Maximum power point tracking based on particle swarm optimization for photovoltaic system on greenhouse application

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Abstract. The Greenhouse is currently a necessity for urban landless people. To save energy, it is necessary to install photovoltaics on the roof of a mini greenhouse to supply electricity. The use of PV is very dependent on climate, temperature, and irradiation, therefore MPPT (Maximum Power Point Tracking) is needed to obtain optimal power. In this paper MPPT for stand-alone PV system based on PSO using input voltage and current of the boost converter is presented. The performance of PSO is validated by Simulink with irradiance and temperature variations. The use of PSO can achieve maximum power for various irradiance. MPPT based PSO was compared by a PV system without MPPT. Based on simulation results PSO provides the power improvement by 29.98 W. Simulation results show that the system designed can optimize power produced by PV.

1. Introduction
Nowadays renewable energy sources such as wind, geothermal, biofuel and solar are the subject of research that continues to be improved throughout the world. This problem has become an important topic especially because of the energy crisis that is developing in the community therefore making it necessary to develop alternative energy as a substitute for fossil fuels [1]. The position of Indonesia which is geographically located on the equator makes Indonesia as one of the countries with abundant solar energy sources with the intensity of solar radiation averaging around 4.8 kWh / m2 per day [2]. Solar energy ranked first in the growth rate of renewable energy in terms of electricity generation with a percentage of around 33%. Followed by wind energy (20%), biofuel (6.1%) and geothermal (4.3%) [3]. This fact shows that the Solar Power Plant has the fastest growth and the greatest potential to continue to be developed.

Several studies have been conducted related to MPPT controls, the MPPT method has been developed, ranging from the simplest to the most complex [4]. For example: constant voltage control, Perturb & Observe, Incremental Conductance, Fuzzy Logic and Neural Network [5-8]. The Perturb & Observe method is widely used because its implementation is simple, one of the disadvantages of this method is that the interference increases with power, the interference becomes greater and the power will decrease after PV power reaches its peak [9]. Another alternative to the MPPT method is Fuzzy Control and Neural Network [7-8]. But the Fuzzy Control method and Neural Network have a complex design and depend on the learning process. Computational-based algorithms were developed to obtain optimal solutions in the MPPT method globally [10-12]. Particle Swarm Optimization (PSO) is very
potential because of its simple structure, easy implementation, and fast computing capabilities. Because PSO is based on search optimization, in principle, it must be able to find MPP for all types of PV Curves, some researchers have used this technique to improve MPP tracking [10-12]. A DC to DC converter is needed to implement MPPT.

This study discusses the implementation of PSO with a Boost Converter type DC-DC converter which aims to maintain PV to always work at maximum power points. Boost Converter produces a larger voltage output depending on the Duty cycle. This system is simulated in Simulink by varying several temperature changes and irradiation during the simulation period. PSO works to maintain the system to be at the maximum power point and its performance compared to PV systems without using MPPT.

2. Photovoltaic system
The photovoltaic system is a device for converting solar energy into DC electricity. PV is characterized by a short circuit (Isc), open connection voltage (Voc), maximum voltage (Vmax) and MPP current. From these parameters I-V and P-V curves will be formed. PV output voltage also depends on load [4,5,7,8]. PV can generally be modeled with one diode or two diodes. The two diode model is more accurate but requires more variables so the model is more complex [5,10].

2.1. Photovoltaic model
The equivalent circuit of PV cells is shown in figure 1.

![Figure 1. PV equivalent circuit [11].](image)

PV modules show nonlinear characteristics as shown in Figure 2. PV curves vary depending on solar irradiation and temperature. Equations (1) and (2) are used to describe the characteristics of a PV array [11,13].

\[
I_{PV} = I_L - I_d - I_o \left( e^{\frac{q(V_{PV} - I_{PV} R_S)}{AKT}} - 1 \right) - \frac{V_{PV} + I_{PV} R_S}{R_{sh}} 
\]

(1)

\[
P_{PV} = V_{PV} \cdot I_{PV}
\]

(2)

Where: \( I_{PV} \) is the current of the PV module (A), \( I_L \) is the current of the generated light (A), \( I_o \) is the diode saturation current, \( q \) is the electron charge (coulomb), \( K \) is the Boltzmann constant (\( j/K \)), \( A \) is the diode factor, \( T \) is the module temperature (k), \( R_S \) is the module resistance (ohm), \( R_{sh} \) is the parallel resistance module (ohm), \( V_{PV} \) is the output voltage (V) module, and \( P_{PV} \) is the PV extracted power (W). To extract the maximum possible power from a PV system, PV modules must operate at the optimum power point. Thus, the momentary maximum power point of the PV module is tracked with the help of a power electronics converter driven by the appropriate MPPT algorithm [5,11,13].
2.2. Boost converter

The design of DC-DC Boost Converter functions to stabilize the voltage by increasing the voltage where the output voltage is higher than the input voltage without having to eliminate the relatively large power so that it can overcome the lack of voltage. The DC-DC converter only changes the voltage level and current level of the DC output, without changing the power during the process of converting the electrical energy. Figure 3 shows schematically the principle of changing the voltage by DC-DC converter [14].

