ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

PSO and P&O based MPPT Technique for SPV Panel under Varying Atmospheric Conditions

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Abstract-This paper presents Particle Swarm Optimization and Perturbation & Observation techniques to find the optimum operating parameters of a solar photovoltaic panel under varying atmospheric conditions. The terminal voltage, current and corresponding duty-cycle, at which the DC/DC converter should be switched to obtain maximum power output, are determined. Simulation of maximum power point tracking of a DSP210 solar panel is done, using both methods, in MATLAB. It is observed from the results that the particle swarm optimization based algorithm can track the maximum power point for the whole range of solar data (irradiance and temperature) and has high conversion performance.

Key Words- **Maximum Power Point Tracking (MPPT), Perturb & Observe (P&O), Particle Swarm Optimization (PSO), Solar PV panel.**

I. INTRODUCTION

The Photovoltaic (PV) generating systems need maximum power point tracker because the output power of the PV panel depends on the operating terminal voltage and current. As the intensity of light falling on the panel varies, its voltage as well as its internal resistance varies. Change in the internal resistance of the panel due to variation in irradiation and temperature causes the mismatch between the source and the load impedance. Thus panel is not able to generate power which it is capable of producing, resulting in lower generation of power. This results in generation of less power than what the panel is actually capable of generating [1].To extract maximum power from the panel, the load impedance should be equal to the internal resistance of the panel.

PV is not a constant DC energy source in which its output power is varied depending strongly on the drawn current to the load. PV characteristics change with temperature and irradiation variation. Thus, the output voltage (V) of PV varies with the current (I). For any PV system, the output power can be increased by tracing the maximum power point (MPP) of the system. To achieve this, a maximum power point tracking (MPPT) controller is required to track the optimum power of the PV system. To extract maximum power from the panel, its internal resistance should be equal to the load resistance. A DC-DC converter is incorporated between SPV panel and the load. This converter adjusts the load resistance seen by SPV equal to the internal resistance of the panel by varying the duty cycle using MPPT algorithm. Therefore the maximum power point tracking (MPPT) is of the paramount importance in Photovoltaic systems. [7]. Various MPPT algorithms such as Incremental conductance method, Voltage control, Current control, DSP and Microcontroller based, have been developed in recent years[10-15].Even though these algorithms are effective, there needs a technique which can track the MPP more accurately and faster at varying atmospheric conditions. This paper proposes the method to track the MPP for a PV module using Perturb & Observe (P&O) and Particle Swarm Optimization Algorithm (PSO) technique at varying irradiation and temperature. The PSO is a swarm intelligence-based algorithm used to find the global optimal solutions. The reasons why PSO has gained the popularity is because it has only a very few parameters that need to be adjusted. Although PSO is still in its infancy, it has been used across a wide range of applications. On the other hand P&O method has simple structure and high reliability. The said techniques find the optimal electrical operating points and corresponding duty cycle at which the maximum power can be transferred. The performance of the proposed MPPT methods is tested by simulation at different irradiation and temperature using MATLAB. DSP210 panel specifications are used for simulation. To highlight the proposed system performance, irradiation and temperature variations were applied in steps. The results are analyzed and compared.

II. MODELLING OF SOLAR CELL

Fig.1 shows the equivalent circuit diagram for a solar cell. It consists of a constant current source, in parallel with a shunt resistance and a diode. The ideality factor of the diode is taken into account for the recombination in the space-charge region. This model accounts for the losses due to the module's internal series resistance, as well as contacts and interconnections between cells and modules.

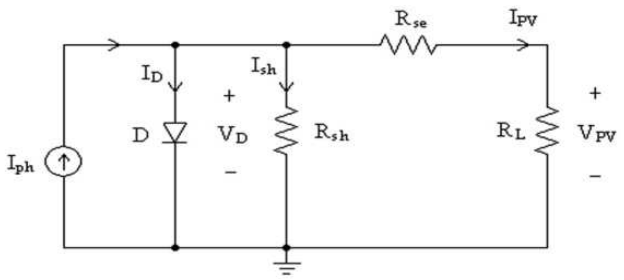

Fig.1: Electrical Equivalent Circuit model of single diode SPV module

It has a relatively good approximation precision and it is perhaps the most suitable model for the diagnostics of PV arrays, as it offers good compromise between approximation precision and simplicity [5].

