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IMPLEMENTATION OF PSO BASED MAXIMUM POWER POINT TRACKING FOR SOLAR PV SYSTEM

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ABSTRACT: The fact that the output of the PV system is dependent upon the solar irradiance and temperature. In order to get maximum power from the solar panels the Maximum Power Point Tracking (MPPT) controllers can play an important role in photovoltaic systems, they have to operate at their maximum power point (MPP) despite the changes in the environment conditions. Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic System. The conventional method uses the incremental conductance MPPT algorithm. This paper presents the modeling and simulation of particle swarm optimization(PSO) based MPPT algorithm for PV array using boost converter. The PSO method is better than the conventional method to improve the output voltage and power. The simulation has been accomplished using MATLAB/SIMULINK.

1. INTRODUCTION

The output of the solar PV system is dependent upon the solar irradiance and temperature. In order to get maximum power from the solar panels the Maximum Power Point Tracking (MPPT) controllers can play an important role in photovoltaic systems; they have to operate at their maximum power point (MPP) despite the changes in the environment conditions. Maximum Power Point Tracking (MPPT), which significantly increases the efficiency of the solar photovoltaic System. To operate the PV array at its maximum power point, the PV system can implement a maximum-power point tracking (MPPT) controller and therefore MPPT algorithms are necessary because PV arrays have a nonlinear voltage-current characteristics. These voltage-current characteristics have a unique point, where the power produced is maximum.

This point depends on the varying environmental conditions. These conditions change during the day and are different depending on the seasons. There are different MPPT control methods used for solar PV systems, Incremental conductance(IC), Perturb and observe(P&O), Constant Current method, Constant Voltage method, Fuzzy Control, and Neural Network Control. Among all these methods Incremental conductance(IC) is commonly used because of their simplicity. For this International Journal of Scientific Research in Science, Engineering and Technology (ijsrset.com) 651 reason, this paper presents the details of Incremental Conductance MPPT using boost converter. The simulation model of the PV based system with MPPT algorithm will be implemented in the MATLAB/Simulink.

2. SOLAR PV SYSTEM

A. MODELLING OF PV SYSTEM

The PV system consists of the photo diode based on which the light energy is converted to DC energy. It will vary based on the irradiance and temperature conditions and the MPPT technique of incremental conductance method is used to track the possible maximum power from the solar modules. The DC output is converted to AC by the inverter circuit and its controlling provides the steady state voltage. The equivalent circuit for the PV array is as shown in fig.1.

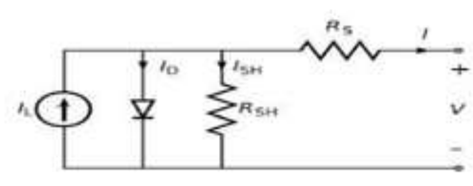

Fig 1 : Equivalent circuit of Photovoltaic system

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The energy in PV modules can be produced based on the movement of the electron-hole pairs based on the input sunlight giving. The output current of the PV module is as in eq.(1).

$$I = I_{PV} - I_D \tag{1}$$

Where

$$I_D = I_0 \left[\exp \frac{V}{AV_T} - 1\right] \tag{2}$$

Then from eq. (1)

$$I = I_{PV} - I_0 \left[\exp \frac{V}{AV_T} - 1\right] \tag{3}$$

The voltage-current characteristics can be derived from the following eq.(4) & (5)

$$I = \left[\exp(\frac{V+I*R_S}{I_{PV}-I_0V_T}) - 1\right] \tag{4}$$

$$P = V\{I_{sc} - I_0\,[\exp \frac{V}{AV_T} - 1]\} \tag{5}$$

Where I_{pv}= Current from the PV cell with light incident.

I_0= Reverse saturation current

R_s= Starting resistance

I_{sc}= Short circuit current

q= Electron charge

K= Boltzmann constant= $1.38x l0^{-23}$

T= Temperature of diode

A= ideality factor =2

The I-V and the P-V characteristics of PV arrays are non-linear which depends on the light intensity (irradiance) and temperature which the curve will shift for every irradiance and temperature based on the atmospheric conditions.

