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Dual Axis Solar Tracking System with Weather Monitoring System

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Abstract
This paper presents the design and implementation of a solar tracking system integrated with weather monitoring capabilities. The system is designed to maximize the efficiency of solar panels by continuously adjusting their orientation to track the sun's position throughout the day. In addition to solar tracking, the system incorporates weather monitoring sensors to collect real-time data on environmental conditions such as cloud cover, wind speed, temperature and light intensity. This data is utilized to dynamically adjust the solar panel's position to optimize energy production and system performance in varying weather conditions. The integration of dual-axis tracking with weather monitoring enhances the overall efficiency and reliability of solar energy systems, making them more adaptable to changing environmental factors and increasing their potential for renewable energy generation.

1. Introduction
The growing demand for a consistent and plentiful energy supply has led governments to enhance the utilization of renewable energy, reducing dependence on conventional sources. Solar energy, particularly harnessed through photovoltaic cells, stands out as a valued renewable source. These cells utilize the photovoltaic effect to convert solar energy into electricity, applicable in various fields such as solar thermal energy, solar heating, photovoltaic applications, and solar architecture [2]. The efficiency of photovoltaic cells is directly linked to light intensity, and since the sun's position changes throughout the day, a dual-axis solar tracker has been developed to continuously track solar radiations, optimizing energy generation [5].
The dual-axis solar tracker, which aligns with the sun's radiations for maximum intensity, significantly contributes to fulfilling the country's energy needs [3]. To maximize energy absorption, the solar panel is kept perpendicular to the sun, achieved through the use of a solar tracker. This integration improves efficiency by 40% compared to fixed panels. Traditional single-axis trackers move from east to west during the day, while modern dual-axis trackers track both east-west and north-south movements of the sun. In this project, we enhance the solar tracking system by integrating it with a weather sensor [7]. This sensor system, featuring temperature, raindrop, and humidity detectors, displays output on a Liquid Crystal Display (LCD). Light Detecting Resistors (LDRs) sense the maximum light intensity, and an Arduino system guides the rotation of servomotors to optimize the solar panel's alignment with the highest light intensity. Servomotors are responsible for rotating the solar panel based on this information. By incorporating weather sensors, the system adapts to varying weather conditions [2]. Over the past million years, human energy needs have increased steadily. Solar energy emerges as a promising and reliable source, free from polluting effects. Maximizing energy efficiency through this method becomes crucial for sustainable and beneficial energy utilization [1].

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1.1. Introduction to Module

1.1.1. Light Detecting Unit

The LIGHT Unit is a light intensity detection sensor that combines an adjustable 10K resistor with a photoresistor. It has the ability to measure light intensity and establish a light intensity threshold. As the intensity of the incident light increases, the photoresistor's resistance lowers.

Four light-detecting resistors arranged in pairs make up the light-detecting unit. These resistors measure light intensity and convert it to analog voltage so that the controller can use it as input. Two sets of Light Dependent Resistors (LDRs) are used; one pair senses the sun's position from east to west, while the other pair follows it from north to south. According to the equation RL = 500/LUX, resistance is inversely related to light intensity and decreases as light intensity rises.

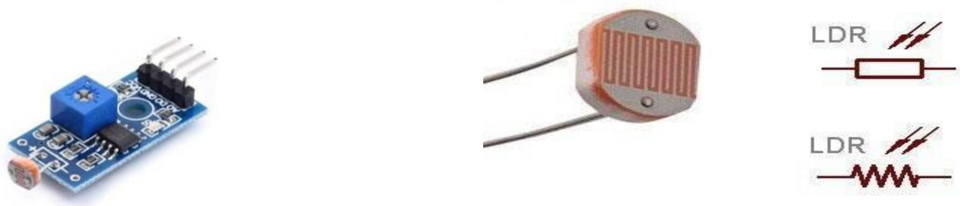

Figure 1: Light Detecting Unit

1.1.2. Monitoring Unit

The central monitoring unit for the entire system is Arduino, as depicted. The light Dependent Resistor (LDR) is linked to the first four pins of Arduino. Arduino receives input from the LDR and, based on that data, issues instructions to the servomotors, directing them to rotate either horizontally or vertically.