Here equations (1) to (13) are used to model SPV cell. The typical I-V output characteristics of PV-cell are given by [1]

$$I_{pv} = I_{ph} - I_r\left[exp\left\{\frac{V_{pv} + I_{pv}R_{se}}{V_t}\right\} - 1\right] - \left[\frac{V_{pv} + I_{pv}R_{se}}{R_{sh}}\right] \quad (1)$$

Where,

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

$$I_{pv} = \frac{\{I_{ph,ref}[1+\alpha(T-T_{ref})]\}G}{G_{ref}} \tag{2}$$

$$I_{pv,ref} = I_{sc,ref} \tag{3}$$

$$I_{pv,ref} = \frac{R_{sh}+R_{se}}{R_{sh}} \times I_{sc,ref} \tag{4}$$

$$I_r = I_{r,ref} \times \left[\left(\left(\frac{T}{T_{ref}}\right)^{\frac{3}{n}}\right) \times exp\left[\left[\frac{q\times E_g}{n\times k}\right]\times\left(\frac{1}{T_{ref}}-\frac{1}{T}\right)\right]\right] \tag{5}$$

$$E_g = 1.16 - \left[\left((7.02\times 10^{-4})\left[\frac{T^2}{T-1108}\right]\right)\right] \tag{6}$$

and

$$I_{r,ref} = \frac{I_{sc,ref}}{exp\left(\frac{V_{oc,ref}}{V_{t,ref}}\right)-1} \tag{7}$$

$$V_t = V_{t,ref}\frac{T}{T_{ref}} \tag{8}$$

$$V_{t,ref} = \frac{n_{ref}kT_{ref}}{q} \tag{9}$$

$$R_{sh} = \frac{4.6}{(G-0.086)(Obtained\ by\ curve\ fitting)} \tag{10}$$

$$I_m = I_{m,ref}\times G \tag{11}$$

and

$$V_m = V_{m,ref} + \{\beta(T-T_{ref})\} \tag{12}$$

$$n = n_{ref}\frac{T}{T_{ref}} \tag{13}$$

III. CHARACTERISTIC OF SOLAR CELL

The I-V and P-V curve of a module is shown in the Fig.2. For a certain value of voltage and current the panel provides a maximum output. The output power of the panel increases as the module voltage increases, it reaches to a peak (called as peak power or maximum power point (MPP) in the module) and drops as the voltage approaches to the open circuit voltage. The peak power or MPP is defined at standard test condition (STC) of irradiation of 1000 W/m2 and 25 0C module temperature, but these condition does not exist for the most of the time, due to which, normally, the module output power will be less than the peak output power. In addition to this, the output current and the voltage are affected by the variations in the irradiation and temperature. Fig.3 and Fig.4 shows the waveforms for the effect of irradiation and temperature on I-V characteristics of a solar cell. Under different conditions, there is a unique point on the curve, called the maximum power point (MPP), at which the photovoltaic cell operates with maximum efficiency and produces maximum output power.

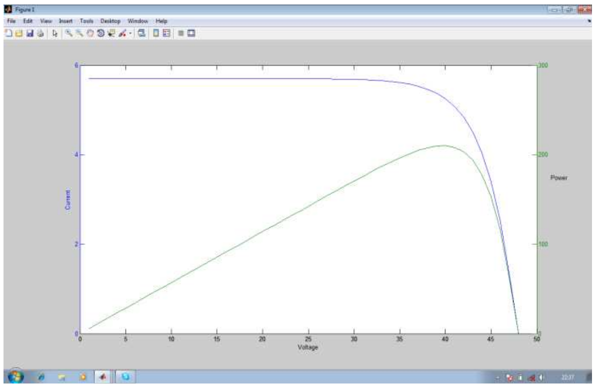

Fig.2: I-V and P-V Curve

With the constant irradiance value, the voltage of the MPP decreases as the temperature increases, resulting in decrease in maximum output power. Whereas under the conditions of constant temperature and decreasing irradiance, voltage at which the MPP occurs changes, thus it decreases the value of the maximum output power.

