Increasing the Output Power of Solar Cell Panels by Using Varying Directional Mirror Angles

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ABSTRACT
Solar energy is a potential renewable energy source to meet electricity needs in an environmentally friendly manner. However, the output power of solar cell panels is greatly influenced by the intensity of sunlight received, which often fluctuates due to changes in the position of the sun and atmospheric conditions. This study aims to examine the increase in the output power of solar cell panels by utilizing directional mirrors to increase the intensity of light falling on the panel surface. The method used is a laboratory experiment with the adjustment of the angle of the directional mirror and measurement of the panel output power in various configurations. The test results show an increase in output power of up to 7.3% at a mirror angle of 100° compared to without a mirror, which indicates the effectiveness of using directional mirrors in improving solar panel performance. These findings provide practical contributions in optimizing solar panel systems for more efficient and economical renewable energy applications.

Keywords: *Solar Energy, Solar Cell Panel, Directive Mirror, Increased Output Power, Renewable Energy Efficiency*

Introduction

Renewable energy is a strategic solution to meet the increasing need for electricity while reducing negative impacts on the environment. Solar energy, as one of the most abundant and environmentally friendly renewable energy sources, has great potential for widespread application. Solar cell panels are the main technology in converting solar energy into electrical energy. However, the output power of solar cell panels is greatly influenced by the intensity of sunlight received. Fluctuations in light intensity due to atmospheric conditions and the position of the sun often cause the efficiency of solar panels to be less than optimal.

Various studies have been conducted to improve the efficiency and power output of solar panels, including the development of new materials, innovative panel designs, and the use of solar tracking systems. One relatively simple yet effective method is the use of directional mirrors to focus and increase the intensity of sunlight on the panel surface. However, studies related to the optimization of the angle, configuration of directional mirrors, and their effects on panel performance are still limited, especially in the context of practical applications and systematic evaluation of power output.

This study aims to examine and test the increase in solar cell panel output power by utilizing a directional mirror as a tool to increase the intensity of light received. The research method uses laboratory experiments with measurements of panel output power at various configurations of directional mirror angles. Light intensity and output power data are analyzed to determine the effectiveness of using mirrors in improving panel performance. The results of the study are expected to provide practical contributions in optimizing solar panel systems for more efficient and economical renewable energy applications.

The problem that arises is how the use of directional mirrors affects the output power of solar cell panels. Therefore, this paper will reveal and examine and test the increase in the output power of solar cell panels using directional mirrors, so that practically and theoretically it can be useful for the development of solar panel technology.

Literature Review

Renewable energy is currently the main focus in efforts to overcome the energy crisis and global climate change. One of the most potential renewable energy sources is solar energy, because of the abundance of sunlight that is available for free and continuously. The use of solar energy through solar cell panels can produce electricity without greenhouse gas emissions, making it environmentally friendly and supporting the sustainability of future energy. However, the output power of solar panels is highly dependent on the intensity of sunlight received, so innovation is needed to maximize its use, one of which is by using directional mirrors to increase the intensity of light falling on the surface of the panel.

The output power of solar panels is highly dependent on the intensity of sunlight they receive. Fluctuations in this intensity are caused by environmental factors such as weather conditions (clouds, rain, fog), the angle of sunlight that changes throughout the day, and air pollution that can reduce the amount of solar radiation reaching the surface of the panel. As a result, the electrical power produced by the panel is often unstable and below its maximum capacity, thus becoming a major obstacle in optimal utilization of solar energy.

The use of directional mirrors is one effective method to increase the intensity of sunlight received by solar cell panels. This mirror functions to reflect and focus sunlight directly onto the surface of the panel, thereby increasing the amount of radiation absorbed. Thus, the use of directional mirrors can increase the output power of the panel without having to increase the size of the panel itself, as well as being an economical solution to optimize the use of solar energy, especially in conditions of low light intensity or when the position of the sun is not ideal.

A. How Solar Cell Panels Work

Solar cell panels or solar cells are devices that convert sunlight energy into electrical energy through the photovoltaic effect. The basic principle of solar panels is the absorption of sunlight photons by semiconductor materials, usually silicon, which causes electron excitation from the valence band to the conduction band, resulting in electron-hole pairs. The movement of these electrons through the internal electric field in the solar cell creates an electric current that can be used for external loads.

