Design and Implementation of a Dual-Axis Solar Tracking System STS

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Abstract.Solar energy is converted into electrical energy using photovoltaic panels. The production of electricity from the solar panel is increased by the increase in the collection of solar radiation by the solar panel. To track the sun in vertical and horizontal directions, a dual-axis tracking prototype has been developed to capture the maximum sun rays by tracking the movement of the sun in four different directions. One axis is horizontal, which allows the solar panel to move left and right. The other axis is vertical and allows the panel to turn up and down. The result of this new development provides the solar panels with extensive freedom of movement. This process makes use of the Light Depending Resistor (LDR), which is important for detecting the sun's light by following the source of the light location. Proteus software is being used to design the circuit for the Arduino mega microcontrollers and H-Bridge IC chip. This implemented system can save more energy and probably offer a greater reduction in cost. The project discusses the process of hardware development and the control process of tracking the sun, as well as the circuit design.

1.Introduction

Solar energy is a very large, inexhaustible source of energy. The power intercepted by the earth from the sun is approximately (1.8*1011) MW, which is many thousands of times greater than the current consumption rate of all commercial energy sources on Earth. Associated with the use of solar energy is that its availability varies widely with time. The variation in availability occurs daily because of the day night cycle and also seasonally because of the earth’s orbit around the sun. To rectify the problems, the solar panel should be such that it always receives the maximum intensity of light. It has been seen in the past that the efficiency of the solar panel is around 10-15%, which does not meet the desired load requirements. So there is a need to improve the panel efficiency in an economical way [1].

2. Solar Tracking System

A Solar tracker is an automated solar panel which actually follows the sun to get maximum power. Even though a fixed flat-panel can be set to collect a high proportion of available noon-time energy, significant power is also available in the early mornings and late afternoons when the misalignment with a fixed panel becomes excessive to collect a reasonable proportion of the available energy. Even when the Sun is only 10° above the horizon, the available energy can be roughly half that of noon (or even higher depending on latitude, season, and atmospheric conditions).Thus, the primary benefit of a tracking system is to collect solar energy for the longest period of the day, and with the most accurate alignment as the Sun’s position shifts with the seasons [1].

3. Design and Implementation

There are broadly three stages involved in the design of a dual axis solar tracking system:

An input stage: It consists of light dependent resistors (LDRs) which are responsible for the conversion of sunlight into voltage. When the light source moves, the intensity of light falling on the four LDRs changes. This change is calibrated into voltage, using voltage dividers.

A control stage: It consists of a microcontroller. It receives the voltages from the LDRs, compares them with the built-in comparators, and generates errors. The microcontroller is programmed to ensure that it sends a required signal to the servomotor to act in accordance with the generated error.

The driver stage employs a direct current (DC) motor. The DC motor has high enough torque to drive the panel so that the position of the solar panel is adjusted in such a way that the LDRs are at equal inclination [2].

Figure 1 depicts the methodology adopted. The main component is the Arduino, a single-board microcontroller. It has an open source physical computing platform and a development environment for writing software for the board and is inexpensive. The other main components are Light Dependent Resistors (LDRs), DC motors, and solar panels. The solar tracking system is done by Light Dependent Resistor (LDR). Four LDRs are connected to the Arduino analog pins AO to A3, which act as the input for the system. The analog value of LDR is converted into digital (Pulse Width Modulation) using the built-in Analog-to-Digital Converter [3].

3.1Arduino IDE:

The software design was done using Arduino IDE which was used for programming. The program was written using the C language. Proteus 8 Simulation Software is used for the simulation and checking the code.

3.2 Light Dependent Resistors (LDRs)

Four LDRs are used as sensors. These LDRs detect any change in sunlight through a voltage divider circuit and generate an output signal accordingly. The four LDRs are connected in series with a 4.7k resistor to form a voltage divider circuit as shown in Figure 2. Any change in light intensity falling on the LDR changes the resistance of the LDR, which will correspondingly change the voltage

