Design of Dual Axis Sun Tracker using Fuzzy Logic Controller

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Abstract
Previous research stated that sunlight energy will be converted into electrical energy more optimally if the surface of the solar cell module is perpendicular to the position of the sun. The daily cycle of the earth's rotation causes the sun's position to change from east to west and the earth's annual evolution around the sun causes the sunrise to tilt to the southeast or northeast by 23.5 degrees. These two conditions occur in equatorial regions such as Indonesia. Various sun tracking methods have been developed so that the surface of the solar cell module is always perpendicular to the position of the sun, whether manually or automatically adjusted. This research develops a method for adjusting the surface direction of solar cell modules based on fuzzy logic control. This system will automatically reorient the surface of the solar cell module every 15 minutes. Two sets of Light Dependent Resistor (LDR) series separated by a boundary plate are used as light sensors. The shadow from the boundary plate will cover one of the LDR series, causing a difference in total resistance between the two sets of LDR series. The difference in total resistance between the two sets of LDR series becomes an analog information signal for the fuzzy logic control system to map the position of the sun. From the test results it was found that for the position of the sun from east to west, there is a difference between the direction of the solar cell module and the position of the sun on average 4 degrees

***Keywords**:* Optimization, Perpendicularity, Sun Tracking, Fuzzy Logic Control

Introduction

The power generated by solar panels is mainly influenced by the intensity of solar irradiance[1] The main device for generating solar energy electricity is a solar cell moduleor solar panel (PV) The amount of electrical energy produced by a solar cell module is influenced by the intensity of sunlight captured by the solar cell module. One way to get optimal light intensity is to position the solar cell module so that it remains perpendicular to the direction of the sun.
Commonly, most solar panels are installed in a fixed position. At the same time, the earth constantly rotates around the sun, meaning that the sun’s position will always move every minute along with the earth’s rotation. The 23.5 degrees’ inclination of the earth, also causes seasonal variation in insolation. In the northern hemisphere this counteracts the variation due to the elliptic orbit and makes the winter time, when the insolation is lowest, occur during the months around December to February[2]. These motions cause the position of the solar panels to be not perpendicular to the sun and results in not maximizing sunlight received by the solar panels. If the sunlight received by the solar panels is not optimal, the power output produced by the PV panel is not optimal. Therefore, adjusting the PV panels’ position is necessary to get the maximum light intensity and increase the power output and system efficiency [3]
Static solar panels can generally produce about 4.5 kWh / day > m2 of power (depending on where the location area is) how much power is created can be expanded using solar panels that automatically move with the sun.[4]

Literature Review

Solar panel

Solar Panel is a component consisting of solar cells with the principle of photovoltaic effect that converts sunlight energy into electrical energy. In this study using solar panels with a maximum power capacity of 10wp with polycrystalline type, because this type of solar panel is suitable for use during hot and rainy weather conditions[4].

Fuzzy Logic

The term logic could be described as the study of correct reasoning while reasoning could be defined as the process of drawing conclusions from the available information. The term fuzzy is associated with uncertainty in a process or data and fuzzy logic is an artificial intelligence technique that uses linguistic terms to perform reasoning and thus facilitates analysis and interpretation of imprecise information. Using linguistic terms in fuzzy logic may reduce the complexities of system modelling as there could be less need for extensive mathematical formulations. The field of fuzzy logic and its applications have evolved greatly in the last few decades with numerous reported publications and applications. Fuzzy logic is distinct from probability theory as the latter is generally applied to problems associated with random characteristics. Probability theory can have limitations in scenarios where the problem is termed in vague linguistic terms or cases where the available information could be imprecise.[5]

The block diagram of Fuzzy Logic is shown as the figure below

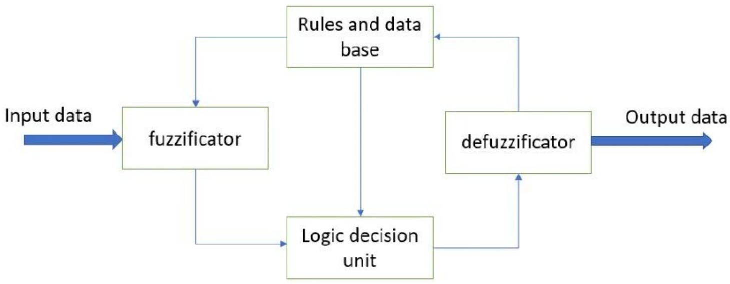

Figure 1. Block Diagram of Fuzzy Logic System [6]

