ADVANCED DUAL-AXIS SOLAR TRACKER INTEGRATED WITH WEATHER MONITORING SENSORS

Mr. S. Rajeev, Assistant professor, Electronics and Communication Engineering, Krishna University College of Engineering and Technology, Krishna, (A.P), India
Chitturi Dhakshinya, B.Tech, Electronics and Communication Engineering, Krishna University College of Engineering and Technology, Krishna, (A.P), India
Chalamcharla Madan Kumar, B.Tech, Electronics and Communication Engineering, Krishna University College of Engineering and Technology, Krishna, (A.P), India
Kuppala Lakshmi Praveena, B.Tech, Electronics and Communication Engineering, Krishna University College of Engineering and Technology, Krishna, (A.P), India
Madireddy Gowtham, B.Tech, Electronics and Communication Engineering, Krishna University College of Engineering and Technology, Krishna, (A.P), India
Jalli Sravani, B.Tech, Electronics and Communication Engineering, Krishna University College of Engineering and Technology, Krishna, (A.P), India

Abstract
The design and deployment of a solar tracking system with weather monitoring features is presented in this paper. By constantly reorienting the solar panels to follow the sun's position throughout the day, the system is intended to optimize the efficiency of the panels. The system uses weather monitoring sensors in addition to solar tracking to gather data on environmental parameters like temperature, light intensity, wind speed, and cloud cover in real time. In order to maximize energy production and system performance under various weather conditions, this data is used to dynamically modify the position of the solar panel. When dual-axis tracking and weather monitoring are combined, solar energy systems become more dependable and efficient overall, increasing their capacity to generate renewable energy and their ability to adjust to shifting environmental conditions.

Introduction

The increasing need for a stable and abundant energy supply has prompted governments to bolster the use of renewable energy, decreasing reliance on traditional sources. Solar energy, particularly captured through photovoltaic cells, is recognized as a valuable renewable resource. These cells employ the photovoltaic effect to transform solar energy into electricity, applicable across diverse areas such as solar thermal energy, solar heating, photovoltaic applications, and solar architecture [2]. The effectiveness of photovoltaic cells is directly connected to light intensity, and as the sun's position shifts throughout the day, a dual-axis solar tracker has been created to continuously follow solar radiations, optimizing energy production [5].

The dual-axis solar tracker, which aligns with the sun's radiations for peak intensity, plays a significant role in meeting the country's energy requirements [3]. To enhance energy absorption, the solar panel is maintained perpendicular to the sun, accomplished through the utilization of a solar tracker. This integration boosts efficiency by 40% in comparison to stationary panels. Conventional single axis trackers operate from east to west during the day, whereas contemporary dual-axis trackers follow both east-west and north-south movements of the sun. In this project, we improve the solar tracking system by combining it with a weather sensor [7]. This sensor system, which includes temperature, raindrop, and humidity detectors, shows output on a Liquid Crystal Display (LCD). Light Detecting Resistors (LDRs) identify the maximum light intensity, and an Arduino system directs the rotation of servomotors to optimize the solar panel's alignment with the highest light intensity. Servomotors handle the rotation of the solar panel based on this data. By integrating weather sensors, the system adjusts to changing weather conditions [2]. Over the past million years, the energy requirements of humanity have gradually risen. Solar energy appears as a viable and dependable source, devoid of polluting impacts. Enhancing energy efficiency through this approach becomes essential for sustainable and advantageous energy use [1].

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Introduction to Module

1.1 Light Detecting Unit

The LIGHT Unit is a light intensity sensor that combines an adjustable 10K resistor and a photoresistor. It has the capacity to assess light intensity and set a threshold. As the intensity of the incident light increases, the photoresistor's resistance decreases. The light-detecting unit is made up of four resistors that are placed in pairs. These resistors measure light intensity and convert it to analog voltage, which the controller can use as an input. Two sets of Light Dependent Resistors (LDRs) are used: one pair senses the sun's position from east to west and the other from north to south. According to the equation RL = 500/LUX, resistance is inversely proportional to light intensity and decreases as it increases.

