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Optimal Power Extraction from Photovoltaic System

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ABSTRACT

This method proposes an improved maximum power point tracking (MPPT) method for the photovoltaic (PV) system using a modified particle swamp optimization (PSO) algorithm. Additional feature of this method is once the maximum power point located; it reduces the steady state oscillation. The proposed method can track maximum power point for the extreme environmental condition such as fluctuations of insolation and partial shading condition. Algorithm is simple. It can be computed very rapidly. Thus its implementation using a low -cost microcontroller is possible. To evaluate proposed method, PSIM simulation is carried out.

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INTRODUCTION

Solar photovoltaic (PV) is considered to be a popular source of renewable energy. It has several advantages such as low operational cost, almost maintenance free and environmentally friendly.

Because of the potential long-term benefits the solar modules are used without considering its high cost. For extracting the maximum power from each module, the Maximum Power Point Tracking method is used. Itis normally employed in conjunction with the power converter (DC-DC converter or inverter). The objective of MPPT is to ensure that the system can always harvest the maximum power generated by the PV arrays. Due to the varying environmental conditions, temperature and solar insolation, the PV characteristics changes continuously. This becomes a major issue in the solar power generation system. To overcome this various MPP Tracking methods are used. Each technique varies in their complexity, accuracy and speed. They also vary according to the control variables used ie, voltage, current, duty cycle.

This method proposes an improved maximum power point tracking (MPPT) method for the photovoltaic (PV) system using a modified particle swamp optimization (PSO) algorithm. Additional feature of this method is a reductionof the steady state oscillation once the maximum power point is located. The proposed method can track maximum power point for the extreme environmental condition such as fluctuations of insolation and partial shading condition. Algorithm is simple and can be computed very rapidly; thus its implementation using a low-cost microcontroller is possible. To evaluate this proposed method, PSIM simulation carried out. Its performance is compared with the conventional Hill-Climbing (HC) method.

MPPT are systematically categorized into two main groups first, which is by far the most popular, is referred to as the conventional MPPT, and the other one is soft computing technique. Three main conventional methods (together with their important variations namely the Perturb and Observe (P&O), Incremental Conductance(IC) and the Hill -Climbing (HC) will be discussed in detail. The soft computing techniques they are becoming more important lately due to the availability of vast and cheap computing power. The techniques that fall into this category include the Fuzzy Logic Controller (FLC), Artificial Neural Network (ANN) and Evolutionary Algorithm (EA), the last, in particular is of interests due to its natural suitability to adapt for multi-modal problem imposed by the partial shading condition. They shall be discussed comprehensively in this paper Beside these, there are other MPPT described in literature: fractional Short Circuit Current(FSC), Fractional Open circuit Voltage(FOV) and Ripple Correlation Control(RCC).These MPPTs have limited accuracy, but they do have their distinct advantages, namely fewer sensors and simpler algorithms: thus they offer

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a reliable and lower cost solution for certain application other techniques include current sweep methods, dc link capacitor drop control, load current and load voltage minimization, dP/dV or dP/dI feedback control, linear current control, state-based MPPT, best-fixed voltage algorithm, linear reoriented coordinate method, and slide control method. They are not as popular and hence have been omitted for brevity.

Thispaperis organized as follows: Section I discuss the introduction to the problem statement and overview of the work. Section II describes the introduction to MPPT and various MPPT techniques Section III gives PSO based MPPT and its details Section IV discuss the simulation diagram and its results. Section V concludes the study.

Operation Of Pv Array:

A. Mppt Control Structure With Power Converter:

Maximum power point tracking (MPPT) is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, though optical power transmission systems can benefit from similar technology. The aim of employing MPPT is to ensure that at any environmental condition (particularly solar insolation and temperature), maximum power is extracted from the PV modules.

This is achieved by matching the PV's MPP with the corresponding power converter's operating voltage and current. Fig 1 shows the general block diagram of MPPT in conjunction with a dc-dc converter. Although a stand-alone dc-dc system is depicted here, the application can be extended to a grid connected PV system by adding other power electronic devices such as inverter and grid components.

