Design of a Solar Panel Tracking System with Dual Axis Based on Arduino to Optimize Solar Panel Power Output

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Abstract. Solar panels are devices that can convert solar energy into electrical energy. People often install solar panels on building roofs, on open land, and even on vehicles like boats and electric cars to produce clean and sustainable electricity. Solar panels are an effort to reduce the use of fossil fuel-based electrical energy, which contributes to global warming. Tropical countries such as Indonesia utilize solar panels. This research aims to design a dual- axis solar panel tracking system based on Arduino for use in various areas. This system aims to address energy issues by utilizing solar energy as an alternative energy source. This tool em- ploys literature and field research methods. This tool will design a Solar Tracker that utilizes sunlight as its input, an LDR as a sensor, an Arduino Uno as a control system, a servo motor as the actuator output to move the solar panel, a lithium battery to store solar panel power, and a dual-axis bracket that serves as a tracker for solar panels and a driver for solar panels that track the sun's movement. The Arduino IDE (Integrated Development Environment) software pro- cesses the Arduino data. The 3rd test (final test) reveals that the solar tracker on the solar panel can generate 5.47 watts of power.

.**Keywords:** solar panel, solar tracker, arduino uno, sensor LDR (light dependent resistor)

1 Introduction

In this era, Indonesia's need for electrical energy is growing. This is due to increased population growth and technological advances that utilize electrical energy. One of the technologies used to produce electrical energy is the use of solar panels. Solar panels are an effort to reduce the use of fossil fuel-based electrical energy, which contributes to global warming. When used in tropical countries like Indonesia, solar panels are effective. The Ministry of Energy and Mineral Resources reported in 2012 that the equator passes through Indonesia. This indicates that Indonesia has abundant solar energy sources, with an average radiation intensity of about 4.8 kWh/m^2 per day and an average sunshine duration of 12 hours per day. The static use of solar panels limits their ability to receive sunlight, as they only receive it from one direction. To receive optimal sunlight, solar panels must follow the sun's movement.

This research develops a dual-axis solar panel tracking system based on Arduino to optimize the power output of solar panels. The dual-axis solar tracker enhances the solar panels' reception of solar energy by incorporating four LDR light sensors, positioned at different angles on the solar cells, to detect the sun's movement. The Arduino microcontroller receives the output from the light sensors, processes the data,

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and then directs the servo motor to move the solar panel accordingly. This solar tracker employs LDR sensors. The bracket serves as a support for the solar panel and the dual-axis actuator, enabling the solar panel to move flexibly in response to the direction of sunlight.

2 Research Methodology

2.1 Location and Time of Research

The research location's coordinates are -6.97661.107.65152, located in the GBA West Bojongsoang District, Bandung Regency, is located at an altitude of 665 meters above sea level. The prototype work spans 5 months and involves two distinct phases. The manufacturing process took place from September to November. Testing the tool took place between January and March.

2.2 Research Methods

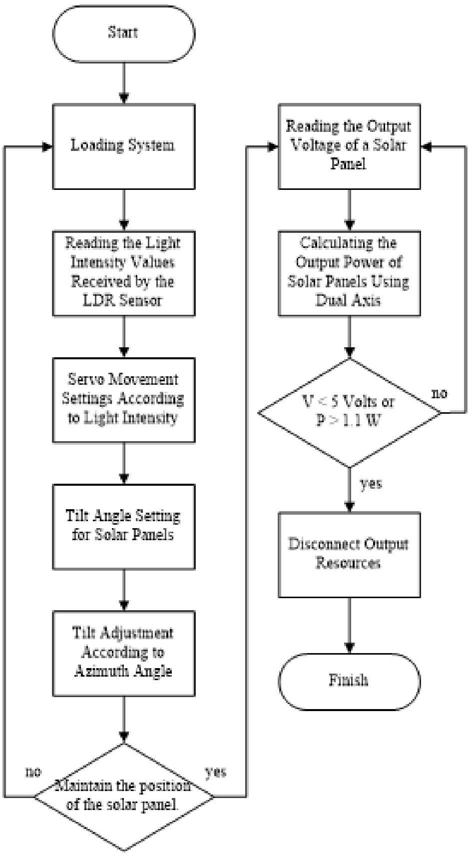

Figure 1 Research Flowchart

The method used is literature observation and experiment. The research process includes problem identification, literature review, data collection, processing, and calculation once the results are prepared for analysis. The figure 1 shows how the research was conducted.