When it comes to dual-axis solar tracker systems, it is critical to incorporate weather sensors in addition to strong monitoring features to maximize efficiency and performance. These systems are able to dynamically adjust panel orientation in order to maximize energy capture and minimize risks during unfavorable weather events. They do this by using light sensors to continuously monitor the sun's position and responding to real-time weather data. IoT-based remote monitoring enables centralized control and data access, and logging features facilitate trend analysis and optimization.

Figure 2: Monitoring Unit

1.1.3. Movement Controlling Unit

The two servo motors make up the movement controlling unit. Arduino generates 5 volts, which is used to power servo motors, which need an input of about 4.5 volts. Two motors control the horizontal and vertical rotation, respectively. This reduces the amount of power consumed because only one motor runs at a time.

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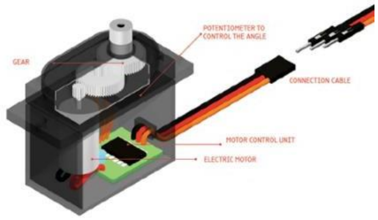

Figure 3: Movement Controlling Unit

1.1.4. Weather Sensor

The weather sensor uses an Arduino as an interface to measure and show the relative humidity and ambient temperature on an LCD display.

A weather sensor typically consists of a number of parts, including barometric pressure, temperature, humidity, and wind speed sensors. Together, these sensors collect information about the current weather, which enables the solar tracker system to modify its operation. For example, in strong winds, the tracker might need to be stowed or locked into place to avoid damage. Similarly, the tracker's operation may need to be adjusted in response to extreme temperatures or humidity levels in order to maximize energy capture and guarantee system longevity.

Figure 4: Weather Sensor

1.1.5. DHT11 Sensor

The DHT11 Temperature & Humidity Sensor has a digital signal output that is calibrated in addition to a temperature and humidity sensor complex. It ensures high reliability and excellent long-term stability by utilizing temperature and humidity sensing technology along with an exclusive digital signal acquisition technique. This sensor connects to a high-performance 8-bit microcontroller that offers excellent quality, quick response, anti-interference capability, and cost-effectiveness. It also includes a resistive-type humidity measurement component and an NTC temperature measurement component.

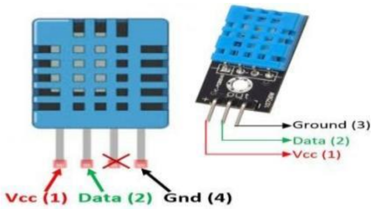

Figure 5: DHT11 Sensor

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1.1.6. INA219 Sensor

The INA219 detects shunts on buses with voltages ranging from 0 to 26 V. The device draws a maximum of 1 mA of supply current from a single 3- to 5.5-V supply. The temperature range for the INA219 is -40°C to 125°C. The INA219 is a power and current monitor that can be interfaced with either SMBUS or I2C.

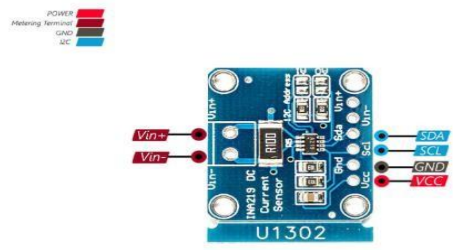

Figure 6: INA219 Sensor

1.1.7. Solar Panel

A solar panel is an apparatus that uses photovoltaic (PV) cells to convert sunlight into electrical power. Materials used in photovoltaic cells generate excited electrons when exposed to light. Direct current (DC) electricity is created when electrons move through a circuit. This electricity can be stored in batteries or used to power a variety of devices. PV modules, solar electric panels, and solar cell panels are other names for solar panels. Typically, solar panels are installed in groups known as arrays or systems. One or more solar panels, an inverter (which changes DC electricity into AC electricity), and occasionally additional parts like controllers, meters, and trackers make up a photovoltaic system. It is possible to generate electricity for off-grid uses with a photovoltaic system.