Light Dependent Resistor

A photo resistor or light-dependent resistor (LDR) or photocell is a resistor whose resistance decreases with increasing incident light intensity. A photo resistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron conduct electricity, thereby lowering resistance. Light dependent resistors (LDR), are light sensitive devices most often used to indicate the presence or absence of light, or to measure the light intensity. In the dark, their resistance is very high, sometimes up to 1MΩ, but when the LDR sensor is exposed to light, the resistance drops dramatically, even down to a few Ohms, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices. They are used in many applications but are sometimes made obsolete by other devices such as photodiodes and phototransistors Specifications Of LDR ¬ Model #:3190 ¬ Vin(input voltage 5volts) ¬ LDR Range 0.1 to 10,000 lux Signal Conditioning Circuits for Light Intensity Measurement Here we are using two signaling condition circuits Signal Condition Circuit Using Instrumentation Amplifier: Resistive sensors such as LDRs, RTDs and strain gages produce small percentage changes [7].

Microcontroller
A microprocessor is the computational intelligence of complex systems, i.e., the central processing unit (CPU), which is optimized to do logical mathematical computations. It usually has mainly on-board communications peripherals to interact with the rest of the system. However, in many fields, including power electronics-based systems, there is the need for communicating with rather complex peripherals like Analog-to-Digital Conversion (ADC) channels, Digital-to-Analog Conversion (DAC) modules, Pulse Width-Modulation (PWM) peripheral, and Inter Integrated Circuit (I2C) communication. Nowadays, the modern definition of embedded system mainly refers to microcontroller. Nevertheless, even a single microprocessor which is specialized[8].

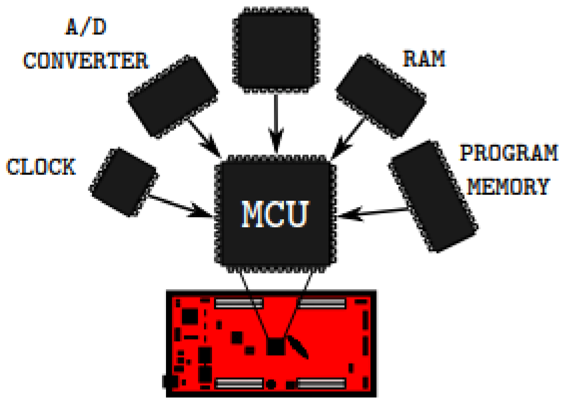

Figure 2. Example of the architecture of a MCU board[8]

DC Motor
Brushed DC motors are commonly used lots of electrical systems or control systems. Such as brushed DC motor is found at automotive control systems, ink jet printers, robotic applications, electric trains, disabled wheelchairs and battery powered hand-drills. Brushed DC motors are preferred commonly due to its simplicity and cost. DC motors have to be controlled at the DC motor applications DC motor is needed to be operated with desired speeds, reverse or forward motion for different time periods to control these types of parameters of the motor, the drive circuit is needed to design. A brushed DC motor is very easy to control and DC motor does not require an external driver to operate. Speed control of brushed DC motor is also easy because the voltage-speed characteristic of brushed DC motor is relatively linear[9].

