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Particle Swarm Optimization Technique for Photovoltaic System

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***Abstract:**Day by day the dependency on renewable energy uses has been increasing because of no greenhouse emission and abundant in nature available freely, this paper, presents a comparative analysis of an optimization technique called Particle Swarm Optimization (PSO) along with Perturb & Observe (P&O) for the extraction of maximum power from the PV panel. The performances of P&O and PSO techniques were compared for different insolations and temperatures. A detailed and rigorous mathematical model along with simulation results and its performance for maximum power extraction from the panel were analyzed by using P&O and PSO. It has been observed that the maximum power obtained from PSO model is more than the maximum power obtained from P&O for different insolations and temperatures. Thus PSO is much better and more suitable for extracting maximum power from PV system.*

***Keywords:**Particle Swarm Optimization, maximum power point tracker, buck boost Converter, Perturb & Observe*

I. INTRODUCTION

The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and drastically affected the environment depleting the biosphere and cumulatively adding to global warming. As conventional remnant fuels are expected to come to an end in the near future, the world recent research increasing exponentially in renewable energy such as solar, wind, geothermal, biomass etc. [1]-[2]. Solar energy is being getting more popular because it is available in abundant and also freely, most of the part of India got 300 sunny days [3]-[4]. Solar energy is a good choice for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic modules. The current capacity of solar PV system depends on its area exposed to sun light and if area is more the current capacity is also more and if area is less the current capacity is also less [5]. PV array is formed when PV modules are connected in series and parallel which is connected as per power requirement capacity [6]-[9].

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In literature many optimization methods such as Perturb and observe, Incremental conductance: Fractional open circuit voltage: Fractional open circuit voltage: Artificial intelligent techniques: Fuzzy Logic Controller, has been discussed.Particle Swarm Optimization [10] is an approach to optimize the solar MPPT. The PSO algorithm is used to minimize the cost of the generated energy for the matching of electricity supply and local demand [11].

Particle Swarm Optimization (**PSO**) technique is being used in solar PV system to produce constant output voltage from converter. The application of PSO greatly improves the performance of MPPT and supply enhanced output power [12-14]. The reduction in total power generation by entire PV system is being reduces due to mismatch in panel design, grading and partial shading. So its efficiency is also being greatly affected [15-16]. So appropriate tracking system along with optimization technique are needed. maximum power point tracking (MPPT). To examine the usefulness of the projectedtechnique, MATLAB simulations are conceded out under varying conditions, of irradiance, temperature changes, of the PV arrays. Maximum output power is extracted from the PV panel for different insolation and temperature using P&O and PSO MPPT techniques. Since PSO is more advanced optimization technique than P & O, therefore its result is much better than P & O. The power obtained from PSO model is more than the power obtained from P & O model, which has been discussed in the following sections.

II. MATHEMATICAL MODEL OF SOLAR CELL

The equivalent circuit of solar cell has been discussed in this section which is a current source connected across a diode, shunt resistance (R_{sh}) and series resistance (R_s). The equivalent circuit is shown in fig 1.

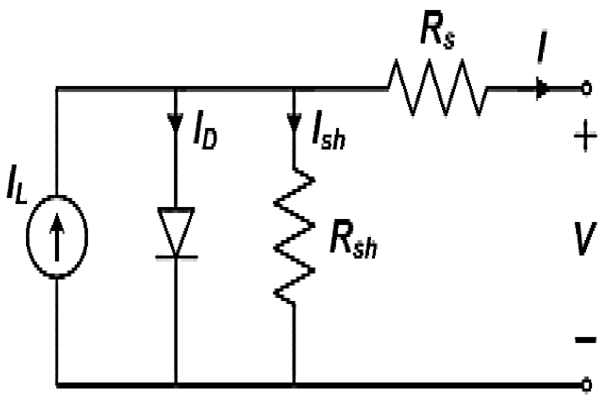

Fig.1. Equivalent circuit of Solar Cell

Where, $\mathbf{R_s}$ = series resistance, it is the resistance offered by bulk material to flow of electrons and the resistance between the bulk material and the metal contact and it is in series with load resistance.
$\mathbf{R_{sh}}$ = shunt resistance, it is the resistance caused by recombination process inside the PVcell.
Diode current is given by

$$I_D = I_o\left(e^{\frac{qV_D}{K T \Upsilon}} - 1\right) \quad (1)$$

Relationship between V_L and I_L seen from the load (neglecting shunt resistance) is given as follows

$$I_{ph} - I_D = I_L \quad (2)$$

$$I_{ph} - I_o\left(e^{\frac{qV_D}{\Upsilon KT}} - 1\right) = I_L \quad (3)$$

Put $(V_D = V_L + R_s I_L)$ in equation(iii)

$$I_{ph} - I_o\left(e^{\frac{q[V_L + R_s I_L]}{\Upsilon KT}} - 1\right) = I_L \quad (4)$$

