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Solar Tracker Prototype Based on Arduino Uno

Setiyono[1], Kunto Wibowo[2]
[1,2] Universitas Gunadarma, Jl. Margonda Raya 100 Pondokcina, Depok 16424, Indonesia

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ABSTRACT

The placement of solar panels to capture solar energy is generally installed in a certain and fixed position (static). The dynamic change in the sun's position from east to west at any time means that the solar panels absorb less energy. So, installing an automatic driving device on the solar panel to adjust its perpendicular position to the sun's rays is very necessary. This Solar Tracker tool has 4 light sensors that function to identify the intensity of sunlight as a signal entered by the Arduino Uno microcontroller. This information is then processed to become a signal to drive horizontal and vertical servo motors. The shaft of this motor is connected to the mechanical circuit of the solar panel via a gearbox to carry out movement. A comparator will compare sunlight information and a reference voltage to control the rotation of the servo motor which can determine the time needed for the motor to rotate or stop. The research results on solar panels using a tracker were that the best voltage and current values were obtained between 12.00-13.00 WIB with an average voltage value of 11.45 V and an average current value of 0.49A.

Corresponding Author:

Setiyono
Universitas Gunadarma, Jl. Margonda raya 100, Pondokcina Depok 16424, Indonesia
Email: setiyono@staff.gunadarma.ac.id

1. INTRODUCTION

The electricity and transportation industries are the main sources of global greenhouse gas emissions, contributing 40% and 24% respectively [1]. In the future, renewable energy sources will be better known as clean energy sources, which are power plants that have the potential for several consumers and the market is growing more rapidly. The fundamental reason is the emergence of global concerns about climate change [2]. One renewable energy that is environmentally friendly is the use of sunlight. Solar energy can be converted into electrical energy using semiconductor devices in the form of photovoltaics made from high-efficiency silicon silica (c-Si) crystals [3,4]. Solar energy can be obtained when the sun emits rays to the earth that move from east to west at a certain time. Nowadays, photovoltaics (PV) is growing in popularity because it is easily available. In Korea, solar panel (PV) devices are widely used to produce solar energy, and are one of the promising sources of renewable energy [5]. Photovoltaic systems can be synergistic or hybrid with other power generation networks such as wind power plants and can be built independently to increase electricity generation capacity [6] [7]. Solar panels are very appropriate for buildings in areas that are difficult to reach by conventional power plants, especially areas with certain heights, for example, mountainous areas [8]. In general, solar panels are installed by consumers in a permanent or fixed position, in a certain direction. This can cause non-continuous energy reception therefore we need a device that can follow the movement of the sun so that the position of the solar panel will always receive maximum sunlight. A solar tracker is a system designed so that solar cells are always in a perpendicular position to sunlight [9,10]. However, if the

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energy used to move the tracker system is greater than the energy produced by the solar panel, then the position updating system is no longer needed [11].

To obtain maximum output power from solar panels without depending on temperature and solar radiation, control is required using the Maximum Power Point Tracking (MPPT) method to maintain PV performance at the MPP (Maximum Power Point) point [12]. However, some external influences such as weather and dust can reduce the maximum power received from solar cells [13]. Based on the number of rotation axes, Solar Tracker Systems can be classified into two, namely: one rotation axis and two rotation axes. Single-axis solar trackers have high-cost drive parts and control systems, this type of solar tracker is more suitable for small-sized solar cells. Single-axis solar trackers generally have a manual elevation angle setting on the second axis which is set at a fixed time period each year [14]. Until now, technology related to controlling solar panels continues to be developed, Nadia AL-Rousan developed an Artificial Intelligence application, an Adaptive Fuzzy Neural Inference System for controlling sunlight tracking on solar panels [15]. In a two-axis Solar Tracker system, the two circuits that track light consist of the same four LDR sensors placed on the east, west, south and north and two electric motors placed on each axis.