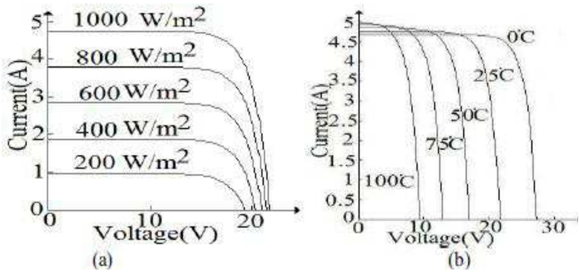

Fig.3: waveforms showing the effect of (a) Radiation and (b) Temperature on I-V characteristics [8]

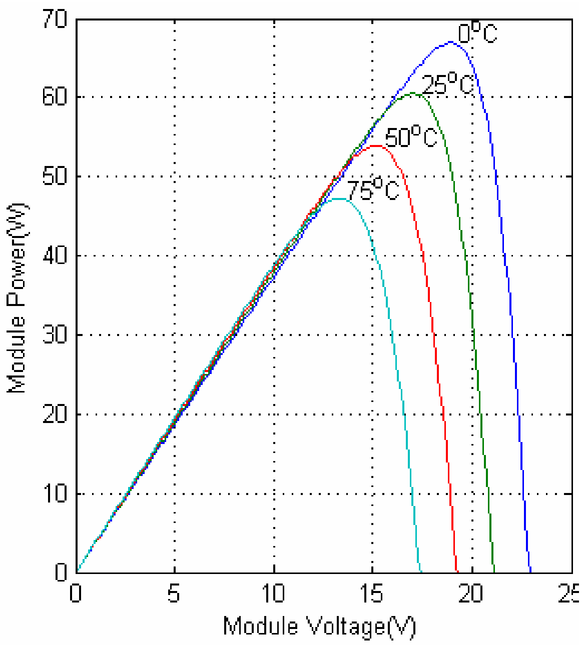

Fig.4: PV curves at various temperatures and Constant irradiation of G=1000W/m2 [5]

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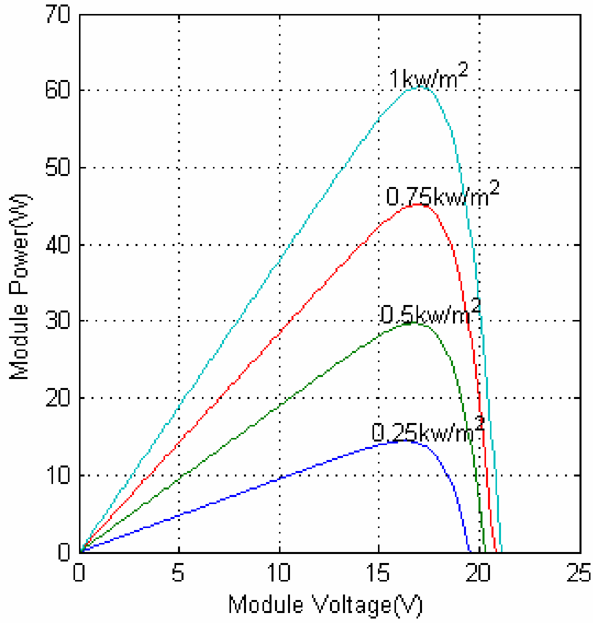

Fig.5: PV curves at various irradiation levels and constant temperature of T=25 0C [5]