The specifications of the selected PV array shown in Table 1

Table 1
Specifications of the PV panel

At Temperature 25^0 C		
Open circuit voltage	V_0	21 V
Short circuit current	I_{SC}	5.45 A
Voltage at max. power	V_m	17.2 V
Current at max. power	I_m	4.55 A
Max. power	P_m	60 W

The PV module can be operated in any point on the I-V curve between the I_{sc} and the V_{oc}. However, the power from the PV module is different in every operating point as shown in the P-V curve in Fig. 2.

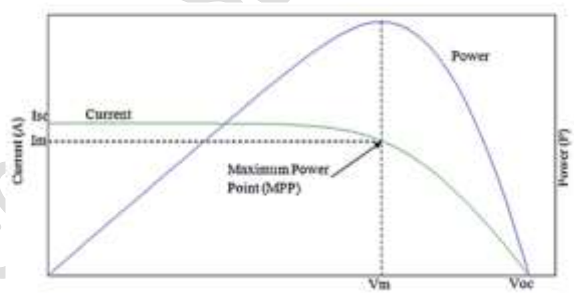

Figure 2. PV array I –V and P–V characteristics

Therefore, a control algorithm is needed in order to ensure that the PV system always operates at the MPP. Fig. 1 is obtained when the temperature and solar irradiation are constant at the standard testing conditions (STC) which are defined as cell temperature = 250 C, incident solar irradiance = $1000W/m^2$, and air mass (AM) = 1.5.

B. PV SYSTEM WITH MPPT CONTROL

Maximum power point tracking, frequently referred to as MPPT, Tracking the maximum power point (MPP) of a photovoltaic array is an essential stage of a PV system The efficiency solar panel is improved by Maximum Power Point Tracking (MPPT) when they set to operate at point of maximum power. The operation of MPPT can only be achieved when a tunable matching network is used as interface for load and the PV array. The main constituent components of a PV system are power stage and controller as shown in fig.3. The power

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stage is optimized using switch mode DC-DC converters (boost, buck-boost), employing pulse width control. The control parameter which is used for synchronizing the network for maximum extraction of power is duty ratio δ. The block diagram of PV system with MPPT control using boost power converter is shown in fig. 3

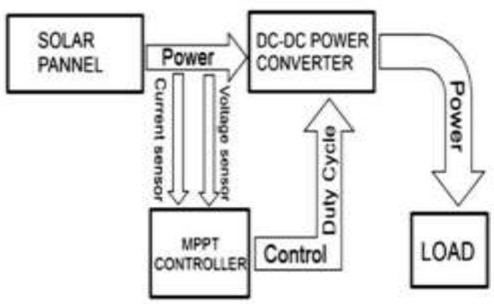

Figure 3.Block Diagram of PV System with MPPT Control

There are different MPPT techniques among all those methods the Incremental conductance(IC) is commonly used because of their simplicity. They differ in many aspects such as complexity, accuracy, sensors required, cost or efficiency, and speed. Based on the control variable it uses, each method can be categorized.

C. MPPT BY INCREMENTAL CONDUCTANCE METHOD

The incremental conductance (IC) algorithm, which is shown in fig. 5, seeks to overcome the limitations of the perturbation and observation algorithm by using the incremental conductance of the photovoltaic. Incremental conductance method generally uses voltage and current sensors to detect the output voltage and current of the PV array hence the complexity of the algorithm increases. The slope of the PV curve is zero at Maximum Power Point. Incremental conductance method uses two sensors, that is voltage and current sensors to sense the output voltage and current of the PV array.

Algorithm works by comparing the ratio of derivative of conductance with the instantaneous conductance. When this instantaneous conductance equals the conductance of the solar then MPP is reached. In general, the IC tracking approaches use a fixed iteration step size, which is determined by the accuracy and tracking speed requirement. The step size may be increased to improve tracking speed, however, accuracy is decreased. Likewise, reducing the step size improves the accuracy, but sacrifices the speed of convergence of the algorithm.