2. RESEARCH METHOD

The solar tracker prototype was made in two stages, namely designing the system block and then implementing it into an electronic control circuit. The outline of the system design is shown in Figure 1.

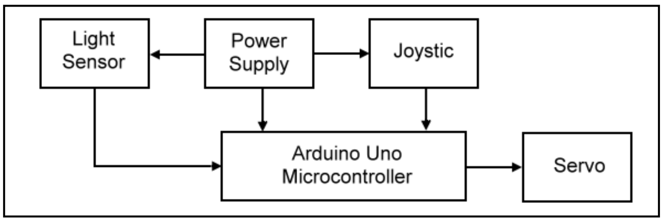

Figure 1. Diagram block

Figure 1 is an image of the block diagram process for designing a solar tracker prototype, each block has a different function. The power supply is a DC voltage supply, the DC voltage source supplies the light sensor circuit, Arduino UNO microcontroller, and joystick. There are 2 inputs, namely a light sensor which will detect the intensity of sunlight, and there is a joystick which will regulate the direction of movement of the solar panels. The process is carried out by the Arduino UNO microcontroller which processes data from the light sensor and joystick in the form of analog signals. The output of all data processed by the Arduino UNO will be sent to the servo to move the solar panel to a position with bright light intensity or according to the direction of movement of the joystick.

2.1. Research Workflow Diagram

The research workflow is shown in Figure 2. The research begins with designing the tool, assembling the tool (including repairs if necessary), and testing the tool as a whole.

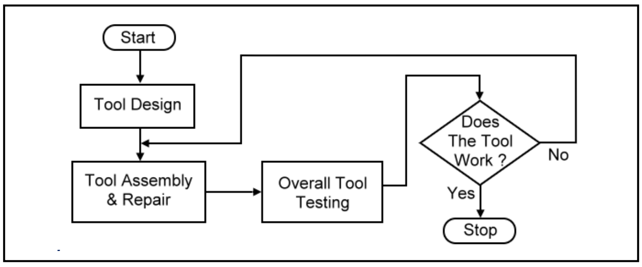

Figure 2. Research workflow diagram

In the process of making a solar tracker prototype, the first step that must be done is designing the tool. The prototype is designed in such a way that it can move the solar panels following the direction of the Sun.

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2.2. Flowchart of Tool Working Principles

The flow diagram of the working principle of the tool can be seen in Figure 3. The power supply as a DC 9V voltage source supplies the light sensor circuit, joystick, and Arduino UNO microcontroller.