The MPPT works by sensing the current and voltage of the PV array; using this information the array power calculated and compared with the present value of MPP. Accordingly, the duty cycle of the converter is adjusted using a PI or hysteresis controller to match the MPP- which in turn, the forces or hysteresis controller to match the MPP- which in turn, forces the converter to extract the maximum power from the array.

An alternative control structure is characterized by directly updating the duty cycle of the power converter; this is known in literature as the direct duty cycle MPPT control. In this scheme the PI block in Fig 1 is eliminated and duty cycle is computed directly in the MPPT algorithm. This scheme offers a number of advantages such as it simplify the tracking structure, it reduces the computation time and no tuning effort is needed for the PI gain.

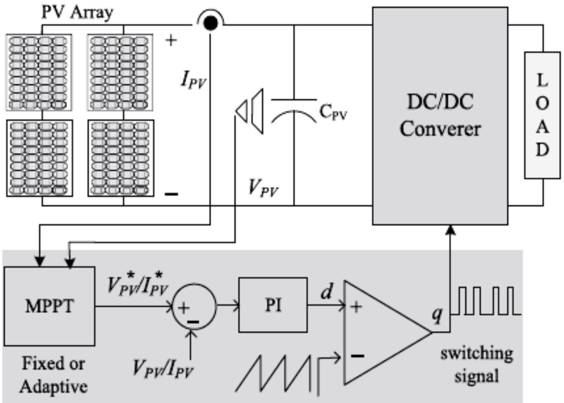

Fig.1: A typical voltage or current based MPPT system.

B.Operation Of Pv Array For Uniform Insolation And Partial Shading:

Fig. 3 shows a PV array in a typical series parallel configuration. The modules are connected in strings, with 3 modules per string. When one of the modules in the string experiences less illumination due to shading, its voltage drop; thus it behaves as a load instead of a generator. A hot spot ensued and typically a bypass diode is connected in parallel with each PV module to protect the shading module from being damaged. Additionally, a blocking diode is connected at the end of each string to provide the protection against reverse current caused by the voltage mismatch between the parallel connected strings.

In normal conditions, i.e., when the solar insolation on the entire PV array is uniform, as shown in fig.3(a) , the PV curve exhibits the typical unique MPP. During partial shading, as the third PV module being less illuminated, the difference in insolation between two modules activate the bypass diode of module 3. As a result two stairs current waveform is created on the IV curve. Consequently, the corresponding PV curve is characterized by several local peaks and one global peak, as depicted by curve 2.

III.PSO-Based Mppt:

PSO is a stochastic, population-based EA search method, modeled after the behavior of bird flocks. The PSO algorithm maintains a swarm of individuals (called particles), where each particle represents a candidate solution. Particles follow a simple behavior: emulate the success of neighboring particles and its achieved successes. The position of a particle is, therefore, influenced by the best particle in a neighborhood *P*best as well as the best solution found by all the particles in the entire population *G*best. The particle position *xi* is adjusted using

$$X_i^{k+1} = X_i^k + \emptyset_i^{k+1} \quad (10)$$

Where, the velocity component Φ*i*represents the step size. The velocity is calculated by

$$\emptyset_i^{k+1} = \omega\emptyset_i^k + C_1r_1\{P_{besti} - x_i^k\} + C_2r_2\{G_{best} - x_i^k\} \quad (11)$$