Figure 3 below is the diagram of DC motor Driver

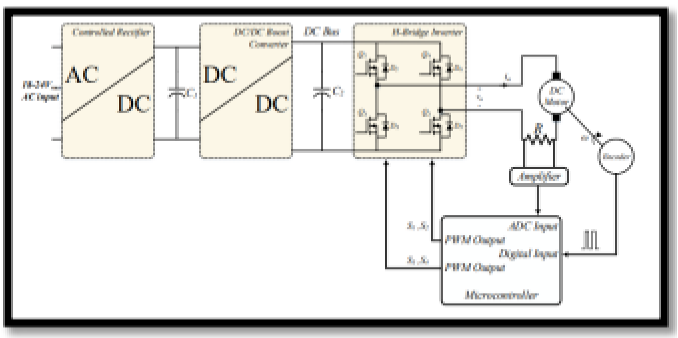

Figure 3. DC motor Driver [10]

Research Methodology

The Rules of Fuzzy logic control

The fuzzy rule base as an If-Then function is as follows:
IF the east sensor is bright AND the west sensor is bright THEN motor rotates moderately
IF the east sensor is bright AND the west sensor is a bit bright THEN the motor spins a lot
IF the east sensor is bright AND the west sensor is dim THEN the motor rotates very far
IF the east sensor is light AND the west sensor is a bit dark THEN the motor is very far away
IF the east sensor is light AND the west sensor is dark THEN motor rotates maximum
IF the east sensor is a bit bright AND the west sensor is bright THEN the motor rotates close
IF the east sensor is a bit bright AND the west sensor is a bit bright THEN the motor rotates moderately
IF the east sensor is a bit bright AND the west sensor is dim THEN the motor spins a lot
IF the east sensor is a bit light AND the west sensor is a bit dark THEN the motor rotates very far
IF the east sensor is a bit light AND the west sensor is dark THEN the motor rotates very far
IF the east sensor is dim AND the west sensor is bright THEN motor rotates very close
IF the east sensor is dim AND the west sensor is a bit bright THEN the motor rotates close
IF the east sensor is dim AND the west sensor is dim THEN motor is rotating moderately
IF the east sensor is dim AND the west sensor is a bit dark THEN the motor spins far
IF the east sensor is dim AND the west sensor is dark THEN the motor rotates very far
IF the east sensor is a bit dark AND the west sensor is bright THEN the motor rotates very far
IF the east sensor is a bit dark AND the west sensor is a bit light THEN the motor rotates very far
IF the east sensor is a bit dark AND the west sensor is dim THEN the motor spins far
IF the east sensor is a bit dark AND the west sensor is a bit dark THEN the motor rotates moderately
IF the east sensor is a bit dark AND the west sensor is dark THEN motor rotates close
IF the east sensor dark AND the west sensor is light THEN motor rotates maximum
IF the east sensor is dark AND the west sensor is a bit bright THEN the motor is very far away
IF sensor dark east AND west sensor dim THEN motor rotates very far
IF the east sensor is dark AND the west sensor is a bit dark THEN the motor spins far
IF the east sensor is dark AND the west sensor is dark west THEN motor rotates moderately

