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Comparing Energy Harvesting Efficiency between Solar Panels: Tracking the Sun vs Ground-Mounted 40 WP Panels

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ABSTRACT

This experiment aimed to evaluate the energy efficiency of a solar tracking panel compared to a ground-fixed solar panel. A 40 WP solar panel with a time-tracking mechanism was used to monitor the sun's movement from morning to evening, while a static 40 WP ground-fixed solar panel was also studied for comparison. The study also included the energy consumption of a 12 V DC motor responsible for orienting the tracking panel to face the sun. Throughout the day, the tracking panel's position was continuously adjusted to align with the sun's position, facilitated by a microcontroller and a gyroscope. The energy consumed by the motor during the tracking process was accounted for. The net energy output of the tracking panel was computed by subtracting the energy expended in tracking from the total energy collected. Following the experimentation, the collected data was analyzed to determine the energy efficiency of the tracking panel in contrast to the ground-fixed panel. The findings revealed that the tracking panel exhibited a 15 percent increase in energy efficiency compared to the ground-fixed panel. These results emphasize the potential benefits of solar tracking technology in optimizing energy capture from solar panels. The implications of these findings are valuable for advancing the design and implementation of solar energy systems, offering increased efficiency and sustainability.

Keywords: Energy Efficiency, Gyroscope, Microcontroller, Solar Panel

ABSTRAK

Percobaan ini bertujuan untuk mengevaluasi efisiensi energi dari panel surya yang dapat melacak posisi matahari dibandingkan dengan panel surya tetap di tanah. Sebuah panel surya 40 WP dengan mekanisme pelacakan waktu digunakan untuk memantau pergerakan matahari dari pagi hingga sore, sementara panel surya tetap 40 WP yang dipasang di tanah juga dipelajari untuk perbandingan. Studi ini juga mencakup konsumsi energi dari motor DC 12 V yang bertanggung jawab untuk mengarahkan panel pelacakan agar menghadap matahari. Sepanjang hari, posisi panel pelacakan terus disesuaikan untuk sejajar dengan posisi matahari, difasilitasi oleh sebuah mikrokontroler dan sebuah giroskop. Energi yang dikonsumsi oleh motor selama proses pelacakan diperhitungkan. Output energi bersih dari panel pelacakan dihitung dengan mengurangi energi yang dikeluarkan dalam pelacakan dari total energi yang terkumpul. Setelah percobaan, data yang terkumpul dianalisis untuk menentukan efisiensi energi dari panel pelacakan dibandingkan dengan panel tetap di tanah. Temuan menunjukkan bahwa panel pelacakan menunjukkan peningkatan efisiensi energi sebesar 15 persen dibandingkan dengan panel tetap di tanah. Hasil ini menekankan potensi manfaat teknologi pelacakan surya dalam mengoptimalkan penangkapan energi dari panel surya. Implikasi temuan ini berharga untuk memajukan desain dan implementasi sistem energi surya, yang menawarkan peningkatan efisiensi dan keberlanjutan.

Kata kunci: Efisiensi Energi, Giroskop, Mikrokontroler, Panel Surya

1. Introduction

Solar energy is increasing become a pivotal component in renewable energy sources. Consequently, it holds great significance for engineering professionals to gain a comprehensive grasp of the associated technology. This research revolves around creating a solar panel tracking system based on microcontrollers. Sun tracking enables the solar array to maintain alignment with the sun, resulting in increased energy generation. This endeavor builds upon the concepts covered in our course, ultimately culminating in a functioning system to validate the design [1]–[3].

A prototype of a single-axis solar tracker system has been successfully developed. This prototype employs a KS42STH40-1204A stepper motor, which adjusts its position based on the DS3231 real-time clock (RTC) timing. At regular intervals, precisely every 30 minutes from 08:15 to 16:15 WIB, voltage and current measurements are taken. This data is collected from both the solar panels equipped with solar trackers and static solar panels. To assess the efficacy of the solar tracker system, a comparison is made between the voltage and current values generated by these two setups. The efficiency improvement is quantified by measuring both panel configurations' open circuit voltage (V_{oc}) and short circuit current (I_{sc}). Notably, the V_{oc} voltage from the solar tracker is 4.83% higher than that of the static solar panel. However, the I_{sc} generated by the solar tracker is 11.11% lower than that of the static solar panel. One limitation of this prototype lies in its miniature form, which results in relatively low light capture due to its size [4]–[6].

