Arduino-Based Solar Tracking System

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ABSTRACT

This research aims to design an Arduino-based Solar Tracking system as a monitoring center, allowing users to monitor panel movements. The method used in this research is an experimental method to determine the performance of the solar tracking tool that has been made, by using a servo motor as a panel driver, LDR sensor and MPU6050 with wireless communication can display information to the user's PC/Smartphone through the blynk application. Where users can monitor panel movements against light in real-time. Based on the test results, the prototype that has been made can be used to monitor solar tracking in real time with an average error of 1.55%.

I. Introduction

The use of solar panels to harness solar energy for power generation has been widely practiced, but the installation of solar panels is still static and does not follow the movement of the sun. As a result, the capture of sunlight is not optimal and, consequently, the electrical power generated is also not optimal [1]. To obtain optimal electrical energy, the solar panel system must also be equipped with a control system that functions to adjust the surface of the panel so that it always faces the sun so that the solar energy can fully fall on the surface of the solar panel [2].

Previous research by Putri Pertiwi Wanajaya has examined the Performance Analysis of Solar Trackers Using Arduino UNO-Based Solar Cells. Based on the analysis of solar tracker performance, it shows that panels that follow the movement of sunlight (solar trackers) produce more power than panels that are in a fixed position [3]. Research by Dwiprima Elvanny Myori et al. on the Sunlight Tracking System in Photovoltaics Based on the previous discussion, the power generated without supervision is 8.71 Watts, while with the use of supervision it increases to 12.46 Watts, an increase of 3.75 Watts, and an increase of 1.67 Watts. Thus, the use of this supervision can increase the output power of solar cells by 1.67 Watts [4]. Jeneiro Rezkyanzah, et al., on the Design of Arduino-Based Solar Tracker as a Support for Solar Cell Working Systems in Absorbing Solar Energy In this study, solar panels work at an angle of 90 to 110° with an average of 1016 cd and produce more voltage at an angle of 31 to 140° than the capacity of 9 V solar cells that can be accommodated. This is proven by the Arduino voltmeter [5]. Roni Syafrialdi and Wildian's study on the Design of Solar Cell Trackers Based on Atmega8535 Microcontrollers with LDR Sensors and LCD Displays shows that the solar cell voltage increases by 11.53% compared to those without solar cell trackers, and the maximum voltage increases by 1.18 V compared to static ones [6]. Research conducted by Muhammad Faishal Ammar and Chalilullah Rangkuti on the Effect of Using a Single-Axis Solar Tracker on a 10-Watt Solar Power Plant found that the power generated by solar panels using a solar tracker increased by 37.88% compared to the power generated by a static solar panel [7].

Based on previous research, I attempted to expand on this research. This solar panel research used a servo motor to modify the solar panel's tilt to follow the direction of sunlight, and then added monitoring for its use. Therefore, I chose the title "Arduino-Based Solar Tracking System.".

II. Method

This research discusses the design and construction of a solar tracking device. The design of this device includes hardware and software design; in this case, the author used an experimental method.

A. Device Design

The device design above is a simple control design for operating solar tracking. The overall circuit design combines the Arduino Uno, NodeMCU ESP32, servo motor, LDR sensor, MPU6050 sensor, and other components. All these components have been designed in a single package known as the device design circuit. A diagram of the entire device circuit can be seen in Figure 1.

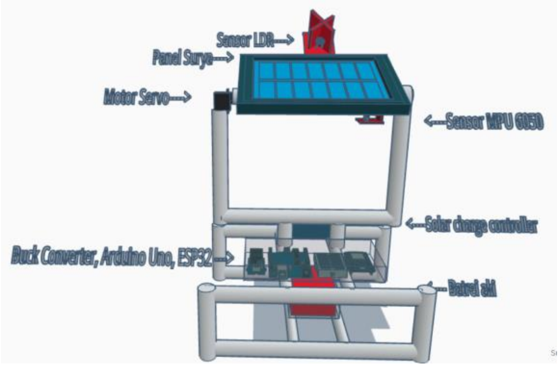

Figure 1. Tool Design

1) Arduino Uno

Arduino Uno is a board based on the Atmega328 microcontroller with 14 PWM input and output pins, 6 analog input pins, a 16 MHz crystal oscillator, a USB connection, and a reset button. Each pin can be used according to your circuit needs and must also support the microcontroller. The voltage source can be easily obtained by connecting it to a computer via a USB port or by using a battery or an AC-DC adapter. As the name suggests, the word uno comes from the Italian word "uno", which means one. In Italian, "Arduino Uno" means one, and "Arduino Uno 1.0" indicates the next release (product) of Arduino Uno 1.0 [10].

