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Solar Tracker Design Based on Arduino Nano to Improve Solar Energy Efficiency

Anderias Henukh*, *Amzal* Heri, *Algiranto, Merta* Simbolon

Department of Physics Education, Universitas Musamus, Merauke, 99611, Indonesia

Abstract. This research aims to develop and build a solar tracking system or solar tracker utilizing the Arduino Nano microcontroller. The primary purpose of this technology is to improve solar panel efficiency by automatically moving them to follow the sun's movement throughout the day. *Solar energy* is a renewable energy source that is becoming increasingly popular to address the difficulties of the energy crisis and climate change. However, the effectiveness of solar panels is directly proportional to the amount of sunlight they get. Therefore, designing an Arduino Nano-based solar tracker is an innovative solution to increase solar energy efficiency. This article discusses the design and implementation of an Arduino Nano-based solar tracker to optimize solar energy production by moving solar panels automatically to follow the sun's movement throughout the day. Is known that the use of a solar tracker can increase the output voltage of solar cells up to 17.14% compared to static and the lowest optimization value was obtained at 17.00, namely at a value of 8.82%, as an implication of the geographical position of the research area, which experiences sunset more quickly.

Keywords: Solar Tracker, Arduino, Energy Efficiency.

* Corresponding author: henukh_fkip@unmus.ac.id

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1 Introduction

Indonesia has an abundance of sunshine. Indonesia's geographical location is near the equator. Even during the rainy season, Indonesia receives sunlight. The abundance of sunlight offers the possibility of using sunlight as an alternative energy source to replace fuel, which is becoming increasingly popular [1], [2].

Energy scarcity in Indonesia is caused by rising energy demand and dwindling fossil fuel reserves. Indonesia has reserves of fossil energy sources such as oil for 23 years, natural gas for 59 years, and coal for 146 years. As a result of this situation, the use of renewable energy sources, including solar energy, geothermal energy, water, wind, and biomass, to replace conventional energy is increasing. Solar energy is Indonesia's most potential alternative to other renewable energy sources. This is owing to Indonesia's geographical location, which is precisely at 6^{o} South Latitude-11^{o} South Latitude and 141^{o} West-95^{o} East, causing Indonesia to become one of the locations that receive high solar radiation all year, with an average power of 4.8 kWh/m^2/day [2]–[6].

Solar energy is a renewable energy source that is becoming more popular due to its environmental friendliness and dependability in generating electricity. However, the effectiveness of solar panels in generating power is directly proportional to the amount of sunshine they receive. To improve efficiency, a solar tracking system known as a solar tracker must be installed. A solar tracker is a system that moves solar panels so that they constantly face squarely toward the sun throughout the day. As a result, the solar panels will receive maximum sunshine at all times, considerably improving electrical energy production[7–9].

One popular method for designing a solar tracker is using an Arduino Nano as the system's brain. Arduino Nano is a flexible, affordable, and easy-to-program microcontroller development platform. Using Arduino Nano as a solar tracker control system provides many advantages, including easily setting tracking time, adjusting movement speed, and monitoring system performance in real-time. Several important aspects in the design of a solar tracker using Arduino Nano include: The tracking method can be a single-axis tracker (movement tracks the sun's position along an east-west axis) or a dual-axis tracker (movement tracks the sun's position horizontally and vertically). Light Sensor: Solar tracker requires a light sensor to detect the intensity of sunlight. This sensor helps Arduino Nano calculate the sun's position and move the solar panel to always face the sun optimally. Drive Motor: Arduino Nano will control the motor responsible for driving the solar panel[4], [10]–[12].

This motor can be a DC motor or a servo motor, depending on the design and complexity of the desired system. Programming and Control: Arduino Nano requires a proper program to set up the tracking logic based on the data from the light sensor. Programming must also include a motor control mechanism to follow the sun's movement accurately and smoothly. Backup Energy: For reliability and to avoid failures, the solar tracker must have a backup power system, such as a battery, to operate the Arduino Nano and light sensor during the night or when there is a lack of sunlight.
By designing and implementing a solar tracker using Arduino Nano, the efficiency of solar panels can increase significantly and produce more electrical energy. This system also enables better monitoring and regulation, thereby increasing the utilization of solar energy as a sustainable and environmentally friendly resource.