A solar tracker is essentially a control system designed to detect and continually adjust the orientation of solar panels to ensure they remain perpendicular to the sun's position throughout the day. This dynamic alignment maximizes the amount of sunlight the panels receive, optimizing light intensity and energy production. The control circuit achieves this by managing the movement of a motor that repositions the panels in sync with the sun's trajectory. Based on the testing of a 100 Wp single-axis solar tracker solar panel, measurements were taken at one-minute intervals between 08:00 and 17:00. The findings indicate that the average sunlight intensity during this period was 408.10 W/m^2, and the accompanying wind speed was recorded at 1.08 m/s. These conditions led to a significant current generation, averaging 19.20 volts. Regarding energy balance, the incoming energy from sunlight totaled 279.05 watts, while the average power or energy output stood at 11.77 watts. This results in an overall efficiency rating of 4.21%, highlighting the effectiveness of the solar tracker system in harnessing solar energy [7].

This study aims to explore the potential of utilizing solar tracker technology as an innovative approach for comparing the efficiency of solar energy collection compared to static solar panels. This research seeks to evaluate and contrast the effectiveness of these two methods in daily solar energy harvesting. The methodology employed in this study is straightforward. The 40 WP Solar Tracker system utilizes a cost-effective microcontroller, providing two degrees of rotational freedom to position the photovoltaic solar cells for optimal sunlight exposure throughout the day. This enhanced alignment results in increased electricity generation. The solar tracking system operates under the control of an ATMega328 microcontroller, which processes data via an ADC (analog-to-digital converter) and logs the information. Subsequently, it communicates the necessary adjustments to the motor controller for optimal solar panel positioning.

2. Method

The research requires several tools and materials, including a 40 WP solar panel, an ATMega328 Microcontroller, an RTC DS3231 [8], a solar tracker, a static panel, an INA219 current sensor [9], an HMC5883L sensor [10], and an LCD. This equipment operates based on a fundamental principle: when sunlight reaches the panel, it absorbs the sun's heat energy in two ways through the tracker and the static panel and converts it into electrical energy. The energy generated is then stored within the ATMega328 microcontroller. To facilitate the functionality of this system, the design incorporates Arduino (ATMega328), RTC, and PLX-DAQ technology. These elements enable continuous storage of energy output and time data, which can be monitored via a liquid crystal display (LCD). Figure 1 depicts the block diagram of the equipment, and Figure 2 illustrates the overall circuit of the equipments.

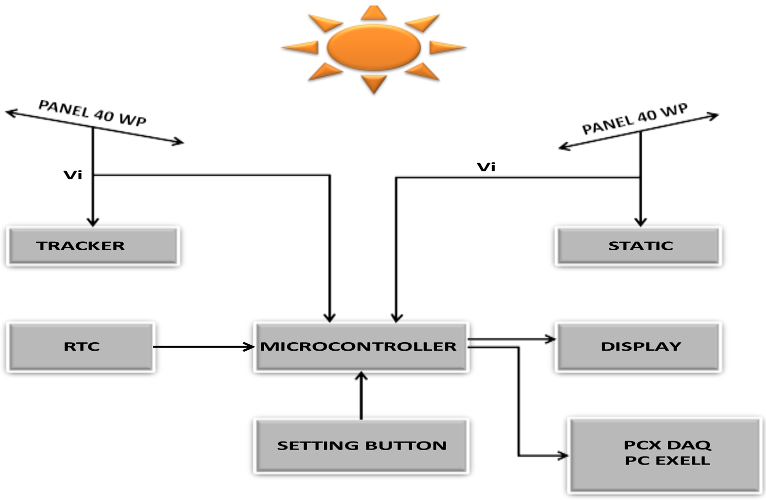

Figure 1. Block diagram of the equipment.