Rearranging and taking log on both sides, we get

$$\ln\left(\frac{I_{ph} - I_L}{I_o} + 1\right) = \frac{q(V_L + R_s I_L)}{\Upsilon KT} \quad (5)$$

Again rearranging, we get

$$V_L = \frac{\Upsilon KT}{q}\ln\left(\frac{I_{ph} - I_L}{I_o} + 1\right) - R_s I_L \quad (6)$$

Open circuit voltage or Maximum Voltage (I_L=0) is given by

$$V_{Lmax} = \frac{\Upsilon KT}{q}\ln\left(\frac{I_{ph}}{I_o} + 1\right) \quad (7)$$

Relation between V_L and I_L seen from load (considering shunt resistance) is given as follows

$$I_{ph} - I_D - I_{sh} = I_L \quad (8)$$

$$I_{ph} - I_o\left(e^{\frac{qV_D}{\Upsilon KT}} - 1\right) - \frac{V_D}{R_{sh}} = I_L \quad (9)$$

Put $(V_D = V_L + R_s I_L)$ in equation (9)

$$I_{ph} - I_o\left(e^{\frac{q[V_L + R_s I_L]}{\Upsilon KT}} - 1\right) - \frac{(V_L + I_s R_L)}{R_{sh}} = I_L (10)$$

Where
I_{ph} = I_{SC} = Photon Current/ Short Circuit Current
I_o = Reverse Saturation Current
I_D = Diode Current
I_L=I_S = Load Current/Series Current
V_D = Diode Voltage
V_L = Load Voltage
V_{Lmax} = Maximum Voltage/ Open Circuit Voltage
R_S = Series Resistance
R_{sh} = Shunt Resistance
q = Electron Charge
K = Boltzmann's Constant
T = Absolute Temperature
ϒ = Cascading Constant (value lies between 1 to 3)

III. SYSTEM DESIGN IN MATLAB

In both models PSO and P&O, three blocks such as PV panel, MPPT block and Buck-boost converter were considered and are shown in Figure 2 and Figure 3.

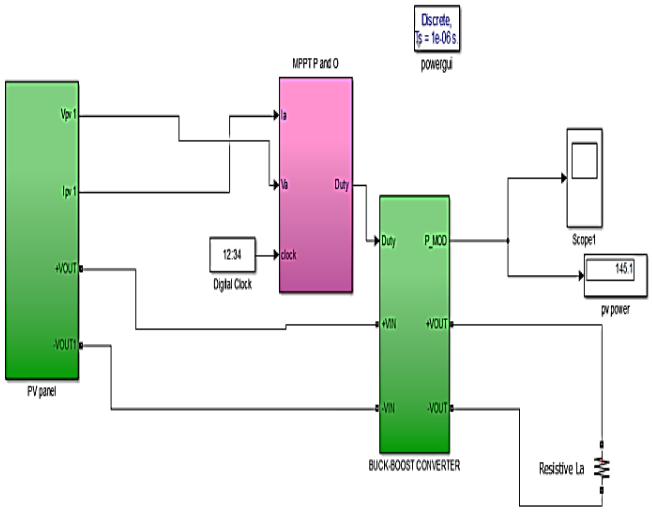

Fig. 2. Simulation Diagram of P & O MPPT Model

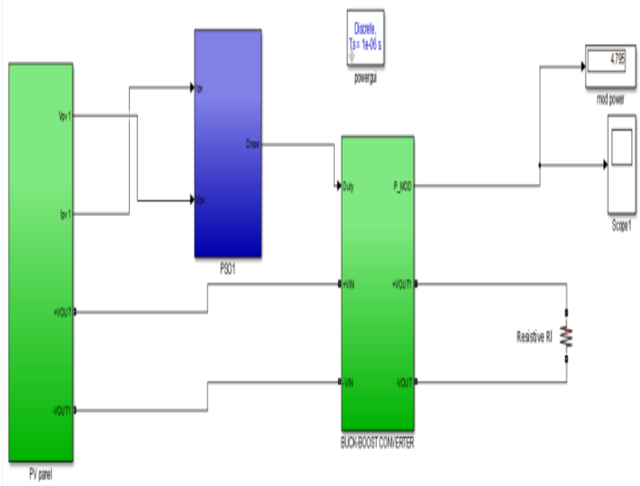

Fig. 3. Simulation Diagram of PSO MPPT Model

IV. RESULT ANALYSIS OF PSO WITH P&O METHOD

The comparative results between PSO and P & O MPPT technique applied of photovoltaic system has been given from figure 4 to figure 11. Maximum output power is extracted from the PV panel for different insolation and temperature using P&O and PSO MPPT techniques.

