Particle Swarm Optimization for Maximum Power Point Tracking Under Varying Atmospheric Conditions

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Abstract. Based on research into Photovoltaic (PV) systems under diverse conditions, and a new maximum power-point tracking approach was developed. Due to the presence of variable circumstances, PV curves have several peaks, decreasing the efficiency of the conventional techniques. As a result, the suggested algorithm, based on the technique of particulate swarm (PSO) optimization, enhances the output power of photovoltaic (PV) systems under such abnormal conditions and outperforms existing methods. The suggested method is evaluated using MATLAB under numerous scenarios involving non-uniform irradiation and varying temperature levels, and to investigate its performance sufficiently, the outputs of the method suggested are compared for the P&O technique This study aims to explain the design and simulation of a particle swarm optimization (PSO) technique with a boost converter for determining the maximum permissible power of solar photovoltaic panels under changing climatic conditions. The simulations showed that the tracker ability of the PSO algorithm is highly effective, much quicker, and has a shorter settling time and overshoot than conventional techniques.

Keywords: Photovoltaic (PV) Systems, DC-DC Converters, Maximum Power Point Tracking (MPPT), Particle Swarm Optimization (PSO).

1 Introduction

Photovoltaics (PV) has become increasingly popular because of its many advantages, including lower operating costs and less pollution. The amount of electricity generated by a photovoltaic module is mostly determined by the circumstances of the surrounding environment, such as temperature and radiation. This is a big drawback because the efficiency of each solar cell is just approximately 20%, which is a significant reduction inefficiency. As a result, determining the peak point of a photovoltaic system is crucial to maximize efficiency and extract the greatest value from solar energy. To provide the maximum load power, the photovoltaic system has only one operating peak that can be reached. The Maximum Power Point (MPP) is the highest point reached during the test. [1]. Maximum power point tracking techniques are categorized into three broad groups. The first group is referred to as the traditional group, which includes the Perturb and Observe (P&O) and Incremental Conductance methods (INC). Because of its unsteady operating point, the P&O-based maximum power point tracking algorithm is successful, but it is unsuited for PV array form [2]. Because of the disruption in the system, this algorithm modifies the power of the module [3], which is necessary for it to work. As a result of this disorder, the power will be amplified, and the disturbance will

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continue in this manner. In any other case, the disturbance is reversible. This is the process by which MPP is obtained. The power continues to oscillate near the MPP and is unable to obtain the proper MPP. To accommodate quick variations in irradiance, this method must be modified. Among the several techniques, the perturb observe algorithm is the most straightforward and cost-effective [4]. Incremental Conductance (INC) is a more advanced version of the (P&O) method to address all of the algorithm's shortcomings. To produce the best output possible, the previous output is continuously compared to the current output. Although the incremental conductance (INC) technique is highly efficient, it is rarely employed due to its complexity in comparison to the Perturb and Observe (P&O) technique [5]. The disadvantages of this category are laziness in monitoring, stable fluctuation at (MPP), and low efficiency. Soft computing solutions are being developed to solve these drawbacks. The second group of techniques includes Evolution Algorithmic (EA), Fuzzy Logic Controllers (FLC), and Artificial Neural Networks (ANN). Additionally, these groups have significant weaknesses because of various complexity, such as the requirement for periodic practice and the utilization of additional memory, in bio-inspired behaviours, it is challenging to apply these features. Implementing a bio-inspired style is difficult. [6]. The third group is the algorithms that are involved under the type of Evolutionary computing, Ant colony optimization (ACO) Particle swarm optimization (PSO), Genetic Algorithm (GA), and Ant colony optimization (ACO) [7]. This paper presents the method for tracking the Maximum PowerPoint for photovoltaic modelling using Particle Swarm Optimization (PSO) at varying temperatures and irradiation. This technique is a swarm intelligence-based algorithm that is used to obtain the global optimal power allowable for a load. The performance of this method is tested by simulation using MATLAB/Simulink and can be divided into three main parts. first, the source of the PV array (DSP210D panel) is mainly dependent on atmospheric conditions like irradiation and temperature. Secondly, the DC-DC step-up boost converter gives higher efficiency and low cost. lastly, the PSO algorithm is used to achieve MPPT from the PV array. The simulation result shows improvement in efficiency compared with the conventional method, also achieved the maximum permissible power produced by solar cells.