1.2. Figure 1: Light Detecting Unit

1.2 Monitoring Unit

The primary monitoring unit for the system is Arduino, which connects to the Light Dependent Resistor (LDR) on its first four pins. Arduino collects input from the LDR and directs the servomotors to rotate accordingly. Dual-axis solar trackers also need weather sensors to improve efficiency. These systems adjust panel angles to capture more energy and respond to bad weather. Light sensors track the sun, while IoT monitoring allows for centralized control and data access, helping with trend analysis and optimization.

Figure 2: Monitoring Unit

1.3. Movement Controlling Unit

The movement controlling unit consists of two servo motors. Arduino generates 5 volts to operate servo motors, which require approximately 4.5 volts. Two motors control horizontal and vertical rotations, respectively. This minimizes the amount of electricity consumed. Only one motor operates at a time.

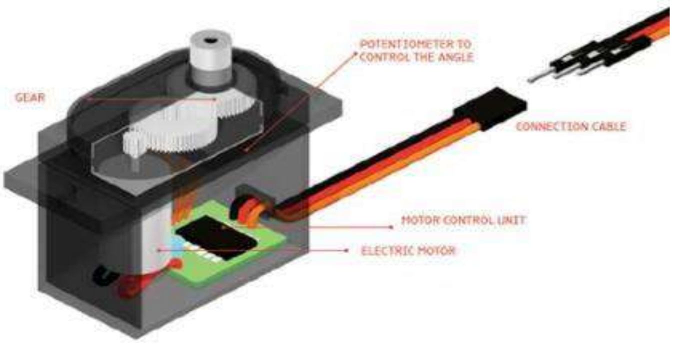
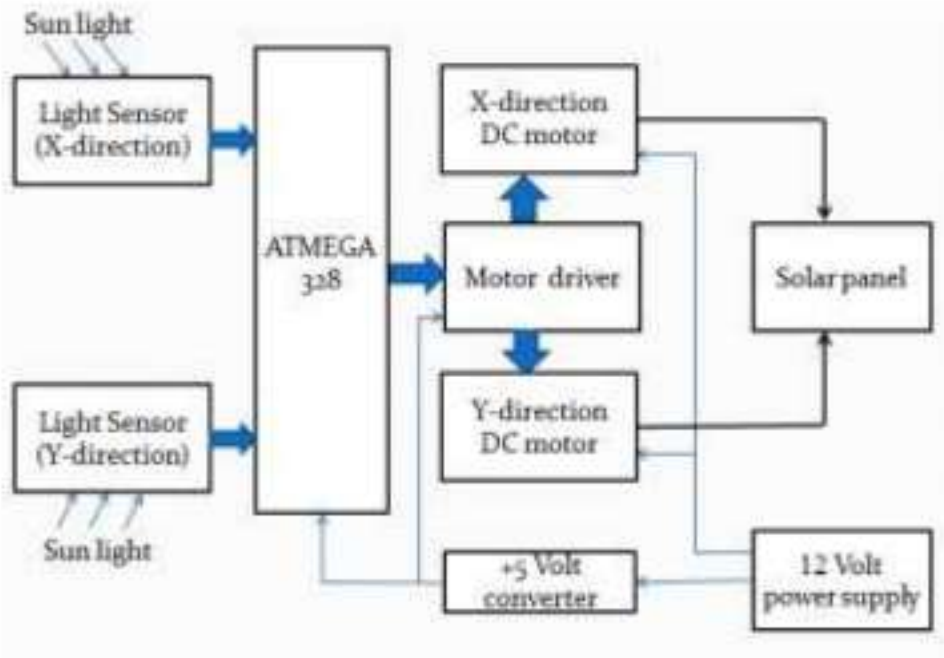


Figure 3: Movement Controlling Unit

Block Diagram



1.4. Weather Sensor

The weather sensor utilizes an Arduino as a medium to assess and display the relative humidity and ambient temperature on an LCD screen. A weather sensor generally comprises various components, including sensors for temperature and humidity. Collectively, these sensors gather data regarding the prevailing weather conditions, which allows the solar tracker system to modify its functionalities

Figure 4 : Weather Sensor

1.5. DHT11 Sensor

The DHT11 Temperature & Humidity Sensor outputs a digital signal and is calibrated for accuracy. It combines temperature and humidity sensing technology for high reliability and stability. The sensor connects to an 8-bit microcontroller, providing quality performance, quick response, and resistance to interference while being cost-effective. It includes components for measuring humidity and temperature