Figure 2. Arduino Uno

2) Arduino IDE

An Integrated Development Environment (IDE), or simply put, an integrated environment used for development. It's called an "environment" because it's the software Arduino uses to program, enabling it to perform tasks that are embedded in the programming syntax. Arduino uses its own programming language, similar to C. The Arduino programming language (Sketch) has been modified to make it easier for beginners to use from the start. Before its release, a program called Bootlader was embedded into the Arduino microcontroller IC. This serves as an intermediary between the Arduino compiler and the microcontroller.[11].

3) Solar Panels

Solar panels are devices that convert sunlight directly into electrical energy. Most solar panels used in everyday life are stationary, making them less effective at absorbing sunlight. To better absorb sunlight, solar panels must always move in the direction of the sun [12].

Figure 3. Solar Panels

4) Servo Motor

A DC servo motor consists of a DC motor, a series of gears, a potentiometer, and a control circuit. With a closed feedback system on the rotor position, the servo motor is informed back to the control circuit inside. [14][15].

Figure 4. Servo Motor

5) NodeMCU ESP32

The NodeMCU ESP 32 is the successor to the ESP8266 microcontroller from Espressif Systems. The ESP32 microcontroller has many advantages over other microcontrollers. These include more pinouts, more analog pins, more memory, and Bluetooth 4.0 low energy. Additionally, the ESP32 microcontroller has Wi-Fi, enabling the use of the Internet of Things.[16][17].

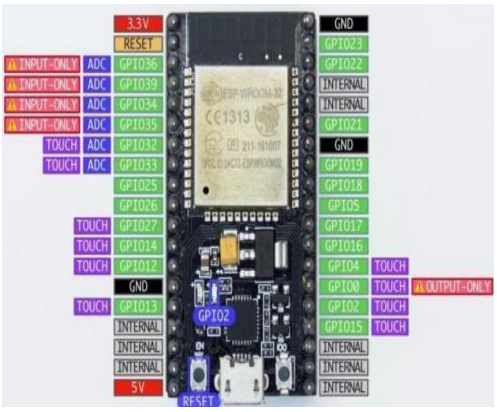

Figure 5. NodeMCU ESp32

6) Solar Charge Controller (SCC)

The Solar Charge Controller (SCC) in a solar panel system, or Battery Control Unit (BCU) or Battery Control Regulator (BCR), is a crucial component. The primary purpose of the SCC is to protect and automate battery charging to optimize the system and increase battery life. The CCR controller connects the solar panel to the battery. If it malfunctions, the panel will overcharge the battery, damaging the cells inside. The SCC can detect when the battery voltage is too low. If the battery voltage drops below a certain level, the SCC will disconnect the load from the battery to prevent the battery from exploding. The battery may even become unusable [19].

Figure 6. Solar Charge Controller

7) Sensor MPU6050

The MPU-6050 is a chip that has a digital motion processor (DMP), which will process the initial data from each sensor into data in the form of quaternions (4 dimensions). In other words, this chip has a 3-axis accelerometer (acceleration sensor) and a 3-axis gyroscope (balance regulator). In addition, the MPU6050's DMP helps reduce errors[20].

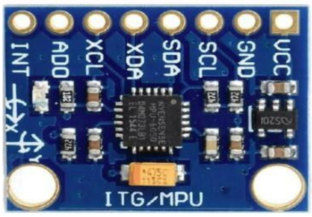

Figure 7. MPU6050

8) LDR Sensor

A Light Dependent Resistor (LDR) is a type of resistor whose resistance changes in response to light. The resistance of an LDR depends on the amount of light received by the LDR. The resistance is greater in dark light than in bright light. This type of resistor, called an LDR, is typically used as a light detector or to measure the amount of light conversion. An LDR consists of a semiconductor disc with two electrodes on its surface.[22][23].

Figure 8. LDR Sensor

9) Buck Converter

A buck converter is a power electronics circuit that can reduce DC voltage according to user needs. They obtain DC voltage and current from a power source or battery[24].

Figure 9. Buck Converter

10) Battery

A battery is a highly efficient electric cell that allows for reversible electrochemical processes to convert into electrical energy (discharge) and chemical energy (recharge) through regeneration of the electrodes used [13].