This paper explains the process for using Particle Swarm Optimization (PSO) to track the Maximum Power Point (MPP) for photovoltaic modelling at varying temperatures and irradiation to achieve the maximum permissible power for a solar photovoltaic panel and therefore increasing the efficiency of photovoltaic systems (PV).

The following is how the paper is structured: Section 2 introduces the output characteristics of PV arrays, as well as the mathematical model of the PV module and the tracking of the Maximum PowerPoint. Section 3 contains an overview and implementation of the PSO algorithm. Section 4 discusses the outcomes of the simulations as well as their practical application. Section 5 presents the work's conclusion, which is the final section.

2 Photovoltaic Modelling

2.1 The Equivalent Circuit of PV Cell Model

In this paper, the equivalent circuit for a single diode model of PV cell consists of a photocurrent I_{ph}, diode, parallel resistance R_{sh} denoting the leakage current, and a series resistor R_s representing the internal resistance to current in the circuit [8]. As shown in Fig 1.

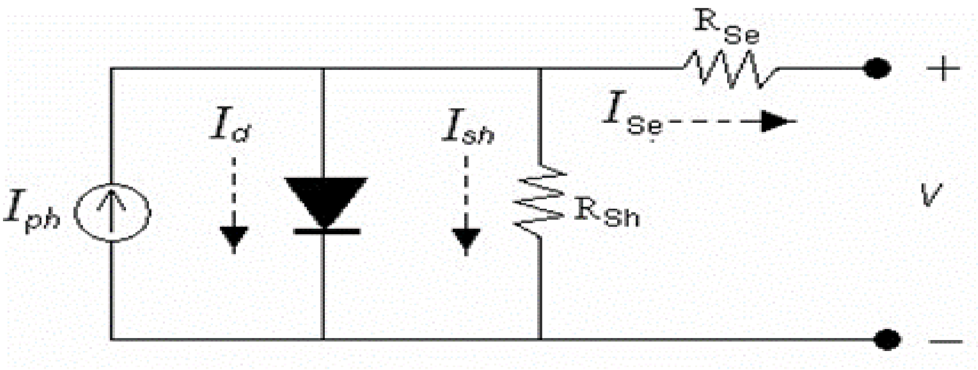


Fig. 1. single diode model of PV cell.

It has relatively good approximate accuracy and maybe the most suitable model for diagnosing the photovoltaic arrays because it provides a good compromise between the approximate accuracy and simplicity [9,10].

2.1 Mathematical Model

A mathematical model describes the terminal voltage and current properties of the solar cell. It is deduced from the physical principles of the PN junction, which generally represents the distinctive behaviour of a photovoltaic cell, that the exponential equation of the single model for a photovoltaic cell may be obtained. The photovoltaic cell that was investigated may be theoretically modelled using the equations that follow. [11]:

$$I = I_{ph} - I_{se} * \left[exp\left\{q\,\frac{(v+R_S I)}{AkT}\right\} - 1\right] \quad (1)$$

$$I = N_p I_{ph} - N_p I_s * \left[exp\left\{q\,\frac{(v+R_S I)}{N_s AkT}\right\} - 1\right] \quad (2)$$

$$I_{ph} = I_{ph}(T_{ref})[1 + a(T - T_{ref})] \quad (3)$$

$$I_{ph}(T_{ref}) = I_{sc}(T_{ref}) * \frac{E}{E_0} \quad (4)$$

$$a = \frac{I_{sc}(T_2) - I_s(T_1)}{I_s(T_1)} * \frac{1}{T_2 - T_1} \quad (5)$$

$$I_d = I_s * \left[exp\left\{q\,\frac{(v+R_S I)}{AkT}\right\} - 1\right] \quad (6)$$

$$I_s = I_{so} * \left(\frac{T}{T_{ref}}\right)^{\frac{3}{A}} * exp\left[\left(-\frac{Eg}{Ak}\right) * \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right] \quad (7)$$

$$I_{so} = \frac{I_{sc}(T_{ref})}{\left(exp\left(q\frac{voc(T_{ref})}{AkT_{ref}}\right) - 1\right)} \quad (8)$$

Where:

V The voltage produced by a PV cell. (Volt).

I The current flowing from a PV cell's output. (Ampere).

Ns The number of series-connected modules.

N_p The number of parallel-connected modules.

I_{ph} In a photovoltaic cell, light produces current. (Ampere).

I_s Saturation current of photovoltaic cells(Ampere).

R_s A photovoltaic cell's series resistance(Ohm).