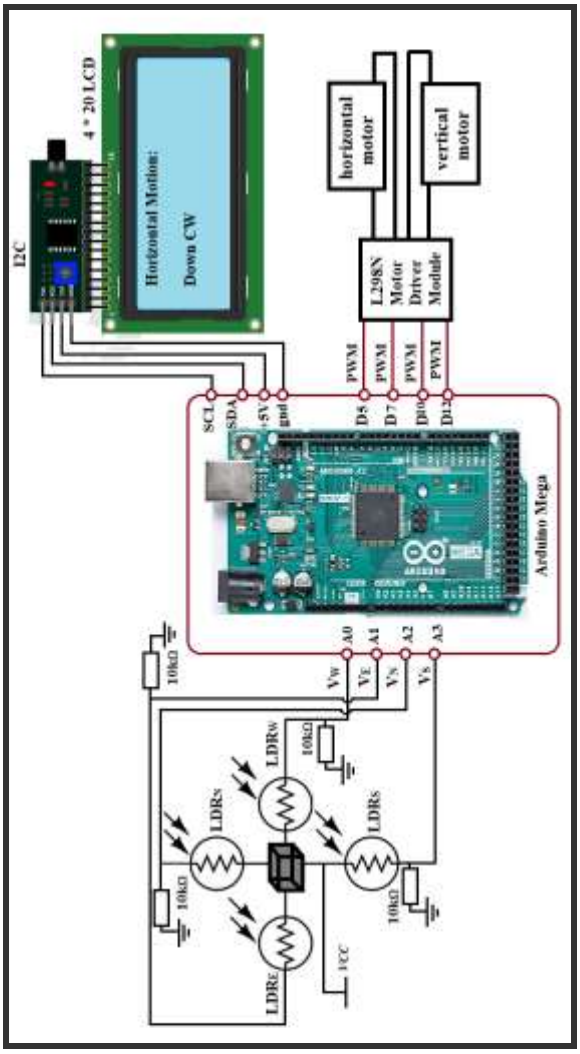

Figure1: Block Diagram of the proposed Dual Axis Sunlight Tracking (DAST) system

output across the 4.7k resistor.The voltage across 4.7kΩ resistor is fed to analog pin of microcontroller

- Voltage from voltage divider circuit of left LDR (L) is fed to analog pin A0 of microcontroller
- Voltage from voltage divider circuit of right LDR (R) is fed to analog pin A1 of microcontroller
- Voltage from voltage divider circuit of down LDR (D) is fed to analog pin A2 of microcontroller
- Voltage from voltage divider circuit of top LDR (T) is fed to analog pin A3 of microcontroller

These voltages are received in analog form, which is then converted to digital form (0–1023) by the microcontroller as shown in Figure 3, a solar sensing device, which comprises a four-quadrant LDR sensor and a cylindrical shade. This device is designed based on the use of the shadow. If the PV panel is not perpendicular to the sunlight, the shadow of the cylinder will cover one or two LDRs, resulting in a differential of light intensity. The best orientation of the PV panel is achieved when the intensity on the east LDR is equal to that on the west LDR, and the intensity on the north LDR is equal to that on the south LDR [4, 9].

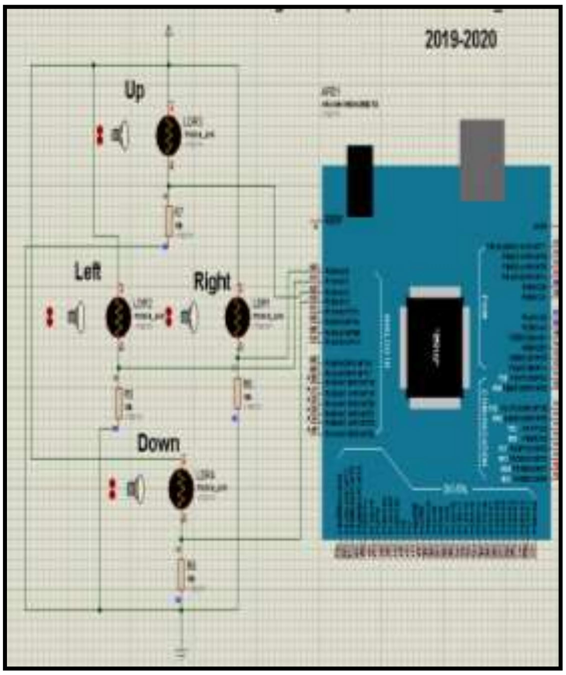

Figure2: LDR sensor circuitry in Proteus

3.3 Arduino Mega Microcontroller

The Arduino Mega has an onboard ATmega2560 microcontroller. It has 16 analog inputs, 54 digital I/O, a USB connection, 4 UART, a power jack, and a reset button. It operates at a 16 MHz frequency. The board can be operated with 5–12 V of external power; if supplied more than this, it can damage the board. It has an onboard 256 KB flash memory, an 8 KB SRAM, and a 4 KB EEPROM.

