Improved Perturb & Observe Method by Particle Swarm Optimization Algorithm for Photovoltaic System

Bechouat Mohcene[1], Chams-Eddine Feraga[2], Attia Mohammed El hadi[3], Moussa Sedraoui[4]

[1] *Faculté des Sciences et Technologie Université de Ghardaia. Noumirat BP 455, route Ouargla Ghardaia 47000*

[2]*Laboratory of Electrical Engineering LGEG. Department of Electrical Engineering and Automatic, University 8 May 1945 of Guelma, Algeria*

[3]*Department of Physics, Faculty of Science, University of El Oued, 39000 El Oued, Algeria*

[4]*Laboratoires des Télécommunications LT, Department of Electronic and Telecommunication, University 8 May 1945 of Guelma, Algeria*

bechouht.mohcene@univ-ghardaia.dz, chferaga@yahoo.fr, attiameh@gmail.com, msedraoui@gmail.com

Abstrac-The Perturb and Observe (P&O) maximum power point tracking (MPPT) algorithm can be not robust where the rapid change in atmospheric conditions, especially it happened in irradiance, caused by the heuristic choice for the duty cycle perturbation and the duty cycle initialization. In this paper, it is shown how to integrate optimization method called Particle Swarm optimization (PSO) in P&O to choice the duty cycle perturbation and the first initialization condition based in maximizing power output. Using a DC-DC converter "Boost" associated with the photovoltaic panel; so working to get the maximum power that is mean, earn a good yield. The results of the simulation performed under the tool Simulink/Matlab shows the effectiveness of the integration PSO optimization method in P&O.

Keywords—Photovoltaic systems, Boost, PWM, MPPT, P&O, PSO

I. INTRODUCTION

Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point (MPP) which depends on panel's temperature and on irradiance conditions. The issue of MPPT has been addressed in different ways in the literature [1, 2]. Among the various techniques proposed, the Perturb and Observe (P&O) maximum power point tracking algorithm is the most commonly used method due to its ease of implementation [3].

In energy solar domain, many researchers have worked to develop MPPT algorithms methods. [4] Has presented simulation and hardware to implement an incremental conductance method MPPT applied to buck chopper by Compared the different MPPT methods, also apply PI control for the buck converter completely neglecting using Pulse With Modulation (PWM) direct way. [5] Shown experimental results on the MPPT when using the increment method specified by a variable give good results, which could remedy the defect of the fixed step length of the incremental conductance method. The step length was changed by setting the threshold, and different threshold settings influenced the maximum power point tracking speed. In 2011, the high performance adaptive perturbation and observation method based on power grid photovoltaic MPPT presented in [6], The oscillation at the point of maximum power for the traditional method perturb and observe has improved by adaptive control functioning to change that P & O value according to climate change in the system, in addition to tracing systems output capacity of the sun d an axis and two-axis is higher than conventional support systems.

Two main drawbacks affect P&O based MPPT in presence of slowly-varying irradiance and temperature, the operating point oscillates around the MPP giving rise to the waste of a more or less significant amount of available energy and, in addition, in presence of rapidly changing atmospheric conditions, the P&O algorithm can be confused [l]. In this paper, it is shown that the negative effects associated to the second drawback can be greatly reduced if the values of the duty-cycle perturbations and the initial condition are customized to the optimized method of the specific dc-dc converter adopted to realize the P&O MPPT. As the system is studied compose a PV array, a boost dc-dc converter and a resistor as load.

The particle swarm optimization (PSO) algorithm is inspired by bird group behavior. Because the PSO algorithm is easy to implement and efficient, it has been widely used in multi objective optimization, pattern recognition, signal processing and other fields, and because of its faster computing speed and good global search capability, it is particularly suitable for large scale mathematical optimization problems; in addition, it has adaptive capability, and is good at solving optimization problems in dynamic environments [8].

In Particle Swarm Optimization PSO algorithm, every particle is located in the space of movement by D-dimensional (number of parameters optimized), and flies with a specified speed. Considering that the Swarm has *P* particles, X_i and V_i are the particle of current position, particle of current flight speed, respectively, P_i is particle of best position over in the current swarm, G_i is swarm's best location global. So the particle's flight speed and direction are determined by its position X_i and velocity V_i That follow an optimized fitness function $f(x)$ minimized or maximized depending on the lens detailed in section 6 [8].

