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COMPARISON OF MPPT ALGORITHMS FOR PHOTOVOLTAIC SYSTEMS UNDER UNIFORM IRRIADIANCE BETWEEN PSO AND P&O

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Abstract:

This paper shows a Comparison between Conventional Method [P&O] and particle swarm optimization [PSO] Based on MPPT Algorithms for Photovoltaic Systems under uniform irradiance and temperature. The main idea is to show that PSO method has a very high tracking speed and has the ability to track MPP under different environmental conditions in addition to an easy hardware implementation using a low-cost microcontroller. MATLAB simulations are carried out under very challenging conditions, namely irradiance and temperature, which reflect a change in the load [KW]. The proposed PSO tracking method Results will be compared with conventional method called [P&O] through MATLAB/SIMULINK.

Keywords: *Perturb and Observe [P&O], Particle Swarm Optimization [PSO]; Maximum Power Point Tracking [MPPT]; Photovoltaic [PV] System.*

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1. Introduction

Renewable energy resources play an important role in electric power generation. There are various renewable resources which are used for electric power generation, such as solar energy, wind energy, geothermal, Biomass and hydro-electric etc. Solar Energy is a good choice for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic arrays. These arrays which consist of N-modules are made up of silicon cells or semi-conductor material. When many such cells are connected in series or parallel, we get a solar PV module. From the P-V characteristics curve of the PV module we can track the maximum point for extraction the maximum power, these criteria called maximum power point tracking [MPP]. From this point of view, we had a various MPPT algorithms. Two MPP tracking techniques are studied and compared in this paper. The first technique is based on particle swarm

optimization and the second one is based on the perturb and observe [P&O method]. The objective of MPPT is to ensure that the system can always crop the Maximum power generated by the PV arrays. However, due to the varying environmental conditions, namely temperature and solar irradiance, as we mentioned before that *P–V* characteristic curve exhibits a maximum Power point (MPP) that varies nonlinearly with these conditions. To capitalize that particular advantage, this paper proposes a MPPT method based on a PSO algorithm and its simulation results compared with the conventional P&O. The main feature of the proposed method [PSO] is the ability to track the MPP under the effect of changing the irradiance and temperature in the presence of uniform condition. And if we compared it to other conventional MMPT techniques, it has a faster tracking speed. Furthermore, the algorithm is simple and can be computed very rapidly; thus, its implementation using allow-cost controller is possible.

This paper is organized by the following. In Section II discusses the modeling of the PV module and array. In Section III, The PV module performance. In Section IV, the techniques of MPPT algorithms. In Section V, system modeling and simulation results. Finally, the Conclusion is made in last section.

2. Modeling of the PV Cells

Fig. 1 shows the equivalent-circuit diagram of PV cell that consist of a source current (I_L), asingle diode (D), and series and parallel resistances (R_s, R_{Sh}).
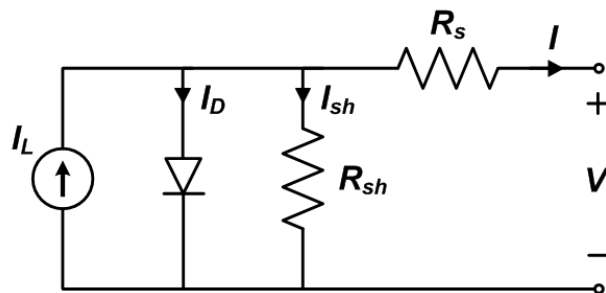

Figure 1: The equivalent-circuit of PV cell model

The output current-voltage (I-V) characteristics can be calculated by using the following equation:

$$I = I_L - I_D - \frac{V_D}{R_P}$$

Where I_D is the diode current and V_D is the diode voltage.