2 Methods

The method used in this study is experimental research with a design and implementation approach. The steps taken in this research include literature study: A literature study was conducted to understand the basic principles of solar tracking, how the light sensor works, the appropriate type of drive motor, and how to use the Arduino Nano as the system's brain. System Design: Design and design of the solar tracker system is carried out. The design includes a tracking mechanism, selecting the right light sensor, a suitable drive motor, and backup resource planning. Material and Component Collection: Materials and components needed to assemble the solar tracker are collected according to the design that has been made. Arduino Nano Programming: Arduino Nano programming controls light sensors, calculates the sun's location, controls motors, and selects the best tracking algorithm. System Construction: The solar tracker is built using the designs and equipment acquired. The components are connected following the design concept. Testing and Evaluation: The solar tracker system is tested under different simulated sunlight conditions to ensure accurate and efficient tracking. The test involves direct observation of the solar panel's position and the Arduino Nano's performance in controlling tracking movements[12,13].

2.1 Tools and Materials

Arduino Nano is a microcontroller based on ATmega328p 16 MHz, which has 13 build LED Pins, 14 Digital I/O Pins, 8 Analog Input Pins, and 6 PWM Pins. To operate optimally, this microcontroller uses 7–12 Volts as input voltage and 20 mA as the current strength. Arduino Nano is also equipped with Mini-B USB to communicate with the programming application interface to upload the code. The LDR Kit functions as an input that will trigger the microcontroller to move the servo base left or right and trigger the servo mount to move the servo up and down to find the angle of incidence of the highest light intensity at that time. Two servos, namely, the base servo, are used to move the solar tracker mounting/pole left or right. While the other servo, namely the mounting servo, moves the panel up and down to find the angle of incidence of light with the highest intensity. Colorful jumper cables connect all the existing components to the Arduino Nano microcontroller board.

2.2 Hardware and software design

At this stage, the hardware and software design is carried out. The design carried out includes size, number of parts and shape. The design results can be seen in the following figure.

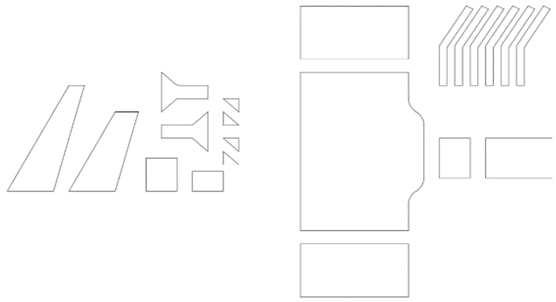

Fig.1. Design of Acrylic Parts

After that, the basic design is carried out as shown in the following figure.

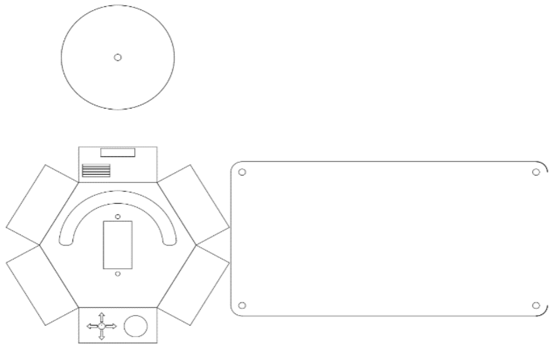

Fig.2. Based Design

Furthermore, the developed solar tracker flowchart can be seen in the following figure.