For comparative power data, use the following formula:

$$P = I \text{ x } V \tag{1}$$

P = Watt
I = Ampere
V = Volt

3 Result and Discussion

3.1 Arduino Software Design

```
#include <Servo.h>

Servo servohori; //horizontal servo(BOTTOM SERVO)
int servoh = 0; //tetapkan servo pada 0 derajat
int servohLimitHigh = 180; //jangkauan maksimum servo adalah 180 derajat
(variabel ini juga dapat anda ubah)
int servohLimitLow = 10;    //jangkauan minimum servo adalah 10 derajat
(variabel ini juga dapat anda ubah)

Servo servoverti; //vertical servo(TOP SERVO)
int servov = 0; //tetapkan servo pada 0 derajat
int servovLimitHigh = 180;//jangkauan maksimum servo adalah 180 derajat
(variabel ini juga dapat anda ubah)
int servovLimitLow = 10; //jangkauan minimum servo adalah 10 derajat
(variabel ini juga dapat anda ubah)

int ldrtopr = 1; //atas kanan LDR A1 pin
int ldrtopl = 2; //atas kiri LDR A2 pin

int ldrbotr = 0; // bawah kanan LDR A0 pin
int ldrbotl = 3; // bawah kiri LDR A3 pin


 void setup ()
 {
  pinMode(A1, INPUT);
  pinMode(A2, INPUT);
  pinMode(A0, INPUT);
  pinMode(A3, INPUT);
  servohori.attach(10); //servo horizontal terhubung ke arduino pin 10
  servohori.write(0);

  servoverti.attach(9); //servo vertikal terhubung ke pin 9
  servoverti.write(0);
  delay(500); //delay
  Serial.begin(9600);
 }

void loop()
{
  servoh = servohori.read();
  servov = servoverti.read();
```

```
  int topl = analogRead(ldrtopl); //pemembacaan nilai analog pada bagian kiri
atas LDR
  int topr = analogRead(ldrtopr); //pembacaan nilai analog pada bagian kanan
atas LDR
  int botl = analogRead(ldrbotl); //pembacaan nilai analog pada bagian kiri
bawah LDR
  int botr = analogRead(ldrbotr); //pembacaan nilai analog pada bagian kanan
bawah LDR

  Serial.println(ldrtopl);
  Serial.println(ldrtopr);
  Serial.println(ldrbotl);
  Serial.println(ldrbotr);


  int avgtop = (topl + topr) / 2; //rata rata LDRs atas
  int avgbot = (botl + botr) / 2; //rata rata LDRs bawah
  int avgleft = (topl + botl) / 2; //rata rata LDRs kiri
  int avgright = (topr + botr) / 2; //rata rata LDRs kanan

  if (avgtop < avgbot)
  {
    servoverti.write(servov -1);
    if (servov > servovLimitHigh)
     {
      servov = servovLimitHigh;
     }
    delay(8);
  }
  else if (avgbot < avgtop)
  {
    servoverti.write(servov +1);
    if (servov < servovLimitLow)
  {
    servov = servovLimitLow;
  }
    delay(8);
  }
  else
  {
    servoverti.write(servov);
  }

  if (avgleft > avgright)
   {
     servohori.write(servoh -1);
     if (servoh > servohLimitHigh)
     {
     servoh = servohLimitHigh;
     }
     delay(8);
   }
   else if (avgright > avgleft)
   {
     servohori.write(servoh +1);
     if (servoh < servohLimitLow)
      {
      servoh = servohLimitLow;
      }
     delay(8);
   }
   else
   {
     servohori.write(servoh); // write berarti menjalankan servo
   }
   delay(50);
```

Figure 2 Arduino Software Result

3.2 Design of Tools

This tool utilizes a 110x60x2.5mm solar panel with a 5V output power of 1.1W and 0-200MA capacity, along with a Dual Axis Bracket. This bracket, shaped like angled elbows and measuring 21cm in total length, 2.2cm in width, and 3mm in thickness, serves as a pan tilt system for supporting solar panels.