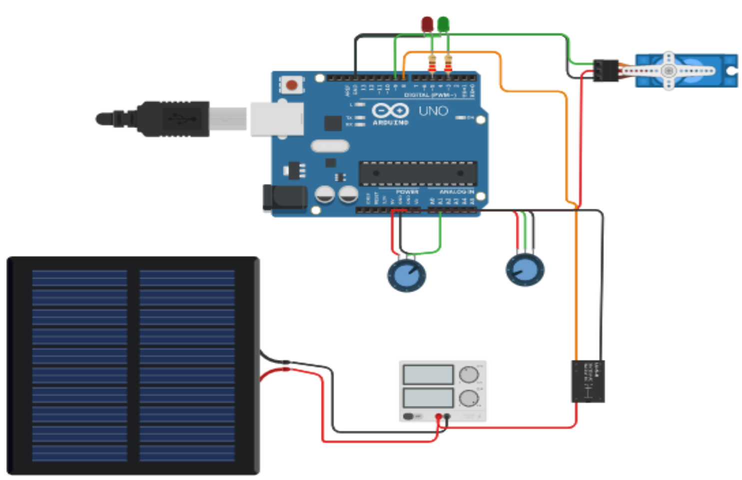

Figure 7: Solar Pannel

1.1.8. Servo Motors

One kind of motor that has extremely precise rotation is a servo motor. Typically, this kind of motor is made up of a control circuit that gives feedback on the motor shaft's current position. This

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feedback enables the servo motors to rotate extremely precisely. A servo motor is used when you want to rotate an object at a certain angle or distance. It consists only of a basic motor that is driven by a servo mechanism. A motor is referred to as a DC servo motor if it is powered by a DC power supply and as an AC servo motor if it is powered by AC power. We will only be talking about the operation of the DC servo motor in this tutorial.

Figure 8: Servo Motor

2. Hardware Implementation of Project

2.1.1. Arduino Uno

The open-source Arduino Uno microcontroller board was created by Arduino.cc and is based on the Microchip ATmega328P microprocessor. It has six analog and fourteen digital I/O pins, and it may be powered by an external 9-volt battery or a USB. The board is the first in a line of USB-based Arduino boards, and it resembles the Arduino Nano and Leonardo.

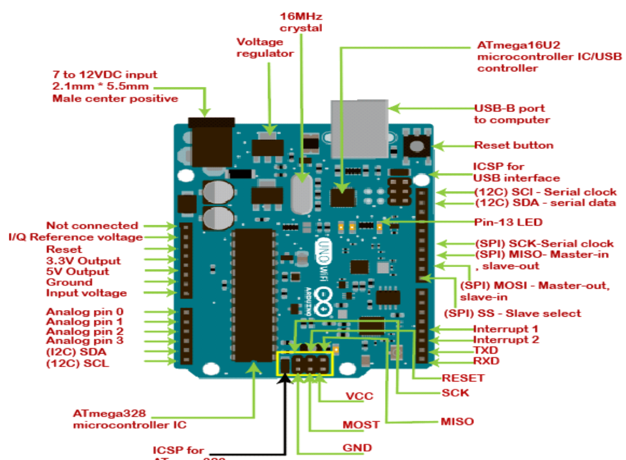

Figure 9: Arduino UNO

The board's ATmega328 microcontroller is preprogrammed with a bootloader, making it simple to upload code without requiring an external hardware programmer. Windows, MAC, or Linux PCs can all run the Arduino IDE (Integrated Development Environment) software; however, Windows is the recommended operating system. IDEs employ programming languages such as C and C++. The Arduino Uno board can be powered by Mirco SD cards for additional data storage, or it can be powered by a USB cable or an Adapter. When linked to an external device, the board's built-in regulating mechanism maintains voltage under control. Resetting the board and starting the running software from scratch is accomplished via a reset pin. 13KB of flash memory on the board is used to store code instructions. It can be turned on immediately using a USB port or an external adapter if it needs 5 V.