The main advantage of this method is it can rapidly track the change in irradiance conditions and respond quickly with a very high accuracy and hence efficiency of the system is better and give better results. However the complexity and the cost of implementation increase. Incremental Conductance method of tracking maximum power point which does not depends on PV module. The advantage of using this method to track MPP is that it is more efficient than the P&O method in a way that it is able to correctly locate the operating point of the PV array. There is a tradeoff between the power efficiency and reliability of tracking MPP. Since the P&O method will move away from the power operating point under rapidly changing light condition and not be able to go back the maximum operating point quickly, this will lead to the inefficient use of the PV array and hence this affects the whole system performance of tracking MPP.

Other advantage of using this method is it does not depends on the device physics. The output voltage and current from the source are monitored upon which the MPPT controller relies to calculate the conductance and incremental conductance, and to make its decision to increase or decrease duty ratio output.

Mathematics of the Incremental Conductance method is discussed below. The output power from the source can be expressed as

$$P = V * I \qquad (6)$$

The fact that P=V*I and the chain rule for the derivative of product yields

$$\frac{1}{V}\left(\frac{dP}{dV}\right) = \frac{1}{V}\left(\frac{d(V*I)}{dV}\right) = \frac{I}{V} + \frac{dI}{dV} \qquad (7)$$

Let us define the source conductance G as

$$G = \frac{I}{V} \quad (8)$$

And the source incremental conductance as

$$\Delta G = \frac{dI}{dV} \quad (9)$$

It is observe that the operating voltage below at the maximum power point if the conductance is larger than the incremental conductance and vice versa. The voltage operating point at which the conductance is equal to the incremental conductance. These equations 10, 11, 12 and are graphically shown in fig. 4.

$$\frac{dP}{dV} < 0\,, if\ G < \Delta G \quad (10)$$

$$\frac{dP}{dV} = 0\,, if\ G = \Delta G \quad (11)$$

$$\frac{dP}{dV} > 0\,, if\ G > \Delta G \quad (12)$$

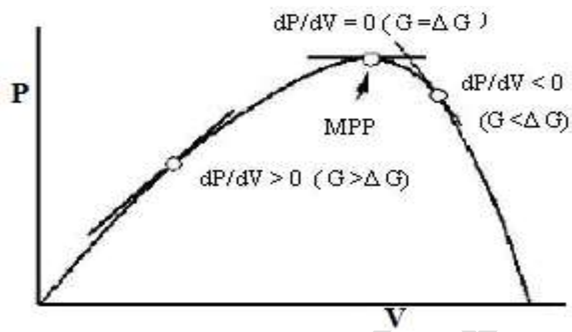

Figure 4. The P-V curve

The program flow chart for this algorithm is shown in fig. 5 the operating output current (I_{in} (k)) and voltage (Vin (k)) are measured from the solar panel. The incremental changes dV and dI are approximated by comparing the most recent measure values for (I_{in} (k)) and (V_{in} (k)) with those measured in the previous cycle (I_{in} (k-1)) and (V_{in} (k-1)). Then G and ΔG are computed as per the equations (8) and (9). From equation (11), if dp/dv = 0 (i.e. G = Δ G) is true, then the system operates at the MPP and no change in operating voltage is necessary, thus the adjustment step is bypassed i.e. no adjustment for the duty ratio and the current cycle ends. If equation (11) is false, equation (10) and (12) are used to determine whether the system is operating at a voltage greater or less than the MPP voltage and hence to increase or decrease the duty ratio by a step-size of some value accordingly.

If the system is operating at the MPP during the previous cycle, the incremental change of the operating voltage is zero (dv = 0). This would lead a division by zero i.e. Δ = di/dv = di/ 0, which is impossible for calculation. To avoid this, the condition (dv = 0) is checked first and if true leads to another branch in the algorithm with further tests on possible changes of the panel's operating conditions. Since the voltage dv = 0, that means the voltage has not changed; now the only useful information about possible changes are found from the current measurement. If di is equal to zero, the operating conditions have not changed and therefore the adjustment of the system voltage is bypassed. If di > 0, the duty ratio is increased by step size and is di < 0, the duty ratio is decreased by step size. The program then returns and starts tracking again until the MPP is reached. The maximum duty cycle ratio is set at 90% and the minimum is at 10% and hence contributes to the efficient power transfer of the converter.