3.4 L298 Motor Driver Module

The L298N H-bridge IC shown in Figure 4 can allow the control of the speed and direction of two DC motors. This module can be used with motors that have a voltage of between 5 and 35V DC with a peak current up to 2A. [5]

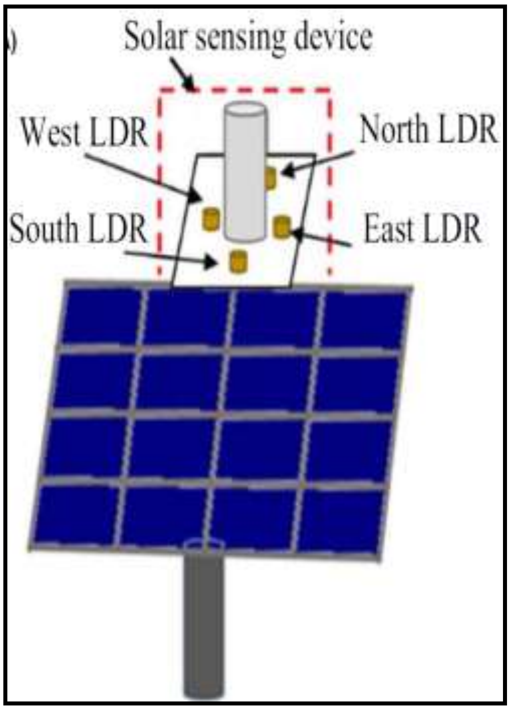

Figure 3: Positions for LDR sensors

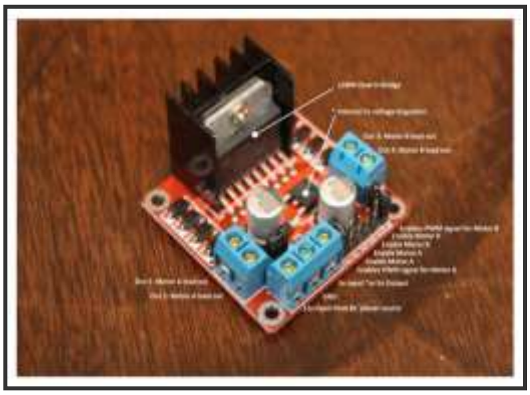

Figure 4: L298N dual H-Bridge Controller Module

In the problem of what kind of driver module we should use, we find that the L298N module is easy to control. It can not only adjust the DC motor's positive and reverse rotation, but it can also modulate the speed by modulating the PWM waveform that the control board outputs; the driver module has the function of over current protection. When the motor gets stuck, it can protect the whole circuit and the DC motor. Therefore, we chose a driver model based on the L298N to drive the DC motor in this experiment [6].

Because the motor has a great sensibility, the current cannot be mutated, and if the current is suddenly cut off, it will produce a higher voltage power tube ends, resulting in damage to the device.

So we applied to the diode in the driver circuit to protect the freewheeling L298 chip. This circuit mainly uses diode unidirectional continuity. This freewheeling circuit diagram is shown in Figure 5[7].