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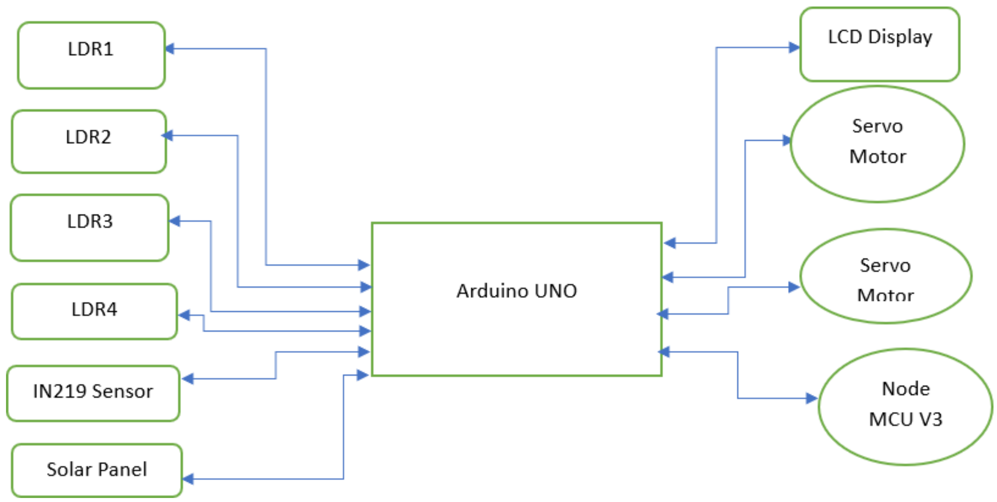

Figure 10: BLOCK DIAGRAM

2.1.2. Node MCU V3

NodeMCU v3 is a development board based on the ESP8266 microcontroller. It's widely used for IoT projects due to its low cost, built-in Wi-Fi capabilities, and compatibility with the Arduino IDE. The board features GPIO pins, analog inputs, PWM outputs, SPI, I2C, and UART interfaces, making it versatile for various projects.

ThingView app, on the other hand, is a mobile application designed for monitoring and controlling IoT devices remotely. It provides a user-friendly interface for visualizing sensor data, receiving alerts, and interacting with connected devices. ThingView supports communication protocols like MQTT, HTTP, and WebSocket, enabling integration with different IoT platforms and devices, including NodeMCU v3.

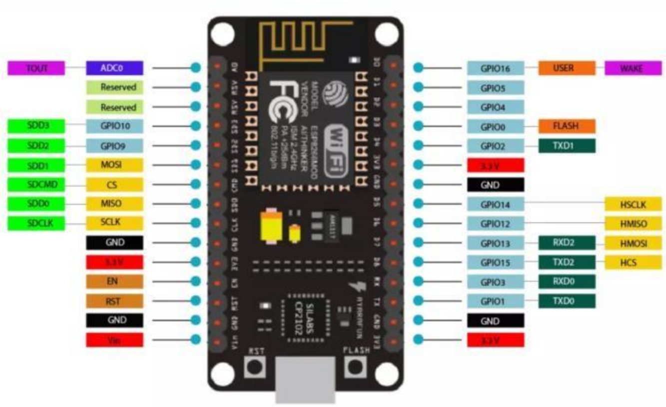

Figure 11: NodeMCU V3

3. Software Implementation of project

3.1. Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform program that runs on