The diode current can be written as:

$$I_D = I_O[e^{\frac{V_D}{aV_t}} - 1]$$

Where a is the ideality factor of the diode and V_t is the thermal voltage, which is given by the equation:

$$V_t = N_S.K.T/q$$

By using KVL, the output voltage terminal can be written as:

V=V_D-IR_S

Where, I, V - the PV cell output current and voltage terminal respectively, Iph[I_L]is the photon generated current, and Io is the diode reverse saturation currents.$N_S$is the number of cells in series. a is the ideality factor, T is the cell temperature in Kelvin, k is the Boltzmann's constant (K=1.380 x 10-23 J/K) and q is the Electronic charge =1.6×10^−19C. The selected PV module for this study is SUNPOWER T5-SPR-308E PV module. Its electrical specifications are shown in (see Table 1)

Table 1: ELECTRICAL SPECIFICATIONS OF THE SIMULATED PV MODULE at 1000 W/m^2, and cell temperature at 25 C

Peak power	P_{max}	100.7KW
Rated voltage	V_{mpp}	273.5V
Rated current	I_{mpp}	5.86A
Open circuit voltage	V_{oc}	64.8V
Short circuit current	I_{sc}	6.24A
Current temp. coefficient	K_i	0.08 [%/C]
Voltage temp. coefficient	K_v	-0.33 [%/C]

3. The PV Module Performance

From table (1), we see the electrical specifications of the PV module which reflect on the current-voltage (I-V), power-voltage (P-V) characteristics at different environmental conditions, temperature and irradiance ''uniformly'' are displayed in Fig. 3
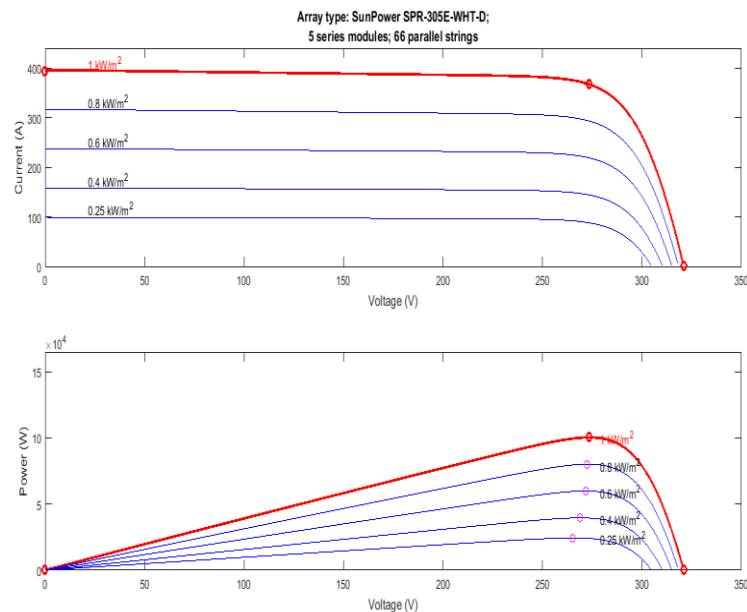

Figure 3: [I-V] [P-V] Characteristics with different irradiance values and a constant temperature (25°C)

From the above figures, it is clear that the PV module has a non-linear characteristic which differs according to solar radiation, temperature and the load condition. Each curve has a different operating point due to the variation in irradiance and temperature as well,at which the module can produce its maximum power. Hence, in order to overcome this problem, a MPPT controller is required, in order to hunt only one global peak point. The main role for MPPT system is to choose a high efficiency DC-DC converter that can operate the PV module at its MPP and be the interface between PV module and the Load.
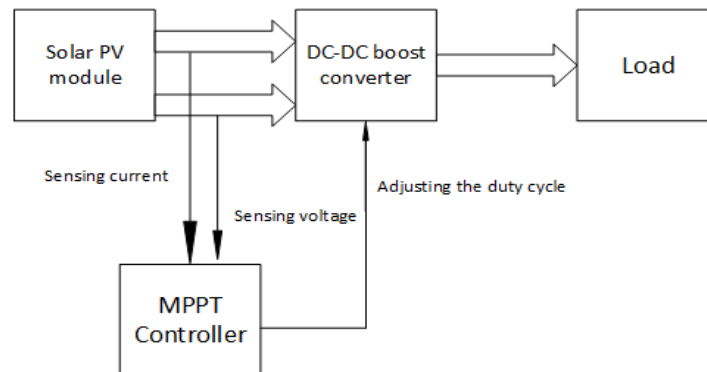
4. Techniques of MPPT