Where *w* is the inertia weight, *c*1 and *c*2 are the acceleration coefficients, *r*1 ,*r*2 ∈*U*(0, 1), *P*best*i* is the personal best position of particle *i*, and *G*best is the best position of the particles in the entire population. Fig.8 shows the typical movement of particles in the optimization process. If the position is defined as the actual duty cycle while velocity shows, the perturbation of the present duty cycle can be rewritten as

$$d_i^{k+1} = d_i^k + \emptyset_i^{k+1} \quad (12)$$

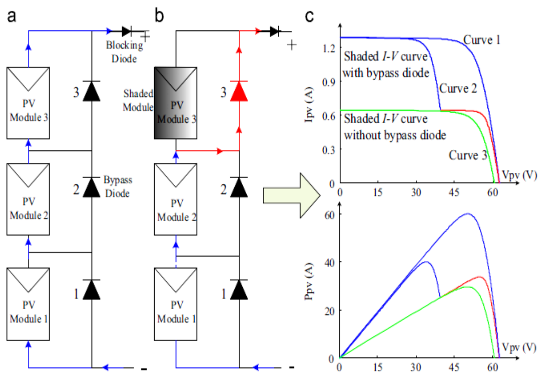

Fig. 2: Operation of PV array (a) under uniform insolation (b) under partial shading (c) the resulting I–V and P–V curve for (a) and (b).

It can be seen that both HC and PSO algorithms have an equivalent structure. However, for the case of PSO, resulting perturbation in the present duty cycle depends on *P*best*i*and *G*best. If the present duty cycle is far from these two duty cycles, the resulting change in the duty cycle will also be large, and vice versa., PSO can be thought of as an adaptive form of HC. In the latter, the perturbation of the duty cycle is always fixed but in PSO it varies according to the position of the particles. With proper choice of control parameters, a suitable MPPT controller using PSO can be easily designed.

(12)

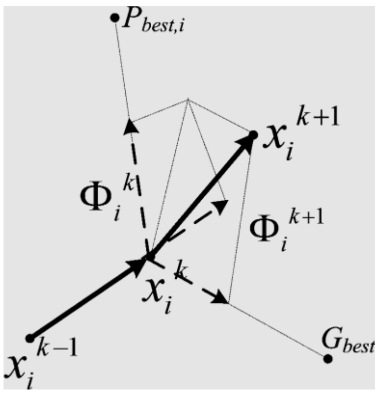

Fig. 4: Movement of particles in the optimization process.

Iv.Application Of Pso For Mppt:

To illustrate the application of the PSO algorithm in tracking the MPP using the direct control technique, first a solution vector of duty cycles with *Np*particles is determined, i.e.

$$x_i^k = d_g = [d_1, d_2, d_3, \ldots\ldots, d_j] \quad (13)$$

j=1,2,3,…….,N_P

The objective function is defined as

$$P(d_i^k) > P\left(d_i^{k-1}\right) \quad (14)$$

To start the optimization process, the algorithm transmits three duty cycles *di* (I= 1, 2, 3) to the power converter. In Fig. 5, duty cycles *d*1, *d*2, and *d*3 are marked with triangular, circular, and square points, respectively. These duty cycles served as the *P*best*i*in the first iteration. Among these, *d*2 is the *G*best that gives the best fitness value (which is the array power), as illustrated by Fig. 5 (a). In the second iteration, the resulting velocity is only due to the *G*best term. The (*P*best*i*−*d* (*i*)) factor in (11) is zero. Furthermore, the velocity of *G*best particle (*d*2) is zero due to the (*G*best− *d* (2)) factor in (11) is zero.

This results in a zero velocity and accordingly the duty cycle is unchanged. As a result, this particle will not contribute to the exploration process. To avoid such situation, a small perturbation in duty cycle is allowed, as shown in Fig. 5 (b), to ensure the change in the fitness value. Fig. 5 (c) shows the particles movement in the third iteration. Because all the duty cycles in the previous iteration attain a better fitness value, the velocity direction of these particles remains unchanged, and subsequently they move toward *G*best along the same direction.

In the third iteration, all duty cycles (*di* , *i*= 1, 2, 3) arrive at MPP with a low value of velocity. In the subsequent iteration, due to very low velocity, the value of the duty cycle is approaching a constant. Therefore, the operating point will be maintained, and the oscillation around the MPP diminishes.