The present work compares the results obtained from PSO and P&O MPPT model for different insolation and temperature. Results for the above models are shown below from figure 4 to figure 11 considering temperature variations from 25˚C to 50˚C and insolation variation from1000 W/m^2 to 1500 W/m^2. In all the cases it has been observed that the response using PSO method is far better that using P&O techniques.Result analysis is also presented in the form of table1 to table4. The error is depicted in the table using PSO and P&O techniques.

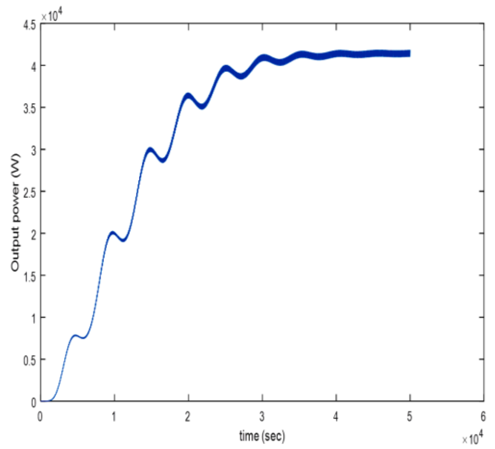

Fig. 4. Output power curve of PSO model at constant isolation 1000W/m^{2}and varying temperature up to 25^{0}C

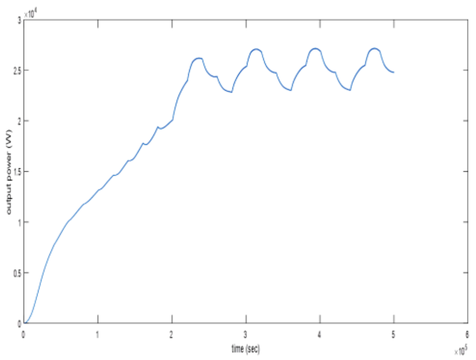

Fig. 5. Output power curve of P&O model at constant isolation 1000W/m^2 and varying temperature up to 25^{0}C

Table- I: Results of PSO and P&O models constant isolation 1000W/m2 and varying temperature up to 250C

Technique used	Pmpp(Calculated)	Pmpp(actual)	Error	Duty cycle
PSO	4.18e04 W	4.2e04 W	0.004	0.65
P & O	2.66e04 W	4.2e04 W	0.36	0.37

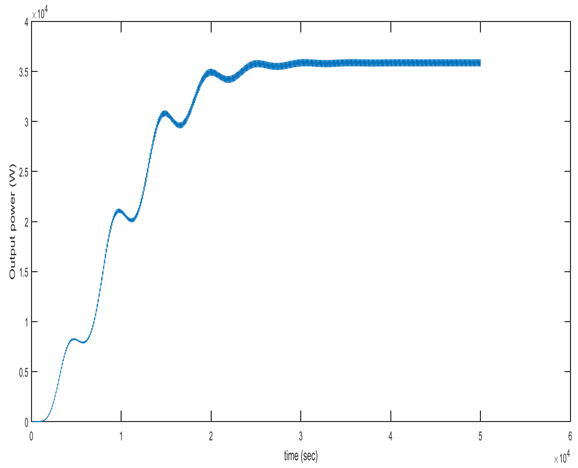

Fig. 6. Output power curve of PSO model at constant isolation 1000W/m^{2}and varying temperature up to 50^{0}C

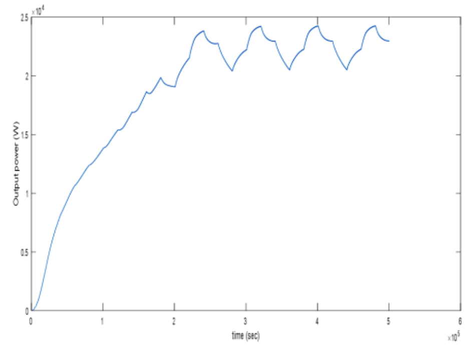

Fig. 7. Output power curve of P & O model at constant isolation 1000W/m^{2}and varying temperature up to 50^{0}C

