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Implementing an Automatic Solar Tracking System Using Arduino

A. Kajaman, A. Sadeg

Assistant Professor, Department of Control Engineering, College of Electronic Technology, Bani Walid, Libya

Engineer, Department of Control Engineering, College of Electronic Technology, Bani Walid, Libya

ABSTRACT: Renewable energy is becoming increasingly usable such as solar systems. It is most important to keep the panels aligned with the sun to maximize power output from solar panels because it is to convert the maximum of the sun's energy less efficiently. Therefore, a means of tracking the sun is required. This is a more cost effective solution than acquiring extra solar panels. This can be achieved by a solar tracking device that moves the panel toward the sun. The main goal of this paper is to design and implement a prototype of a two-axis solar tracking system based on an Arduino Uno microcontroller, which will keep the solar panels aligned with the sun to maximize efficiency. This tracker is programmed to detect sunlight falls on Lights Dependent Resistors (LDR) installed on the panel. The servo motor aligns the solar panel to receive maximum intensity of light.

KEYWORDS: Energy, Solar Tracking, Sunlight.

I. INTRODUCTION

Nowadays, the energy deficiency problems faced by the world are urging researchers to find an alternative energy source that would complement conventional fossil fuels. Alternative energy sources include solar, nuclear and wind. The power of solar radiation is generating solar energy. It is the cleanest energy source which can pollute the climate the least. The main problem with solar energy is its dilute nature. Even in the hottest regions of the earth, the solar radiation flux available rarely exceeds 1KW/M, which is insufficient for technology utilization. This problem can be rectified by a device solar tracker which ensures the maximum intensity of sun rays hitting the surface of the panel from sunrise to sunset.

The small number of available resources makes contemporary society look for measures to accomplish the demands of energy sources. As civilization advances, the depletion of traditional fuels due to human practices threatens sustainable development and growth issues. The scarcity of energy and its source guided us towards the optimistic approach of using the alternative resources bestowed to humankind solar, and tidal. The sun is an imperative source of energy, so solar energy is an eco-friendly resource compared to other sources. The advancement of technology has out-turn fostered techniques to utilize this energy for its good use [1].

Photovoltaic systems are operated to transform the solar power into electricity. Solar tracking device utilizes this expropriated solar power through the channel of photovoltaic arrays, an oriented scaffolding of photovoltaic cells that are used to convert light energy into electricity on the principle of the photovoltaic effect. The difference is that the electrons in photovoltaics are not emitted but instead contained in the material around the surface, creating a voltage difference.

II. OVERVIEW

Solar cells are forged with crystalline silicon. It is the most commonly used material in a solar cell. The use of silicon in the solar cell has been very efficient and low cost. Two forms of crystalline silicon can be used to make solar cells. The fabrication of solar cells with materials other than silicon is slightly expensive, thus making silicon the best material to be used in solar tracking systems [2].

A single axis tracker tracks the sun from east to west, and a two-axis tracker tracks the daily east to west movement of the sun and the seasonal declination movement of the sun. Most solar power systems use lenses and tracking systems to focus a large area of sunlight into a small beam to convert light into electric current using the photoelectric effect.

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Results indicate that the increase in the power efficiency of tracking solar plate on normal days is 26 to 38% compared to the fixed plate. It varies at any level during cloudy or rainy days [3].

Badran in 2013 discussed a new innovative tracking approach of water distillation taking advantage of the highest possible concentration of parabolic trough collector. Through the use of Image Processing Technique to catch the core of the sun as the target and using artificial intelligence techniques to predict the sun position in abnormal climatic conditions [4].

III. PROBLEM STATEMENT

There is a severe shortage of electric power in many countries, and therefore modern technologies must contribute to the production of electricity and the exploitation of renewable energy. In this model, solar energy was used to generate electricity through solar tracking, so that solar energy was used as much as possible more than fixed panels. For the system to be implemented successfully, the objectives must be achieved which are designing a suitable structure for the horizontal and vertical movement of the solar panel and implementing an electronic circuit for light intensity sensing by LDR and servo motor control for panel movement.

IV. PROPOSED SYSTEM

The whole system is divided into two main stages: hardware and software. The hardware consists of (a servo motor, solar panel, LDR sensors, and Arduino board). Each part is tested, implemented separately, and then integrated to construct the system. The software part was done by using C language with an Arduino.