The drawbacks of these techniques are mainly two. The first and main one is that they can easily lose track of the MPP if the solar insolation level changes rapidly. The other one is the oscillations of the voltage and current around the MPP in the steady state. This is due to the fact that the control is discrete and the voltage and current are not constantly at the MPP but oscillating around it.

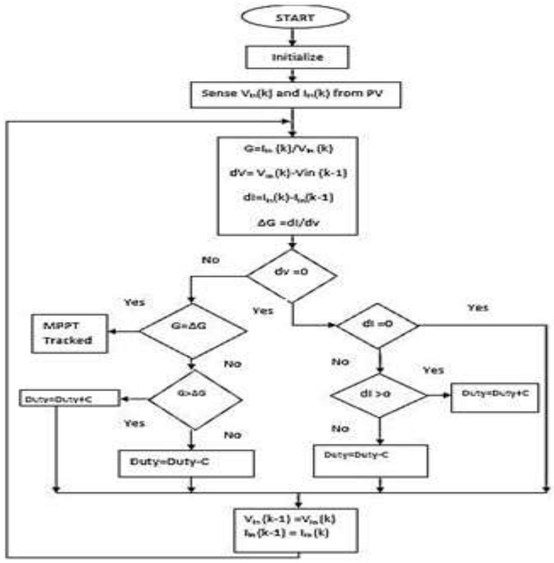

Fig. 5.Flowchart of the IC method.

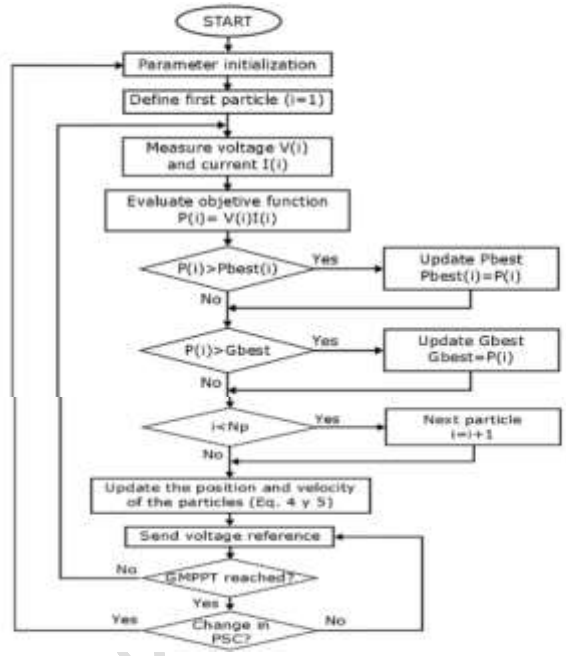

Fig.6. Flowchart of the PSO Algorithm

D. PSO ALGORITHM:

A basic variant of the PSO algorithm works by having a population (called a swarm) of candidate solutions (called particles). These particles are moved around within the search-space according to a few simple formulae. The movements of the particles are guided by their own best known position within the search-space as well as the entire swarm's best known position. When improved positions are being discovered these will then come to guide the movements of the swarm. The process is repeated & by doing so it is hoped, but not guaranteed, that a satisfactory solution will eventually be discovered.

The PSO algorithm maintains multiple potential solutions at one time

• During each iteration of the algorithm, each solution is evaluated by an objective function to determine its fitness

• Each solution is represented by a particle within the fitness landscape (search space).

• The particles "fly" or "swarm" through the search space to find the maximum value returned by the objective function

Fig.6 represents the PSO algorithm which is processed based on the objective function. The voltage and current values are taken to calculate the power with objective function and the individual best solution and the global best solution are computed and updated continuously with the best solution. The algorithm is repeated until the maximum power is obtained.

E. BOOST CONVERTER

The boost converter is nothing but a DC/DC converter, which has boosting the voltage to maintain the maximum output power constant for all the conditions of temperature and solar irradiance variations. The MPPT uses the converter to regulating the input voltage at the PV MPP and providing load-matching for the maximum power transfer. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT. There are several different types of dc-dc converters, buck, boost, buck-boost topologies, have been developed and reported in the literature to meet variety of application specific demands .The topology used for DC to DC converter is boost converter. The boost converter is shown in fig. 7 .when the switch S is on, the current builds up in the inductor L due to the positive inductor voltage is equal to the input voltage.