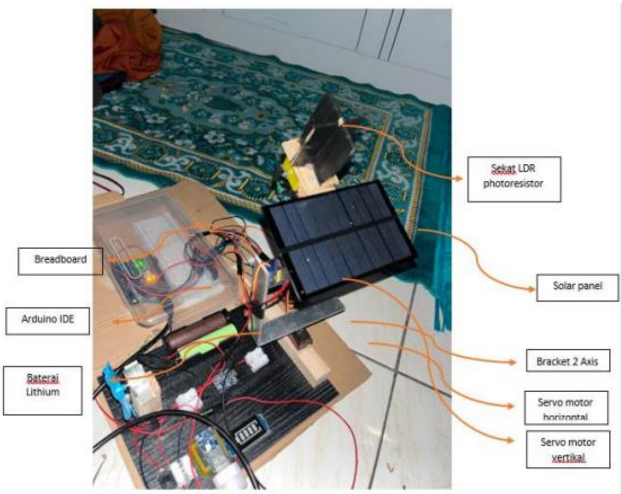

Figure 3 Solar Tracker Prototype

3.3 Test Result

Due to unpredictable weather conditions, testing solar panels with a solar tracker yields different results at each measurement time. We took the measurements three times to confirm the tracker's proper functioning. The greater the output voltage, the greater the power produced. Here are the results of the first experiment's output measurement using a digital multimeter.

Table 1 shows that using the tracker during the first power output test resulted in a greater power output compared to the fixed position at 90 degrees. Because the weather was clear during the test, we recorded the highest power output between 08:00 and 12:00. The total power generated by the tracker is 2.76 Watts.

Meanwhile, in table 2, the second power output test produced a greater power output when using a solar tracker compared to a fixed position. The highest power output occurred only between the hours of 10:00 and 11:00 due to the cloudy weather during the test. The total power generated by the tracker is 2.26 Watts.

Table 1 the First Measurement of Voltage and Current Yielded Result

Time (WIB)	Solar panels generate voltage (V)	Solar panels generate current (mA)	Solar Panels generate power output (Watt)	Description
07.00	4.92	19.90	0.09	Cloudy
08.00	5.22	33.21	0.17	Clear
09.00	5.39	37.82	0.20	Clear
10.00	5.45	80.99	0.42	Clear
11.00	5.51	95.98	0.52	Clear
12.00	5.75	110.11	0.63	Clear
13.00	5.48	70.09	0.38	Cloudy
14.00	4.80	32.16	0.15	Rain
15.00	4.75	22.14	0.10	Rain
16.00	4.47	15.09	0.06	Rain
17.00	4.15	9.01	0.03	Rain
18.00	3.65	3.04	0.01	Rain

Table 2 Second Measurement of Voltage and Current Yielded Result

Time (WIB)	Solar panels generate voltage (V)	Solar panels generate current (mA)	Solar Panels generate power output (Watt)	Description
07.00	4.98	11.17	0.05	Cloudy
08.00	5.15	24.52	0.12	Clear
09.00	5.20	39.41	0.20	Clear
10.00	5.54	87.83	0.48	Clear
11.00	5.61	98.10	0.55	Clear
12.00	5.15	60.02	0.30	Clear
13.00	5.09	33.88	0.17	Cloudy
14.00	5.02	29.16	0.14	Rain
15.00	4.98	22.14	0.11	Rain
16.00	4.80	19.10	0.09	Rain
17.00	4.17	11.04	0.04	Rain
18.00	3.16	3.70	0.01	Rain

In table 3, the third power output test shows that the power is greater when using a solar tracker compared to a fixed position. The hours of 08:00-17:00 generated the most power because the weather during the testing was clear throughout the day. After three testing trials, this third test produced the best power output. The total power generated by the tracker is 5.47 Watts.