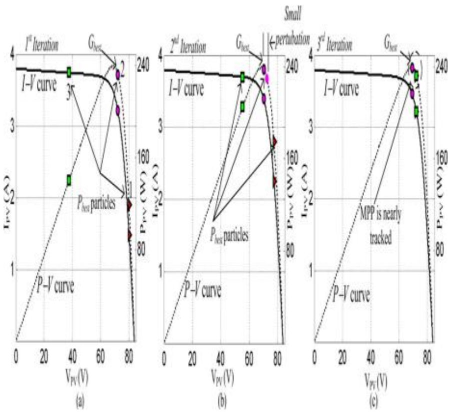

Fig. 5: PSO particle movements in searching for the MPP.

A.tracking during partial shading:

When the PV array is operating in a uniform solar insolation, the resulting *P*−*V* characteristic curve of the array exhibits a single MPP. However, under partial shading, the *P*−*V* curves are characterized by multiple peaks, i.e., with several local and one global peak as depicted in Fig. 6. In this example, the *I*−*V* curve is characterized by four stairs while the *P*−*V* curve is characterized by four peaks.

The latter are labeled as *P*1, *P*2, *P*3, and *P*4. It can be observed that the time derivative of power *dP*/*dV*is zero for the global as well as all the local peaks. Furthermore, the slope of its right and left sides has the same signs. Since all conventional MPPT methods are based on the slope and sign value of dP/*dV*, the algorithm could not distinguish the local (*P*1, *P*2, and *P*4) and global peaks (*P*3) correctly. It is very likely that the MPPT is being forced to trap into the local peak, resulting in reduced output power and thus greatly deteriorates the efficiency of the PV system. On the other hand, since the PSO method works on the basis of search technique, the global peak can be tracked without any difficulty.

Fig. 6.Depicts the tracking capability of PSO during partial shading. Similar to the previous *P*−*V* curve, the proposed method transmits three duty cycles, which serve as *P*best particles. It can be seen that the voltage and current contributing to these initial duty cycles (*P*best*i*) are away from the global peak (*P*3). But in the later phases of iterations, it successfully finds the global peak, *P*3.

A. Modified Pso Structure:

It is very important a proper initialization of duty cycles in PSO, in the case of slow variations in solar insolation. The change in duty cycle from the previous one should be small to track the MPP. The change in the duty cycle is large; the particles will have to search a large area of the *P*−*V* curve. MPP will be tracked at the expense of large fluctuations in the operating point.

Certain amount of energy will be wasted during the exploration process. Second serious problem needs to be considered is when the change in the insolation is small but occurs very rapidly. The tracking should be fast enough to follow the new MPP very accurately. The large change in the operating point can also occur due to a large change in insolation.

If the change in the duty cycle is small, the convergence toward the MPP could be slow. This could be more critical for the case of partial shading. As duty cycles are not allowed to explore a larger area of the $P-V$ curve, the final MPP could settle at a local instead of global peak.

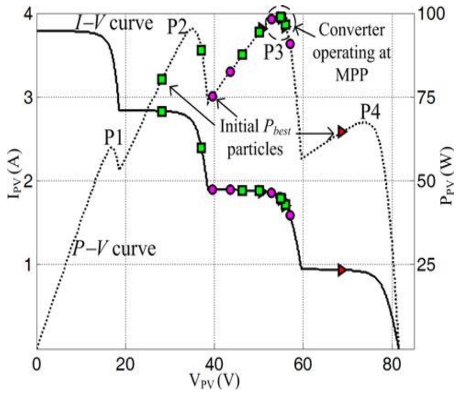

Fig. 6: MPPT tracking by PSO during partial shading.

To overcome these two disadvantages, the conventional PSO should be modified. The duty cycles are initialized in two phases. First, the previous duty cycles are decreased or increased linearly by a factor *K*1. From this we can get that once the PSO reaches MPP, all the three duty cycles are at almost the same value due to the zero velocity.

In order to search the $P-V$ curve for the new MPP, the second phase involves the perturbation of two extreme duty cycles (*d*1 and *d*3) in positive and negative directions with a constant value of *K*2.