The remainder of the paper is organized as follows. The introduction is presented in section 1. Problem overview presented in section2. The photovoltaic equivalent circuit model is given in section 3. In the same section the simulation and validation of the photovoltaic model presented. A typical solar power system and a conventional MPPT P&O technique are reviewed in Section 4. The optimization method PSO presented in Section5. The system configuration of the optimization method PSO and adaptive MPPT method are addressed in Section6. The simulation results are shown in section7. Finally, conclusions are drawn in Section 8.

II. Problem Overview

Considering the way MPPT is find voltage V_{mpp} or current I_{MPP} integrated mission planning for PV system should work to extract the maximum power output P_{MPP} under a certain temperature and irradiance. Majority methods of MPPT respond to changes in climate change parameters irradiance and temperature, others useful specifically if the temperature is almost constant and irradiance varying. The Validation of MPPT of a truly depends variation the both (irradiance and temperature). [9]. in this paper, variation in the irradiance for confuse P&O method by integrates PSO in it.

III. The Photovoltaic Equivalent Circuit Model

The actual use of the equivalent circuit can be made by the experimental photovoltaic array terminal characteristics, as shown in Fig.1:

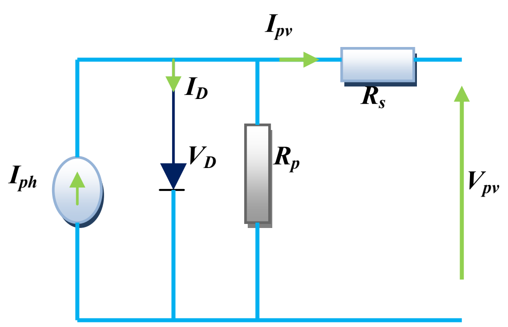

Fig.1. The equivalent circuit model of photovoltaic array

The relation between the output current and voltages photovoltaic array can be defined as formula (1):

$$I_{pv} = I_{ph} - I_D - \frac{V_{pv} + R_s \cdot I_{pv}}{R_p} \quad (1)$$

The current through diode is given by:

$$I_D = I_0\left[exp\left(q\left(V_{pv} + I_{pv} \cdot R_s\right)/K \cdot T\right) - 1\right] \quad (2)$$

Where,

I_{pv} : Solar cell current (A).
I_{ph} : Light generated current (A).
I_O : Diode saturation current (A).
q : Electron charge (1.6×10-19 C).
K : Boltzmann constant (1.38×10-23 J/K).
T : Cell temperature in Kelvin (K).
V_{pv} : Solar cell output voltage (V).
R_S : Solar cell series resistance (Ω).
R_p : Solar cell shunt resistance (Ω).

We also defined in the disconnect condition: $I_{pv} = 0$, $V_{pv} = V_{Oc}$ *"open circuit voltage"*. In the maximum power point: $I_{pv} = I_m$, $V_{pv} = V_m$.

$$I_{pv} = I_{sc}\left[1 - C_1 \cdot exp\left({V_{pv}}/{C_2 V_{oc}} - 1\right)\right] \quad (3)$$

$$C_1 = \left(1 - {I_m}/{I_{sc}}\right) \cdot exp\left({-V_m}/{C_2 V_{oc}}\right) \quad (4)$$

$$C_2 = \left({V_m}/{V_{oc}} - 1\right) \Big/ \ln\left(1 - {I_m}/{I_{sc}}\right) \quad (5)$$

Formulation of short-circuit current of photovoltaic array needs , open circuit voltage, voltage and current of MPP, then computation C_1, C_2 calculate by formula (4), (5) and characteristic photovoltaic array I-V curve which determined by formula (3). So, characteristic of photovoltaic array in different irradiance and temperature can be simulated through the real-time adjustment of V_{Oc}, I_{sc} "short circuit current", V_m , I_m , the simulation performed in Simulink/Matlab tool and the curves I-V, P-V are shown in Fig. 2, Fig. 3 and Fig.4, respectively .

In Fig.2, the model of PV panel as a constant dc source created using the subsystem block from Simulink library browser, which included all functions of PV panel. The model has three inputs irradiance, temperature and voltage input. This model generates current.