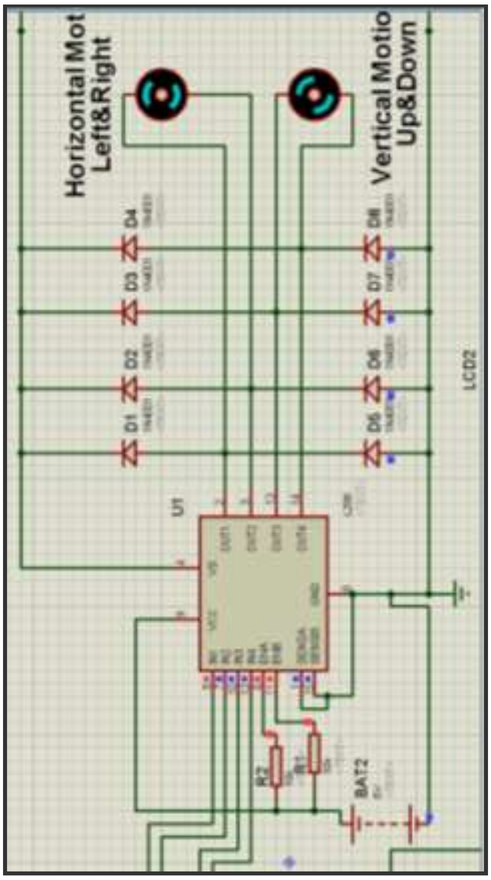

Figure 5: L298 Motor Driver Module in Proteus

3.5 DC Motor:

For providing horizontal and vertical movement to the solar tracker, we have put in two high-power DC motors (horizontal motor and vertical motor). The DC Gear Motor shown in Figure 6 has a working voltage of 3-9V, 281 RPM, rated current of 250mA, and rated power of 1W [8].

3.6 Power Supply:

A 6 V rechargeable battery is used to supply power to solar tracking mechanism. The battery can receive power from solar panel. 6 V from rechargeable battery is used to supply Arduino microcontroller. To supply two servos and relay module 6 V is used.

Figure 6: DC Gear Motor

4.Simulation of the System Using Proteus Software

4.1 Proteus Software:

The Proteus simulator is used for checking the feasibility of a program and the workings of the designed system without actual implementation on hardware. The control algorithm was first tested in the Proteus environment. In this simulation environment, the errors are found and the algorithm is corrected. After the simulation, the electronic circuit is set up.

4.2 Software implementation:

The software implementation consists of coding the algorithm for the tracking system in the Arduino IDE environment and uploading it to the microcontroller. The flowchart describing the microcontroller operation is presented in Figure 7.

The algorithm is based on the analog values returned by the left LDR and the right LDR, as well as the up LDR and down LDR. For horizontal tracking, the average values from the right LDR and left LDR are compared, and if the left LDR receives more light, the horizontal DC motor (HDSM) will move in that direction (rotates clockwise (CW)). The DC motor will continue to rotate until the difference result is between a threshold value (less than or equal 0.1V), which means that the solar tracker is approximately perpendicular to the light source. If the right LDR receives more light, the horizontal DC motor (HDCM) moves in that direction (rotates counterclockwise (CCW)) and will continue to rotate until the difference result is less than or equal to 0.1V. The same way is used for vertical tracking. The use of the threshold value as a hysteresis band in the algorithm aims to reduce the power consumption and ensure smooth movements of the DC motor. That means if the difference result is in the hysteresis band (less than or equal to 0.1V), the horizontal DC motor (HDCM) always stops. And if the difference result is outside the hysteresis band (more than 0.1V), the DC motor will start to rotate CCW or CW. The same principle is used for vertical DC motor (VDCM) operation.

