

Dual Axis Solar Tracker Using Astronomic Method Based Smart Relay

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Abstract—Solar energy is a renewable energy. Solar energy can be utilized using solar panels. The use of solar panels mostly uses static or silent methods. The static method on solar panels cannot produce optimal electrical energy. This is because the intensity of sunlight received by solar panels is less than optimal. So that the resulting electrical energy is not optimal. Therefore we need a system that can control solar panels automatically. this system must also be able to follow the direction of movement of sunlight. This study discusses the dual axis solar tracker using smart relay-based astronomical methods. This study adjusts the angle of the solar panels to determine the movement of the sun. This study uses a smart relay to regulate the rotation of the DC motor (Linear Actuator) and the motor power window which functions as a driving force for solar panels. Astronomical method is used for tracking sunlight. This method is based on the position of the sun according to the lunar calendar. This method uses an angle sensor in the form of a variable resistor for elevation and a rotary encoder as an azimuth angle sensor. The results obtained from this study are the optimal electrical energy output from solar energy.

Keywords—renewable energy, dual axis, solar tracker, solar panel, astronomical method

I. INTRODUCTION

Solar energy is one of the most attractive because of its abundant availability, even though only at certain times. The application uses are quite diverse, such as battery charging, public street lighting, electricity generators for households, heating systems in swimming pools, and others [1]. The advantage of using this alternative energy is in terms of maintenance and pollution-free [2]. One of the tools that utilize solar energy is solar panels. Solar panels work to convert light energy into electrical energy. Solar panels generate DC electric current (direct current). The main obstacle to solar panels is their relatively low efficiency [3]. In its use, many solar panels are installed statically and do not take into account the optimal point of sunlight [4]. This causes the intensity of sunlight received to be less than optimal. The electrical energy generated from the solar tracker will be maximized if the solar panels are always perpendicular to the direction of the sunlight [5]. In other words, solar panels must follow the direction of movement of sunlight (solar tracker system). Therefore we need a system that can control solar panels automatically so that they remain perpendicular to the direction of the sun [6]. This study uses a smart relay to regulate the rotation of the DC motor (Linear Actuator) which functions as a driving force for solar panels [7]. This study discusses a solar panel tracker using smart relay-based astronomical methods.

II. RESEARCH METHODOLOGY

Several components and the method in this research will be described in the following below.

A. Solar Panel

Solar panels are used as the main source in the dual axis solar tracker system. Solar panels can convert solar energy into electrical energy using the principle of the Photovoltaic effect. The photovoltaic effect is a phenomenon in which an electric voltage arises due to the connection between two electrodes which is connected to a solid or liquid system when receiving sunlight energy. In 1839 the photovoltaic effect was applied by Henri Becquerel. Basically, a Solar Cell is a Photo Diode (Photodiode) with a large surface according to Figure 1. The surface area of the Solar Cell makes this Solar Cell device more sensitive to incoming light and produces a Voltage and Current that is stronger than a photo diode in general.



Fig. 1. Solar panel

B. Linier Actuator

The Linear actuator is a motion that moves linearly or moves in a straight line by utilizing the difference in air pressure on the actuator. The actuator has a working principle if the actuator wants to move forward, then the air pressure applied to the forward side must be greater than the air pressure on the reverse side according to Figure 2. Likewise, vice versa, when the actuator wants to move backwards, it must be greater than the air pressure on the forward side. The movement speed of the actuator will be affected when there is a difference in air pressure on the forward and reverse side.



Fig. 2. Linier actuator

C. Motor Power Window

The motor that drives the regulator rotates clockwise or the opposite direction moves the window regulator to be converted into an up and down motion. DC motors are widely used for power window motors according to Figure 3. An electric motor uses electrical energy and magnetic energy to produce mechanical energy. Motor operation depends on the interaction of two magnetic fields. Simply stated, an electric motor works on the principle that two magnetic fields can be made to interact to produce motion. The purpose of the motor is to produce a driving force (torque).