A Ideality factor (Unit less).

K Boltzmann constant (Joule per kelvin).

T Cell temperature (Kelvin).

q Electron charge (coulomb).

T_{ref} Reference temperature (Kelvin).

I_{sc} Short-circuit current of a photovoltaic cell under normal conditions circuit at 25°C and 1000 (Watt per square meter).

a Short-circuit current temperature coefficient at I_{sc}(Ampere).

R_{sh} A photovoltaic cell's shunt resistance(Ohm).

E Illumination of photovoltaic cells (Watt per square meter).

I_{s0} Saturation current at T_{ref} (Ampere).

E_g The bandgap for silicon (Electron volt).

2.2 Maximum Power Point Tracking

When solar panels work at the voltage which the global maximum for the photovoltaic characteristic curve is found, the maximum power (MP) is obtained so that the maximum output power of the solar module can be obtained, especially for an operating point. A photovoltaic function is known as Maximum PowerPoint (MPP). This point is often at the knee of the solar panels. To summarize, the I-V curve of a solar module has a point called the Maximum Power Point (MPP) that always occurs at the knee of this curve and is where photovoltaic power generation is maximum**.** Fig 2 shows the MPP located on the knee of the I-V curve and defined by a black dot. The MPP position is changed continuously when the temperature and irradiation values are changed. The temperature and irradiation have a dynamic nature, so the MPP tracking algorithm can work primarily in real-time by continually updating the duty cycle and thus keeping tracking accuracy and speed [12]. The Simulink model is composed of two major components, the tracking algorithm used to track the MPP, and the DC-DC boost converter to convert the producing voltage for the required load level [13]

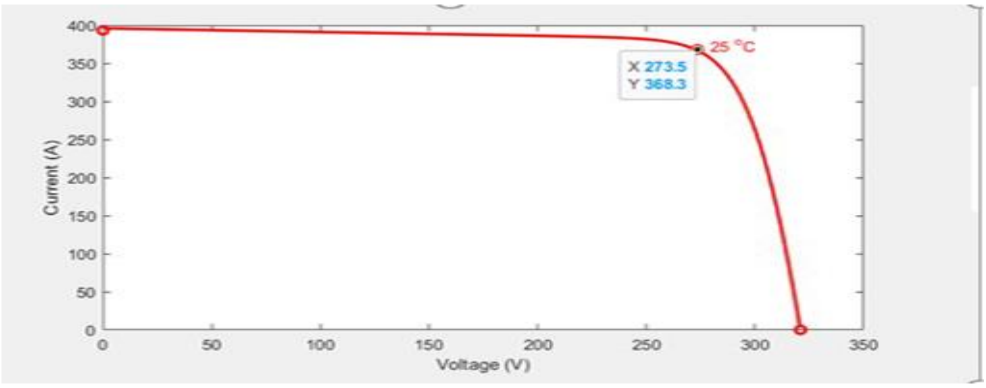


Fig 2. I-V characteristic curve.

3 PSO Algorithm

3.1 Overview of the PSO Algorithm

A simple and effective meta-heuristic method, which applies to a multivariable optimization function with numerous local optimal points, is known as the particle swarm optimization method. It is inspired by fish schooling, bird flocking, and others. PSO operates on the pair of main teachings; one is to get from the past data and the other to carry current information among the swarm agents [14].

PSO algorithm contains many particles. Each particle will replace the data obtained during the research process and provided the solution to find the best choice. According to the simple mathematical relationships, these particles move in the search field and the velocity and position of the particles are updated according to Eqs. (1) and (2) [15].

In this study, the particles of the PSO algorithm are taken to search for the optimal duty cycle space and the fitness function is the output power of the PV system. By the following equations, this particle positions di is updated [16].

$$d_i^{k+1} \quad = d_i^k + v_i^{k+1} \tag{1}$$

Where:

v_i is the step size at the iteration $k+1$

d_i^k is the position of the particle

$$v_i^{k+1} = w v_i^k + c_1 r_1 \left(P_{best} - d_i^k\right) + c_2 \, r_2 (G_{best} - d_i^k) \tag{2}$$

Where:

r_1 and r_2 are random values from [0,1]; w is the inertial weight; c_1 and c_2 are the acceleration coefficient; G_{best} is the best position in the whole population; P_{best} is the best position of particle i .