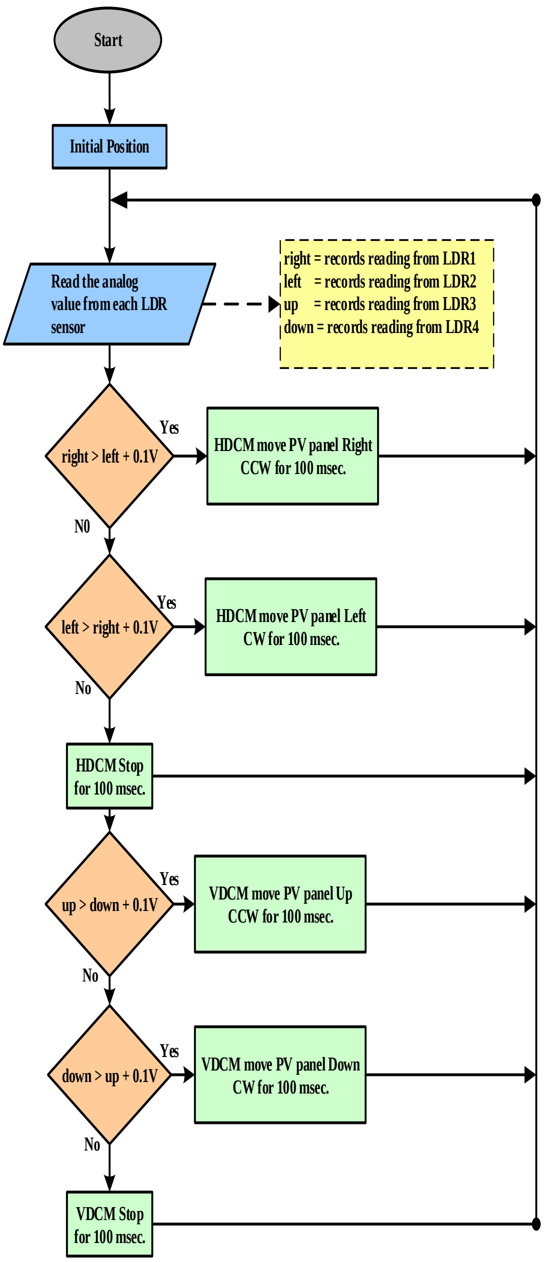

Figure 7: The algorithm for automatic Dual-Axis solar tracking (DAST)

The use of the threshold in the algorithm makes the solar tracker robust, work with high precision, and it does not consume too much energy. The used algorithm is based on simple instructions that do not require extensive calculations. Hence, low-cost microcontrollers can easily implement this algorithm in order to reduce the system cost.

5. Tracking Process

DC motor movement will follow the condition of the LDR. In the dual axis solar tracking system, there are 2 DC motors. One motor is used to control vertical (up & down) motion and another motor is used to control horizontal motion (right & left). The microcontroller responsible for sunlight tracking receives the voltage from the voltage divider circuit formed by the LDR and generates output for two DC motors accordingly.

- First, Microcontroller receives the voltages from voltage divider circuit formed by LDR using 4 analog pin (A0, A1, A2, A3).
- Second, it will compare the voltage received by circuit and generates output to two motors as follow:

Case 1: LDR1(right) light intensity = LDR2 (left):

Figure 8 is the first case of the programming part. This compares the entire sensor to one fixed value, which means the sensors on the right and left are receiving the same light intensity. The position of light is placed at position 5, where light is distributed equally. Therefore, the DC motor for horizontal motion stays in the same position (stops) instead of rotating. In real applications, this is where the solar panel is perpendicular to the sunlight and the production of power can be improved.

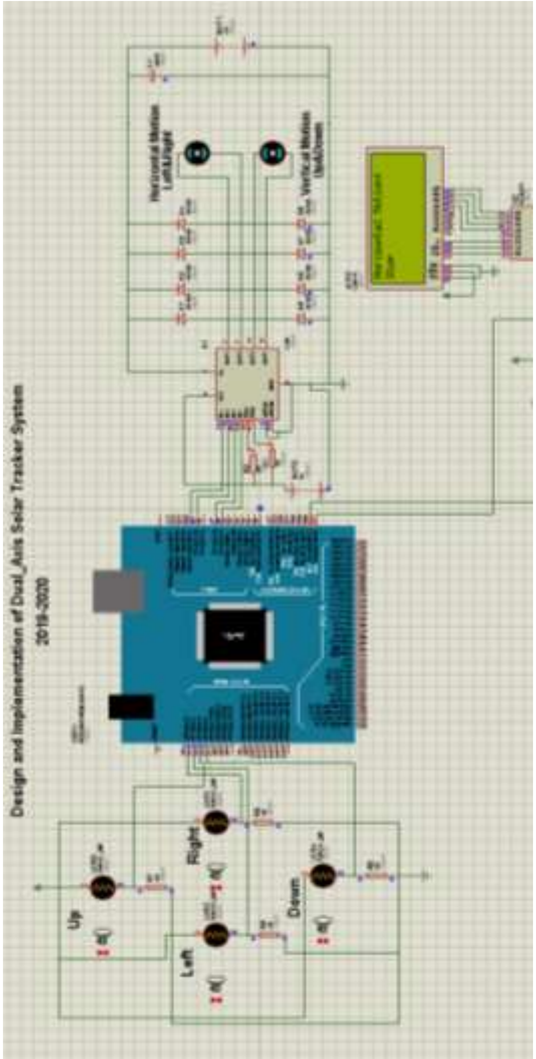

Figure 8: Condition for LDR1(right) light intensity = LDR2 (left)

