

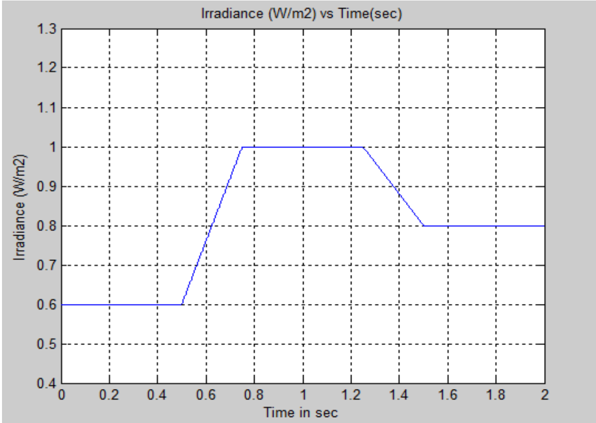


**Figure 10.** Solar Irradiance in W/m2

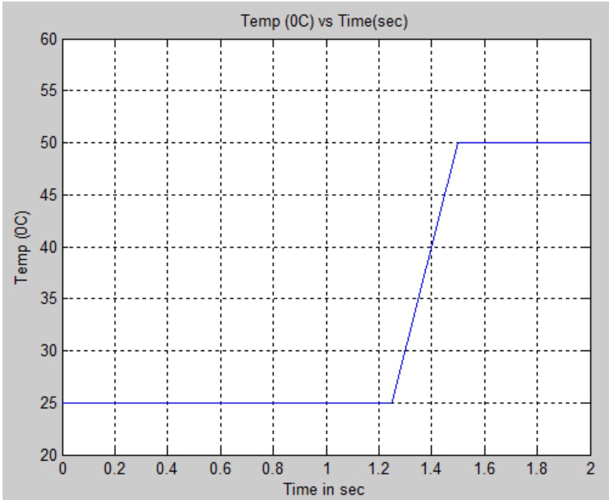


**Figure 11.** Solar Temperature in (0C)

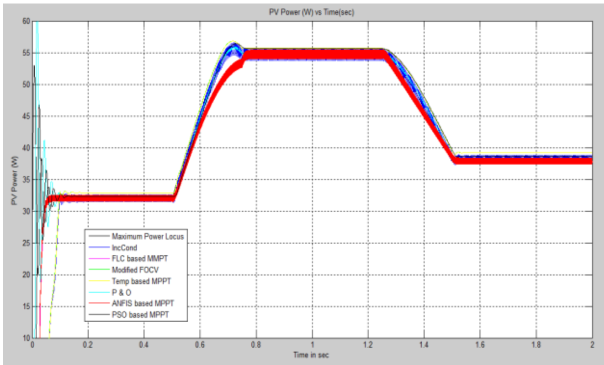

**Figure 12.** Simulation results of Output power of the converter tracked using PSO based MPPT algorithm with other Methods

## V. CONCLUSION

Particle Swarm Optimization (PSO) with an efficient duty cycle initialization has been demonstrated in this paper. PSO method has certain merits when compared to other techniques they are listed as follows, Simple structure, Easy Execution and has a very fast convergence speed to the preferred solution and it has very high tracking speed. Hence PSO technique can be employed for MPPT of Solar PV panels

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