Fig. 7 proposes a systematic method to estimate value of *K*1. It shows relationship between the array maximum power *P*MPP and thecorresponding duty cycle *G*best

*G*best is the duty cycle which is responsible for the dc–dc converter to operate at *P*MPP.

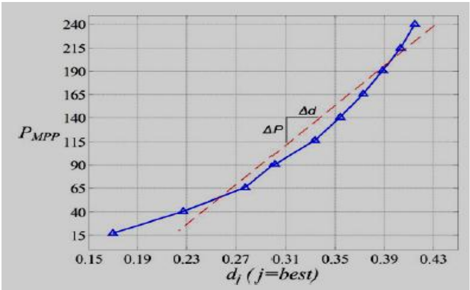

Fig. 7: Relationship between the *G*bestduty cycle and *P*MMP.

The response is obtained by reducing the solar insolation from $\lambda = 1$ to λ =0.1with a step size of 0.1. There exists a quadratic relationship between *P*MPP and *d*best. The dotted line shows the change in array power with duty cycle can be obtained usingof the $I-V$ curve. There by larger change in the operating power.

$$d_{new} = d_{old} - \frac{1}{K_1}\left(P_{old,MPP} - P_{MPP}\right) \qquad (15)$$

Where *K*1 =Δ*P*MPP/Δ*d*is the slope of the linear segment.

In case of increase in insolation, the load line will always be at the right side of *V*MPP. The difference between *V*MPP and *V*OC is not large, a low change in operating power is observed. If the same value of *K*1 is used for this case, *d*old will not be properly scaled. So PSO will utilize more iteration to reach at MPP. To avoid such problem, different pairs of *K*1 values are used for each of the two cases

The value of *K*1 is selected accordingly using the following relationship:

$$K_1 = \begin{cases} K_1 \, if \, \Delta P > 0 \\ \frac{K_1}{2} \, if \, \Delta P < 0 \end{cases} \qquad (16)$$

Where

$$\Delta P = (P - P_{old}) \qquad (17)$$

Note that Δ*P* >0 and Δ*P* <0 indicate decreasing and increasing insolation, respectively. For getting the new duty cycle *d*1 and *d*3 are equally displaced in positive and negative directions, respectively by a factor of *K*2 i.e.,

$$d_{i,new}^{k} = [d_1 - K_2, d_2, d_3 + K_2] for K_2 > 0.05 \qquad (18)$$

If K2= 0.05 in the above equation selected then fluctuations in the operating power of the PV array will not be too large. In case of partial shading fluctuations depends on the operating voltage of PV array. This allows the PSO algorithm to explore a wider range of the $I-V$ curve so that global peak could be tracked. Fig. 8.Shows the complete flowchart of the proposed method.

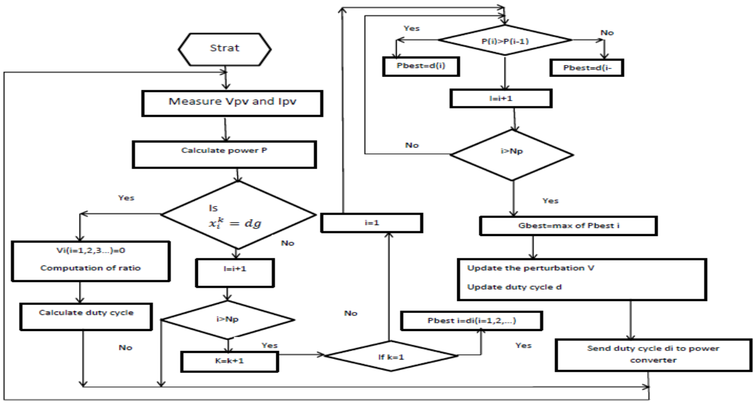

Fig. 8: The complete flowchart of the proposed method.

I. Simulation Results And Discussion:

Fig. 9 shows the PSIM– simulation model of the PV system used in this study. The buck–boost dc/dc converter is utilized due to several reasons namely 1) it exhibits superior characteristics with respect to the performance of PV array's MPP; and 2) it follows the MPP at all times, regardless of the solar insolation, the array , the array temperature, and the connected load.