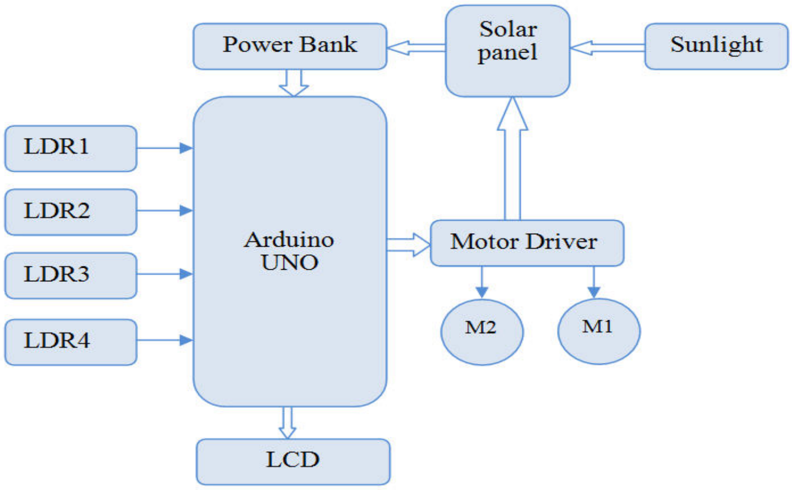

Fig. 1 System block diagram

A. *Arduino UNO Microcontroller*

The Arduino UNO processor was selected, which is one of the first, most widely used, and easiest to teach Arduino boards. Arduino Uno as shown in Figure 2 is a microcontroller board based on the ATmega328P microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

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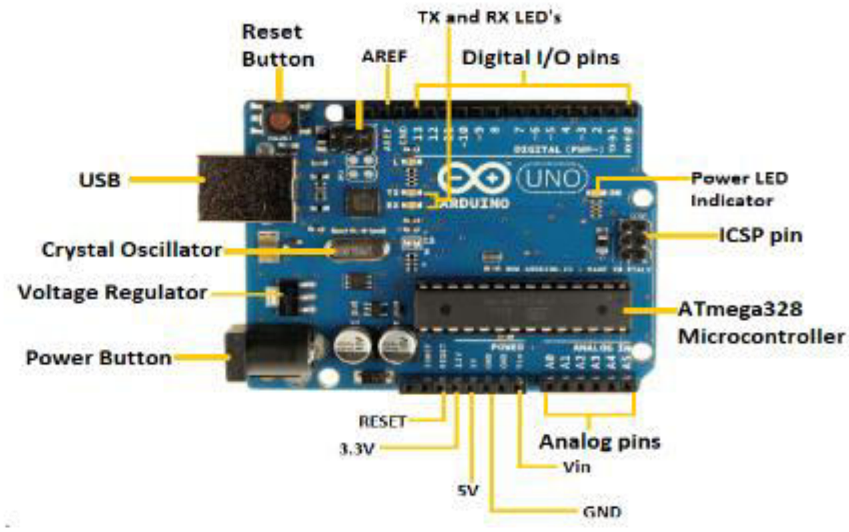

Fig. 2 Arduino UNO (ATmega328P)

Table 1. Arduino Uno Technical Specifications

Microcontroller	ATmega328P - 8 bit AVR
Operating Voltage	5V
Input Voltage	7-12V
Input voltage Limits	6-20V
DC Current on 1/0 Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Frequency	16 MHz

B. ***Servo Motors***

Servo motors are electrical devices that can push or rotate an object with great precision. These motors are used to rotate at specific angles or distances. It is made up of a motor that runs through a servo mechanism. It can be getting a very high torque servo motor in a small and lightweight package. Due to these features, it is being used in many applications like planes and robotics.

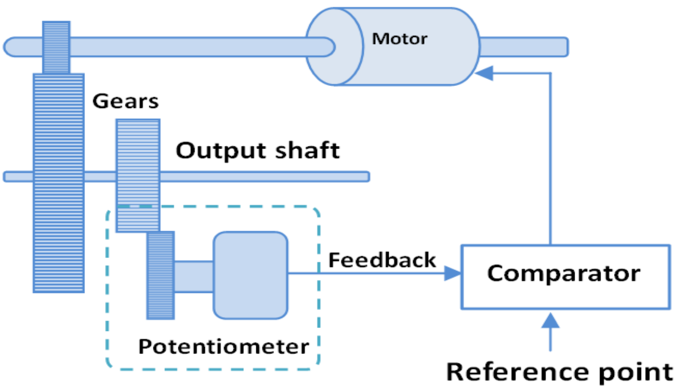

Fig. 3 Servo motor mechanism

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The servo motor works on the automatic closed loop system. The controller is required for this closed-loop system which is composed of a comparator and some feedback. For producing an output signal, the comparator is used to compare the required reference signal and this output signal is sensed by the potentiometer. Based on the feedback signal, the motor starts working ON for the desired time when the logical difference is higher and the motor would be OFF for the desired time when the logical difference is lower.