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Windows, macOS, and Linux and is designed with C and C++ functionalities. With the aid of third-party cores, it may also be used to build and upload applications to other vendor development boards and Arduino comparable boards. The IDE's source code is made available under the terms of the GNU General Public License, version 2. Specific code structuring guidelines are used by the Arduino IDE to support the languages C and C++. Many standard input and output operations are provided by a software library from the Wiring project, which is provided by the Arduino IDE. With the GNU toolchain, which is also included with the IDE release, user-written code only needs two basic functions to be built and linked into an executable cyclic executive program. These functions are for initiating the sketch and the main program loop, and they are done so by using a program stub called main (). The executable code is converted by the Arduino IDE using the program avrdude into a text file with hexadecimal encoding, which is then loaded into the Arduino board by a firmware loader program. Typically, official Arduino boards are flashed with user code using the avrdude uploading tool.
The Processing IDE is a parent of the Arduino IDE; however, starting with version 2.0, the Processing IDE will give way to the Eclipse Theia IDE framework, which is built on Visual Studio Code. Other vendors began to develop proprietary opensource compilers and tools (cores) that could create and upload sketches to microcontrollers that weren't supported by Arduino's official range of microcontrollers as the platform for Arduino software gained popularity.

Figure 12: Thing View Free

3.2. Thing View Free:
ThingView Free is a mobile application that allows you to wirelessly connect and interact with Arduino boards from your smartphone or tablet. Here are some key details about it:
Purpose:
- Facilitate communication between Arduino microcontroller boards and mobile devices over Wi-Fi or Bluetooth.
- Enables remote monitoring and control of Arduino projects and prototypes

Features:
- User-friendly interface to send commands and data to the Arduino.
- Receive sensor data and feedback from the Arduino in real-time.
- Configure I/O pin modes (INPUT, OUTPUT, etc.) and write digital/analog values.
- Graphing capabilities to visualize sensor data over time.
- Example sketches and libraries provided for common use cases.

Compatibility:
- Works with Arduino boards like Uno, Mega, Nano, ESP8266, ESP32 etc.
- Requires installing firmware on the Arduino to enable Wi-Fi/Bluetooth connectivity.
- Available for both iOS and Android mobile devices

This app bridges the gap between physical Arduino projects and virtual control/monitoring from mobile devices. It's useful for IoT projects, robotics, home automation prototypes and more where

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you want to interact with the Arduino remotely. The free version likely has basic functionality while a paid pro version may offer advanced features.

Figure 13: Done Compiling and Uploading of Code

Figure 14: Output of Serial Monitor

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4. Working

The solar panel fixed to a structure in the dual axis solar tracking system spins in response to the sun's location as detected by the sensor. Four resistors and four LDRs, respectively, are linked to the Arduino's four analog pins, A1, A2, A3, and A4. These components are internally coupled in a voltage divider pattern, as seen in Figure 3. As seen in fig.3, the Arduino's digital pins 9 and 10 provide PWM inputs to the two servo motors. Essentially, LDRs are the primary light sensors. Two solar panels that are mounted to the structure support the servo motor. The microcontroller receives an upload of the Arduino program. The model functions as follows: each LDR senses in the following directions: top, bottom, left, and right. It also detects the amount of sunlight falling on each LDR. When two top and two bottom LDRs' analog readings are compared for north-south tracking, the vertical servo will move in the direction where the bottom set of LDRs receives more light. The servo motor travels in that direction if the upper LDRs detect more light. For angular deviation, the analog values from two left and two right LDRs are compared. The horizontal servo will move in the direction indicated if the right set of LDRs detects lighter than the right set.