The average output voltage is expressed by the following equation (3):

\[ \frac{V_o}{V_d} = \frac{1}{1-D} \]  

(3)

3. MPPT based on PSO

The PSO algorithm was introduced by R. Eberhard and J. Kennedy in 1995. PSO is an optimization method of artificial intelligence that adopts the social behavior of flocks of birds or fishes. The social behavior of the organism both as an individual and as a herd (swarm) is used as the basis for designing the PSO algorithm. Simple algorithm structures and fast convergence rates, which are only controlled by a number of parameters, make this population-based optimization algorithm widely used by researchers from academia and industries. The following are the equations used in the PSO optimization algorithm [15]:

\[ v_i^{k+1} = \omega v_i^k + c_1 \text{rand}_1 \times (pbest - s_i^k) + c_2 \text{rand}_2 \times (gbest - s_i^k) \]  

(4)

Each iteration of the inertia weight value is updated through equation (5).

\[ \omega = \omega_{\text{max}} - \frac{\omega_{\text{max}} - \omega_{\text{min}}}{\text{Iter}_{\text{max}}} \times \text{Iter} \]  

(5)

Each iteration of the particle position is updated through equation (6):

\[ s_i^{k+1} = s_i^k + v_i^{k+1} \]  

(6)

Where: \( v_i^{k+1} \) is the particle velocity at iteration \( k \), \( \omega \) is the inertia weight factor, \( c_1 \) and \( c_2 \) are called acceleration constants, \( \text{rand}_1 \) and \( \text{rand}_2 \) are random numbers and \( s_i^k \) is the particle position in the search space at iteration \( k \), \( pbest \) is called local best and \( gbest \) is called global best.
For the MPPT system based on the PSO algorithm designed, the particle position is determined as the duty cycle that will be given to the DC-DC converter boost and particle speed is set as a change in duty cycle, while the evaluation function of the fitness value or objective function is chosen as the maximum power generated in PV. The procedure of the PSO algorithm designed is presented in the flow diagram as shown in Figure 4.

![PSO flowchart](image)

**Figure 4.** PSO flowchart.

4. Results and discussion

The overall system block diagram is shown in Figure 5, which consists of a Photovoltaic circuit, boost converter, MPPT block using the PSO algorithm, I and V sensors, and PWM drivers.

![Block diagram of PV system with MPPT algorithm](image)

**Figure 5.** Block diagram of PV system with MPPT algorithm.

Simulation parameters related to the system are summarized in Table 1.

| Model                      | MY100M-12 |
|----------------------------|-----------|
| Maximum Power (Pmax)       | 100 W     |
| Voltage at Pmax (Vmp)      | 17.6 W    |
| Current at Pmax (Imp)      | 5.70 A    |
| Open-Circuit Voltage (Voc) | 22.0 V    |
| Short Circuit Current (Isc)| 6.06 A    |
| Max System Voltage         | 700 V     |
| Temperature Range          | -45 °C - +80 °C |
The MPPT algorithm was designed and simulated using Matlab Simulink. Mosfet used has a switching frequency of 20 KHz and the Duty Cycle value was adjusted to the results of the calculation of the MPPT algorithm. The output voltage of the boost converter depends on the Duty Cycle value which can be expressed in equation (3). Figure 6 shows the PV model with MPPT using the PSO algorithm. The simulation was done by giving irradiation changes at a constant temperature of 25° C. The first simulation irradiation was 400 W/m then increased gradually to 1,000 W/m.

![Figure 6. PV system with PSO algorithm MPPT](image)

The simulation results show a comparison between PV voltage and current in Figures 7 and 8:

![Figure 7. Voltage output of PV.](image)  ![Figure 8. Current output of PV.](image)

The output voltage and Power of the PV system model with MPPT using the PSO algorithm as shown in Figures 9 and 10:

![Figure 9. Voltage output of MPPT.](image)  ![Figure 10. Power output of MPPT.](image)

Tracking duty cycle and comparison between MPPT power and non MPPT power are presented in Figures 11 and 12:
Based on the simulation results, it was observed that the MPPT method using the PSO algorithm proved to be able to detect irradiation changes and maintain PV performance at the MPP point by adjusting the Duty Cycle. The task function of the PSO algorithm is to determine the Duty Cycle value along with changes in sunlight irradiation so that the output voltage in Boost Converter remains at MPP point. The best parameters obtained from the test results was the weight of inertia $0.3$, $c_1 = 1.2$; $c_2 = 2$; and the maximum iteration is $300$.

5. Conclusion
Simulation results of PV systems with MPPT based PSO algorithm when given an irradiation value of $800 \text{ W/m}^2$, output system power without MPPT is $33.14 \text{ W}$, while using MPPT with PSO algorithm increased to $80.91 \text{ W}$. This MPPT system managed to increase the average output power of $29.98 \text{ W}$. This shows that PV systems with MPPT have better performance compared to ones without MPPT.

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