C. *Servo Motor Control*

The Servo motor works on the PWM (Pulse width modulation) principle, which means its angle of rotation is controlled by the duration of the applied pulse to its control pin. A high-speed force of the dc motor is converted into torque by gears. In a dc motor, force is less, and distance (speed) is high and when force is High, the distance is less.

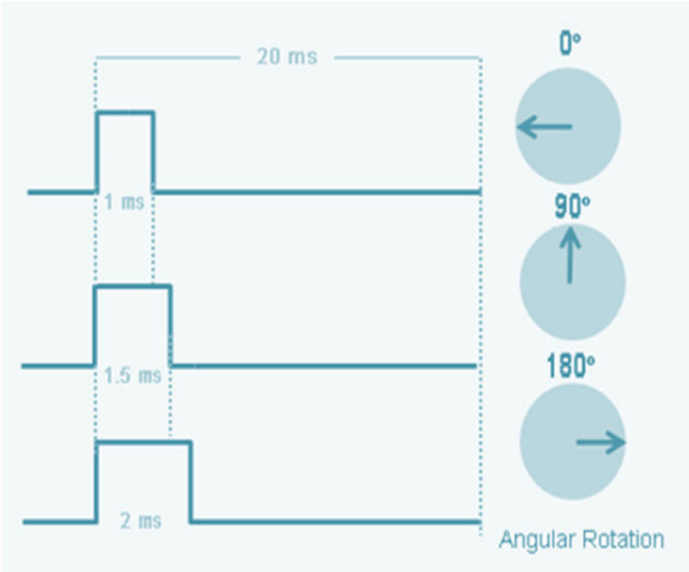

Fig. 4 Servo motor PWM

D. *MG995 Servo Motor*

The unit comes complete with 30cm wire and 3 pin 'S' type female header connector that fits most receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum and Hitec. This MG995 Metal Gear Servo can rotate approximately 120 degrees (60 in each direction). It can use any servo code, so it is great for those who want to make stuff move without building a motor controller with feedback & gearbox, especially since it will fit in small places. It also comes with a selection of arms and hardware to get set up nice and fast [5].

Table 2. MG995 specifications

Weight	**55 g**
Dimension	**40.7 x 19.7 x 42.9 mm.**
Stall torque	**8.5 kgf·cm (4.8 V), 10 kgf·cm (6 V)**
Operating speed	**0.2 s/60º (4.8 V), 0.16 s/60º (6 V)**
Operating voltage	**4.8 V a 7.2 V**
Dead band width	**5 µs**
Temperature range	**0 ºC – 55 ºC**

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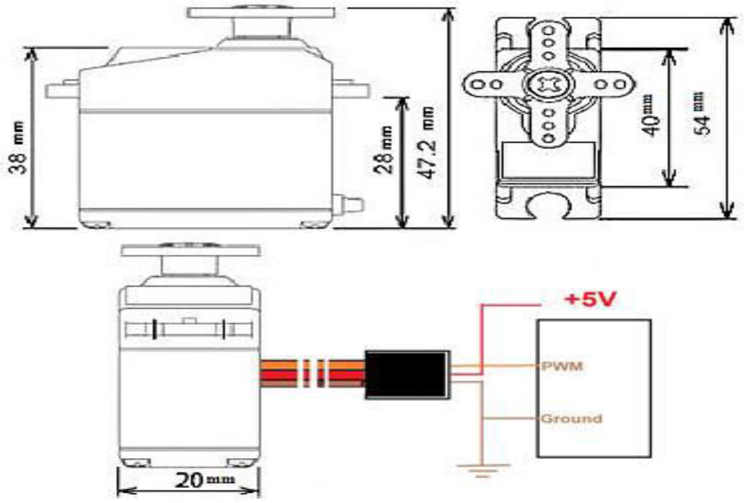

Fig.5 MG995 Servo motor construction

E. Light Detecting Resistors

The light-dependent resistor LDR is responsive to light once light rays drop on it, then immediately the resistance will be changed. The resistance value will be decreased when the light level increases. The resistance values of LDR in darkness are high whereas in bright light it will be dropped to small values. The resistors are used in many applications because of change in resistance. The LDRs can be designed by using semiconductors to have light-sensitive properties. The famous material used in this resistor is cadmium sulphide. In electronic circuits, the LDR symbol is used that mainly depends on the resistor symbol, however, it illustrates the light rays in the arrow form. In this way, it follows the same principle that is used for phototransistor and photodiode circuit symbols wherever arrows are utilized to demonstrate the light dropping on these types of components [6].