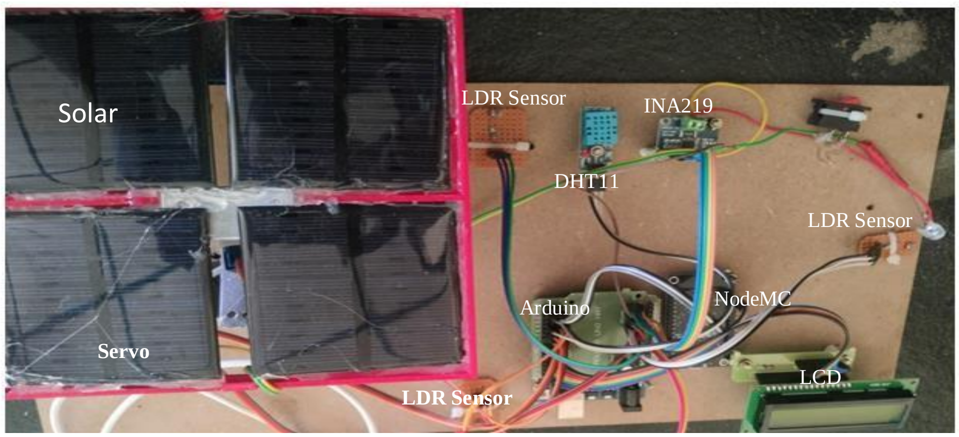

Figure 15: Realtime implementation of the device (off state)

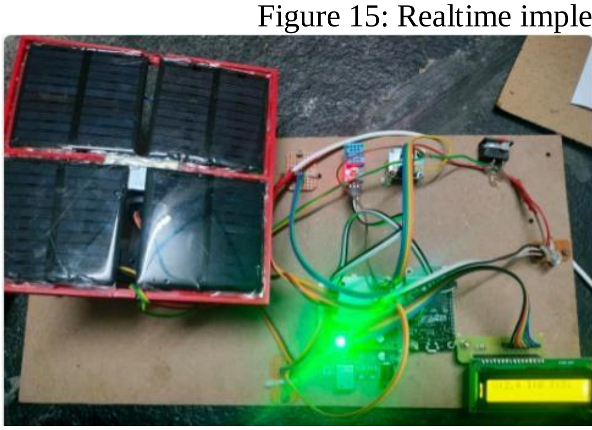

Figure 16: Realtime implementation of the device (on state)

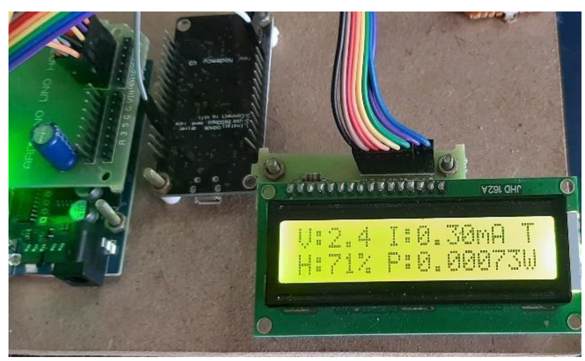

Figure 17: Output display of the device

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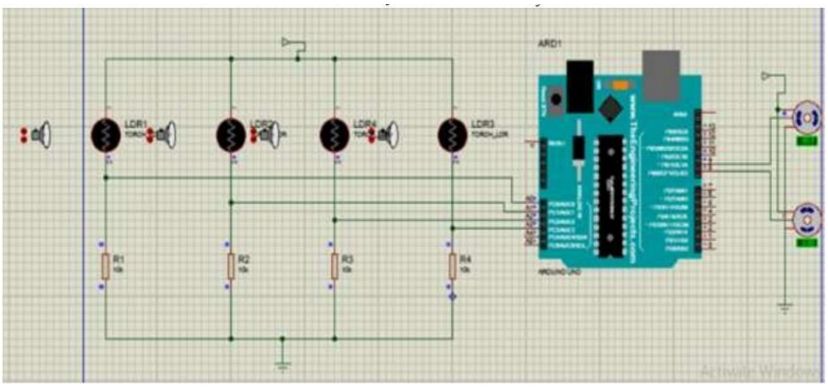