Figure 2: block diagram of a MPPT system

4.1. Perturbation and Observation Algorithm (P&O)

This technique is based on the relationship between the PV module output power and its output voltage, and we can get the maximum power point by adjusting duty cycle ratio until reaches that dp/dv is equal to zero. From the disadvantages of P&O algorithm is that it produces oscillations around the MPP in the steady state condition. In addition, we cannot operate the module at its maximum output power under various environmental conditions, we can see that from the following flowchart in fig.4.
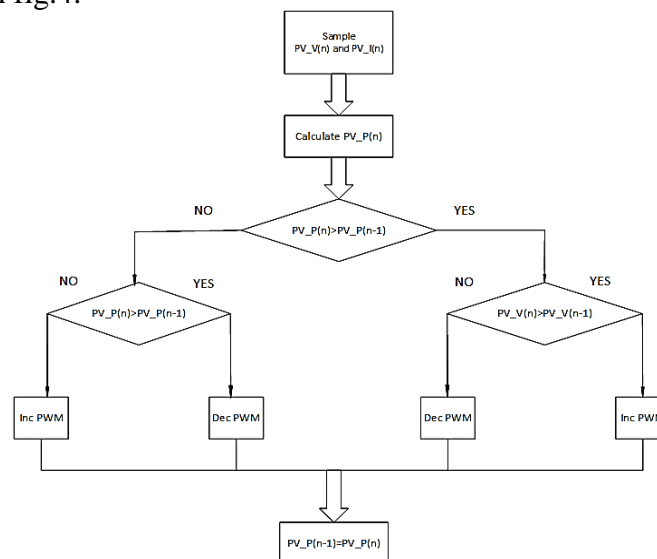

Figure 4: Flowchart of P&O algorithm

4.2. Incremental Conductance (IncCond) Algorithm

The Incremental Conductance (IncCond) algorithm appeared to overcome the disadvantages of the P&O method under the environmental effects. The relationship between the voltage and power can be expressed as follows:

$$\frac{dp}{dv} = 0 \text{ at MPP} \tag{1}$$

$$\frac{dp}{dv} > 0 \text{ on the left side of MPP} \tag{2}$$

$$\frac{dp}{dv} < 0 \text{ on the right side of MPP} \tag{3}$$

Hence, the PV module operating point at its maximum output power can be calculated based on the relationship of $\frac{DI}{DV}$ and its tracking search around MPP whatever on it, left or on the right side.

The above relationships shows that the PV module operates at its MPP when the IncCond dI/dV is equal to its direct conductance -I/V. while if the PV module IncCond dI/dV is greater than the its conductance -I/V, then the controller would increase the PV module voltage by adjusting the duty ratio of a DC –DC converter, otherwise, the perturbation would be in the opposite direction or to increase the duty ratio of the converter in order to reduce the voltage and shift the operating point back to the MPP as shown in the flow-chart in fig.5
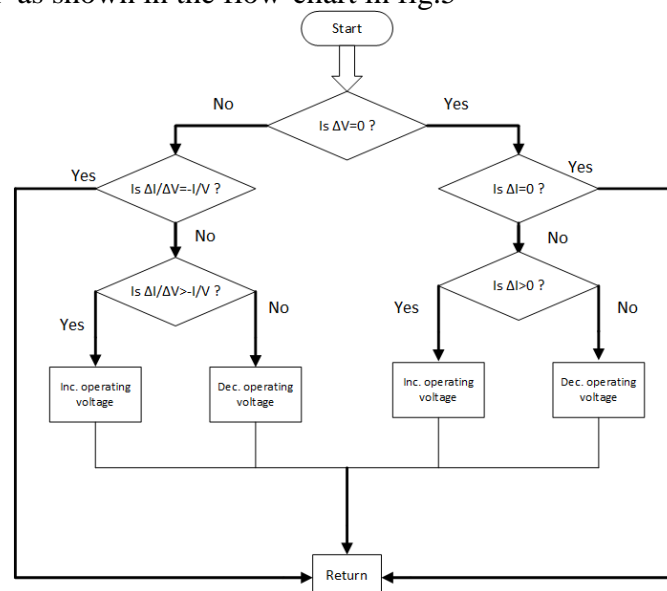