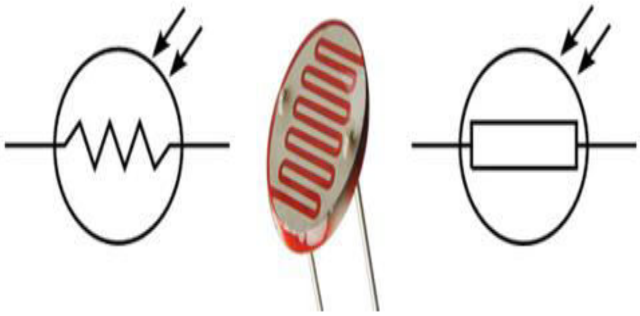

Fig. 6 Light dependent resistor

V. DESIGN AND IMPLEMENTATION

The components of the system will be individually tested with its software and hardware, to check its performance and response, this is necessary for system implementation. This step explains the function of the components used in the project. Testing the elements of the system is done by wiring each component with Arduino and testing it with a simple code to identify the properties of components.

A. Hardware System Construction

After testing the model's components, the system's parts are combined, forming the final proposed system for an automatic solar tracking system. Figure 7 shows the real picture of the model after the final wiring of the model to be followed.

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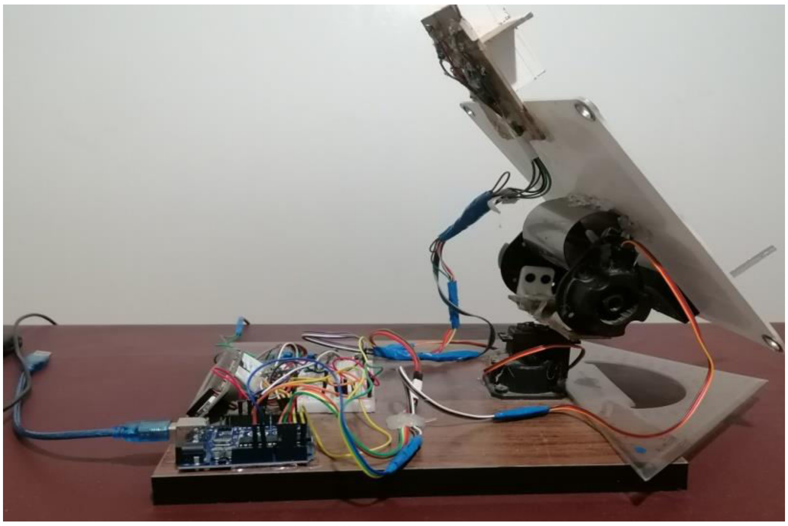

Fig. 7 System hardware configuration

B. Installing the MG995 servo motor

The MG995 servo motor is installed on the surface of a wooden board to put the chassis on. This type of servo motor is selected to bear the weight of the chassis to move it horizontally 0 degrees right and 180 degrees left. Therefore, these angles maintain the smoothness of the chassis and move safely around it so as not to cut the connecting wires.

C. Building a solar tracking system

Solar trackers are devices used to orient photovoltaic panels, reflectors, lenses or other optical devices toward the sun. Since the sun's position in the sky changes with the seasons and the time of day, trackers are used to align the collection system to maximize energy production.

Fig. 8 Movement structure shape configuration.

D. Installing the servo motor SG990

The following mechanical figure shows the servo motor which is responsible for the horizontal axis movement. This model is installed above the MG995 servo motor on a cylinder to install the other servo motor type SG90 to make the cylinder move vertically up and down and install the solar panel on this cylinder to move the model vertically 90 degrees down and 20 up and responsible for this movement is Servo motor type SG90.

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Fig. 9 Installing the SG990 servo motor

E. ***Dual-axis trackers***

Dual-axis trackers are working as the rotation axes with two freedom degrees. Dual-axis trackers are used for optimal solar energy levels because they can follow the sun vertically and horizontally. The sun's position has been divided into five areas: EAST, WEST, NORTH, SOUTH, and CENTER.