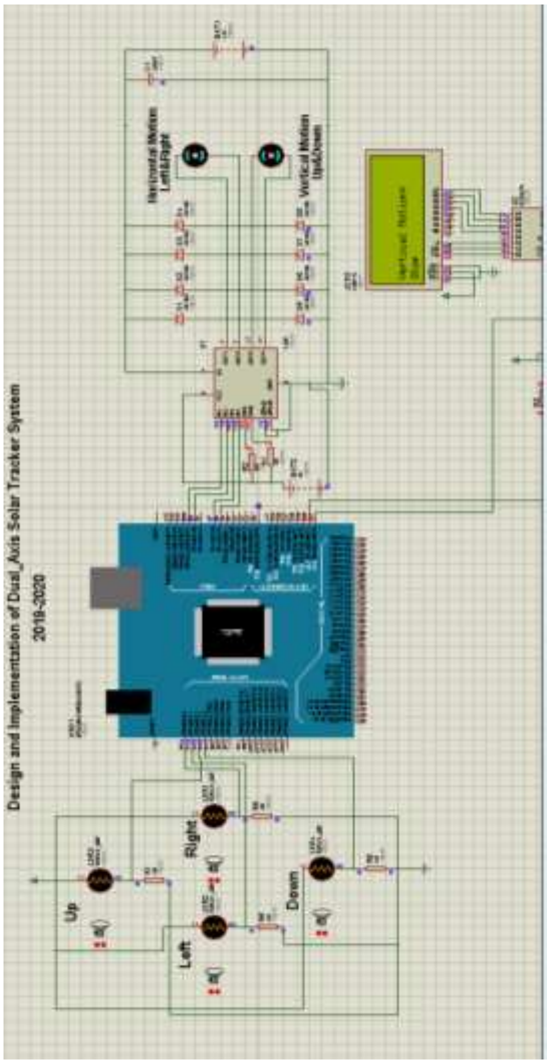

Figure 9: Condition for LDR3 (up) light intensity = LDR4 (down)

Case 2: LDR3 (up) light intensity = LDR4 (down):

Figure 9 is the second case of the programming part. This compares the entire sensor to one fixed value, which means the sensors for up and down are receiving the same light intensity. The position of light is placed at position 5, where light is distributed equally. Therefore, the DC motor for vertical motion stays in the same position (stops) instead of rotating. In real applications, this is where the solar panel is perpendicular to the sunlight and the production of power can be improved.

Case 3: LDR3 (up) light intensity > LDR4 (down) + 0.1V:

If the difference between (up) and (down) is found to be greater than the tolerance level here set as 0.1 V (20 in digital), then the microcontroller tells the motor responsible for vertical motion to move in the direction of the LDR, whose voltage is found to be greater compared to the other. The motor will move in the direction of the up LDR if (up) is greater than (down) (counter clockwise direction (CCW)) as shown in figure 10.