Figure 5: flowchart of incremental conductance algorithm

4.3. Particle Swarm Optimization [PSO]

Particle swarm optimization (PSO) is an intelligence optimization theory was developed by Eberhart and Kennedy in 1995. The basic concept of this algorithm was inspired from the foraging behavior of birds and fish schooling, and this concept appeared to reduce search and optimization problems that related to the conventional ones. In this algorithm, a group of fishes or birds are used as a particle; each particle flying in the search space has its location and velocity that is updated through every iteration. In order to decide the direction and distance of their movement, each particle marked as P_{best} ,and the best particle among all of them marked

as G_{best}. This algorithm is done when the maximum number of iteration is finished or the velocity of the particles reaches approximately zero as shown in fig.6
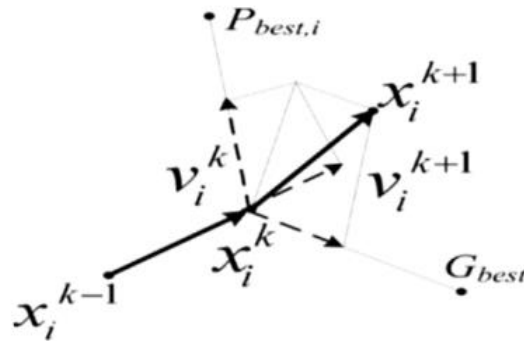

Figure 6: The movement of particles

$$V_i(K+1) = w.V_i(K) + c_1 r_1.\left(P_{best} - x_i(K)\right) + c_2 r_2.(G_{best} - x_i(K)) \qquad (1)$$
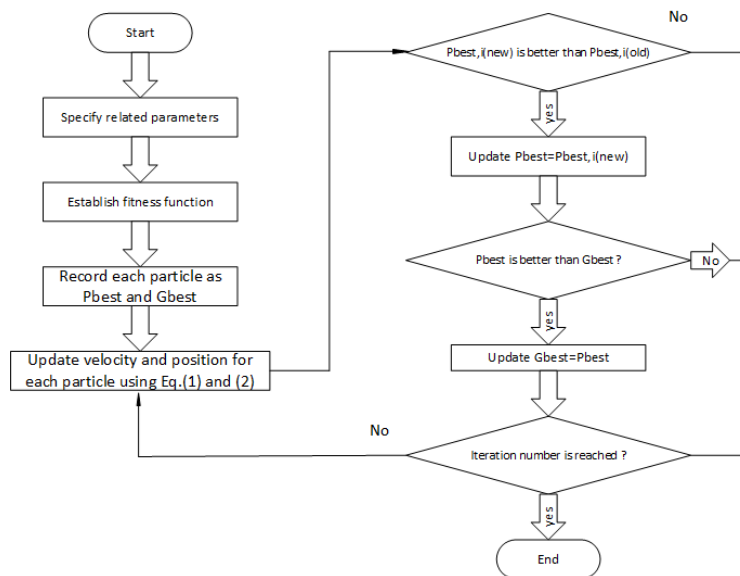$$x_i(K+1) = x_i(K) + V_i(K+1) \qquad (2)$$