3.2 Implementation for PSO Algorithm

The first step is to determine the number of particles to be used and the search parameters to be used, as well as the velocity and position limits. Initialize the velocity and position of each particle using a random number generator in Step two. The fitness value of each particle is calculated in Step three. Step four. The G_{best} particle is the particle with the highest fitness score (Global Best). Update the velocity and position of each particle concerning the G_{best} .
Repeat Steps three and four as many times as necessary until the ideal solution has been found. The optimal value is obtained by performing Step seven G_{best} at the end of the final iteration. Step eight, calculate the Duty-cycle using the given equation $D = \frac{1}{1+\sqrt{\frac{R_{in}}{R_{out}}}}$.

4 Simulation Result

In the MATLAB program, the Simulink model as shown in Fig 3 consists of a PV array (DSP210D) panel, a step-up DC-DC boost converter, and PSO MPP tracker that simulated to study and verify the performance and accuracy of this method. The used solar panel contains 6 parallel strings and 2 series cells per string. The cell temperature is assumed to be constant at 25°C and 1000 W/m^2 irradiation.

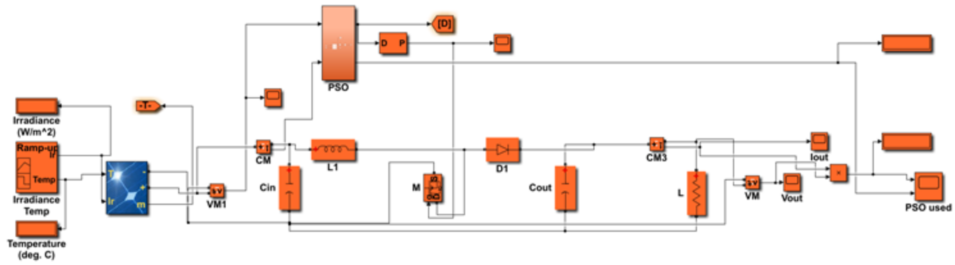
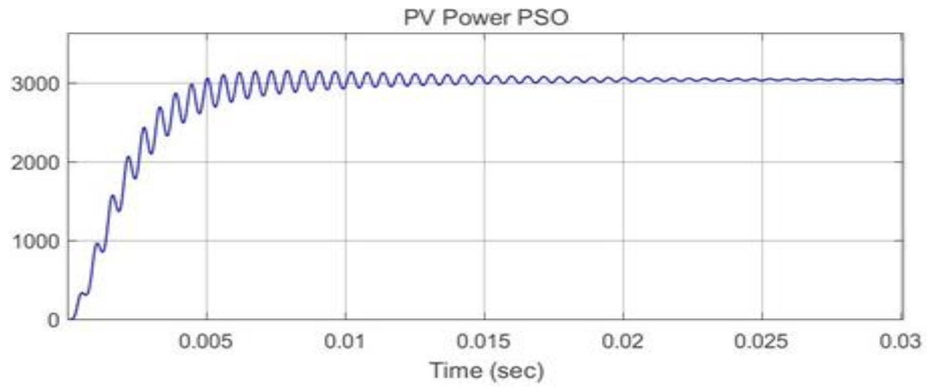
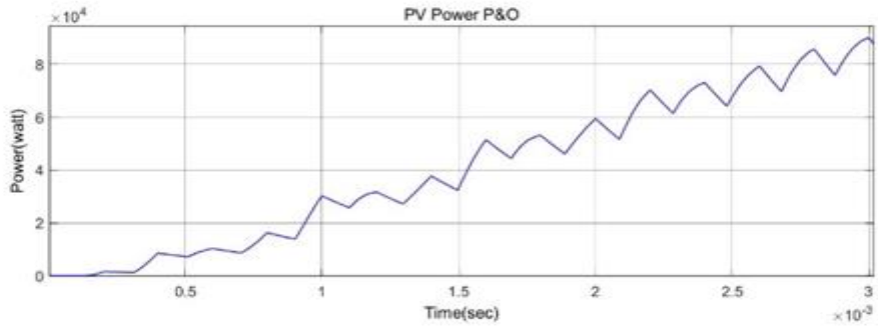


Fig.3. The Simulink model for system configuration.