Fig. 3. Motor power window

D. Smart Relay

The smart relay used is the zelio type according to Figure 4. Zelio is a Smart Relay made by Schneider Telemecanique. Programming on the Zelio Smart Relay can be done in two ways, first using a programming console (provided a screen and program buttons that are integrated on the zelio device) and the second using the help of a PC (personal computer). This research uses Zelio Soft 2 software. Smart relay used refers to Zelio Soft 2 software.



Fig. 4. Smart relay

E. Astronomical Method

Astronomical method is a method to find out the position of the sun based on the hour, date, month and year against the coordinates of Longitude and Latitude. The parameters used are the elevation angle and solar azimuth.

State Polytechnic of Madiun has geographic coordinates 7 ° 38'51.2 "S 111 ° 31'36.4" E. Rounding to 7 ° 38'S and 111 ° 31'E. Then converted to longitude and latitude using the formula contained in the Zelio Soft 2 program. Longitude is used as the basis for determining the division of time throughout the earth. Any distance of 15 degrees east longitude or west longitude will show a time difference of 1 hour (60 minutes). Madiun city is located at 111 BT.

Flowchart to determine the movement of the solar panels so that they can follow the sunlight according to Figure 6. The movement of these solar panels is based on elevation and azimuth values. The elevation value is used to move the linear actuator. while the azimuth value to drive the motor power window.

F. FBD Suntrack

This function calculates the position of the sun. This depends on the two angles calculated by the function, they are the elevation angle and the azimuth angle.

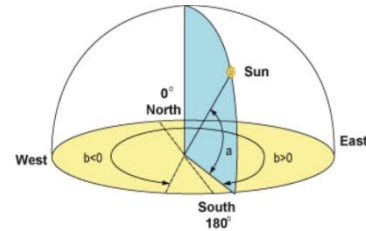


Fig. 5. The positions angles (elevation and azimuth) of the sun.

The Suntrack function block has the following inputs:

- a. Activation: This is a boolean. Until this input is activated, the two outputs (Elevation angle a and Azimuth angle b) are equal to 0. This input is active if it is not connected.
- b. Longitude: This integer has a value between -18000 and 18000, representing the longitude of the equipment location from 180°00 West to 180°00 East.
- c. Latitude: This integer has a value between -9000 and 9000, representing the latitude of the equipment location from 90°00 South to 90°00 North.
- d. Time zone: This integer represents the time difference in minutes between the UTC and the country where the controller is located.

To convert the geographical coordinate Longitude (or Latitude) $m^{\circ}n'$ of a point from degrees, minutes to h in hundredths of degrees, apply the formula :

$$h = 100 \times (m + \left(\frac{n}{60}\right)) \tag{1}$$

- if Longitude is West (or Latitude is South), negate h
- if h is fractional, round it to the nearest integer value.