Figure 7: flowchart of conventional PSO

As we can see from the above equations, the location and the velocity of the particle is updated in every iteration till reached the required value from the fitness function which is the maximum power of the PV module in this paper

P_{best}: Personal best position for the particle itself

G_{best} : Global best position among all particles

x_i : The location of particle

v_i: The velocity of the particle

r_1, r_2: Random numbers between [0,1]

K: number of iterations

c_1, c_2: Cognitive and social coefficient respectively

W: inertia weight

5. System Modeling and Simulation Results

A 100-KW grid connected PV array system model simulated in MATLAB/SIMULINK and consist of PV array connected with a signal builder which corresponding to irradiance and temperature as well. And MPPT controller to track MPP by using two codes for P&O and PSO. that output duty cycle that is adjusted through DC-DC boost converter and VSC (average model), moreover through step down transformer till reached utility grid, and its implemented from powersim/simulink library. We used a variable irradiance with different step size of w/m^2 and temperature as well, that will show a simulation resultsfor current, voltage, duty cycle and power tracked respectively.
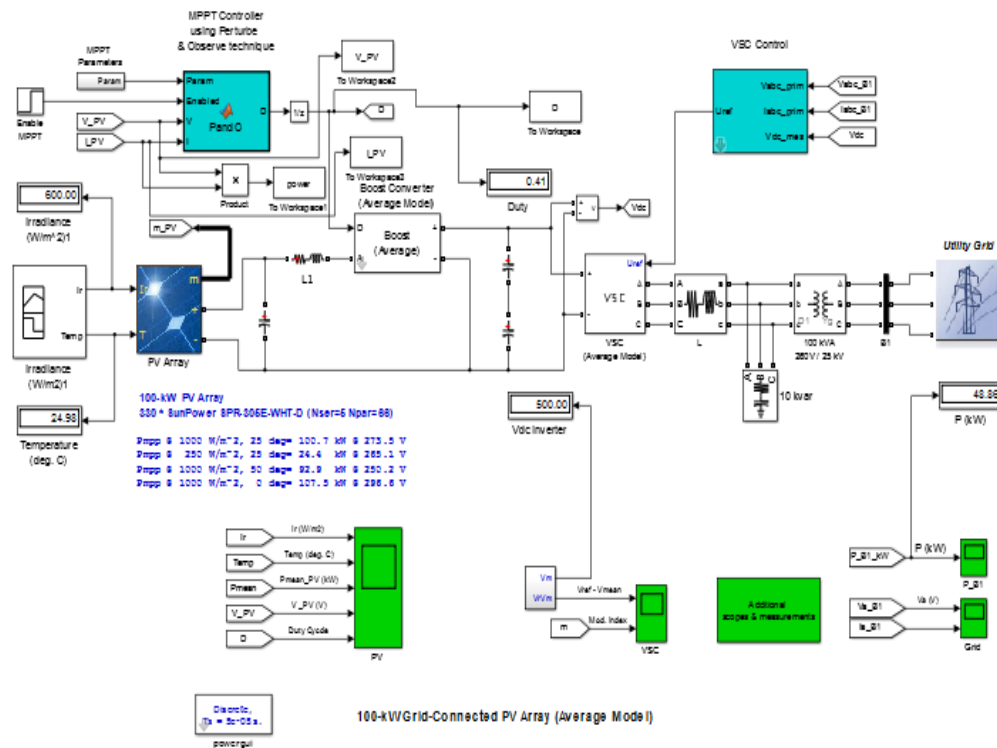

Figure 8: Simulink/matlab system model

Simulation results are carried out under uniform irradiance with different cases 1000,600,800 w/m^2 respectively, between PSO and P&O.And as shown in the following table.2 that PSO has a fast-tracking speed and has the ability to track MPP under various irradiance than P&O algorithm which is slow in tracking