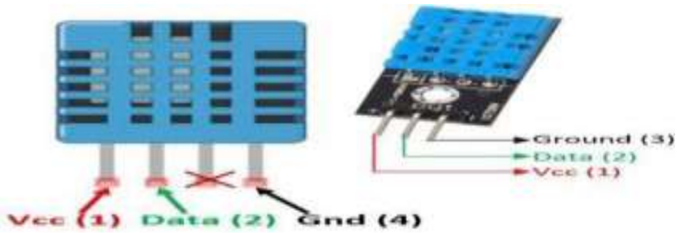


Figure 5: DHT11 Sensor

1.6. Solar Panel

A solar panel uses photovoltaic (PV) cells to convert sunlight into electricity. When exposed to light, materials used in photovoltaic cells produce excited electrons. Electrons move via a circuit to generate direct current (DC) power. This electricity can be stored in batteries and utilized to power a variety of devices. Solar panels are often referred to as PV modules, solar electric panels, or solar cell panels. Solar panels are typically organized in groupings known as arrays or systems. A photovoltaic system is made up of one or more solar panels, an inverter (which converts direct current to alternating current), and, on occasion, other components including controllers, meters, and trackers. Photovoltaic systems can generate electricity for off-grid applications.

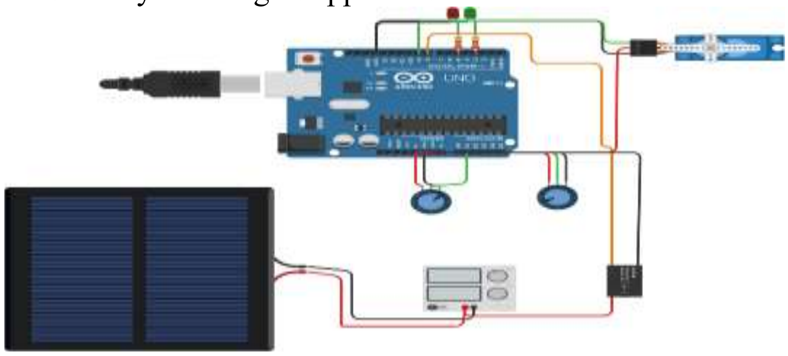


Figure 6: Solar panel

1.7. Servo Motors

The weather sensor employs an Arduino as an interface to gauge and display the relative humidity and ambient temperature on an LCD screen. A weather sensor generally comprises several components, including sensors for barometric pressure, temperature, humidity, and wind speed. Collectively, these sensors gather data regarding the present weather conditions, which allows the solar tracker system to adjust its functioning accordingly. For instance, during periods of strong winds, the tracker may require stowing or securing to prevent potential damage. Likewise, the operation of the tracker may need to be modified in response to extreme temperatures or humidity levels to optimize energy capture and ensure the longevity of the system.

Figure 7: Servo Motors

2. Hardware Implementation of Project

2.1. Arduino Uno

The Arduino Uno microcontroller board, developed by Arduino.cc, is based on the Microchip ATmega328P microprocessor and is available as open-source. It features six analog and fourteen digital I/O pins, and can be powered by an external 9-volt battery or via USB. This board is the first in the series of USB-based Arduino boards and shares similarities with the Arduino Nano and Leonardo. Figure 9: Arduino UNO. The ATmega328 microcontroller on the board comes preloaded with a bootloader, which simplifies the code uploading process, eliminating the need for an external hardware programmer. The Arduino IDE (Integrated Development Environment) software is compatible with Windows, Mac, and Linux PCs, although Windows is the preferred operating system. These IDEs use programming languages like C and C++. The Arduino Uno can be powered using Micro SD cards for extra data storage, or it can receive power through a USB cable or an adapter. When connected to another device, the onboard voltage regulation system ensures voltage levels are stable. A reset pin allows for resetting the board and restarting the currently running software. The board has 13KB of flash memory designated for storing code instructions. It can be powered on instantly via a USB port or an external adapter when 5 V is required.