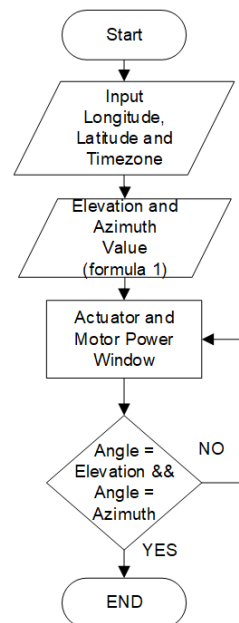


Fig. 6. Flowchart dual axis solar tracker

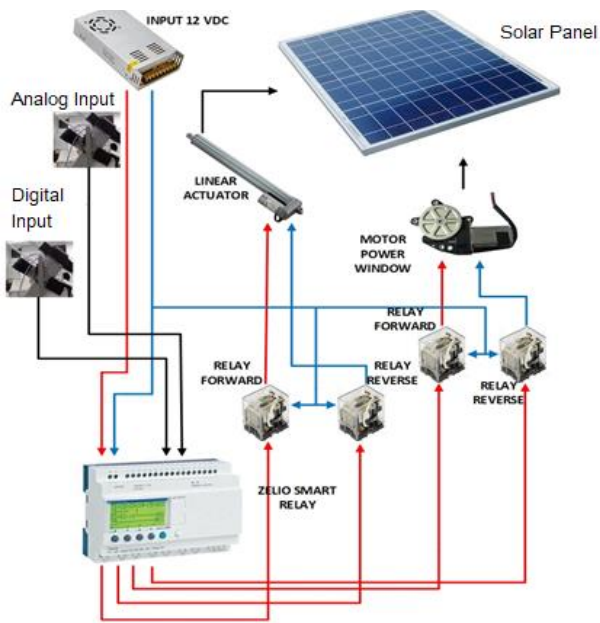


Fig. 7. Flowchart dual axis solar tracker

The function of the circuit based Figure 7 on the circuit scheme is as follows:

1. Zelio Smart Relay in the circuit, the main control is the input and output commands.
2. The potentiometer angle sensor is used as an analog input on the Zelio Smart Relay.
3. The rotary encoder angle sensor is used as a digital input for the Zelio Smart Relay.
4. DC 12V relay is used to control the actuator motor and power window motors.
5. Actuator motors and power window motors are used to drive the solar panels.
6. Solar panels have a role to store solar energy which is then converted into electrical energy.

III. RESULTS AND DISCUSSION

The design of the framework for the dual axis solar tracker system is as shown in Figure 8.



Fig. 8. Framework Dual Axis Solar Tracker System

Hardware installation that is connected to the PLC as shown in Figure 9.

- 1) Connect the potentiometer angle sensor to 0V IB and + 24VDC.
- 2) Connect the rotary encoder angle sensor to + 5VDC 0V (from the voltage regulator) and In (from the relay).

- 3) Connect the relay outputs to I1 and + 24VDC.
- 4) Connect the relays Q1 and Q3 (on the panel box) to Q1 and Q3 on the PLC trainer, then the common jumper between ports.
- 5) Connect the relays Q7 and Q9 (on the panel box) to Q7 and Q9 on the PLC trainer, then the common jumper between ports.
- 6) Connect the relay outputs Q1 and Q3 to the actuator.
- 7) Connect the relay outputs Q7 and Q9 to the motor power window.