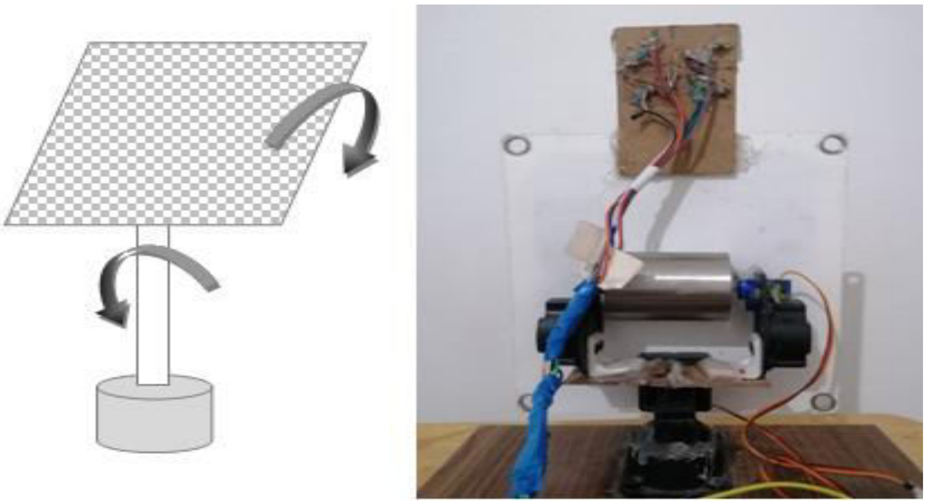

Fig. 10 Dual-axis tracking movement

F. ***Designing of LDR place***

LDR is used as the main light sensor. Four LDRs are put into divided quarters top, bottom, left, and right. For east-west tracking, the analog values from two top LDR are compared and if the top set of LDR receives more light, the vertical servo will move in that direction. If the bottom LDR gets more light, the servo moves in that direction. The values from two left LDR and two right LDR are compared for angular deflection of the solar panel. If the left set of LDR receives more light than the right set, the horizontal servo will move in that direction. If the right set of LDR has more light, the servo moves in that direction.

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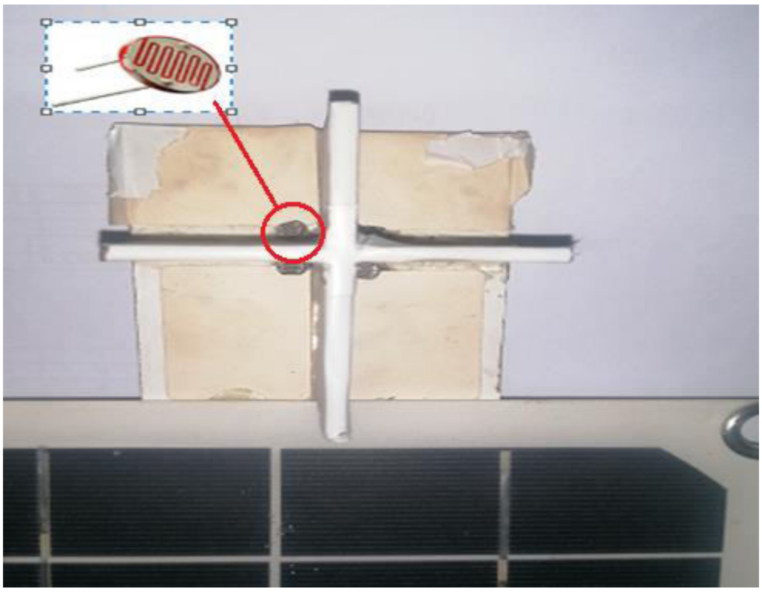

Fig. 11 LDR design structure

G. *LDR Implementation*

The potential divider on the top is 5V, on the bottom is 0V, and in the middle, connected to A0, is valued between 5V and 0V and varies as the LDR resistance according to the light level. As both resistors are in series, the same current must flow through them. The LDR resistance drops with light, which causes the current in both resistors to increase, therefore, the voltage across the other (non-LDR) increases as the LDR resistance varies with light, and the Volt at A0 will increase too.

Technically, voltage on A_0 :

$$Va_0 = 5 * R_1/(R_1+LDR) \qquad (1)$$

Where Va0 is the voltage on the A_0 pin, LDR is the top resistor value, and R_1 is the bottom resistor value; The LDR has a high value when no light is present. The value of resistance of the LDR depends on the type. In this case, it is about 10kΩ. As the light level increases the resistance drops, which makes the current increase, which in turn, makes the voltage at A_0 increase.

$$\text{Vout} = \frac{R1}{R1+LDR} \times Vin \qquad (2)$$

LDR Values (1.84Ω minimum , 190Ω maximum)

Voltage Divider equation from Eq. 1:

$$\frac{5V \times R_1}{R_1 + 1.84} = 4V$$

Unknown resistance value will be 7.36Ω. Therefore, 10kΩ resistors are chosen instead of the value that was calculated theoretically, which is 7.36Ω to draw a current of less than 5V, and the circuit works stably and prevents the passage of large current from the source and ensures that the parts of the circuit are not damaged in terms of cost. It is possible to choose a resistance of 7.36 Ω that has been calculated theoretically and the circuit will work, but it is better to test the resistance of the largest value for the passage of a small current.