11) Blynk App

Blynk is a platform that runs on iOS or Android systems that allows you to control Arduino, Raspberry Pi, Wemos, and other types of modules over the internet. This application has many features that make it easier to use. How to create a project in this application is very easy, in just 5 minutes by dragging and dropping. Blynk is not connected to a specific board or module. This application allows us to control anything remotely while still connected to the internet. This is what is called the "Internet of Things"[25].

III. Results and Discussion

A. Research Results

1) Tool Block Diagram

A block diagram is a way to design a system or electronic device to understand several components as a whole to form a system that is in accordance with the plan. This system is designed to recognize the Arduino Uno as the main component, the LDR Sensor as a light intensity detector, the Servo Motor as a panel driver, and the MPU6050 as a panel tilt meter. Then the value will be displayed by the ESP32 through the Blynk application. The basic concept is as follows.

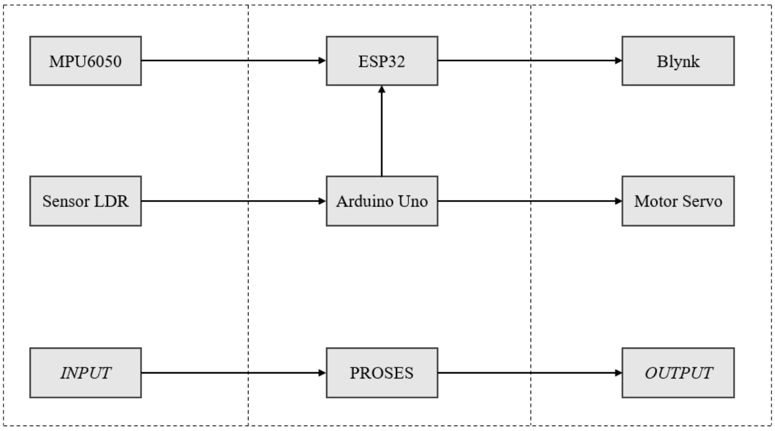

Figure 10. Block Diagram

2) System Flowchart

A system flowchart is used to sketch or arrange tools between one component and another. This provides an overview of how the tool operates as intended. To clarify the system workflow, here is a general overview of a system flowchart.

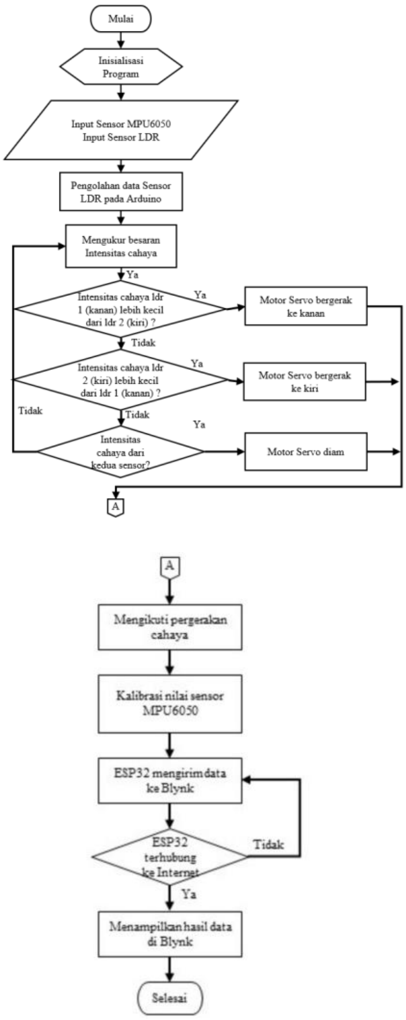

Figure 11. System Flowchart

3) Tool Design

The main components in the circuit include Arduino Uno, Solar Panel, NodeMCUESP32, Servo Motor, LDR Sensor, MPU6050 Sensor, Solar Charge Controller, Buck Converter, Battery. The following components are connected to each other in the image below:

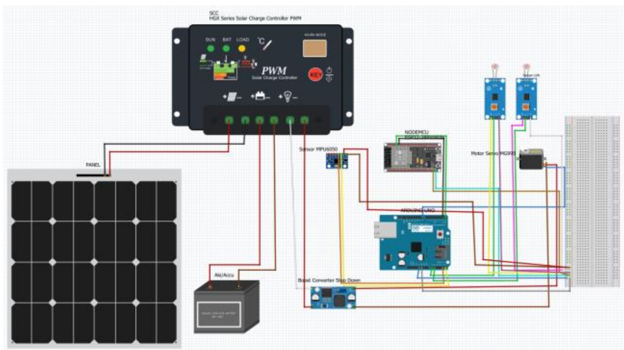

Figure 12. Schematic Diagram of the Tool

4) Tool Design Results

This research resulted in a design consisting of several stages, starting with component assembly and overall testing. Overall testing of this design is useful for determining the performance and success rate of the design. From the results obtained, the workings of each interconnected component can be analyzed. This design consists of a solar panel, Arduino Uno, NodeMCU ESP32, LDR sensor, servo motor, MPU6050, solar charge controller, buck converter, and battery.