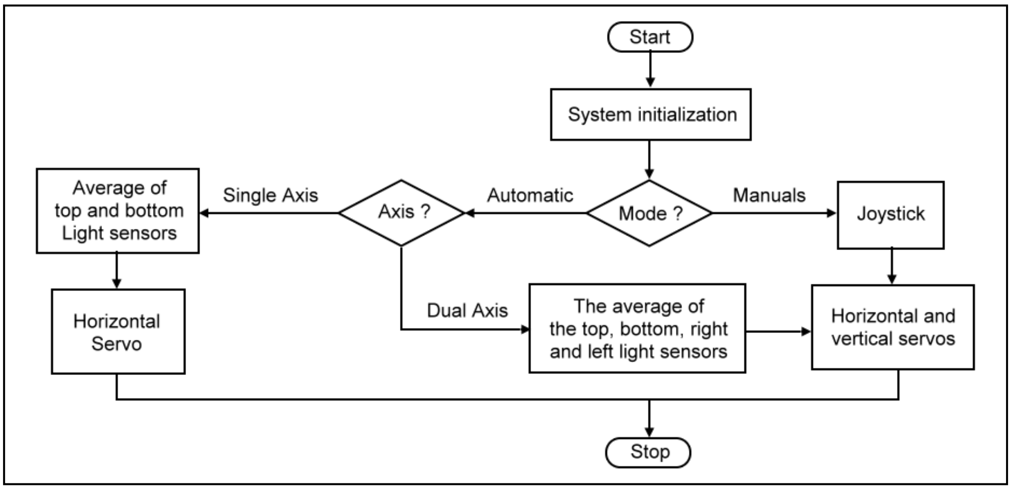

Figure 3. Flowchart of Working Principles

The way this tool works starts with initializing the Arduino UNO microcontroller, then the Arduino UNO will detect whether the mode selected is manual or automatic. When manual mode is selected, the joystick will read and move the horizontal servo and vertical servo. When in single-axis automatic mode, it will calculate the average of the up-down light sensors and activate the horizontal servo towards brighter light. When in dual axis automatic mode it will calculate the average from the up-down sensor and right-left sensor and activate the horizontal and vertical servos.

2.3. Control Circuit

The tool components used in the entire solar tracker prototype system can be seen in Figure 4.

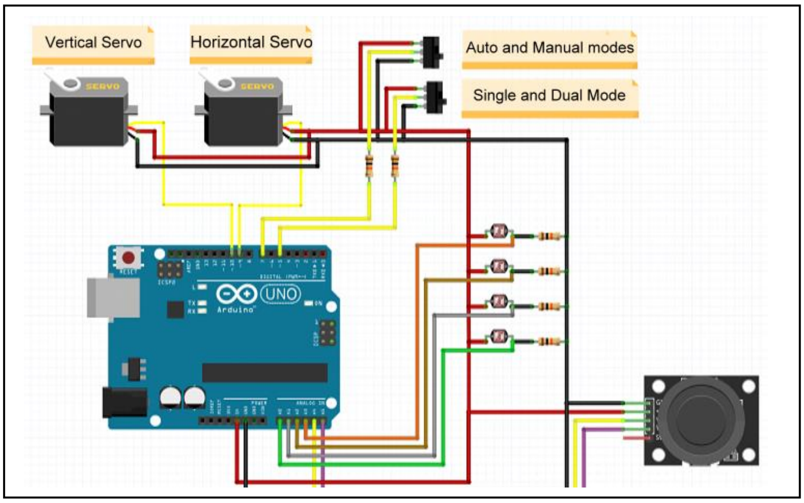

Figure 4. Schematic circuit of the tool

Figure 4 shows the entire series of components used in the solar tracker prototype using a light sensor and joystick. In the input section there is a power supply as a voltage source. In the input section there are 4 light sensors placed at the top left, top right, bottom left and bottom right. The light sensor functions to detect sunlight which will then be processed by the Arduino UNO microcontroller and will move the servo horizontally and vertically following the direction of the sun. The joystick functions as a manual driver which is processed by the Arduino UNO microcontroller and will later move the horizontal and vertical servos.

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2.4. Hardware Prototype

This stage carries out the design of all components, starting from making the solar tracker prototype frame to installing the electronic components on the solar tracker prototype.

Figure 5. Solar Tracker Frame, Light Sensor Housing, Component Box

Figure 5 explains the hardware of the solar tracker system being made. The important parts of the tool are the light tracking unit, light sensor and control box.

2.5. Software

Making software is a program of all the commands that will run this tool. It could be said that this is the most important part in creating a condition program. The program code will be created as below:

```
include <Servo.h>
int switch1Pin = 5; //onoffswitch
int switch2Pin = 7; //singledualswitch
int ldrtopl = A0; //top left
int ldrtopr = A1; //top right
int ldrbotl = A2; //bottom left
int ldrbotr = A3; //bottom right
int left_joystick_x = A4; //Horizontal
int left_joystick_y = A5; //Vertical
void setup() {
servohori.attach(9); //Servo X
servohori.write(90);
servoverti.attach(10); //Servo Y
servoverti.write(90);
delay(500);
pinMode (5, INPUT_PULLUP); //onoffswitch
pinMode (7, INPUT_PULLUP); //singledualswitch
pinMode (9, OUTPUT);
pinMode (10, OUTPUT);
Serial.begin(9600);
}
```

The void setup defines the input and output, where the horizontal servo or servo X is connected to digital pin 9 and the vertical servo or servo Y is connected to digital pin 10. For manual and automatic selectors it is connected to digital pin 5 and for single axis or dual axis selectors it is connected to digital pin 7. The light sensor is connected to analog pins A0 to A3 and the vertical horizontal joystick is connected to analog pins A4 to A5.