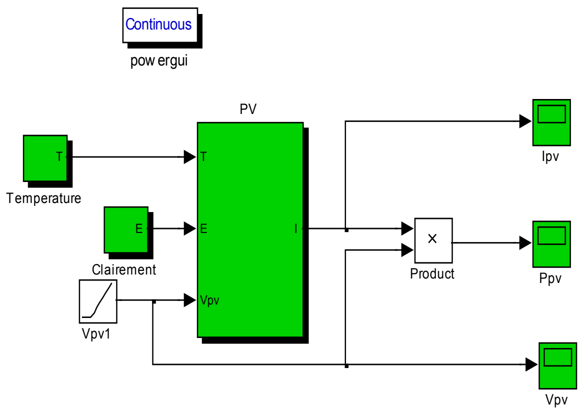

Fig.2. Block diagram of a PV panel

Fig.3 shows Current-Voltage and Power-Voltage characteristics of a PV model for constant irradiance.

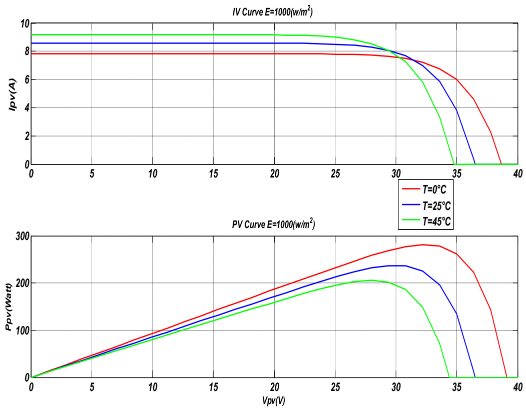

Fig.3. Influence of the temperature with constant irradiance

Fig.4 shows Current-Voltage and Power-Voltage characteristics of a PV model for constant temperature.

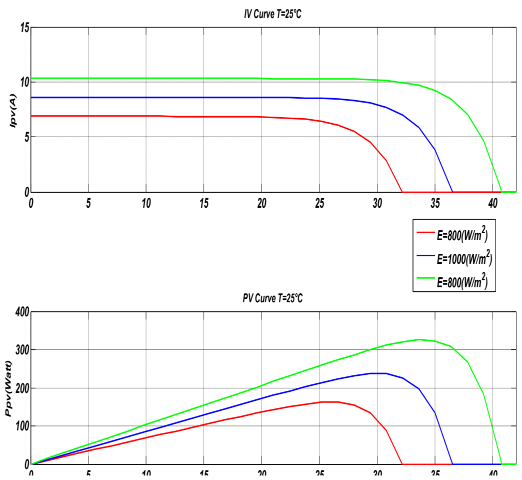

Fig.4. Influence of the solar radiation for constant temperature

From Fig.3, Fig.4 proves that our model closely representative of reality and this is what allows us to apply all control methods for MPPT. Results also allow validation of the model.

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

The DC/DC converter should always operate in the maximum power point tracking to maximize the PV generator efficiency and consequently increase the efficiency of the PV system. The optimum power of PV generator fluctuates instantaneously with the climatic conditions (irradiance, temperature).

Simply, The MPPT algorithm based on the derivation of the power over the voltage equals zero in the maximum bridge. Several methods work this principle and make comparison among them is Perturb and Observe (P&O).

The perturbation and observation (P&O) is a widely used approach in the search for MPPT because it is simple and requires only measures voltage and current of the PV module V_{pv} and I_{pv} respectively, it can detect the point of maximum power even during variations in irradiance and temperature.

The method P&O function with disturbance voltage V_{pv} respectively; it can track the maximum power point even when there are variations in irradiance and temperature.

The following shortened flowchart shows the algorithm of the P&O method. At each cycle, V_{pv} *(k)* and I_{pv} *(k)* are measured to calculate $P_{pv}(k)$. $P_{pv}(k-1)$ value calculated in the previous cycle by V_{pv} *(k-1)* and I_{pv} *(k-1)*, where the duty cycle *D* is desired output to use in Pulse With Modulation "PWM" to control the boost. So the P&O generate the best duty cycle [12].

Fig.5 shows the P&O MPPT Implemented by driver circuit, where PWM calculated and generated the duty cycle *D* sent to the switch *S* through it.