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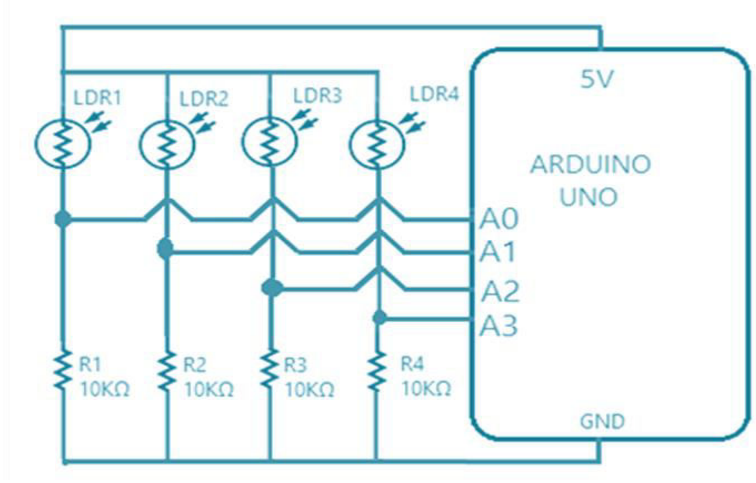

Fig. 12 Connecting LDRs with Arduino

H. ***System architecture diagram***

In automatic mode, the microcontroller converts the analogs values of LDR sensors (pins A_0 to A_3) into digits then it controls two servomotors (up-down and left-right) using two Pulse-Width Modulation (PWM) signals to track the sun. The rotation movements occur in two axes, from east to west according to the daily sun's path and in elevation from south to north according to the seasonal sun's path is used to switch between the two modes. The output voltage changes according to the light intensity. The top of the potential divider is 5V, the ground is at 0V, and the output of the voltage divider is connected to an analog input (A_0 for instance) of the microcontroller. The value of resistors used in voltage dividers is 10kΩ two 180 degrees servomotors are used. A servomotor (MG995R) to control the solar tracker, according to the vertical axis, which is the left-right servomotor, and a micro servo motor (SG90) to control the solar tracker according to the horizontal axis.

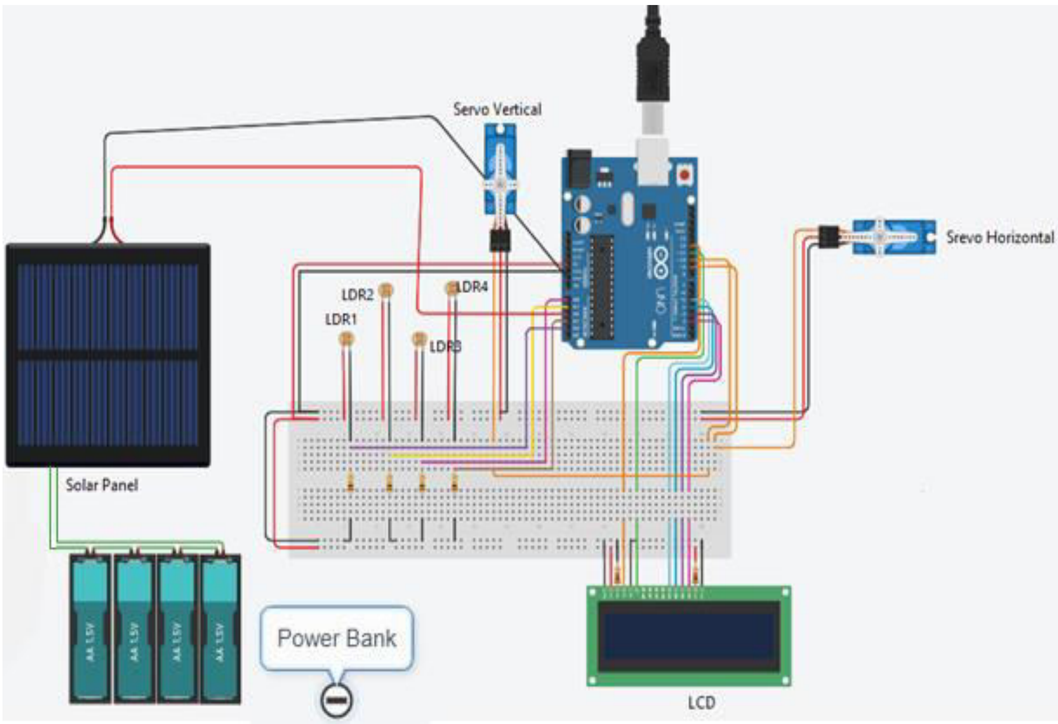

Fig. 13 System architecture diagram.

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VI. RESULTS

The angles of the servo motors were tested by placing a protractor on the horizontal and vertical sides to measure angles and comparing them between the readings of the protractor and the readings on the LCD screen. It is close to the ideal value which shows that the results of the angles of the motors work as required to determine the angle of the solar panel. The values of the horizontal and vertical angles can be read from the LCD screen.