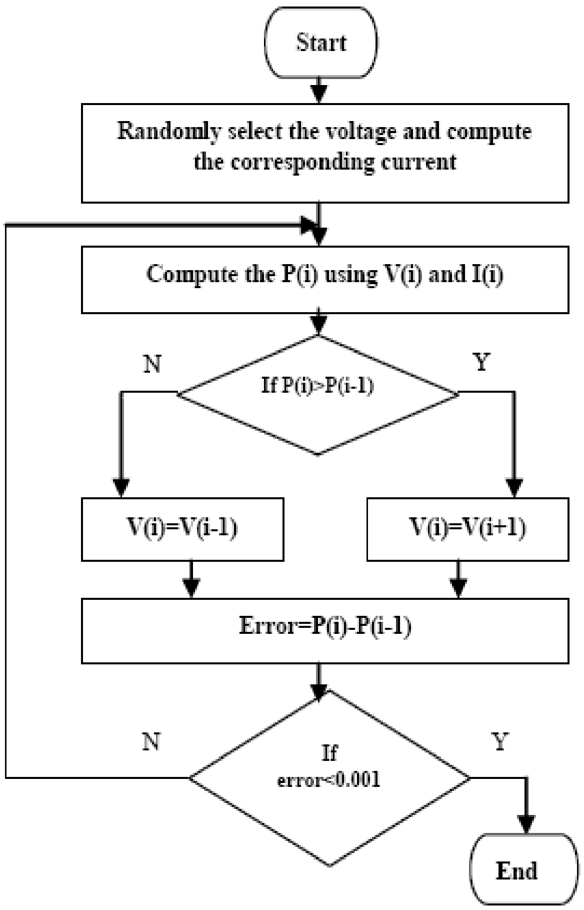

Fig.6: P&O method flow chart

IV. MPPT USING PERTURB AND OBSERVE (P&O) METHOD

Perturb-and-observe (P&O) method is most commonly used in practical PV systems for the MPPT control. This method has simple implementation, high reliability, and tracking efficiency. Fig. 6 shows the flow chart of the P&O method. The present power P (i) is calculated with the present voltage V (i) and current I (i) of the PV panel, and is compared with the previous power P (i-1). If the power increases, keep the next voltage change in the same direction as the previous change. Otherwise, change the voltage in the opposite direction.

V. PARTICLE SWARM OPTIMIZATION APPLICATION TO MPPT CONTROL

In this section the problem involved in solving the MPPT control using PSO technique is discussed. The PSO method is a simple and effective meta-heuristic approach that can be applied to a multivariable function optimization having many local optimal points. The PSO uses several cooperative agents and each agent shares the information attained by each individual during the search process. Here PSO initializes the variables randomly in a given space. The number of decision variables determines the dimension of space. Each optimization problem is to search the solution space of a particle, each particle runs at a certain speed in the search space, the speed of particles is in accordance with its own flight experience and flight experience of other examples with dynamic adjustments. In the optimization space, each particle has decided to adapt the objective function value, and recorded their own best position Pi found so far, and the entire group of all particles found in the best position Pg. Velocity and position update formula are as follows[3].

$$V_i^{k+1} = wV_i^k + c_1 r_1 \left(P_i^k - X_i^k\right) + c_2 r_2 \left(P_g^k - X_i^k\right) \quad (14)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (15)$$

Where

V_i^{k+1} is the particle velocity,

X_i^{k+1} is the current Position of a particle,

P_i^k is the Pbest and

P_g^k is the Gbest,

r_1 & r_2 is the random number between 0 & 1,

c_1 & c_2 are learning factors. Usually c_1=c_2=2.

Algorithm for PSO Implementation:

Step 1- Set the number of particles and searching parameters along with the limit for position and velocity

Step 2- Randomly initialize Position and velocity of each particle.

Step 3- Compute the fitness value of each particle.

Step 4- The particle having the best fitness value is set as Gbest (Global Best).

Step 5- Update the position and velocity of each particle with respect to the Gbest.

Step 6- Repeat Step 3 & 4 till the optimum solution is reached.

Step 7- Gbest at the end of the last iteration gives the optimized value.