Table 2: PSO simulation results under uniform irradiance at 25 C

Irradiance w/m^2	P [KW]	Duty cycle
1000	99.5	0.47
600	58.71	0.58
800	79.42	0.41

As shown from the above table. When, a step change of irradiance happened its corresponding to sampling time. At 1000 w/m^2 occurs at t=0.06 sec, 600 w/m^2 at t= 2.0 sec and 800 w/m^2 at t=4.01 sec. respectively. On the other hand, P&O simulation results are taken also as a comparison with PSO algorithms in order to show the tracking performance at the same step change of irradiance at 25 Cas shown in the following table.3

Table 3: P&O simulation results under uniform irradiance at 25 C

Irradiance w/m^2	P [KW]	Duty cycle
1000	80.39	0.58
600	48.22	0.5
800	64.32	0.57

As shown in from the previous tables, PSO algorithm has a perfect tracking speed from power point of view than P&O algorithm. Simulation curves are showed fig.9 consists of current, voltage, duty cycle and power tracked under step change of irradiance at25C.
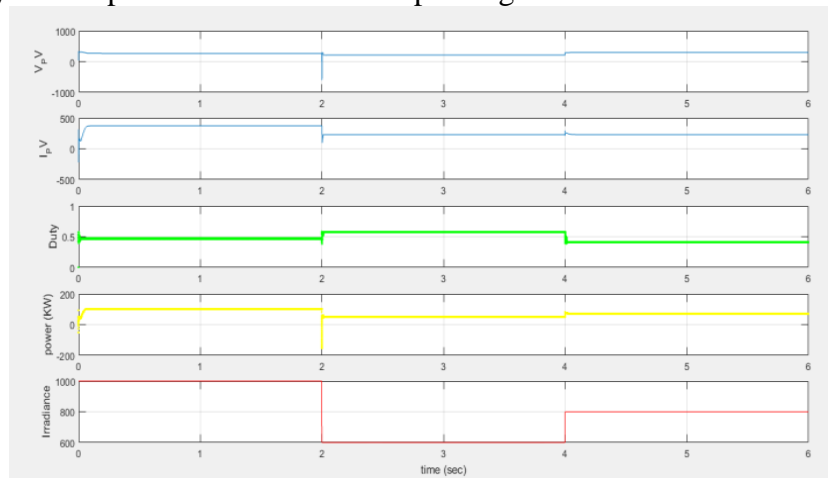