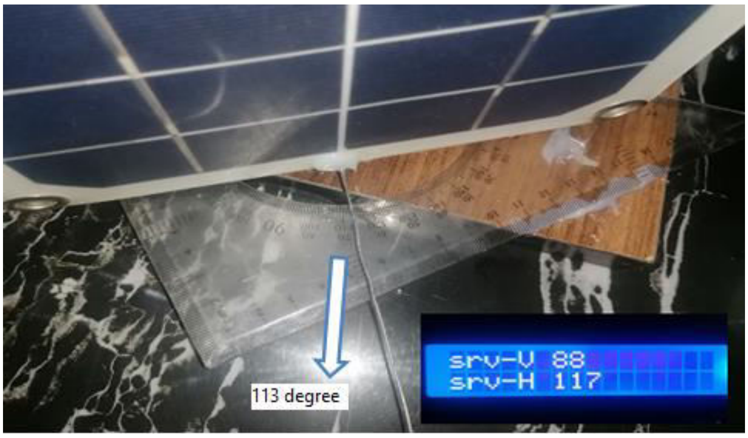

Fig. 14 Horizontal angle test

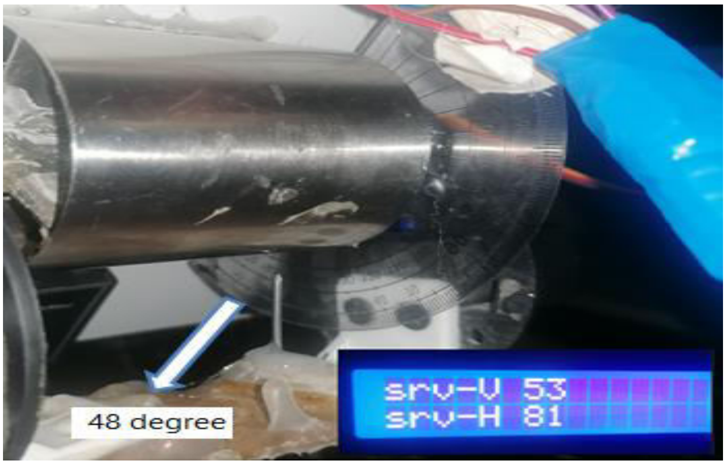

Fig. 15 Vertical angle test

Table 3. Angle comparison

LCD Angle H	Protractor Angle H	LCD Angle V	Protractor Angle H
180	176	90	176
166	162	84	162
146	140	71	140
125	122	68	122
94	90	61	90
72	68	53	68
51	48	46	48
35	32	38	32
18	15	20	15

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VII. VALIDATION

The results will be validated by the correlation coefficient. It is a method used to identify the relationship between two variables. A correlation of -1.0 means a perfect negative correlation, while a correlation of 1.0 means a perfect positive correlation. A correlation of 0.0 means has no relationship between the variables.