Step 8- Compute the Duty-cycle using the given formula.

$$D = \frac{1}{1 + \sqrt{\frac{R_{in}}{R_{out}}}}$$

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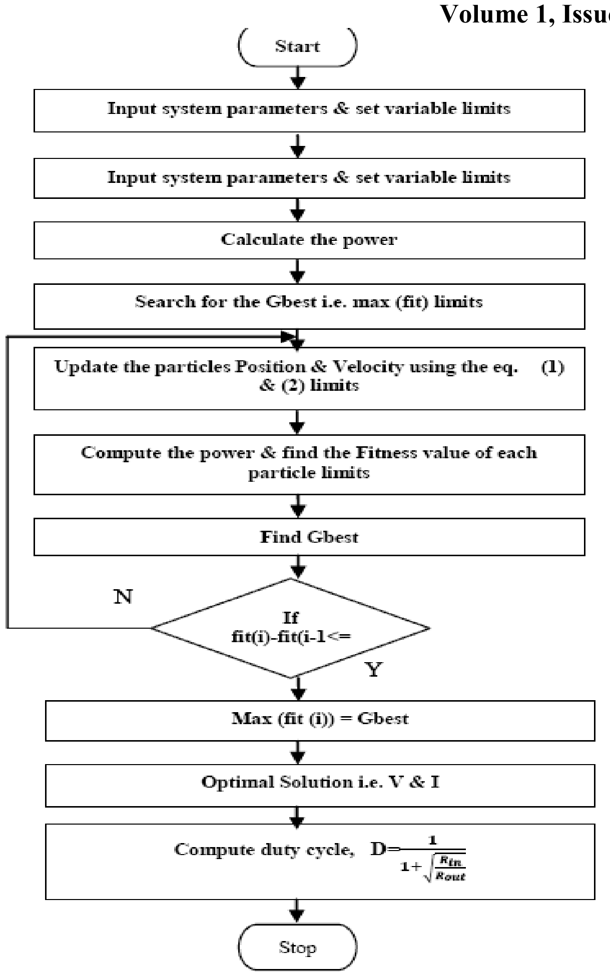

Fig. 7: PSO method flow chart

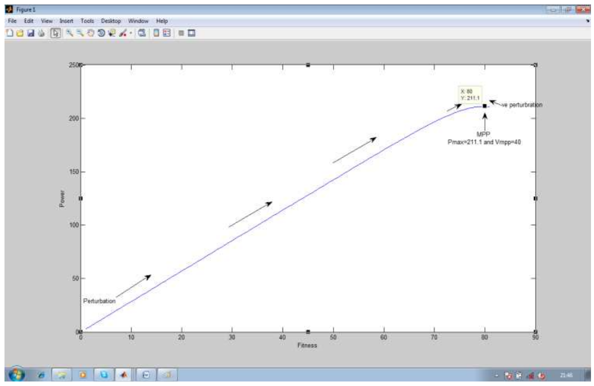
Fig.8: Fitness Vs Power curve

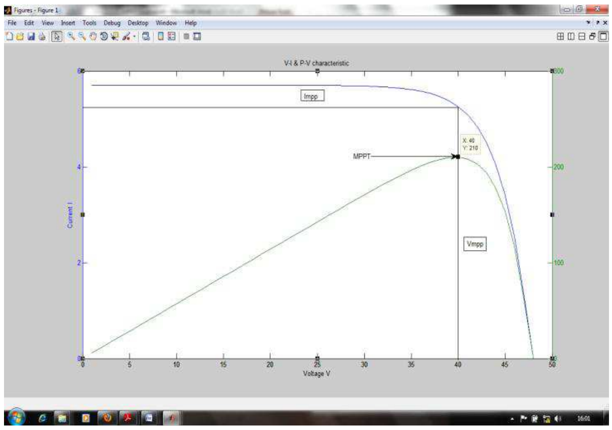
Fig.9: MPPT using PSO technique

VI. SIMULATED RESULTS

Table 1 shows the simulated results using PSO technique and P&O method. Here we can see that both PSO and P&O method were successfully able to track the maximum power point for a PV panel at any given Irradiation G & Temperature T respectively. The table shows the optimized and un-optimized output for DSP210D panel. Panel specifications are as follows.