Figure 13. Front and back view

5) Implementation of Hardware Design Results

a. Implementation of Arduino Uno Design Results

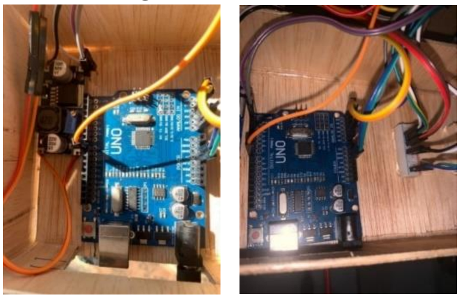

Figure 14. Arduino Uno Design Results

Based on Figure 14, it can be seen where the Arduino Uno is connected to the Breadboard, NodeMCU ESP32, SensorLDR, Servo Motor, and MPU6050. Where the 5V and GND pins are connected to the breadboard, the TX and RX pins are connected to the TX and RX pins on the NodeMCU ESP32, the A0 and A1 pins are connected to the AO pins on the LDR, pin 8 is connected to the signal pin on the servo motor, the A4 and A5 pins are connected to the SCL and SDA pins on the MPU6050 sensor. The Arduino as the main controller processes data from the sensors and controls the motor that moves the panel.

b. Implementation of NodeMCU ESP32 Design Results

Figure 15. NodeMCU ESP32 Design Results

Based on Figure 15, it can be seen where the 5v, GND, RX and TX pins of the NodeMCU ESP32 are connected to the TX, RX pins to the Arduino and 5v, GND to the breadboard. The NodeMCU ESP32 acts as an internet connection to send and receive data wirelessly to the Blynk application so that it can be monitored remotely.

c. Implementation of Servo Motor Design Results

Figure 16. Servo Motor Design Results

Based on Figure 16, it can be seen where the VCC and GND pins of the servo motor are connected to the OUT+ and OUT- pins on the buck converter, the servo motor signal pin is connected to pin 8 on the Arduino. The servo motor acts as a solar panel driver.

d. Implementation of Solar Charge Controller Design Results

Figure 17. Solar Charge Controller Design Results

Based on Figure 17. It can be seen where the battery, solar panel, Arduino, IN+ and IN- pins of the Buck Converter are connected. The Solar Charge Controller functions to manage the power flow between the solar panel, battery and load.

e. Implementation of the MPU6050 Sensor Design Results

Figure 18. MPU6050 Design Results

Based on Figure 18. It can be seen where the VCC and GND pins of the MPU6050 are connected to the breadboard, the SCL and SDA pins of the MPU6050 are connected to pins A4 and A5 on the Arduino. The MPU6050 measures the tilt or angle of the panel to keep it at the optimal angle.

f. Implementation of Battery Design Results

Figure 19. Battery Design Results

Based on Figure 19, you can see where the battery is connected to the Solar Charge Controller. The battery stores the energy generated by the solar panel.

g. Implementation of LDR Sensor Design Results

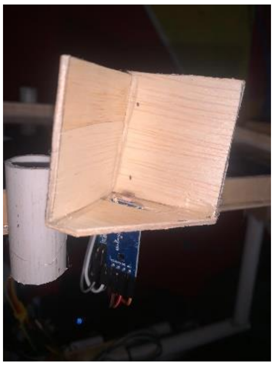

Figure 20. LDR Sensor Design Results

Based on Figure 20, you can see where the VCC and GND pins of the LDR are connected to the Arduino via a breadboard. The LDR output pin is connected to pins A0 and A1 on the Arduino. The LDR functions to detect the presence of light.

h. Implementation of Buck Converter Design Results

Figure 21. Buck Converter Design Results

Based on Figure 21, you can see the IN+ and IN- pins on the Solar Charge Controller, while the OUT+ and OUT- pins are connected to VCC and GND on the Servo Motor. The Buck Converter functions to regulate the appropriate voltage for the components.

i. Implementation of Solar Panel Design Results

Figure 22. Solar Panel Design Results

Figure 22 shows the solar panel connected to a solar charge controller. The solar panel has a capacity of 20 watts. The solar charge controller then regulates the energy absorbed by the panel for use or storage in the battery.