Table 3 Third Measurement of Voltage and Current Yielded Result

Time (WIB)	Solar panels generate voltage (V)	Solar panels generate current (mA)	Solar Panels generate power output (Watt)	Description
07.00	5.31	35.41	0.18	Cloudy
08.00	5.75	87.90	0.45	Clear
09.00	5.78	98.90	0.57	Clear
10.00	5.84	105.80	0.61	Clear
11.00	5.85	114.47	0.66	Clear
12.00	5.89	118.10	0.69	Clear
13.00	5.73	107.56	0.61	Clear
14.00	5.66	101.33	0.57	Clear
15.00	5.57	95.18	0.53	Clear
16.00	5.52	73.25	0.40	Clear
17.00	5.15	30.72	0.15	Clear
18.00	4.86	11.25	0.05	Cloudy

Table 4 Comparison Results of Solar Panel Power Output

Solar Panels generate power output		
First Experiment	Second Experiment	Third Experiment
2.67	2.26	5.47

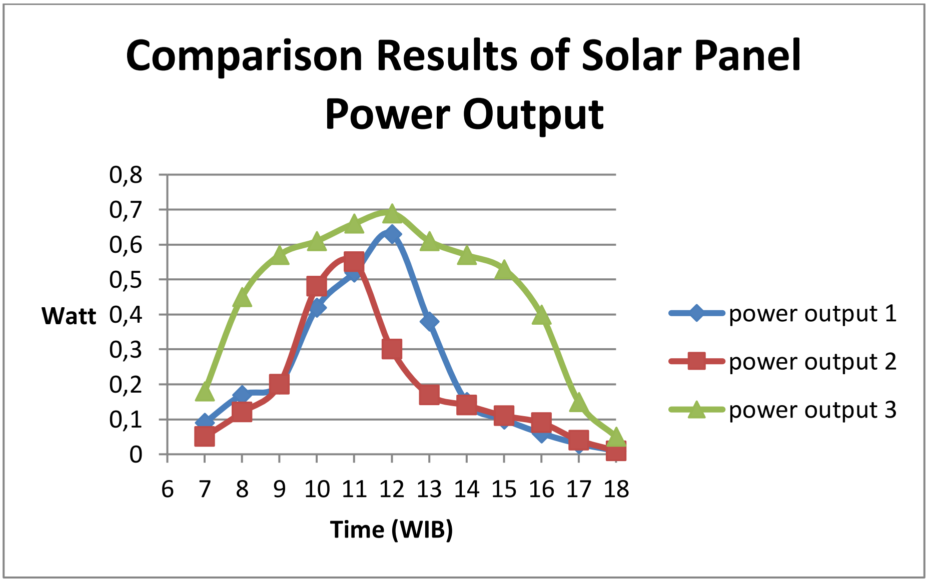

Figure 4 Comparison Result of Solar Panel Power Output Graph

We conducted the output power testing of the solar panel with the tracker in three testing sessions, as shown in Table 4 and Figure 4 above. The testing time is from 07:00 to 18:00. The first test produced 2.76 watts of power at the tracker position. This test was quite successful because, at the time of the first test, the weather conditions had changed and the sun was shining only from 08.00 to 12.00. The second test generated 2.26 watts at the track position. The results of the second test were not good because during the second test, the weather conditions were still variable, and it was only clear from 10:00 to 11:00. The third test produced a power output (watts) of 5.47 watts at the tracker position, and this result is good because the weather was clear throughout the day.

4 Conclusion

The solar tracker prototype, based on an Arduino Uno with LDR light sensors, can direct the solar panel towards the sun by following its movement, according to the results obtained. In the first test conducted on January 23, 2024, from 07:00 to 18:00 WIB, a power output of 2.76 watts was produced. The second test, carried out on February 9, 2024, resulted in a power output of 2.26 watts, and the third test conducted on March 20, 2024, yielded a power output of 5.47 watts.

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