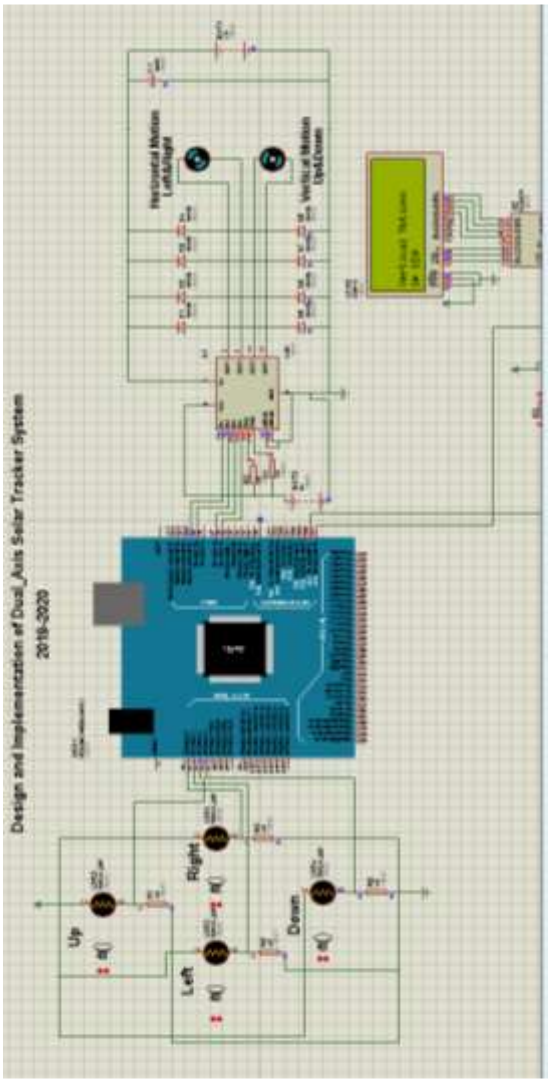

Figure 10: Condition for LDR3(up) light intensity > LDR4 (down) + 0.1V

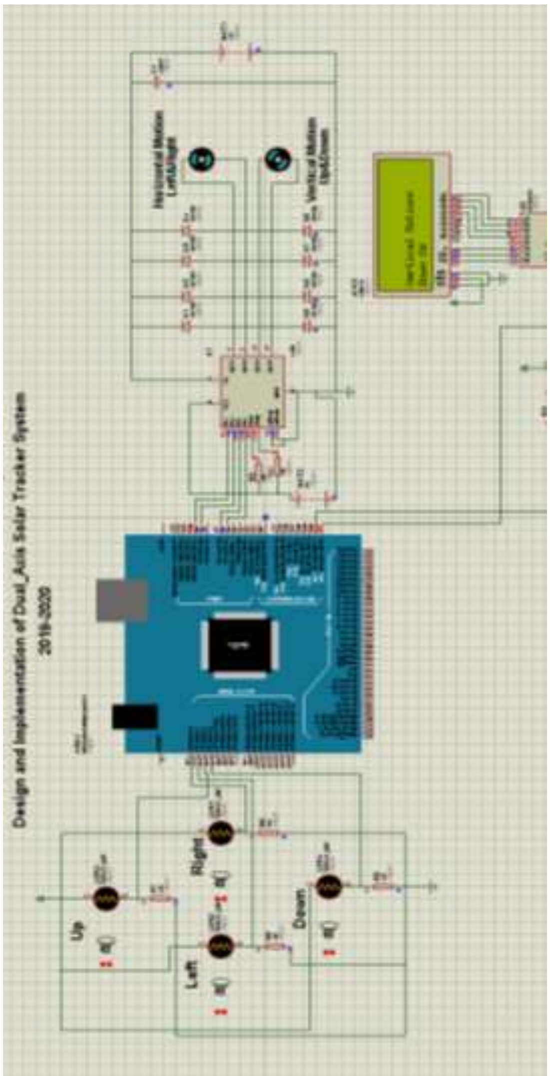

Figure 11: Condition for LDR3 (up) light intensity < LDR2 (down) + 0.1V

Case 4: LDR3 (up) light intensity < LDR2 (down) + 0.1V:

Similarly, if the (down) voltage is found to be greater than (up), then the microcontroller tells the motor responsible for vertical motion to move in the direction of the down LDR (clockwise direction (CW)) as shown in figure 11.

Case 5: LDR1(right) light intensity > LDR2 (left) + 0.1V:

If the (Right) voltage is found to be greater than the (Left), then the microcontroller tells the motor responsible for horizontal motion to move in the direction of the right LDR (counter clockwise direction (CCW)) as shown in figure 12.