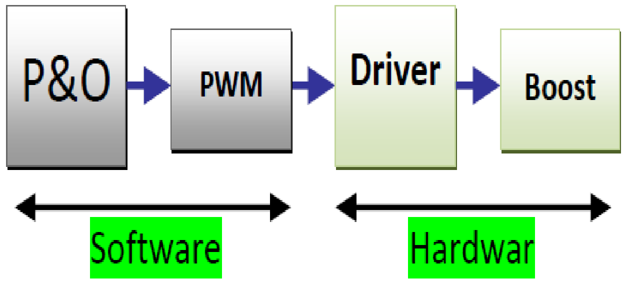

Fig.5. PWM implementation

The program flow chart P&O is shown in Fig.6.

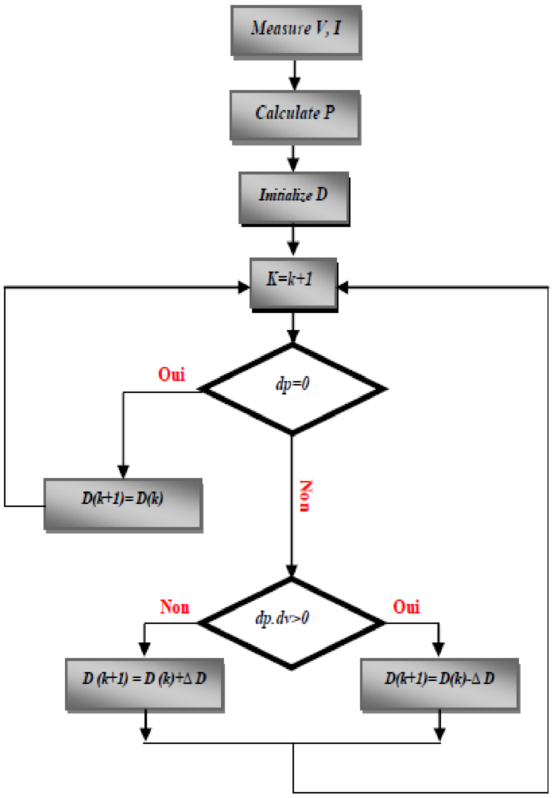

Fig.6. P&O flow chart

The question proposed is how to choose the initialization of duty cycle D, also the duty cycle perturbation ΔD?

Some researchers have demonstrated the choice of duty cycle perturbation ΔD as [3] where depends system parameters. Also [10] select the duty cycle perturbation ΔD by:

$$\Delta D(k) = \propto \cdot\, \beta\big(P(K) - P(K-1)\big) \tag{6}$$

Where α is the constant value to control the movement toward the MPP and the accuracy of convergence for MPPT, β is the sign of step dependent on perturbation direction. So, in this paper the answer to the previous questions is having an optimization method PSO able to find the initialization duty cycle D, also the duty cycle perturbation ΔD from the system presented in the next section.

V. PARTICLE SWARM OPTIMIZATION

PSO determines the optimal solution of particles by several iterations. The optimal solution in each iteration can be identified, and is called P_{best}. When all of the particles have been found, G_{best} can be determined, and the principal factors influencing particles looking for the optimal solution are the velocity updating and position updating of particles. The velocity updating equation is expressed as formula (7), and the position updating is expressed as formula (8). The program flow chart is shown in Fig.7.

$$V_i(t) = W + V_i(t-1) + Rand_1 \cdot R_1 \cdot (P_{best} - X_i) + Rand_2 \cdot R_2 \cdot (G_{best} - X_i) \tag{7}$$

$$X_i(t) = X_i(t-1) + V_i(t) \tag{8}$$

Where Vi is the velocity of each particle, i is the number of particles, W is the Inertia Weight, $Rand_1$ and $Rand_2$ are learning constants, R_1, R_2 are random number between 0 and 1, P_{best} is the optimal solution for each particle up to now, G_{best} is the optimal solution for all particles up to now, and X_i is the position of each particle [8].