When S is off, the voltage across L reverses and adds to the input voltage, thus makes the output voltage greater than the input voltage. For steady state operation, the average voltage across the inductor over a full period is zero. By designing this circuit we can also investigate performance of converters which have input from solar energy.

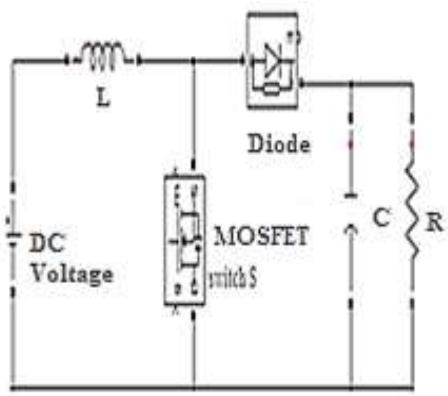

Fig. 7.Circuit diagram of boost converter

The boost converters will present low ripple on the PV module side, so here in this experimental work, boost converter is used to verify the output power results.

3. SIMULATION RESULTS

The flowchart of the PSO MPPT algorithm has been implemented in MATLAB/Simulink as shown in fig. 8, which includes the PV module, the boost converter, and the MPPT algorithm. The converter circuit topology is designed to be compatible with a given load to achieve maximum power transfer from the solar arrays. The power will be maximum for along the variations of temperature and solar irradiance in the PV array which is giving to input to DC-DC converter. We consider photovoltaic cell with Irradiance is 1000 w/m2 and temperature is 250c.The simulation results of the output power of the PV module, output voltage & output current waveforms are shown in fig. 9, 10 and 11.

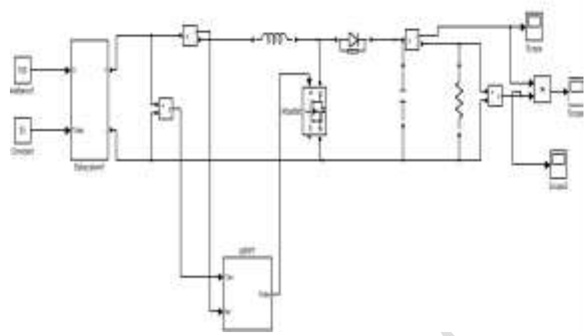

Figure 8.simulation model of PSO MPPT algorithm

The maximum power point tracking of the module for the PSO method is carried out using Matlab/Simulink and the maximum power tracked for the considered 1000W module is 992.56 W.

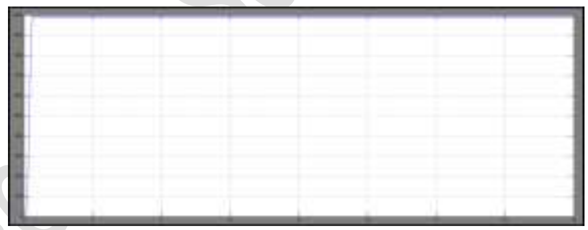

Figure 9. PV Output power

Fig. 10. Output Voltage

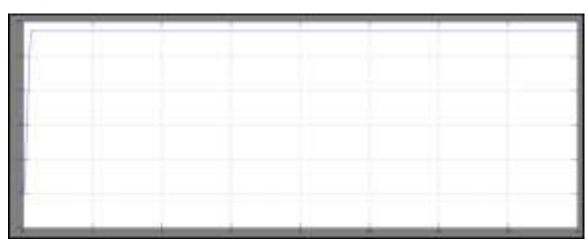

Fig. 11. Output Current

4. CONCLUSION

Simulation of the PV system with PSO MPPT algorithm has been verified in the MATLAB/SIMULINK. This method computes the maximum power and controls directly the extracted power from the PV cell. The PSO algorithm is found to be better compared with the INC method to improve the performance of the PV array output. The voltage ,current and power values are examined through the MATLAB/SIMULINK. It is found that a maximum power of 992.56 W is achieved.

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