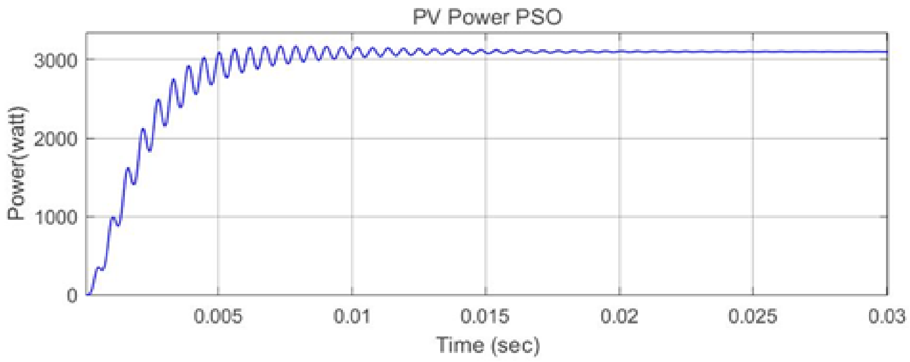
Fig 4 depicts the results of a simulation of a PV system using the PSO and P&O algorithms, respectively. This figure illustrates the results gained by employing PSO with P&O MPPT techniques, where the maximum output power is obtained for varied temperature and irradiation conditions. It has also been observed that the PSO method is more efficient and increases its effectiveness. Thus, the cost is lower. Additionally, this algorithm has a shorter settling time, which results in less oscillation and overshoot. These properties result in high steady-state output power with high accuracy and stability when compared to conventional algorithms. As a result, we can track the real MPP under a variety of conditions.



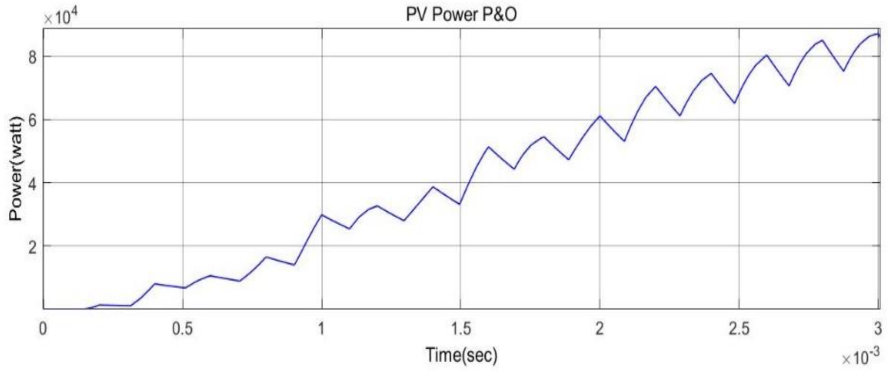
(a) The PSO model's output power curve at constant isolation $\mathbf{1000}\ \boldsymbol{w/m^2}$and temperature $\mathbf{25^0}$



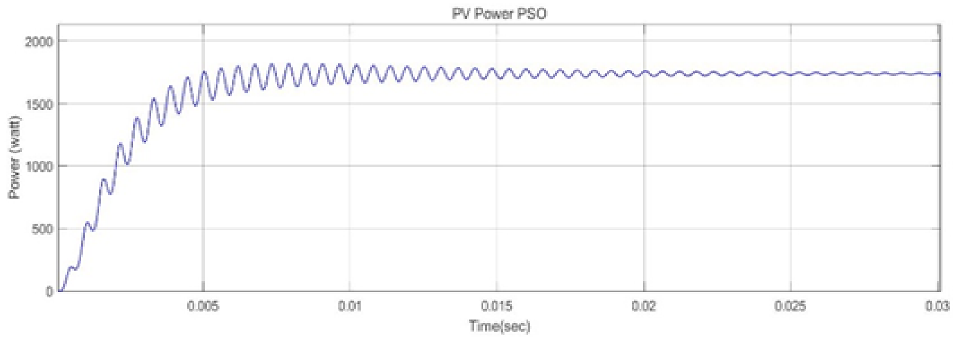
(b) The P&O model's output power curve at constant isolation $\mathbf{1000}\ \boldsymbol{w/m^2}$and temperature $\mathbf{25^0}$