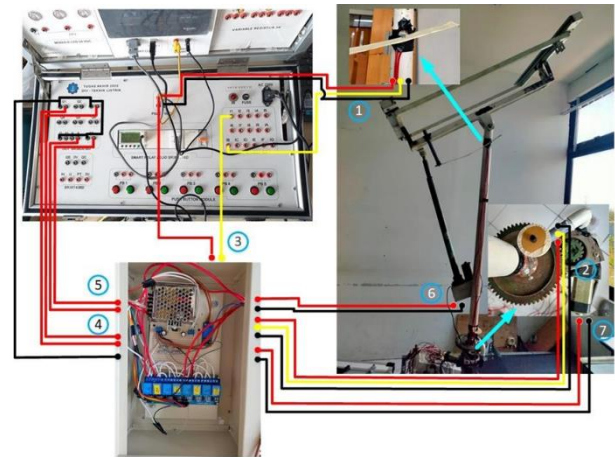


Fig. 9. Dual Axis Solar Tracker System Installation

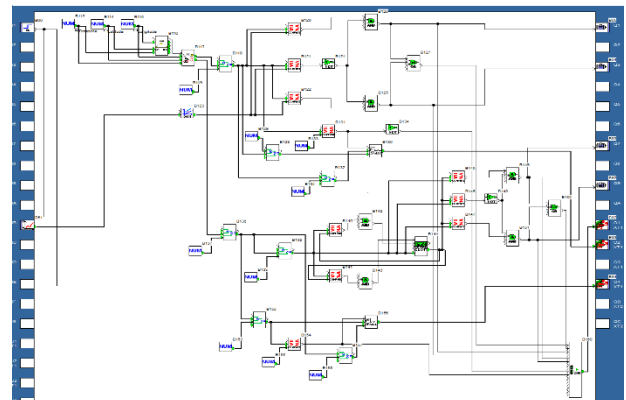


Fig. 10. Dual Axis Solar Tracker System Program

This study uses Zelio Soft 2 software for smart relay settings. The following is the overall program in Zelio Soft 2 according to Figure 10. This overall program is a combination of the tracking program block, the actuator program block, and the power window motor program block. The tracking program block consists of FBD sunrise sunset and FBD suntrack. The tracking program block requires data input of longitude, latitude and timezone values. The actuator program block is used to regulate the actuator movement. The analog input used in the actuator program block is a potentiometer. The motor power window program block is used to regulate the movement of the motor power window. The input used in this program block is a rotary encoder sensor. A description of the symbols that exist in the overall solar tracker program can be explained in table 1.

TABLE I. SYMBOL DUAL AXIS SOLAR TRACKER PROGRAM

No	In	Out	Type Data	FBD Symbol	Function
1.	I1	-	Digital Input		Rotary Encoder
2.	IB	-	Analog Input		Potentiometer
3.	-	Q1-Q3	Digital Output		Actuator Indicator
4.	-	O7-Q9	Digital Output		Motor Power Window Indicator
5.	-	O1 XT1	Integer Output		Forward/Reverse
6.	-	O2 XT1	Integer Output		Elevation Value
7.	-	O4 XT1	Integer Output		Azimuth Value

After the program in Zelio Soft 2 has been completed. Then the thing that needs to be done is to upload the zelio soft program 2. The way to upload is to first select the "transfer" menu then transfer the program and select PC> Module. Then it will come out as in Figure 11. After that select check all and OK.

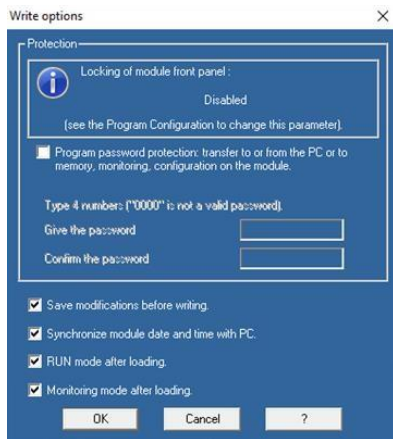


Fig. 11. Upload Program

The results and analysis of the dual axis solar tracker system testing are divided into several parts. First, testing the elevation and azimuth values. Both test the angle of the actuator and the power window motor. This test is used to determine the performance of the actuator and motor power window during the tracking process.

In the Zelio Soft 2 program, there is a sunrise and sunset FBD which will determine when the tracking will start, when the tracking will stop and also the tracking time. Testing for elevation, azimuth with potentiometer voltage was carried out on June 25, 2020. Data on elevation and azimuth values can be seen through the Zelio Soft 2 program on FBD suntrack. Meanwhile, the potentiometer

voltage value must be measured using a multimeter. After the measurements were made on June 25, 2020, data was obtained as in table 2.

TABLE II. DUAL AXIS SOLAR TRACKER TEST DATA

Time (WIB)	Elevation		Azimuth	
	Value	Angle (°)	Value	Angle (°)
06.30	480	4,8	6560	65,6
07.30	1800	18	6230	62,3
08.30	3000	30	5730	57,3
09.30	4210	42,1	4860	48,6
10.30	5200	52	3480	34,8
11.30	5820	58,2	1280	12,8
12.30	5810	58,1	-1350	-13,5
13.30	5180	51,8	-3520	-35,2
14.30	4190	41,9	-4890	-48,9
15.30	2990	29,9	-5740	-57,4
16.30	1700	17	-6260	-62,6
17.30	360	3,6	-6580	-65,8