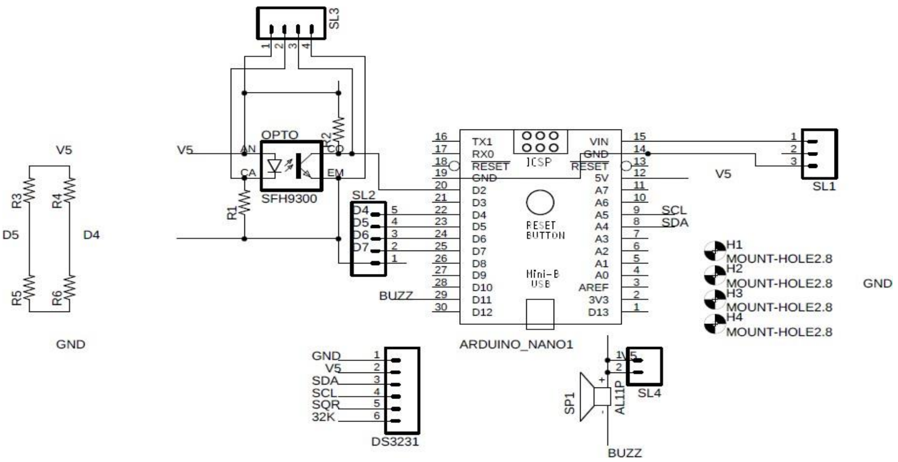

Figure 2. Overall circuit of the equipment.

3. Result and Discussion

3.1. Testing the HMC5883 Magnetor Sensor

The test result of the HMC5883 Magnetometer is shown in Figure 3. The primary objective of integrating the HMC5883 magnetometer sensor into this research is to as certain the extent of rotation and the direction of Earth’s magnetic field.

```
HMC5883 Magnetometer Test

------------------------------------
Sensor:        HMC5883
Driver Ver:    1
Unique ID:     12345
Max Value:     800.00 uT
Min Value:     -800.00 uT
Resolution:    0.20 uT
------------------------------------

X: 31.82  Y: 21.64  Z: -1.02  uT
Heading (degrees): 46.82
2000/1/1 0:9:53 Mon

X: 31.82  Y: 21.64  Z: -1.22  uT
Heading (degrees): 46.82
2000/1/1 0:9:54 Mon

X: 31.64  Y: 21.55  Z: -1.12  uT
Heading (degrees): 46.86
2000/1/1 0:9:55 Mon
```

Figure 3. HMC5883 magnetometer sensor test results.

3.2. Creating a Data Logger System

The RTC DS 3231 test serves the purpose of retrieving real-time data based on a predefined schedule. The information variables extracted from the RTC DS 3231 encompass seconds, minutes, hours, days, dates, months and years. The results is shown in Figure 4.

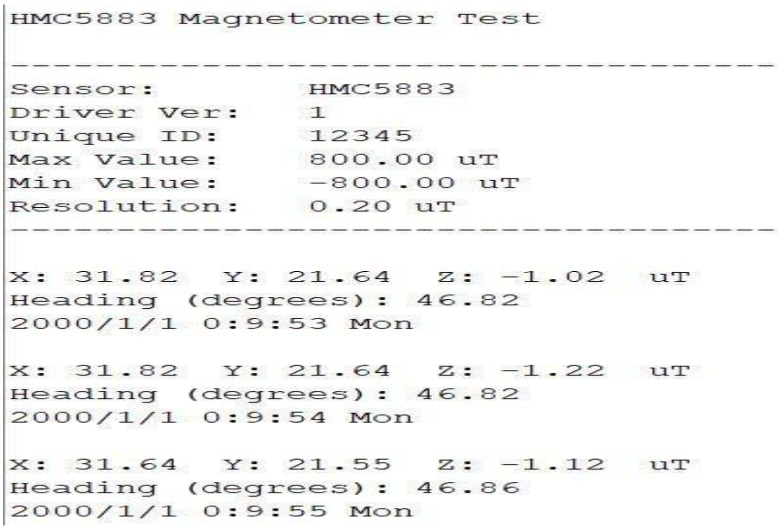

Figure 4. RTC DS3231 test results.

3.3. Calculating Energy Efficiency

To compute the energy efficiency of both tracking solar panels and static solar panels, we can employ equation (1).

$$\text{Efficiency Energy} = \frac{\text{Electrical Output}}{\text{Solar Energy Input}} \times 100\% \tag{1}$$

where energy output also called electricity output represents the power or energy produced by the solar panel typically misured in watts (W) and solar input energy on the other hand is the amount of the solar energy that impinges on the surface of the solar panel, generally quantified in watts per square meter (W/m^2).

For a panel equipped with a tracking system:

- Input Energy for the tracker = 8 hours × 40 watts = 320 W.
- Solar tracker output energy = Total energy received – Energy consumed by the system.
- Output energy = 297.55 W (total energy received) – 28.61 W (energy consumed by the system) = 268.94 W.