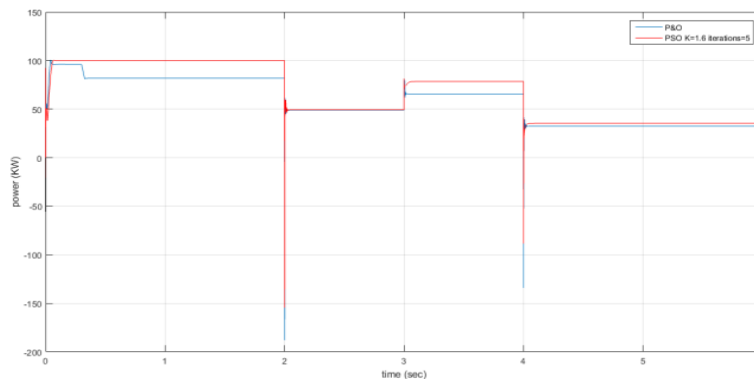Figure 9: simulation curves

Figure 10: Comparison simulation curves between PSO and P&O

From fig.10 we see that PSO has a fast tracking with better accuracy for MPP, if we look at t=2 sec we found the oscillation of particles and the tracking performance which jumps quickly to the next change of environmental conditions at the next sampling time till it ends at t=6 sec
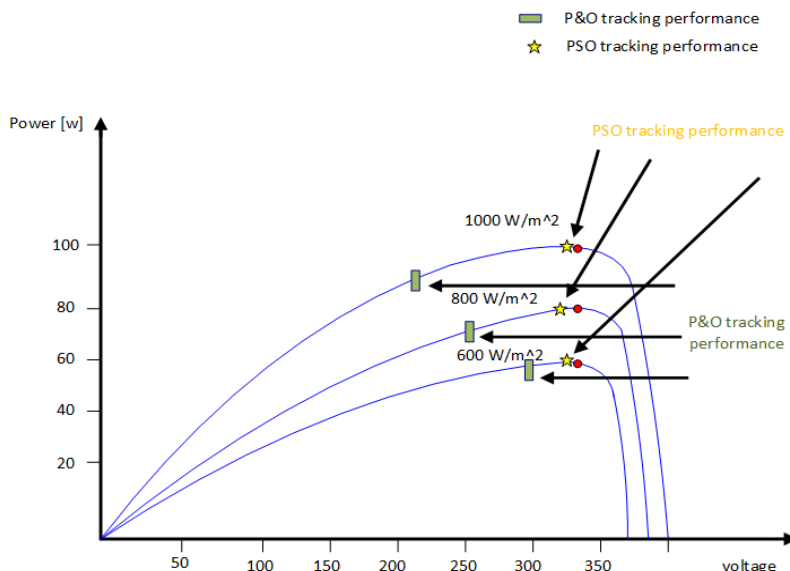
Figure 11: Tracking comparison between PSO and P&O

From fig.11 we have three redideal points of irradiance at 1000,800, 600 w/m^2 which has the maximum power of 100.7, 80.7, 59.8 KW respectively. Its shown the tracking performance on P-V curve characteristics between both techniques PSO and P&O, and it's clear that the swarm particles are nearby the MPP with very low tolerance, but P&O are far away from MPP , which reflect that PSO is more convenient for tracking maximum power point than P&O.

As a comparison point of view between PSO and P&O its seems that:

A] PSO:

1] Almost zero steady state oscillation

2] High tracking speed and accurate

3] Ability to track MPP under various environmental conditions

4] Easy hardware implementation using low cost micro-controller

B] P&O:

1] Large amount of power losses and not accurate

2] Tracking efficiency is low if it's compared with PSO

3] In hardware implementation, it's require fast controller speed & more sensor devices that leading to increase the system cost

Table 4: Comparison between my proposed work and ref.[11]

Irradiance w/m^2	1000	800	600
Power tracked for the reference work [kw] using PSO	60 KW	48 KW	34 KW
Power tracked for my proposed work [kw] using PSO	99.5 KW	79.42 KW	58.71 KW
Power tracked for the reference work [kw] using P&O	59 KW	35 KW	30 KW
Power tracked for my proposed work [kw] using P&O	80.39 KW	64.32 KW	48.22 KW

As shown from table.4 the comparison between my proposed work and ref.[11] it's clear that maximum power point tracking in the three cases of irradiance are higher than of the ref[11],on the other hand my proposed work shows that PSO is better than all conventional techniques, PSO is able to track MPP in my proposed working:

1) High tracking efficiency
2) Fast convergence to reach GMPP with oscillation of the particles
3) Tracking MPP with complex Simulink model and with minimum number of iterations.

If we see a uniform example with four pv modules with 1000 w/m^2 , the therotical max. power: 84.31 KW with my PSO control method its tracking is 84.10 KW with optimization time @ 0.057 which is better a little bit from ref[11]

6. Conclusion

In this paper, a PSO algorithm has the ability to crop MPP by the source of particle oscillation around MPP to get accurate and efficient results as shown in the previous tables. Simulation/MATLAB results are carried under step change of irradiance to show the dynamic behavior and response of the controller. And from the above pros of PSO it could locate the MPP under partial shading conditions due its accuracy and fast-tracking speed also it could be implemented in a simple way with low-cost microcontrollers.

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