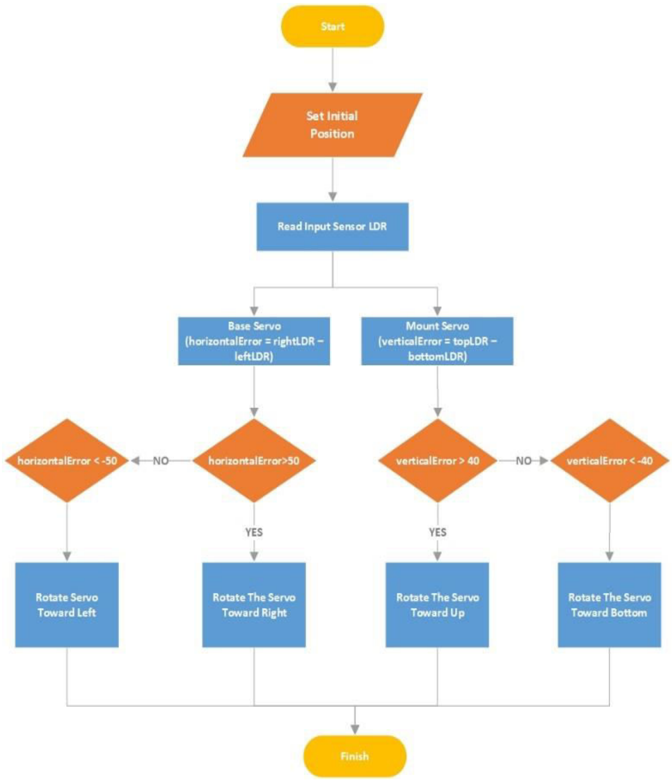

Fig.3. Solar Tracker Flowchart

When the solar tracker is turned on, the microcontroller system will initialize the initial positions of the two servos. Then the system will read the incoming LDR sensor value. There are 2 conditions created by the system, namely horizontalError = rightLDR – leftLDR on the base servo and verticalError = topLDR – bottom LDR on the mounted servo (topLDR = (rightLDR + leftLDR)/2). When the horizontal error value is <-50 on the base servo, the system will move the servo to the left. The opposite happens when the horizontal error value> 50, then the system will trigger the servo to move to the right. On the servo mount, a servo motor functions to move the panel up and down. When the vertical error value is <-40, the servo will rotate the panel down. Furthermore, when the value of verticalError> 40, then the servo will rotate the panel up.

Then the circuit used in this solar tracker and how it works can be seen in the following figure.

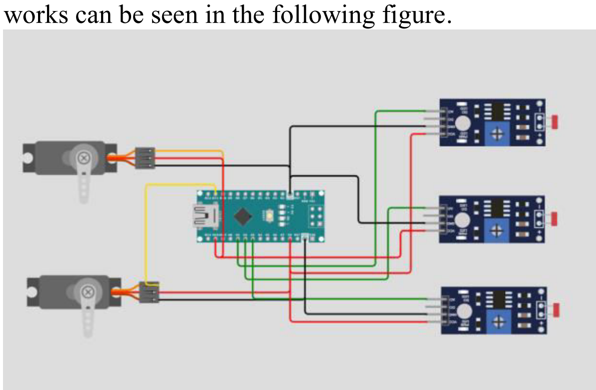

Fig.4. Circuit of Solar Tracker

This solar tracker system comprises an Arduino Nano microcontroller, 2 servo motors and 3 LDR KIT sensors. Arduino Nano functions as the processing center of the system that processes input from the LDR sensor and gives commands to the actuators, which in this case, are 2 servos. The servo base functions to rotate the mounting or panel pole left and right, while the servo mount functions to rotate the panel up and down

3 Results and discussion

Figure 5 depicts the results of designing and testing the entire series as a microcontroller-based solar tracker design ATmega328p with LDR sensor and LCD. A solar tracker is constructed using an ATmega328p microcontroller and a sensor. The system circuit light sensor, 5V power supply, ATmega328p microcontroller minimum system with LCD viewer, and stepper motor driver circuit support the LDR and LCD.

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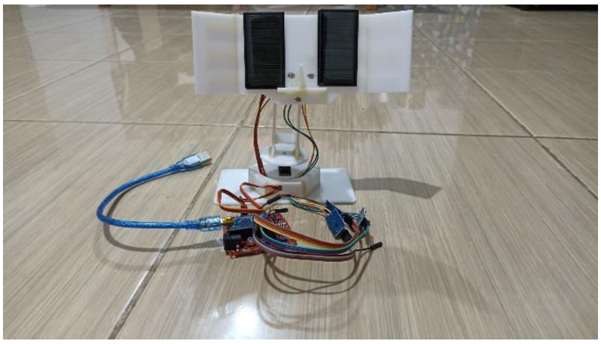
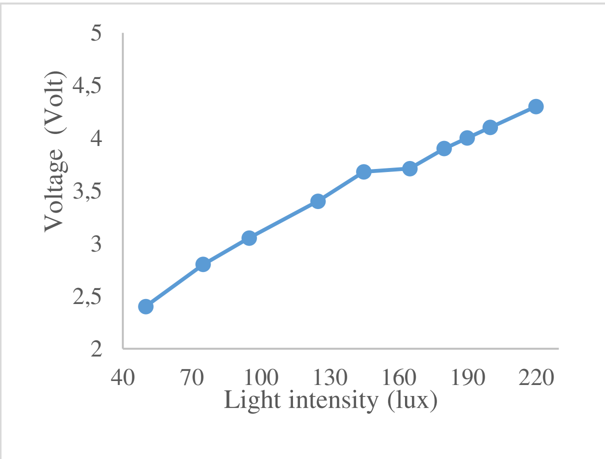