Indeed, the tracker panel demonstrates a 14.93% higher efficiency when compared to static panels. It is important to note that while the increase in efficiency is notable, it may not always justify the additional costs associated with implementing a tracking system. Evaluating the cost-effectiveness of a solar tracker should consider factors such as the initial setup cost, maintenance expenses, and the expected increase in energy production over time. Depending on the specific circumstances and goals of the solar installation, the cost-benefit analysis may vary, and it is crucial to consider all relevant factors before deciding whether to utilize a solar tracker.

Table 1. Comparison of solar tracker and static panels.

Metric	Solar Panel with Tracker	Static Solar Panel
Total Energy Generated (Wh)	297.55	221.15
Energy for Tracker Control (Wh)	28.61	-
Net Energy Obtained (Wh)	268.94	221.15
Efficiency (%)	84.04%	69.11%
Efficiency Improvement	14.93%	-

Table 1 summarizes the main metrics for comparing solar panels equipped with tracking systems to static solar panels. It includes total energy generation, energy consumption for tracker control, net energy obtained, and efficiency percentages. The "Efficiency Improvement" row emphasizes the efficiency enhancement attained with solar panel trackers. Figure 5 compares solar panel trackers and static panels in the research.

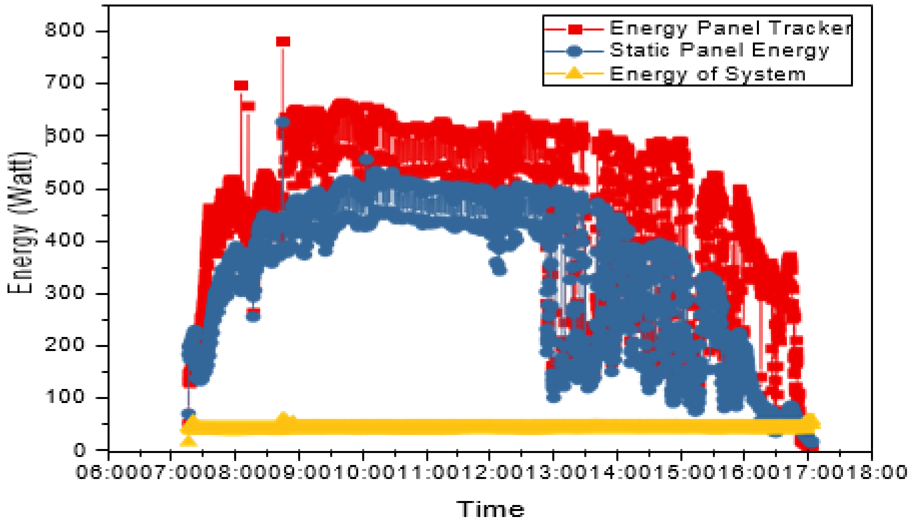

Figure 5. Research chart comparison of solar panel trackers and static panels.

In this research, the total energy obtained with the tracker panel was 268.94 Wh, resulting in an efficiency of 84.04 % after subtracting the energy consumed by the tracker (28.61 Wh). With static panels, a total energy of 221.15 Wh was generated, yielding an efficiency of 69.11 %. Comparing the energy output of the two panels, the tracker panel demonstrated at 14.93% higher efficiency.

In a prior study conducted by Kiyak et al, in 2016, a different approach was used. They employed the fuzzy logic method and achieved an energy output of 103.8 Wh with an energy consumption of 3.6 W for fuzzy logic control, resulting in an efficiency comparison of 2.39%. This significant difference in efficiency can be attributed to various factors, including the use of a 20 WP panel, different data collection hours (from 11:00 to 16:00), and the application of a distinct control method [11].

4. Conclusion

Solar cells equipped with trackers demonstrate a significant boost in efficiency, yielding an improvement of up to 14.93% compared to solar cells with static installations. The total energy generated by the 40 WP Solar Cell with a tracking system is 297.55 Wh. However, it is essential to note that 28.61 Wh of this energy is consumed for tracker control. Consequently, the net energy obtained from the Solar Cell with a tracker is 268.94 Wh. In contrast, the total energy harvested from the 40 WP Solar Cell in a static installation amounts to 221.15 Wh. This comparison underscores the substantial efficiency gains achievable with solar cell tracking technology.

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