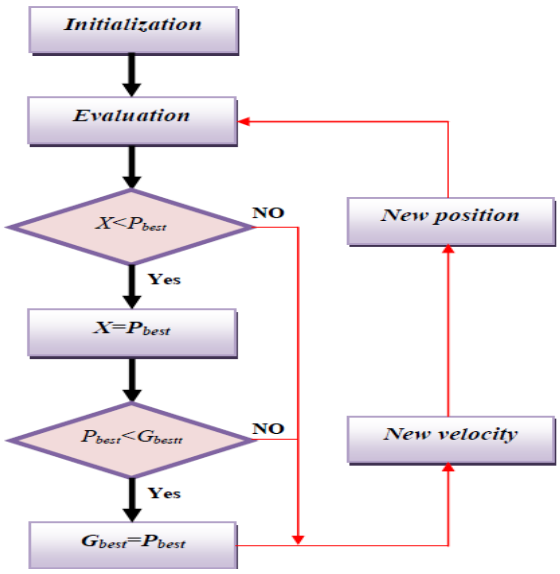

Fig.7. PSO flow chart

VI. PSO AND P&O MPPT

In order to keep the output of the solar panel at its maximum power point, this paper uses the MPPT algorithm of the P&O method, but the duty cycle perturbation of the traditional P&O method and the first duty cycle are fixed. Therefore, the maximum power point can be reached rapidly when the step is large. However, there is oscillation in the steady state, so that the output power decreases. This oscillation is very low when a small the duty cycle perturbation is used in the steady state, and the maximum power point is reached after a longer time. Therefore, this paper uses PSO optimization method for adjust the duty cycle perturbation e and the initialization. Thus, the maximum power point can be reached faster compared with the P&O method for the duty cycle perturbation and the first initialization are fixed heuristic choice.

The pseudo code that describes the integrate PSO in P&O is the following [11]:

***Initialization* (creation of the initial swarm)**

For i=1 to number of swarm "iteration''
    For j=1 to number of particles
    Create the member ship function for the particle j
    Run the simulation of the PV
    Evaluate finesse

End j
Rank the particles on their fitness function
Update new swarm by comparison the position of the particles
End i

The block diagram (Fig.8) shows the strategy optimization of P&O parameters “the duty cycle perturbation, the duty cycle initialization”:

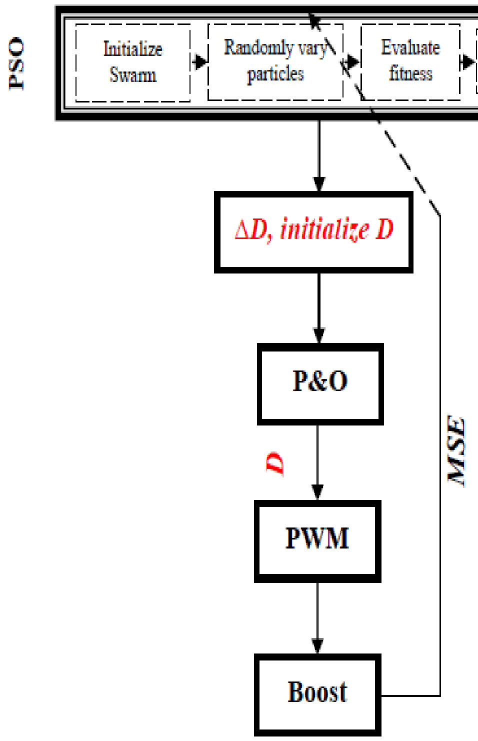

Fig.8. Distributed PSO and P&O MPPT concept

PSO speed to suit for a better solution in the calculation, it is calculated to make a minimizing objective function mean square error (MSE calculated by the following formula:

$$MSE = \frac{1}{nT}\sum_{i=1}^{n} e(k)^2 \qquad (9)$$

Where: n is the total number of samples and T the sampling time, *e(k)* is the difference between the value of the out power and the value of the PV power. The goal is to extract the maximum power.

VII. SIMULATION AND RESULTS

To demonstrate the performance of the proposed controller, MATLAB/Simulink was used for simulation. An example, a boost has been studied where TABLE.I showed the “PSO” parameters:

TABLE.I PSO PARAMETERS

Size of the swarm	$Rand_1$	$Rand_2$	W
20	**0.0001**	**0.0001**	**0.5**

The models shown in Fig.9 were simulated. Simulation and results for boost converters have been recorded to make sure that comparison of the circuit can be obtained accurately. The voltage and the power are the main points of comparison to take into account. The temperature fixed to 25°C and the irradiance is varying illustrated in Fig.10.