B. Discussion

1. Tool Test Results

a. Control Test Results

Using the Blynk application, we obtained the slope and LDR sensor values. This test was conducted over three days. For more details, see the table.

Table 1. Test Results 1

Clock	Left LDR Value	Right LDR Value	Tool Angle Measurement Results (°)	Manual Angle Measurement Results (°)	Difference (°)
09:00	143	169	67	67	0
10:00	179	154	69	69	0
11:00	127	101	79	80	1
12:00	113	106	90	90	0
13:00	120	95	102	104	2
14:00	149	122	119	117	2
15:00	171	141	129	129	0
16:00	105	92	138	137	1
17:00	163	146	145	146	1
Average Error %					0,77

Based on Table 1 above, the test results are from 9:00 AM to 5:00 PM, where the panel position is from east to west. In this test at 10:00 AM and 11:00 AM, the sunlight was blocked by clouds, so the results obtained from the LDR sensor value were less effective. In this test, the average error obtained within 1 hour was 0.77.

Table 2. Test Results 2

Clock	Left LDR Value	Right LDR Value	Tool Angle Measurement Results (°)	Manual Angle Measurement Results (°)	Difference (°)
09:00	182	212	59	64	5
10:00	111	138	67	66	1
11:00	60	75	79	78	1
12:00	57	86	90	90	0

Clock	Left LDR Value	Right LDR Value	Tool Angle Measurement Results (°)	Manual Angle Measurement Results (°)	Difference (°)
13:00	118	102	106	110	4
14:00	55	26	121	122	1
15:00	97	68	138	137	1
16:00	64	40	147	147	0
17:00	156	139	158	155	3
Average Error %					1,77

Based on Table 2 above, the test was conducted between 9:00 AM and 5:00 PM, with the panels positioned east to west. In this test, the weather at 9:00 AM was cloudy, resulting in less effective results. The average error within one hour of this test was 1.77.

Table 3. Test Results 3

Clock	Left LDR Value	Right LDR Value	Tool Angle Measurement Results (°)	Manual Angle Measurement Results (°)	Difference (°)
09:00	150	173	62	64	2
10:00	109	138	67	66	1
11:00	187	210	77	80	3
12:00	192	215	97	90	7
13:00	137	102	109	110	1
14:00	139	109	131	132	1
15:00	142	118	143	144	1
16:00	124	94	156	156	0
17:00	113	84	162	165	3
Average Error %					2,11

Based on Table 3 above, the test was conducted between 9:00 AM and 5:00 PM, with the panels positioned east to west. This test, conducted between 11:00 AM and 12:00 PM, yielded less effective results. The average error within an hour was 2.11.

The results of tests 1, 2, and 3, conducted at the same time, revealed different sensor values. This is because the light intensity measured in test 1 differs from the results obtained in tests 2 and 3. However, these results are not yet valid, as this test is based solely on observations of the LDR sensor and has not been further tested with other sensors.

b. Test Results on the Blynk Application

1. Measurement display on the blynk app

Figure 23. Online view on blynk

In Figure 23 above is the display of the Blynk application in online condition where the icon above is lit in green and the measurement results on Blynk with the results obtained are a slope of 69□, the resistance value obtained from the left LDR is 179 and the value from the right LDR is 154.

Figure 24. Offline view on the blynk app

In figure 27 above, the Blynk application display is displayed in offline mode. You can see that the icon above is not lit green, indicating that the tool is not active. The measurement results that appear in the Blynk application are based on the previous measurement results in online mode.

IV. Conclusion and Suggestions

Based on the research conducted on the Arduino-based solar tracking system, it can be concluded that it successfully operated, measuring the panel's tilt, automatically moving according to the light, and directly sending tilt data to the Blynk application for direct control and monitoring, accessible via smartphone or PC. The NodeMCU, which features a Wi-Fi module, makes it easier for users to control and monitor it anytime, anywhere.

Based on the test results, this tool still has several shortcomings. Therefore, the author recommends several things in the development of this tool: developing the Arduino-based solar tracking system on a larger scale, such as for large companies and offices. Adding sensors that can automatically measure incoming current and power. The Blynk application, which is used as a medium, is expected to be developed using a custom application for greater safety and effectiveness.

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