The converter is designed for continuous inductor current mode with the following specifications: $C1 = 1000\mu$F, $C2 = 1000\mu$F, $L = 1$ mH, and 50-kHz switching frequency. The buck converter consists of an MOSFET, and its trigger pulse is controlled by means of an MPPT controller. In this paper, we are using improved PSO technique. And the DLL block of PSIM is used to provide the MPPT controller output, i.e., for the MOSFET in the proposed simulation diagram.

The main aim of this project is to avoid the problems due to the environmental changes and partial shading. In this project, we used the Maximum Power Point Tracking Technique and in this Modified Particle Swarm Optimization technique is used for controlling the gate pulse of the MOSFET used in the buck converter. From the simulation diagram, we will get that the output power is reaching its maximum value before the 500milli seconds. And the oscillations after the instant of maximum power are reduced.

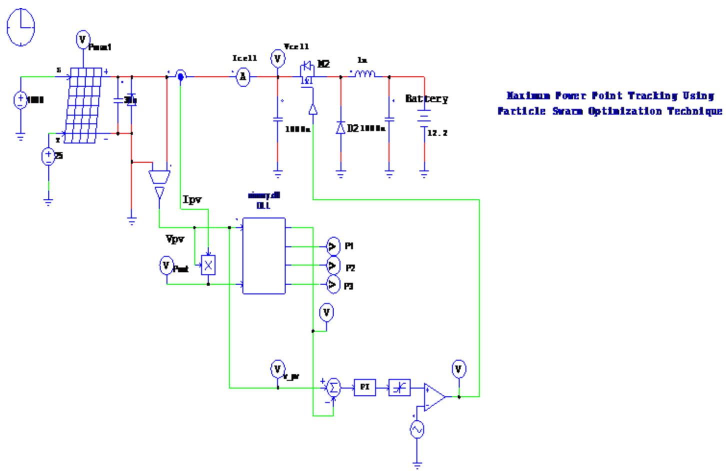

Fig. 9: Simulation diagram for improved PSO method for MPPT tracking of PV panel.

The above figure 11 shows that the current from the cell and voltage of the cell and the voltage across the PV array. The Voltage and current are remains constant after a few milliseconds from starting instant of the simulation.

Conclusion:

In this paper, to track the MPP of a PV system the PSO with the capability of direct duty cycle is used. Here we study more about modified PSO method. For improving the tracking speed a simple efficient method is proposed. The proposed method have a number of advantages: a) it has a faster tracking speed; b) it exhibits zero oscillations at the MPP; c) it could locate the MPP for any environmental variations including partial shading condition and large fluctuations of insolation and d) the algorithm can be easily developed using low-cost microcontrollers.

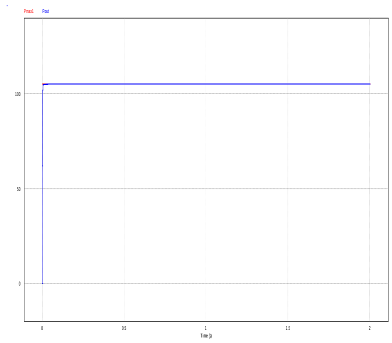

Fig. 10: Waveform for the maximum power and power output.

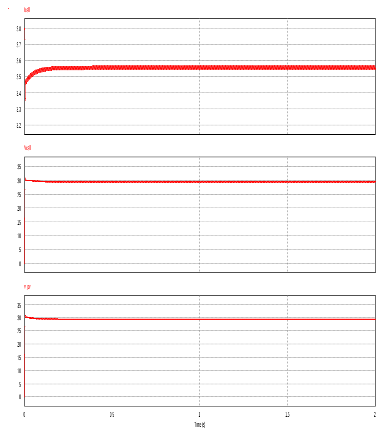

Fig.11: simulation results corresponding Icell, Vcell, and Vpv.

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