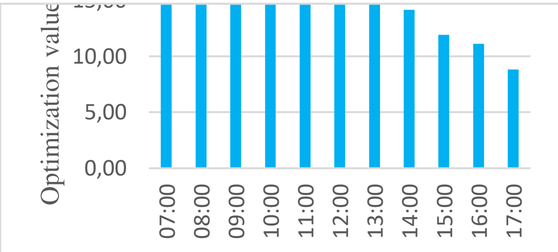
Fig.5. Solar Tracker

Design of a solar tracker based on ATmega328p microcontroller with sensor. The LDR and LCD are supported by the hardware that comprises the system circuit light sensor, 5V power supply, ATmega328p microcontroller minimum system with LCD viewer and stepper motor driver circuit.

3.1 Solar cell characteristics

The solar cell used is Amorphous 6 V/0.200mA. Solar cell output voltage the greater if the intensity of the light it receives is higher, as seen in Figure 6





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The test is carried out indoors by utilizing a light source from a flashlight whose intensity can be adjusted manually. The test was performed ten times to change the light intensity value, with the maximum output voltage value obtained being 4.3 volts. In this test, it can be seen that there is a linear increase in the output voltage.

3.2 Comparison of the output voltage of a solar cell using a solar tracker

This test compares the output voltage of different solar cells using a solar tracker with a static solar cell. This test also aims to bserve whether the solar tracker is functioning properly, namely, moving to direct the solar cell toward the light source. The test results can be seen in Figure 7.

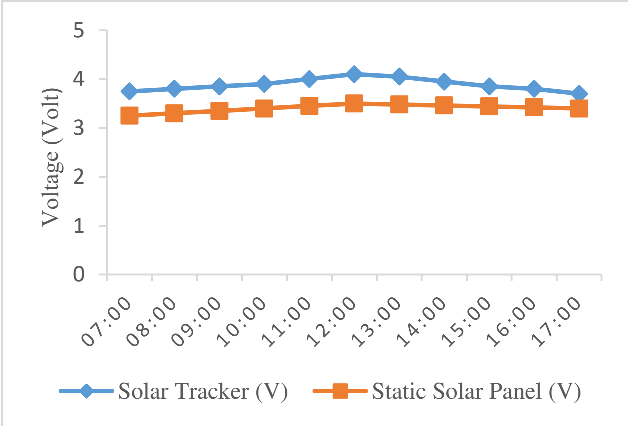

Fig.7. Graph of Comparison of Static Solar Cell Output Voltage and Solar Tracker.

As observed in the image above, the output voltage value of the solar panel on the solar tracker is greater than the output voltage value of the static mode solar panel. The output value of the solar tracker is higher because it dynamically adjusts the position of the solar panels in response to changes in the direction of sunlight. As a result of this modification, the solar panel receives more sunlight, resulting in a higher output voltage value than the static mode solar panel used for comparison. Other research has found that utilizing solar trackers can improve the effectiveness of absorbing thermal energy from the sun [1, 14, 15].

Next, we compare the output voltage value on the solar tracker and static mode following the figure 8 below.

Fig.8. Graph of Optimizing the Output Voltage of A Solar Cell That Uses Solar Tracker.

The graph of the output voltage optimization value shows that the biggest optimization value occurs at 12.00, namely 17.14%. In that position, the sun is at its highest peak intensity so that the solar panels can also receive maximum light. When the sun is at that time, its position is not perpendicular to the solar panels due to geographical position. This factor causes a big difference in the light reception level where static mode solar panels tend to be installed perpendicular to the sky. The lowest optimization value was obtained at

17.00, namely at a value of 8.82%, as an implication of the geographical position of the research area, which experiences sunset more quickly.

Various past research findings also suggest that utilizing solar trackers can improve the efficiency of absorbing heat energy from the sun because solar trackers can detect and follow the sun's direction to maximize heat energy usage. Increasing the efficiency of this heat energy is critical for humanity in lowering their reliance on fossil fuels.

4 Conclusion

According to the research, using a solar tracker on a mini solar panel with a maximum voltage of 6 volts and a maximum current of 0.200mA can increase the output voltage of solar cells by up to 17.14% compared to static, and the lowest optimization value was obtained at 17.00, namely at a value of 8.82%, as an implication of the geographical position of the research area, which experiences sunset more quickly.

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