Solar cells are composed of layers of n-type and p-type semiconductors that form a pn junction. When sunlight hits the surface of the panel, the photon energy is absorbed and generates electrical charge carriers. The electric field at the pn junction then separates the charge carriers, producing an electric current. The voltage generated per cell is usually around 0.5 to 0.6 Volts, so several cells are arranged in series in a panel to achieve the desired output voltage and power.

The energy conversion efficiency of solar panels is highly dependent on material quality, cell design, and environmental conditions. Currently, solar panel technology has developed with various cell types such as monocrystalline, polycrystalline, and thin-film, each with different efficiency, cost, and application characteristics. Understanding these basic working principles is essential to optimize the use and development of solar panel technology.

B. Factors Affecting Solar Panel Output Power

The output power of solar panels is not only influenced by the material and design capabilities, but also by a number of external and environmental factors. The main factors that affect the output power of solar panels include:

a. Sunlight Intensity

The intensity of solar radiation reaching the surface of the panel greatly determines the amount of energy that can be absorbed. The greater the light intensity, the higher the electrical power generated. However, this intensity can fluctuate due to weather conditions such as clouds, fog, and air pollution.

b. Angle of Incidence

The angle at which sunlight hits the panel surface affects how much light is absorbed. The panel works best when sunlight falls perpendicularly. As the sun moves from morning to evening, this angle changes, so does the output power.

c. Panel Temperature

High panel temperatures can reduce energy conversion efficiency. Generally, increasing temperatures cause an increase in internal resistance and a decrease in the output voltage of solar cells. Therefore, thermal management is important to maintain panel performance.

d. Dirt and Dust

Accumulation of dust, dirt, or other substances on the panel surface blocks light from entering and significantly reduces power output. Regular maintenance and cleaning are required to maintain optimal performance.

e. Material Degradation

Over time, panel materials can degrade due to UV exposure, extreme weather, and corrosion, which reduces efficiency and power output.

f. Panel Settings and Orientation

Proper placement of the panels with the appropriate orientation towards the sun and tilt angle is essential to maximize light absorption. Understanding these factors allows the design of a more efficient and optimal solar panel system in producing maximum electrical power.

C. Technology of Using Mirrors and Reflectors in Solar Energy

To overcome the limitations of light intensity directly received by solar panels, mirror and reflector technology has begun to be widely used to focus and increase solar radiation falling on the panel surface. This technology is included in the category of solar concentrator systems that utilize optical principles to increase light intensity.

There are several types of mirrors and reflectors used in solar energy technology, including:

a. **Flat Mirrors**

Flat mirrors are used to reflect sunlight onto solar panels at certain angles to increase the intensity of light received. This system is relatively simple and inexpensive, but the mirror angle setting must be precise to be effective.

b. **Curved Mirrors (Curved Mirrors)**

Concave or convex mirrors are used to focus sunlight onto a specific point or area on the panel. Concave mirrors can increase light intensity by collecting rays from a larger area and concentrating them onto the panel.

c. **Parabolic Reflector**

Parabolic reflectors are widely used in concentrator solar power generation systems because of their ability to focus light to a single focal point with high efficiency. However, the cost of manufacturing and setting them up is more complex.

d. **Multi-Mirror Reflector (Heliostat)**

This system uses many mirrors that automatically follow the position of the sun to focus light onto the panel or energy receiver. Usually used in large-scale solar power plants. The use of mirrors and reflectors helps increase the output power of solar panels without having to physically enlarge the size of the panels, thus saving costs and land. However, the use of mirrors also poses technical challenges, such as the need for dynamic angle adjustments and maintenance of the reflector system to keep it clean and optimal.

Several studies have been conducted to test the effectiveness of using directional mirrors in increasing the output power of solar cell panels. These studies focus on the effect of mirror configuration, reflection angle, and reflector type on light intensity and panel efficiency. For example, one study examined the use of flat mirrors mounted around solar panels to reflect sunlight onto the panel surface. The results showed an increase in output power of up to 15% in daytime conditions with moderate light intensity. However, effectiveness is highly dependent on the angle of the mirror installation and the position of the sun.

Another study used specially designed concave mirrors to focus light onto a limited area of the solar panel. They reported an increase in energy efficiency of up to 25% compared to panels without mirrors. The angle of the mirrors was manually adjusted every two hours to track the position of the sun.

In addition, another study developed a parabolic reflector system with automatic tracking that can increase light intensity up to three times. This system is able to significantly increase the output power of solar panels, but requires a larger investment cost and complex maintenance.