The Block Diagram of the hardware

Figure 4 below is the block diagram of the hardware system

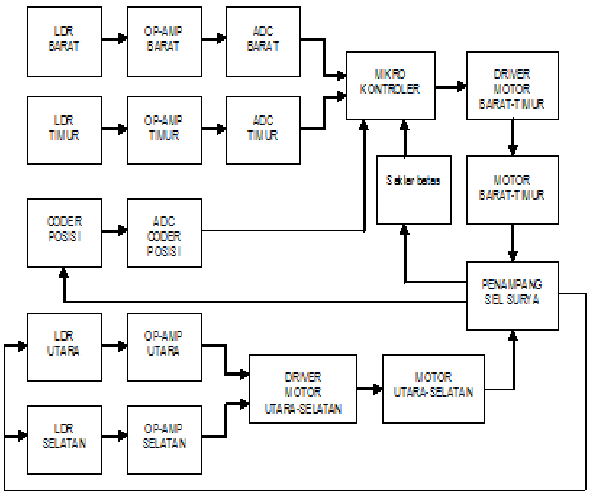

Figure 4. Block Diagram of the hardware system

The LDRs Concept

Figure 5 below is the LDRs concept

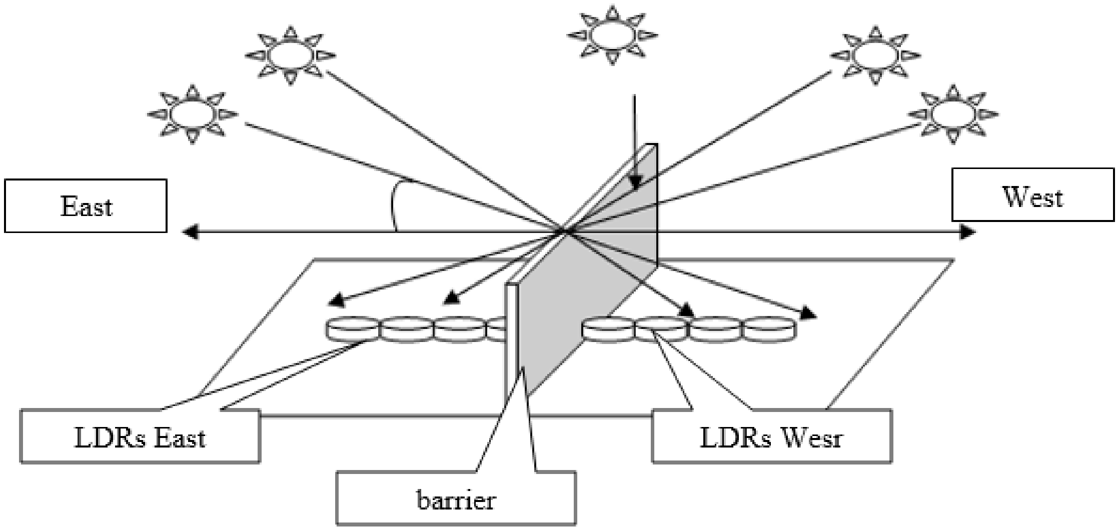

Figure 5. The LRDs Concept

How it works

The west and east LDRs function as sensors to detect the position of the sun in the west or east direction based on the intensity of the light it receives. Variations in light intensity are converted into voltage variations to be transmitted to the op-amp circuit. The op-amp circuit amplifies as needed. The op-amp output is an analog quantity, in the range of 0 Volt DC to 5 Volt DC. By ADC, these analog quantities are converted into digital (binary) codes, because the microcontroller can only read digital codes. Next, the digital codes (high-low) are sent to the microcontroller to be processed according to the rules programmed into the microcontroller. The microcontroller acts as the main control center and will send digital signals to the east-west motor driver. The signals received by the motor driver circuit are in the form of digital codes to regulate the performance of the motor turning right (CW), turning left (CCW) and off. The driver circuit is the final circuit to control the motor. The results of DC motor operation moving CW or CCW, in the form of an east-west cross-section in the range 50 to 1750 from the frame The cross-sectional position is read by a marker (coder). The results of the marker (coder) reading are still analog quantities, which then need to be converted into digital codes by the ADC. The results of the ADC coder's work are forwarded to the microcontroller for further processing.

The cross-sectional position control system in the north-south direction is designed to be simpler than the east-west direction control system. This is because the maximum position of the sun to the north or south is only 23.5 0, and occurs once every six months. A light sensor in the form of an LDR is still needed to map the position of the sun in the north or south. After being strengthened by the op-amp, the output signal with a maximum voltage of 5 Volts DC is forwarded to the north-south motor controller (driver) circuit, to control the DC motor to move CW or CCW, and turns off. The rotation of this DC motor causes a change in the direction of the cross section to north or south.

Results

Measurement of The LDRs Resistant

Table 1. Measurement of the west sensor (LDR)

No	High of barrier plat (cm)	shadow (cm)	Sun position from east (^{0})	Resistance of LDR (ohm)
1	2	3	4	5
1	2	>= 4	<=20	1650
2	2	3.50	29,7	1340
3	2	3.00	33,6	1235
4	2	2.50	38,6	1108
5	2	2.00	45	988
6	2	1.50	53,1	822
7	2	1.00	63,4	688
8	2	0.50	75,9	425
9	2	0	90	329

Table 2. Measurement of the East sensor (LDR)

No	High of barrier plat (cm)	shadow (cm)	Sun position from east (^{0})	Resistance of LDR (ohm)
1	2	3	4	5
1	2	0	90	297
2	2	0.50	104,1	322
3	2	1,00	116,6	496
4	2	1,50	126,9	660
5	2	2,00	135	1030
6	2	2,50	141,4	1175
7	2	3,00	146,4	1340
8	2	3,50	150,3	1500
9	2	>=4	>=160^0	1650

Mechanical system testing is done by assembling all sub-systems, which consist of power supply, sensors, coder, op-amp, ADC, microcontroller, motor and mechanical devices. Tests were conducted throughout the day from 8.30 to 16.30. in sunny conditions. The purpose of this test is to compare the orientation (direction) of the solar cell module to the position of the sun.