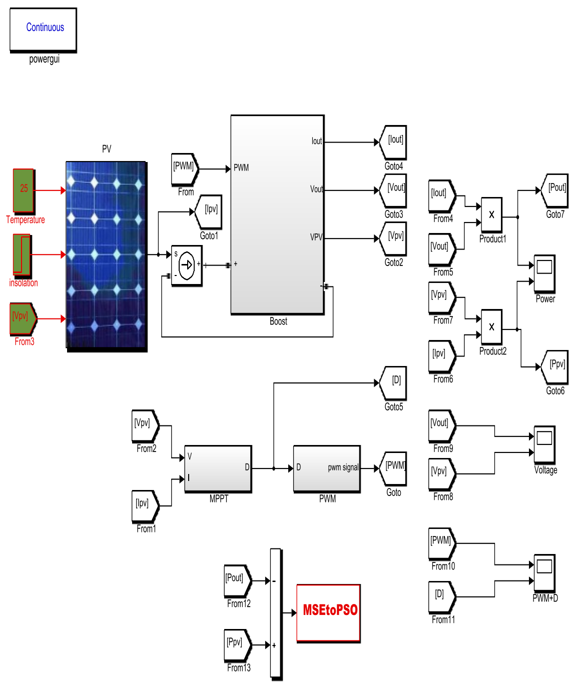

Fig.9. Simulink model of boost converter using PSO P&O MPPT

The simulation result at constant temperature (T=25°C) with changes in the Irradiance (400 to 600w/m²):

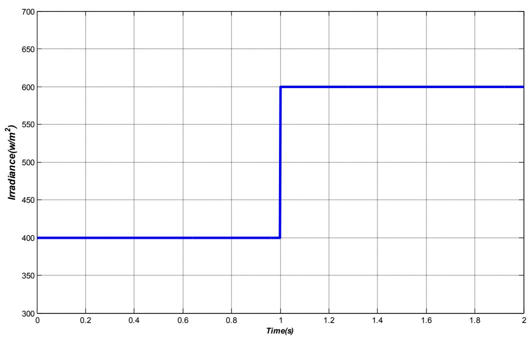

Fig.10. Changing irradiance curve

Fig.11 illustrates the out voltage compared with PV voltage panel.

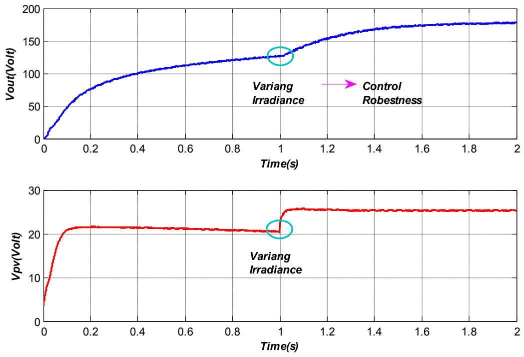

Fig.11. PV voltage and out voltage

Fig.12 illustrates the power out compared with power PV panel.

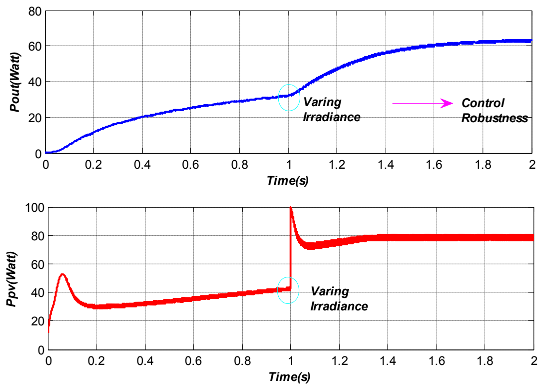

Fig.12. PV power and out power

It can be seen from results that the output of the PV panels clearly changes due to the change of the used converter as that variation of the converter affect of the output of the PV panel.

Output values of the solar panel do not provide same input voltage value to controller. This is because the Switch controller that varies the value of duty cycle will change the input value that sense by the controller PSO and P&O MPPT.

This system show that PSO and P&O MPPT controller will work best with boost.

VIII. Conclusion

In this paper PSO method working to find the optimal choice of the duty-cycle perturbation and the firs initialization for duty cycle to be adopted when using the P&O MPPT algorithm has been carried out.

PSO and P&O MPPT method is implemented with MATLAB-SIMULINK for simulation. The MPPT method simulated in this paper is able to improve the dynamic and steady state performance of the PV system simultaneously. As an example, a boost been studied.

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