Figure 18: Dual Axis Solar Tracking System

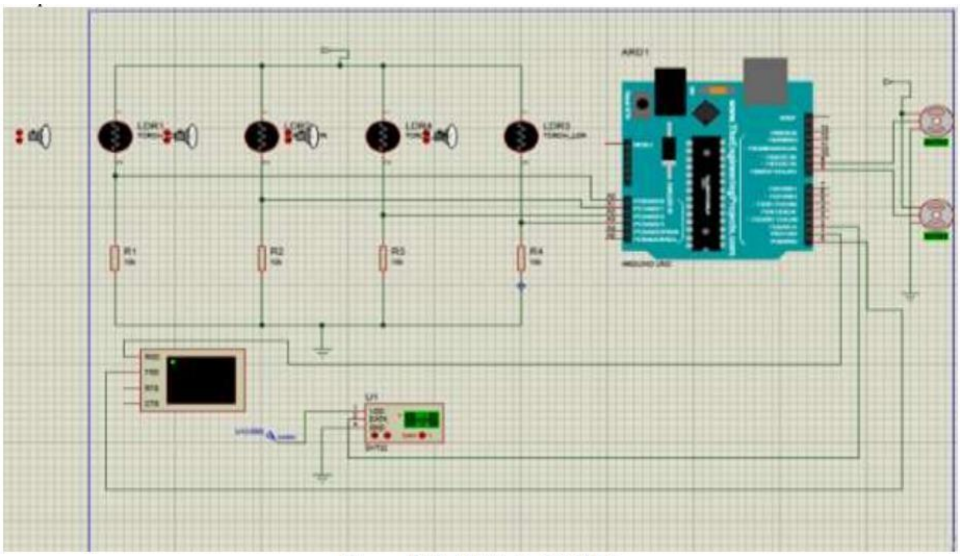

Figure 19: Weather Monitoring

5. Construction Steps:

- Grab a PCB board. Using adhesive, secure the solar panel in the PCB's middle.
- Attach the two solar panel wires to the four corners of the panel and mark the locations for the four LDRs to check the output.
- To make soldering easier, now cut one of the LDR's two leads so that one is longer and the other is shorter to show the polarity.
- Place these four LDRs into the PCB's designated spots.
- Bend the aluminum strips with perforations into the corresponding forms as depicted in the image.
- Using one of the bent metal strips, place it on the rear side of the PCB with the help og glue.
- Solder the two LDR leads in the circuit as shown.
- Attach 10k Ω resistors to the other ends of the LDR's leads.
- Attach wires to the four leads of each of the four LDRs.
- To obtain the output from the LDRs, now link them to them using bus wires. Deliver the output to the appropriate pins on the Arduino board.

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- As indicated in the image, insert it into the metal strip that has been perforated.
- At this point, solder the resistors and connecting wires in accordance with the circuit.
- Insert two additional wires to provide the VCC and GND supplies through the perforated metal strip.
- Solder the resistors and other wire to one side of the LDR and one of the wires to the other.
- Use wires to short the resistors and the LDR's leads.
- At this point, use screws and glue to secure the servo motor to the metal strip. Attach them to the appropriate pins on the Arduino board.
- The 16*2 LCD display is initially linked to the I2C module.
- Next, as illustrated in Figure 4, the Arduino's 5-volt supply is linked to the VCC pin, and the I2C module's ground is connected to the Arduino's ground.
- The Arduino is linked to the ground, Vcc, and signal pins of the DHT11 sensor.
- Next, take another piece of aluminum perforated metal that has been bent into the shape indicated in the picture.
- Attach a second servo motor to this metal strip using glue and screws. Your solar tracker system is now prepared.

6. Results

Consequently, the system's experiment results were achieved by installing it on the rooftop.

Outputs of dual axis solar tracker: -

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7. Conclusion

The combination of a weather monitoring system and a dual axis solar tracking system provides a comprehensive approach to maximize solar energy generation while maintaining dependability and operating efficiency. Through the dynamic adjustment of solar panel orientation in response to both sun position and current weather, this type of system maximizes energy harvest, reduces negative environmental effects, and improves system resilience. The potential for sustainable energy generation in a variety of environmental conditions is highlighted by the synergy between solar tracking and weather monitoring, opening the door to a more effective and robust renewable energy infrastructure.

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