In general, the use of directional mirrors has been shown to be effective in increasing the light intensity and power output of solar panels, especially in areas with variable or low solar intensity. However, most studies highlight the importance of optimizing the angle and dynamic settings so that the system can perform optimally throughout the day. In addition, other challenges identified include the potential for panel overheating due to increased radiation, the need for weather-resistant reflector materials, and designing a system that is economical and easy to maintain.

Research Conceptual Framework

The conceptual framework of this research is described as follows:

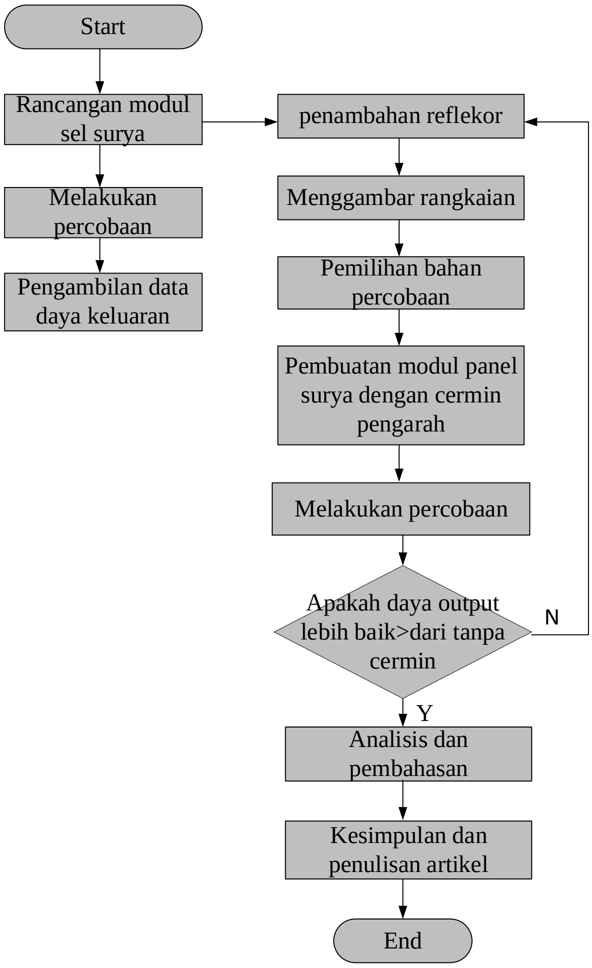

Figure 1. Research Flow Diagram

A. Design and Design of Experiments for Directing Sunlight to Solar Cell Panels

1. Description of the Solar Cell Panel Used

Solar Cell Panel Type: Monocrystalline Silicon Solar Cell

Nominal Power Capacity: 100 Watt peak (Wp)

Dimensions: 100 cm x 50 cm x 3 cm

Energy Conversion Efficiency: ±18%

Output Voltage: 18 Volts (open-circuit voltage)

Maximum Output Current: 5.56 Ampere

B. Operating Characteristics: This panel works optimally at sunlight intensity of around 1000 W/m² and temperature of around 25°C.

Function in Experiment: This solar panel will receive direct light as well as reflected light and will be focused by the directional mirror to measure the increase in output power due to the increase in light intensity.

C. Type and Configuration of Directional Mirrors

1. Types of Mirrors

Mirror Material: Aluminum coated mirror with high reflectance (>90%) to maximize sunlight reflection.

2. Mirror Shape: Flat mirror with smooth surface and anti-reflective coating to reduce light loss.

Mirror Size: 50 cm x 50 cm (per mirror unit), quantity adjusted according to configuration.

3. Directional Mirror Configuration

Primary Configuration:
Flat Mirror Array: Several flat mirrors are installed at certain angles to reflect and direct sunlight onto the surface of the solar cell panel.
Reflection Angle: The mirror angle is adjusted manually using a hinge mount so that the light reflection angle can be adjusted according to the position of the sun throughout the day (manual tracking).