The test results are shown in table 3 and Figure 6 below:

Table 3. Mechanical system testing

No	time	Sun position to the east (^{0})	shadow (cm)		Position of the cross section to the frame (^{0})	difference (^{0})
			west	east		
1	8.30	38.6	2.5	0	30	8.6
2	9.00	41.6	2.25	0	30	11.6
3	9.30	53.1	1.5	0	50	3.1
4	10.00	57.9	1.25	0	57	0.6
5	10.30	63.4	1	0	75	11.6
6	11.00	75.9	0.5	0	80	4.1
7	11.30	82.8	0.25	0	90	7.2
8	12.00	87.1	0.1	0	90	2.9
9	12.30	90	0	0	90	0
10	13.00	87.1	0	0.1	90	2.9
11	13.30	97.2	0	0.25	100	2.8
12	14.00	104.1	0	0.5	100	4.1
13	14.30	116.6	0	1	120	3.4
14	15.00	122.1	0	1.25	120	2.1
15	15.30	126.9	0	1.5	130	3.1
16	16.00	138.4	0	2.25	140	1.6
17	16.30	141.4	0	2.5	145	3.6

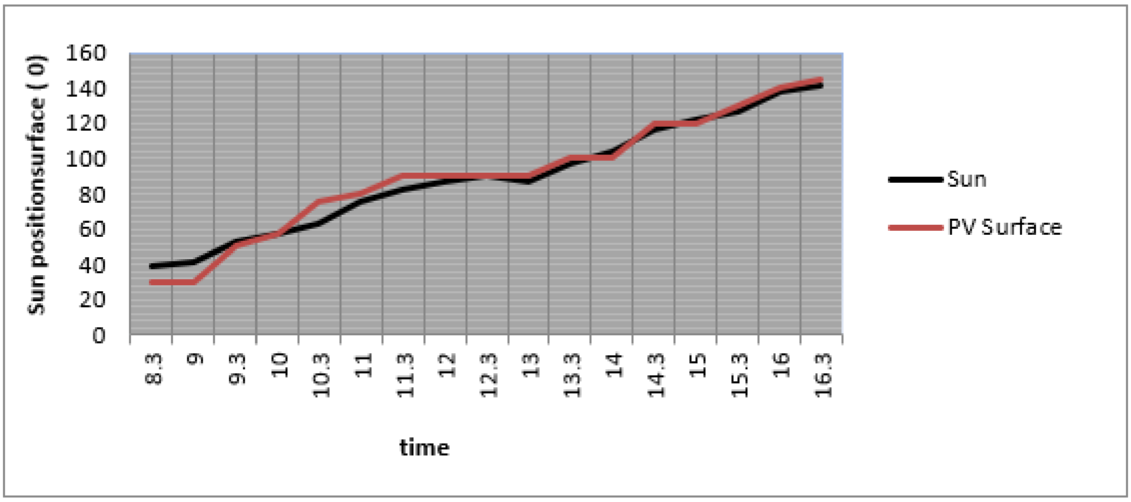

Figure 6. the comparison of the position of the sun to the position of the cross section

Conclusion

The system for regulating the direction of the solar cell module following the sun's position using fuzzy logic control can function properly.
For east-west orientation, the difference between the direction of the solar cell module to the sun's position is an average of 4.270, this difference can be caused by several things, namely accuracy measuring instruments, tolerances of the potentiometer coder and other electronic components, the torque of the motor, the delay time of the relay on the motor driver, human error, and the characteristics of the fuzzy logic controller system.

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