Table- 2: Results of PSO and P&O models at constant isolation 1000W/m2and varying temperature up to 500C

Technique used	Pmpp(Calculated)	Pmpp(actual)	Error	Duty cycle
PSO	3.62e04 W	3.81e04 W	0.049	0.65
P & O	2.294e04 W	3.81e04 W	0.39	0.37

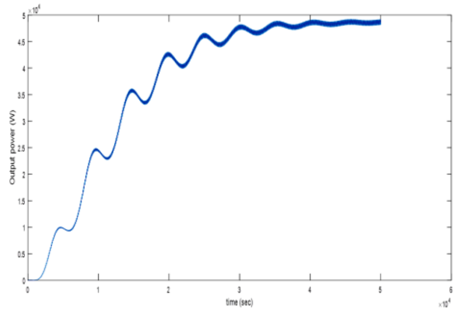

Fig. 8. Output power curve of PSO model at constant temperature 25^{0}C and varying isolation up to1000 W/m^2

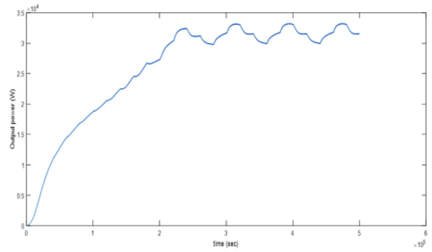

Fig. 9. Output power curve of P & O model at constant temperature 25^{0}C and varying isolation up to1000 W/m^2

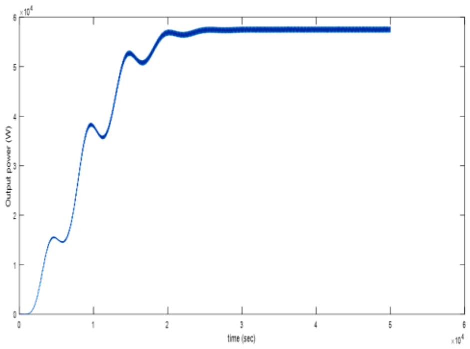

Fig. 10. Output power curve of PSO model for constant temperature 50^{0}C and varying isolation up to1000 W/m^2

Table- 3: Results of PSO and P&O models at constant temperature 25^{0}C and varying isolation up to1000 W/m^2

Technique used	Pmpp(Calculated)	Pmpp(actual)	Error	Duty cycle
PSO	4.916e04 W	5.21e04 W	0.057	0.687
P & O	3.233e04 W	5.21e04 W	0.37	0.37

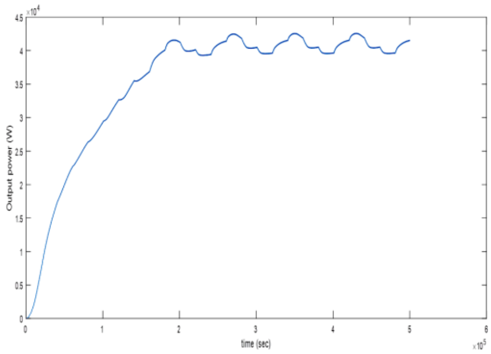

Fig. 11. Output power curve of P&O model for constant temperature 50^{0}C and varying isolation up to1000 W/m^2

Table- 4: Results of PSO and P&O models at constant temperature 50^{0}C and varying isolation up to1000 W/m^2

Technique used	Pmpp(Calculated)	Pmpp(actual)	Error	Duty cycle
PSO	5.808e04 W	6.001e04 W	0.032	0.687
P & O	4.151e04 W	6.001e04 W	0.308	0.37

In this work MATLAB Simulink has been used and compared the performance of their results for P&O, PSO for different temperature and isolation.After going through the results it can be concluded (table4) that output power obtained from PSO model is much higher than the power obtained from P&O model for different insolation and temperature. Therefore, PSO MPPT technique is much better than P&O MPPT technique.

V. CONCLUSION

P&O and PSO MPPT techniques were reviewed. The performances of P & O and PSO techniques were compared for different insolation and temperature. After running simulation of both MPPT models, it has been found that the maximum power obtained from PSO model is more than the maximum power obtained from P&O for different insolation and temperature. Thus it can be concluded that PSO is much better and more suitable for extracting maximum power from PV system.

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