Fuzzy Maximum Power Point Tracking (MPPT) controller for photovoltaic system on mini greenhouse

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Abstract. Greenhouse is currently used is urban farming. Smart greenhouse technology allows farmers to monitor their plants easily. This system requires much electrical energy supply. In order to save energy, additional electricity supply is needed. For this reason, photovoltaic is installed on the roof of the greenhouse. The obstacle in the installation of photovoltaic cells is that the power produced is not optimal, due to the movement of the sun's position. For this reason, Maximum Power Point Tracking (MPPT) technology is used. In this paper, fuzzy logic was used for MPPT based on I and V from PV. The aim is to find the maximum operating point of a photovoltaic module so that it can increase the output power ratio of photovoltaic modules in varying temperatures and radiation levels. Simulation is done using MATLAB, so that a ratio of output power ratios is generated with and without using an MPPT. By using the fuzzy MPPT controller, it produces optimum power, at P PV max= 250 W, P out max= 160 W, P PV max = 174.8 W, P out max = 125 W, P PV max = 98.97 W, P out max = 75 W. This power will be used to supply electricity for 2 15 W lamps, 12 volts for the mini greenhouse.

1. Introduction

Indonesia is an agricultural country. Nevertheless, with the increasing density of the population, it has an impact on reducing land for food production. In urban areas, greenhouse farming is the solution. Greenhouse farming system allows farming with limited land. By using smart greenhouse technology, using artificial intelligence and automation, the climate in a greenhouse can be regulated, according to the needs of plant growth. By using this automation system, it further reduces electricity consumption [1,2].

In recent years, Indonesia has experienced an electricity crisis. Electricity needs are increasing, along with the increasing population. Various types of alternative energy have been developed to overcome this electrical energy need. One that was developed was to use solar panels, capturing solar energy to produce electrical energy. In this article, the use of solar panels to supply electrical energy to greenhouses is discussed, so that it does not depend on electricity supply from the National Electric Company (PLN) [3].

The main problem with using solar panels to supply energy is the changing position of the sun. The position of the sun greatly determines the amount of solar energy that can be absorbed. To overcome this problem, Maximum Power Point Tracker (MPPT) technology is used. This MPPT control is used to increase the efficiency of the solar panels used [4-7].
Several methods are used to improve the performance of this MPPT. One of them is using fuzzy logic control. The use of MPPT-based fuzzy logic control (FLC) is to improve the efficiency of stand-alone solar energy systems. By using a fuzzy controller, we can search for the maximum power point (MPP). The proposed system performance is simulated using Simulink in Matlab with varying irradiance and temperatures of solar cells [8-12].

The converter used is cuk converter. The use of this converter produces the optimum duty cycle, resulting in optimum power, based on simulation results [13-16]. During modeling, the performance of fuzzy MPPT systems will be compared to the performance of conventional systems using the Perturb and Observe (P & O) methods.

2. Photovoltaic modelling
PV systems can be classified into two groups, namely stand-alone systems and grid-connected systems. In stand-alone systems the solar energy produced is adjusted to the energy demanded. Because the solar energy produced cannot meet energy needs at one time, an additional storage system (battery) is used. If the PV system is connected to other resources (diesel or wind generators) then this is called a hybrid PV system [17].

MPPT is a method for obtaining maximum power from an energy source (solar, wind and other energy) in various environmental conditions and load conditions. The maximum power point in various lighting conditions is shown in figure 1. The highest lighting level is shown in the uppermost curve, while the lower lighting level is shown in the bottom curve. The maximum power point of various lighting conditions is connected to an almost vertical line.

\[\text{Figure 1. Maximum power points at various lighting levels.}\]

The techniques used in MPPT include protrude and observe, incremental conductance, fractional open-circuit voltage, fuzzy logic control, artificial neural networks, ripple correlation control, current sweeps, and so on [18].

One method that is often used, among others, is the method of perturb and observe/hill climbing. The output cell of the PV cell is perturbed with a small value. If the increase in current causes an increase in power, then the current will continue to increase. If the increase in current causes a decrease in power, the current is then lowered. This small variation is made periodically by the controller. Thus the power point is expected to shift towards the maximum power point.

The greater the value of perturbation the faster the maximum power point is reached. But this can cause oscillations around the maximum power point. If the perturbation value is too small, the system’s response will be slow. This problem can be resolved by minimizing the value of perturbation if the system approaches the maximum work point [19,20].

Later it will be compared, the MPPT output uses the P & O method and by using fuzzy control method. The output is compared using different levels of irradiance.
3. System design
In the initial stage, the characteristics of PV are used. For this simulation, use the 1SolTech 1-STH-250 (250W) PV type Solar Panel. This type of PV has a 250 W power rating, Imp 8.15 A, Vmp 30.7 V, Isc 8.66 A. The character of this PV is tested using different levels of irradiance [21], namely: 1 kW / m², 0.7 kW / m², and 0.4 kW / m². Figure 2 is the result of testing the character of PV as follows:

![Figure 2. Test results characteristic of 3 types of lighting level values.](image)

The voltage, current and power produced are as follows at table 1.

| No | E_e (KW/m²) | V (Volt) | I (Ampere) | P (Watt) |
|----|-------------|----------|------------|----------|
| 1  | 1           | 30.71    | 8.15       | 250      |
| 2  | 0.7         | 30.65    | 5.7        | 174.8    |
| 3  | 0.4         | 30.41    | 3.25       | 98.97    |

3.1. Simulation of a photovoltaic system using the Perturb and Observe (P & O) method
Figure 3 shows The next step is to simulate this photovoltaic system using the MPPT method using the Perturb and Observe (P & O) method. System simulation using Simulink MATLAB as follows:
Figure 3. Simulation circuit using P & O method.

Figure 4. Maximum photovoltaic output power compared to the output power of the P & O MPPT system.

From the Figure 4 can be seen that at $P_{PV\ max} = 250\ W$, $P_{out\ max} = 175\ W$, when $P_{pv\ max} = 174.8\ W$, $P_{out\ max} = 150\ W$, and when $P_{pv\ max} = 98.97\ W$, $P_{out\ max} = 100\ W$. That response is visible to the oscillating system.

3.2. Simulation of a photovoltaic system using the MPPT Fuzzy method

Figur 5 and figur 6 are the Membership input functions, photovoltaic voltages and currents are given as follows:

Figure 5. Membership function input voltage.  

Figure 6. Current input membership function.

Figure 7 is a simulation circuit of photovoltaic models using MPPT Fuzzy is as follows:
Figure 7. Fuzzy MPPT Simulation Series.

Figure 8. Output power simulation results.

From Figure 8 it can be seen that when P PV max = 250 W, P out max = 160 W, when P PV max = 174.8 W, P out max = 125 W, and when P PV max = 98.97 W, P out max = 75 W. The resulting system’s output is stable, and there is no ripple. From the results of comparison in resulting output responses, it can be seen that the output using MPPT Fuzzy produces a more stable response compared to using the P & O method. By using the Fuzzy MPPT method, the resulting ripple can be reduced.

4. Conclusion
From the simulation results, the results of Fuzzy MPPT output response are more stable and doesn’t ripple compared to using MPPT P & O. The output of the MPPT Fuzzy system when P PV is max = 250 W, P out max = 160 W, when P PV max = 174.8 W, P out max = 125 W, and when P PV max = 98.97 W, P out max = 75 W.

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