TABLE III. ACTUATOR DATA

Time (WIB)	Actuator Angle (°)	Time (WIB)	Actuator Angle (°)
06.30		12.30	
10.30		16.30	

TABLE IV. MOTOR POWER WINDOW DATA

Time (WIB)	Motor Power Window Angle (°)
06.30	
10.30	



Time (WIB)	Motor Power Window Angle (°)
12.30	
16.30	

TABLE V. TRACKING ON AND TRACKING OFF SYSTEM

Date/ Month/ Year	Tracking ON (WIB)	Tracking OFF (WIB)	Time Tracking
01/01/2020	05.44	18.17	12 hr, 30 min
01/02/2020	05.57	18.24	12 hr, 27 min
01/03/2020	06.02	18.17	12 hr, 15 min
01/04/2020	06.00	18.01	12 hr, 1 min
01/05/2020	06.01	17.50	11 hr, 49 min
01/06/2020	06.05	17.46	11 hr, 41 min
01/07/2020	06.10	17.51	11 hr, 41 min
01/08/2020	06.10	17.57	11 hr, 47 min
01/09/2020	05.59	17.56	12 hr, 57 min

The next test is the actuator test and the power window motor test. Actuator testing uses a 12 VDC source on the actuator and connects it to the zelio soft program 2. The results of the actuator test are as in table 3. Testing the power window motor using a 5VDC source on the motor power window and connecting it to the zelio soft program 2. The test results of the power window motor can be seen in table 4. It can be seen that changing the test time clock can change the angle value of the actuator and motor power window.

In table 5, data is obtained in the form of tracking on and tracking off. tracking on, namely when the system will start working and tracking off, namely when the system will stop working. Furthermore, the tracking time is obtained by finding the difference between tracking on and tracking off. This data is obtained from testing every month on the 1st in 2020.

The last test is a test based on the condition of the solar panels. Static condition means the condition when the solar panel is still (static). In this condition, we can see the output from the dual axis solar tracker. System test data in static conditions can be seen in table 6.

The next test is in tracking conditions or the movement of the solar panels to follow the direction of the sun. There are two directions of tracking movement, which are seen from the north-south slope angle and the east-west slope. In this condition, the results of the output voltage from the dual axis solar tracker are also seen. System test data in static conditions are shown in table 7. Table 7 shows that the tracker condition can be done well. The output voltage of the tracking condition is greater than the static condition.

TABLE VI. STATIC CONDITIONS

No	Time (WIB)	Voltage (V)	North - South Slope Angle (°)	East - West Slope Angle (°)
1	09.00	21	89,9	50
2	10.00	21	89,9	50
3	11.00	21	89,9	50
4	12.00	21	89,9	50
5	13.00	21	89,9	50
6	14.00	20	89,9	50
7	15.00	20	89,9	50

TABLE VII. TRACKING CONDITIONS

No	Time (WIB)	Voltage (V)	North - South Slope Angle (°)	East - West Slope Angle (°)
1	09.00	21,5	89,9	64
2	10.00	21,2	89,9	77
3	11.00	22,0	89,9	84
4	12.00	21,2	89,9	89
5	13.00	21,0	89,9	95
6	14.00	21,5	89,9	100
7	15.00	21,0	89,9	114

From this research we can find out that every month the sun shifts. therefore, if the solar tracker is in a static condition it will not be able to produce optimal output. So we need a dual axis solar tracker system that can follow the direction of the sun.

IV. CONCLUSION

Potentiometer as an elevation angle sensor is working properly. Rotary encoder as azimuth angle sensor is working properly. The tracking program can start and end automatically according to the desired place by entering longitude, latitude, and timezone on the FBD sunrise sunset.

For further development of tools, other sensors that are more accurate and can be applied on a large scale can be used. You can also add loads to the dual axis solar tracker system to find out the system performance. Future developments of this astronomical method can be compared with other methods of the solar tracker. So that we can find out which method is the most optimal for the solar tracker in Indonesia.

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