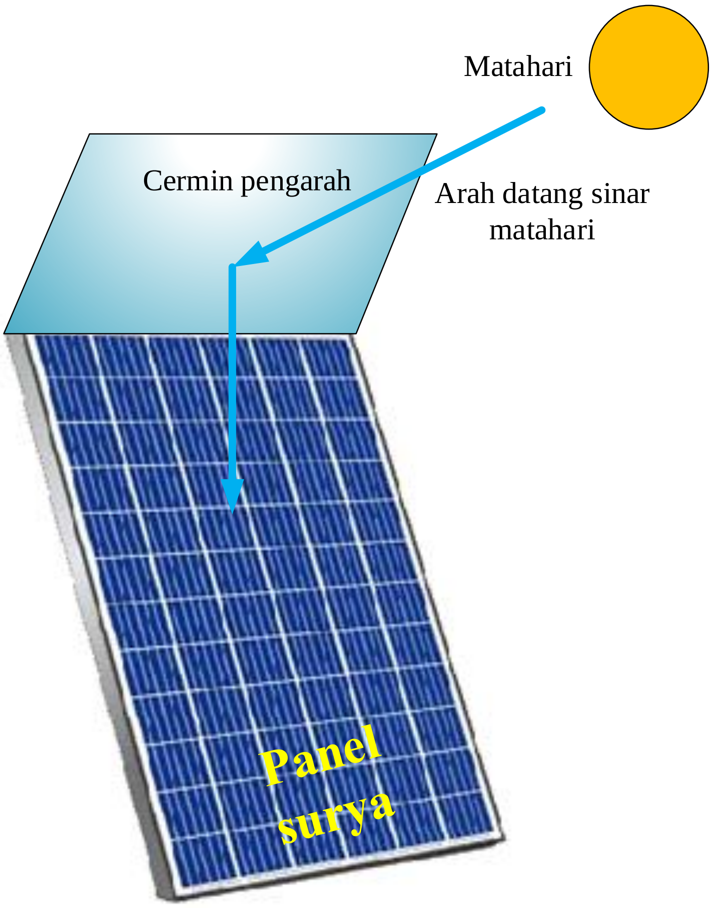

Figure 1. Directional mirror design

Results and Discussion

Panel Output Power Measurement Results

$$P = V.I = 20,11\,V \,.\, 0,041\,A = 0,82\,watt$$

The data was obtained from measuring the voltage and battery charging current when the solar cell was exposed to sunlight.

Table 1. Solar panel output power

Average instantaneous power (watts)		
Without directional mirror	With directional mirror	Mirror tilt angle (degrees)
0.82	0.88	90
	0.88	100
	0.86	110
	0.83	120

From the table, it can be seen that there is an influence of the reflected light from the mirror even with the changing angle of the incoming sunlight. So it can be concluded that the influence of the Directive Mirror on Output Power can increase the energy of the installed solar panels.

From Table 1, it can be seen that there is an increase in the instantaneous output. The increase occurs for all reflector angles on all three test days. The largest increase occurs at a reflector angle of 100 °, which is 7.3%. Detailed analysis can be seen in the following figure:

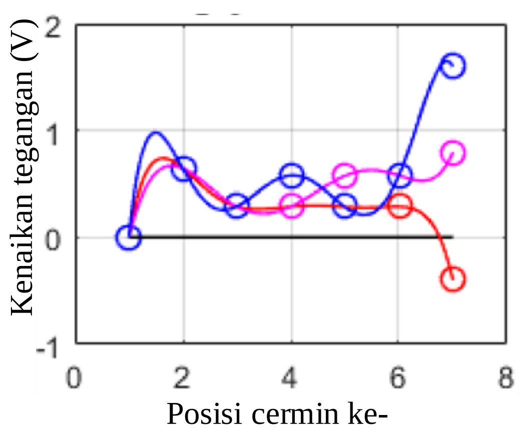

Figure 2. Voltage increase graph with mirror

Explanation of the power increase mechanism as follows:
The increase in power is due to the collection of sunlight by the mirror which can add energy to ionize the barrier in the solar cell. Enough energy will release electrons and separate them so they can be channeled to the solar cell load.
Previous study results have not tested for a 90o angle which can actually increase output power before 100o. However, in terms of accuracy, it is greatly influenced by weather and humidity, where in each data collection it is necessary to ensure the same humidity that affects the reception of sunlight by the solar panel.

Conclusion

The use of directional mirrors has been proven to increase the output power of solar cell panels by focusing and increasing the intensity of sunlight received by the panel. In the experiments conducted, the increase in output power was recorded at all angles of the tested mirrors, with the largest increase of 7.3% at an angle of 100°. This shows that directional mirrors are a simple and effective solution to increase the efficiency of solar panels without the need to enlarge the physical size of the panel. However, optimal effectiveness is greatly influenced by the setting of the mirror angle and environmental conditions such as humidity and weather. Therefore, further development with a dynamic mirror angle setting system and long-term evaluation is recommended so that the use of directional mirrors can be optimized for various real conditions in the field.

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