- Max output Power: 210 W
- Open circuit voltage: 47.8 V
- Short circuit Current: 5.7 A
- Temperature coefficient of open circuit voltage0.0028 V/0C
- Temperature coefficient of short circuit current 0.0003 A//0C

Fig 8 and fig 9 shows the simulated characteristic of the dsp210d pv panel at stc i.e. 25 0c and 1000w/m2using PSO and P&O technique. Simulation results show that PSO-based MPPT algorithm can quickly and accurately find the maximum power of each module and the system achieved a true sense of the maximum power output. Table I gives the results for the tests conducted by the authors under various atmospheric conditions.

VII. NOMENCLATURE

I_{PV}, V_{PV}	Solar cell current (A) and voltage (V)
I_D, V_D	Diode current (A) and voltage (V)
I_{ph}	Light generated current (A)
I_{sc}	Short circuit current (A)
V_{oc}	Open circuit voltage (V)
G	Irradiance (W/m^2)
T	Temperature (K)
n	Diode ideality factor (0≤n≤1)
k	Boltzman's constant (1.381X10-23J/K)
q	Electron charge (1.602 X10-19C)
I_r	Reverse saturation current (µA)
R_{sh}, R_{se}	Shunt resistance (Ω), Series resistance (mΩ)
Vt	Thermal voltage(= nkT/q) in mV
V_m , I_m	Maximum power point voltage (V),Current (A)
P_m	Maximum power point Power (W)
α	Temperature co-efficient of short circuit current.
β	Temperature co-efficient of open circuit voltage.
Ref	Second suffix represents all parameters at reference condition (G=1000W/m2 and T=250C)
NS, NP	Number of cells in series & parallel

ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

TABLE I: Simulated results using PSO and P & O techniques

G W/m²	T⁰C	Theoretical Output of SPV Panel			SPV Panel output using PSO			SPV Panel output using P&O		
		Voltage V (volts)	current I (Amps)	Power P (Watts)	Voltage V (Volts)	Current I (Amps)	Max Power (Watts)	Voltage V (Volts)	Current I (Amps)	Max Power (Watts)
1000	25	38.56	5.44	210.0	39.70	5.29	**210.05**	40	5.25	210.002
800	25	38.24	4.30	164.65	39.10	4.22	**165.37**	39	4.23	165.16
600	25	28.68	3.40	097.76	38.22	3.17	**121.07**	38	3.19	121.04
400	25	19.12	2.27	043.58	37.08	2.10	**078.09**	37	2.11	78.08
1000	35	35.50	5.36	190.30	36.69	5.40	**198.26**	37	5.35	198.20
1000	40	33.83	5.35	181.00	35.23	5.48	**193.06**	35	5.49	192.29
1000	45	32.79	5.29	173.50	33.99	5.48	**186.59**	34	5.48	186.59
750	29	35.84	4.09	146.88	37.69	3.99	**150.43**	38	3.95	150.34
800	35	38.23	3.94	150.87	36.15	4.30	**155.56**	36	4.32	155.55
600	40	28.67	3.50	100.39	33.87	3.24	**110.07**	34	3.23	110.05
950	45	34.32	4.72	162.00	33.87	5.20	**176.40**	34	5.18	176.36
500	39	23.89	2.94	070.47	33.53	2.70	**090.74**	34	2.67	090.65

VIII. CONCLUSION

Simulation of Maximum Power Point Tracking of a Solar PV panel using Particle Swarm Optimization and Perturbation & Observation techniques is presented. Comparison of SPV panel output with and without optimization is presented. The results show that particle swarm optimization technique given better results. Hence PSO technique can be employed for MPPT of Solar PV panels.

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ISSN: 2277-3754
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 3, March 2012

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