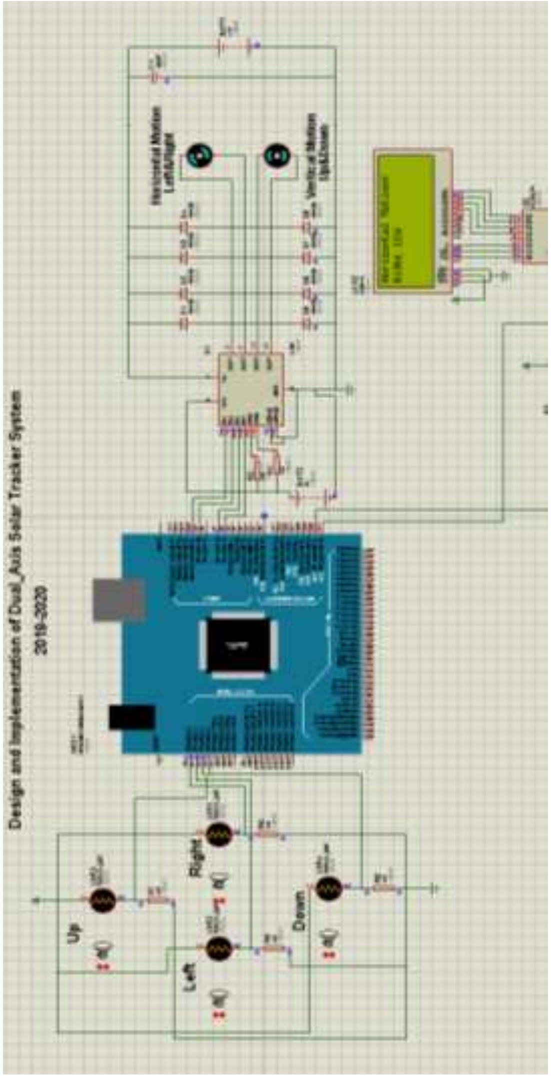

Figure 12: Condition for LDR1(right) light intensity > LDR2 (left) + 0.1V

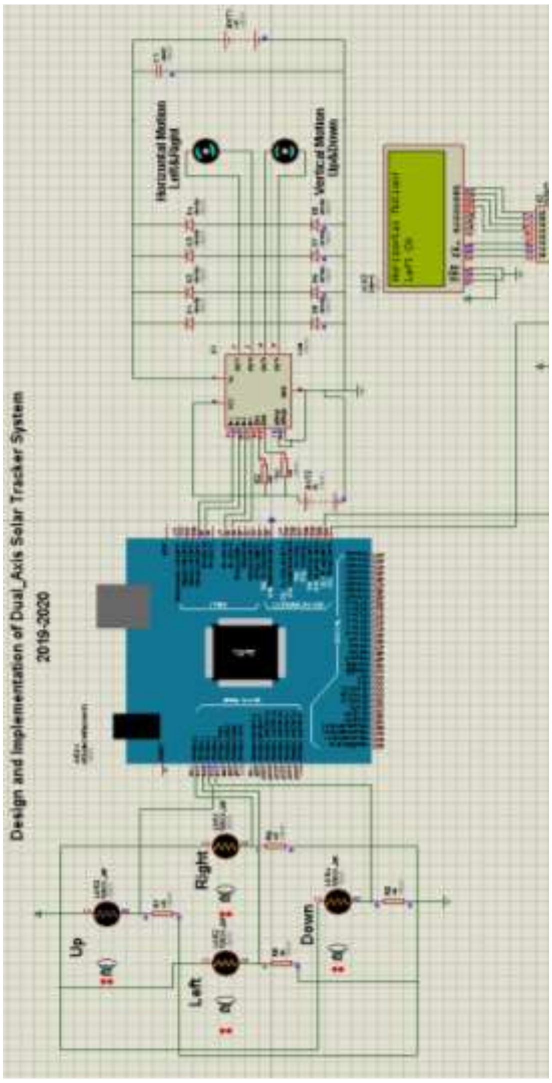

Figure 13: Condition for LDR1(right) light intensity < LDR2 (left) + 0.1V

Case 6: LDR1(right) light intensity < LDR2 (left) + 0.1V:

Similarly, if the (Left) voltage is found to be greater than the (Right), then the microcontroller tells the motor responsible for horizontal motion to move in the direction of the left LDR (clockwise direction (CW)) as shown in figure 13.

6. Conclusion

Both single-axis and dual-axis are highly efficient in terms of the electrical energy output when compared to the fixed mount system.

Compared to a single axis solar tracker, the dual axis tracker has more efficiency. The main contribution of this work is the development of a two-axis solar tracker prototype that uses four sensors to predict the sun's apparent position. By using the Proteus software, it helps to design the draft for the hardware dual axis solar tracker. The Arduino helps to make the circuit easier, which saves a lot of time and energy. In this system, further research can be done to make the system more precise and complete.

In this work, all the objectives have been achieved, which is, firstly, to design a model of a dual-axis solar tracker by using software (Proteus). The design has been shown and analyzed. Secondly, to program the micro-controller on Arduino (ATmega328p) so that the rotation of the DC motor can be controlled by the microcontroller and H-bridge. The programming part consists of 5 cases which have been stated and analyzed.

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