2.6. Single Axis Automatic Software Design

Software design for a single-axis automatic program is a program for a light sensor that functions to control the X-axis servo motor. By comparing the top and bottom light sensors.

Single Axis Automatic Software Design

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```
int avgtop = (topl + topr) / 2; //above average
int avgbot = (botl + botr) / 2; //lower average
if (avgtop < avgbot){
servohori.write(servoh -1);
if (servoh > servohLimitHigh){
servoh = servohLimitHigh;
}
delay(100);
}
else if (avgbot < avgtop){
servohori.write(servoh +1);
if (servoh < servohLimitLow){
servoh = servohLimitLow;
}
delay(100);
}
else{
servohori.write(servoh);
}
delay(50);
```

3. RESULTS AND DISCUSSION

Testing on the solar tracker prototype was carried out for three days from 7.00 – 17.00 WIB, with data taken every 1 hour. Solar panel voltage and current testing is carried out without load to obtain Voltage (V) and Current (I) values, weather conditions are categorized as clear and cloudy. The position of the solar panel is observed using the Arduino application which will display the position of the servo motor in degrees. Solar panel voltage and current measurements are measured using a multimeter.

Table 1. First Day Tool Data Collection

No	Time	Voltage (V)	Current (I)	Weather Conditions	Servo X Position	Servo Y Position
1.	7.00	10.50	0.36	Cloudy	140°	180°
2.	8.00	11.00	0.40	Cloudy	130°	180°
3.	9.00	11.30	0.44	Bright sky	120°	180°
4.	10.00	11.36	0.48	Bright sky	110°	180°
5.	11.00	11.60	0.50	Bright sky	100°	180°
6.	12.00	12.18	0.66	Bright sky	90°	180°
7.	13.00	12.05	0.65	Bright sky	80°	180°
8.	14.00	12.00	0.62	Bright sky	70°	180°
9.	15.00	11.70	0.53	Bright sky	60°	180°
10.	16.00	11.55	0.50	Bright sky	50°	180°
11.	17.00	11.12	0.38	Cloudy	40°	180°

Table 1 shows the values of voltage, current, servo X position and sevo Y position obtained from 140° – 40°. The highest voltage and current values were obtained at 12.18 V and 0.66 A at 12.00, and the lowest voltage and current values were 10.50 V and 0.36 A, so the difference between the voltage at the highest and lowest values was 1.68 V and the difference between the current at the highest and lowest values was 0.3A. The highest voltage and current values are at 12.00 WIB, with the solar panel positioned at 90°. It can be seen that the time range that gets the highest voltage and current values is around 11.00 – 13.00 WIB.

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Table 2. Second Day Tool Data Collection

No	Time	Voltage (V)	Current (I)	Weather Conditions	Servo X Position	Servo Y Position
1.	7.00	11.10	0.40	Bright sky	140°	160°
2.	8.00	11.20	0.42	Bright sky	129°	160°
3.	9.00	11.30	0.46	Bright sky	123°	160°
4.	10.00	11.35	0.49	Bright sky	120°	160°
5.	11.00	11.60	0.53	Bright sky	100°	160°
6.	12.00	12.35	0.62	Bright sky	95°	160°
7.	13.00	12.10	0.58	Bright sky	86°	160°
8.	14.00	11.50	0.50	Bright sky	82°	160°
9.	15.00	11.00	0.43	Cloudy	75°	160°
10.	16.00	10.48	0.40	Cloudy	64°	160°
11.	17.00	10.33	0.35	Cloudy	55°	160°

Table 2 shows the values of voltage, current, servo X position and sevo Y position obtained from 140° – 55°. So that the highest values of voltage and current are 12.35 V and 0.60 A at 12.00, and the lowest values of voltage and current are 10.33 V and 0.31 A, so the difference in voltage at the highest and lowest values is 2.02 V and the difference in current at the highest and lowest values is 2.02 V. 0.27A. The highest voltage and current values are at 12.00 WIB, with the solar panel positioned at 95°. It can be seen that the time range that gets the highest voltage and current values is around 11.00 – 13.00 WIB.