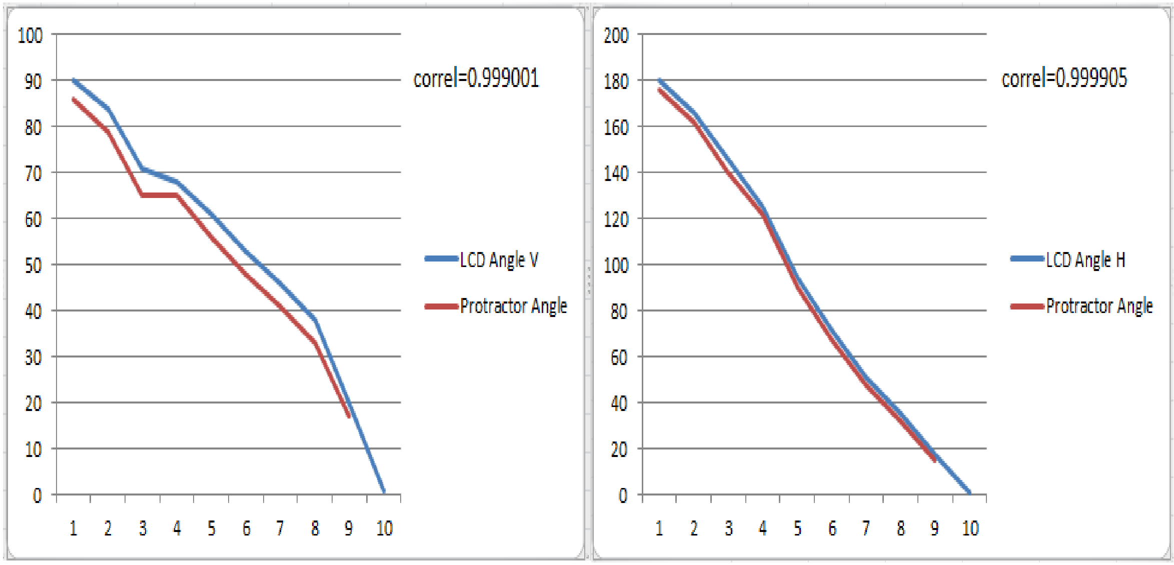

Fig. 16 Correlation coefficients between the theoretical and practical angles

VIII. CONCLUSION

In conclusion, the performance of the two-axis solar tracking system was successfully analyzed. It can be concluded that the dual axis solar tracking system is better than the fixed solar panels in terms of the angels results and following the light sun. Therefore, this system is designed effectively to capture the maximum source of sunlight and make use of solar energy to solve the problem of electricity. The results was validated using correlation coefficient which shows the correlation factor was about 0.999 for both angels vertical and horizontal.

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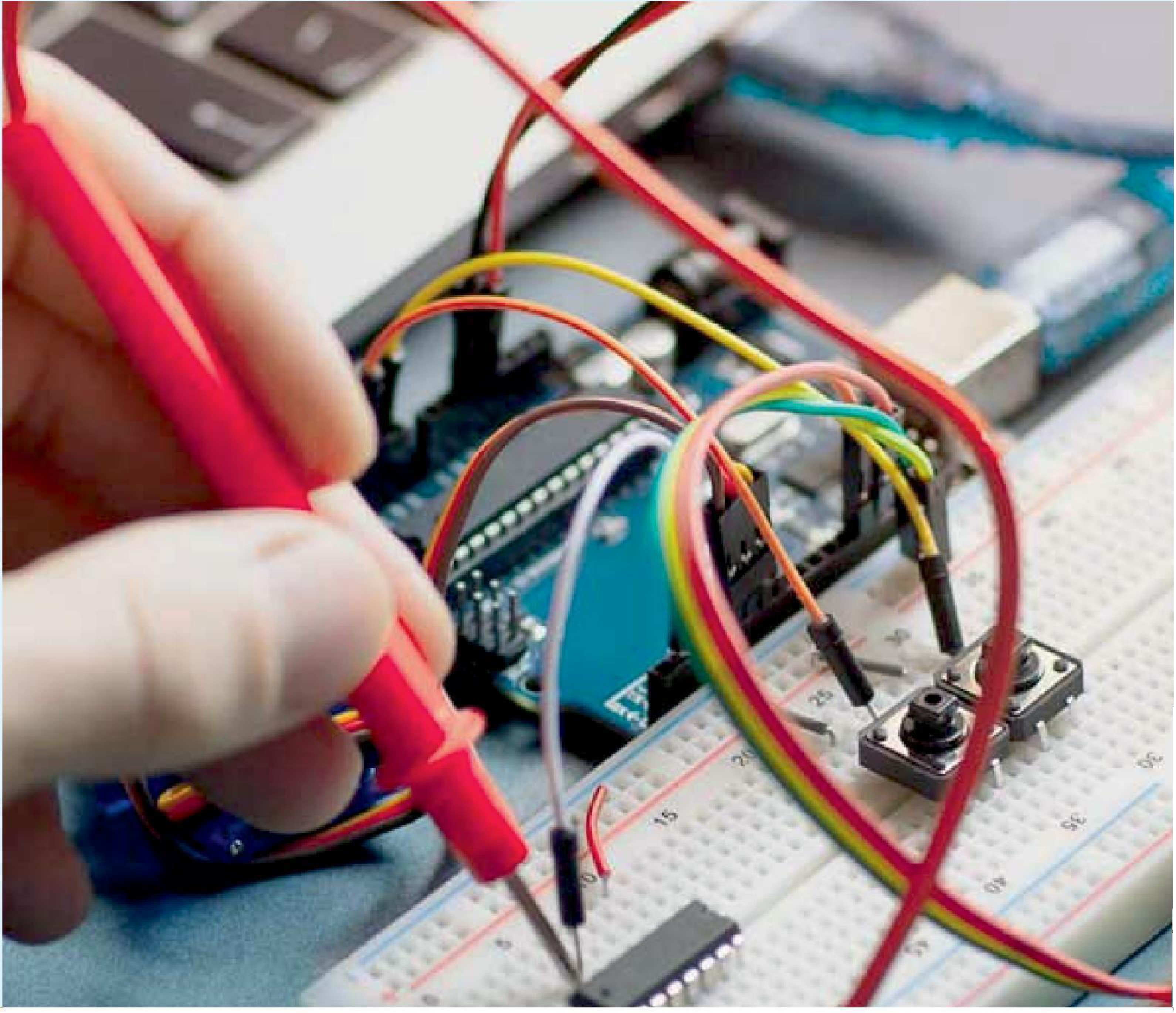

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