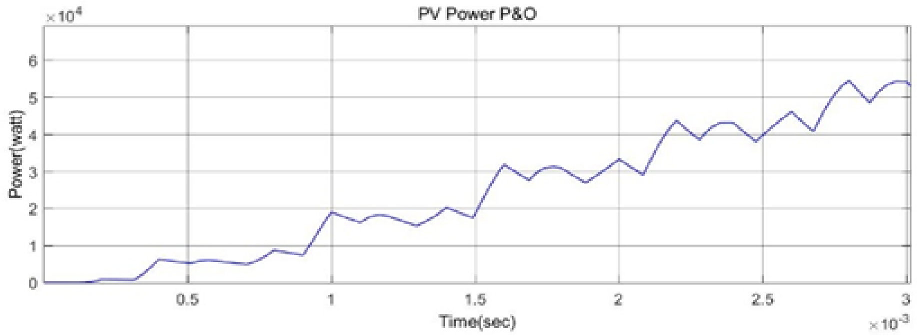
(c) The PSO model's output power curve at constant isolation 1000 $\boldsymbol{w/m^2}$and temperature $\mathbf{45\ C^0}$



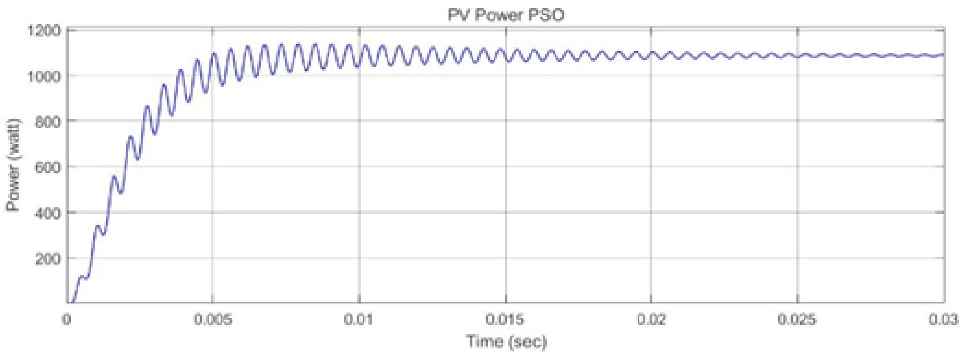
(d) The P&O model's output power curve at constant isolation $\mathbf{1000}\ \boldsymbol{w/m^2}$ and temperature $\mathbf{45^0}\boldsymbol{C}$



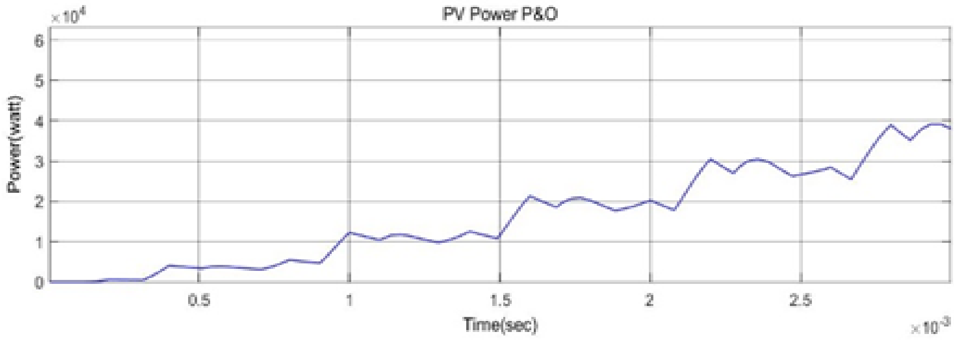
(e) PSO model output power curve at various isolation at to $\mathbf{750}\ \boldsymbol{w/m^2}$ and temperature $\mathbf{25^0}\boldsymbol{C}$



(f) P&O model output power curve at various isolation at $\mathbf{750}\ \boldsymbol{w/m^2}$ and temperature $\mathbf{25^0}\boldsymbol{C}$



(g) Step isolation output power curve for the PSO model **(600-1000)** w/m^2 and temperature 25^0C



(h) Step isolation output power curve for the P&O model **(600-1000)** w/m^2 and temperature 25^0C

Fig.4. The output power of PSO and P&O algorithm

5 Conclusion

The purpose of this research is to simulate and execute Maximum Power Point tracking using a particle swarm optimization algorithm to obtain the maximum permissible power for photovoltaic panels. So, the PSO is used under varying atmospheric conditions to achieve the best results in various circumstances. The simulation results showed the PSO algorithm gives more efficiency than conventional algorithms. In addition, the output response of this technique is faster, with less overshoot and low oscillation than classical techniques. In the future, we want to connect Multi-Level Inverter with DC-DC boost converter with PSO technique to achieving pure AC output waveform with less overshoot and Total Harmonic Distortion Thus, we increased the efficiency by using the photovoltaic source.

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