Table 3. Third Day Tool Data Collection

No	Time	Voltage (V)	Current (I)	Weather Conditions	Servo X Position	Servo Y Position
1.	7.00	10.85	0.35	Cloudy	140°	160°
2.	8.00	11.21	0.42	Cloudy	130°	160°
3.	9.00	11.29	0.44	Bright sky	120°	160°
4.	10.00	11.36	0.47	Bright sky	110°	160°
5.	11.00	11.64	0.56	Bright sky	100°	160°
6.	12.00	12.16	0.63	Bright sky	90°	160°
7.	13.00	12.40	0.73	Bright sky	80°	160°
8.	14.00	12.07	0.60	Bright sky	70°	160°
9.	15.00	11.86	0.58	Cloudy	60°	160°
10.	16.00	11.24	0.46	Cloudy	50°	160°
11.	17.00	11.20	0.44	Cloudy	40°	160°

Table 3 shows the values of voltage, current, servo X position and sevo Y position obtained from 140°-40°. So that the highest voltage and current values are 12.40 V and 0.73 A at 13.00, and the lowest voltage and current values are 10.85 V and 0.35 A, so the difference between the voltage at the highest and lowest values is 1.85 V and the difference between the current at the highest and lowest values is 1.85 V. 0.38 A. The highest value of voltage and current at 13.00 WIB, achieved with the solar panel position at 80°. It can be seen that the time range that gets the highest voltage and current values is around 12.00-14.00 WIB.

3.1. Servo Axis Testing

Servo axis testing is carried out using an Arduino idea which will show the magnitude of the servo movement due to changes in the direction of the light sensor.

Table 4. Servo Axis Testing of Light Sensors

No	Light Sensor				Servo	
	Top Left	Top right	Bottom left	Bottom right	Horizontal	Vertical
1	<500	<500	>500	>500	180°	0°
2	>500	>500	<500	<500	0°	180°
3	<500	>500	<500	>500	180°	0°
4	>500	<500	>500	<500	0°	180°

Table 4 shows the angles of the horizontal and vertical servo motors according to the light sensor values. When the top left light sensor is <500, the top right light sensor is <500, the bottom left light sensor is >500, the bottom right light sensor is >500 then the horizontal servo is at an angle of 180º and the vertical servo is at an angle of 0º. When the top left light sensor is >500, the top right light sensor is >500, the bottom left light sensor is <500, the bottom right light sensor is <500 then the horizontal servo is at an angle of 0º and the vertical servo is at an angle of 180º. When the top left light sensor is <500, the top right light sensor is >500, the bottom left light sensor is <500, the bottom right light sensor is >500 then the horizontal servo is at an angle of 180º and the vertical servo is at an angle of 0º. When the top left light sensor is >500, the top right light sensor is <500, the bottom left light sensor is >500, the bottom right light sensor is <500 then the horizontal servo is at an angle of 0º and the vertical servo is at an angle of 180º.

4. CONCLUSION

The prototype of the sun ray tracker that was built can work well, the sun ray tracking process is carried out by four LDR sensors which will detect the movement of the sun rays and convert them into input for the microcontroller to give commands to the motor to move right to left or up and down. There are two working modes of this tool, namely automatic mode and manual mode. Automatic mode will work based on the top and bottom light sensors for horizontal movement using a single axis and the top, bottom, right and left light sensors for vertical movement using a dual axis. The average measurement results for 3 days show the highest voltage and current values at 12.00 with voltage levels of 12.15 V and 0.64 A.

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