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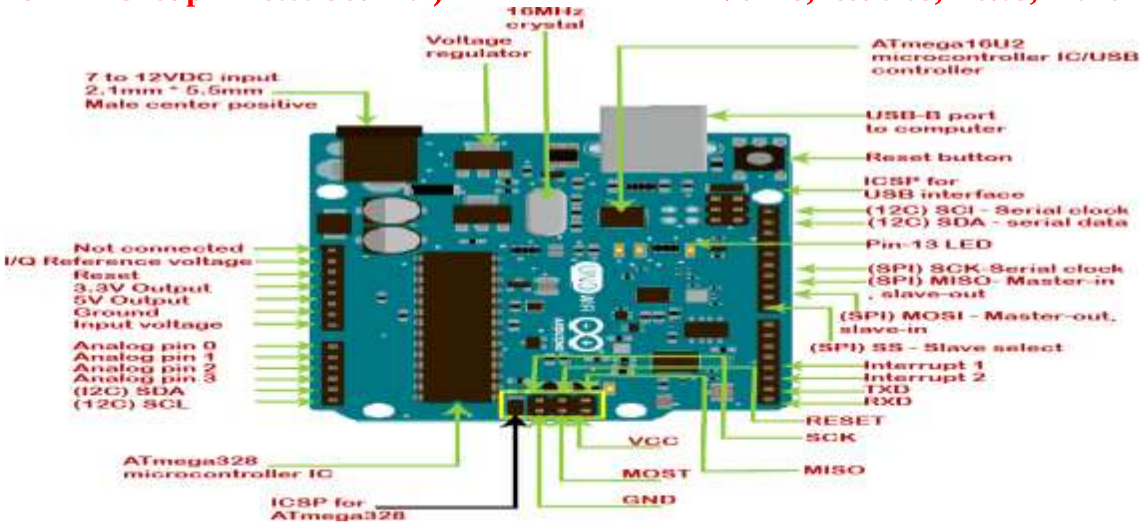

Figure 8: Arduino UNO

2.2. Node MCU V3

The NodeMCU v3 is a development board centered around the ESP8266 microcontroller. It is favored for IoT projects because of its low cost, integrated Wi-Fi, and compatibility with the Arduino IDE. The board features GPIO pins, analog inputs, PWM outputs, SPI, I2C, and UART interfaces, making it ideal for various projects. Conversely, Blynk app is a mobile application that enables you to monitor and control IoT devices remotely. It provides an easy-to-use interface for checking sensor data, receiving alerts, and interacting with connected devices. Blynk app works with a range of IoT platforms and devices, including NodeMCU v3, using communication protocols such as MQTT, HTTP, and WebSocket.

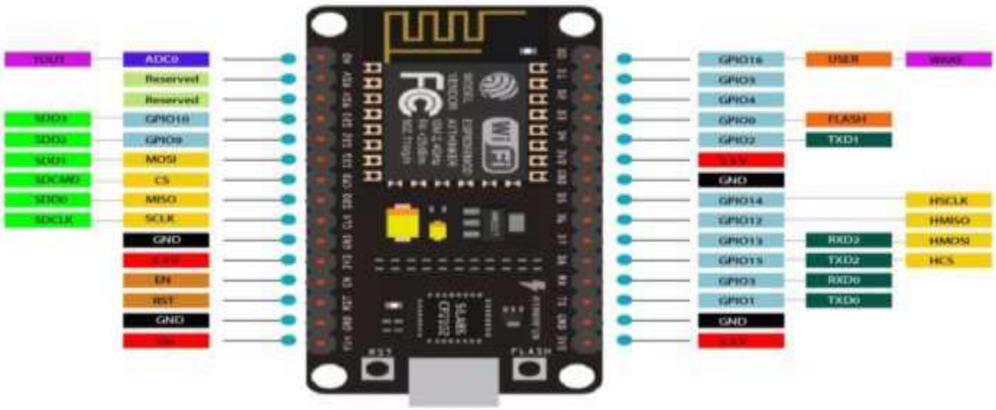

Figure 9: Node MCU V3

3.Software Implementation of project

3.1. Arduino IDE

The Arduino Integrated Development Environment (IDE) is a versatile software application that is compatible with Windows, MacOS, and Linux, integrating features from C and C++. It streamlines the development and uploading of applications to various Arduino boards and similar devices. The source code for the IDE is released under version 2 of the GNU General Public License. The wiring project provides standard input and output capabilities. The Arduino IDE converts the generated user code into an executable circular executive program, which is subsequently uploaded to the Arduino board via a firmware loader. Additionally, other companies have created their own open source compilers and tools for microcontrollers.

Figure 10:Done compiling and uploading of code

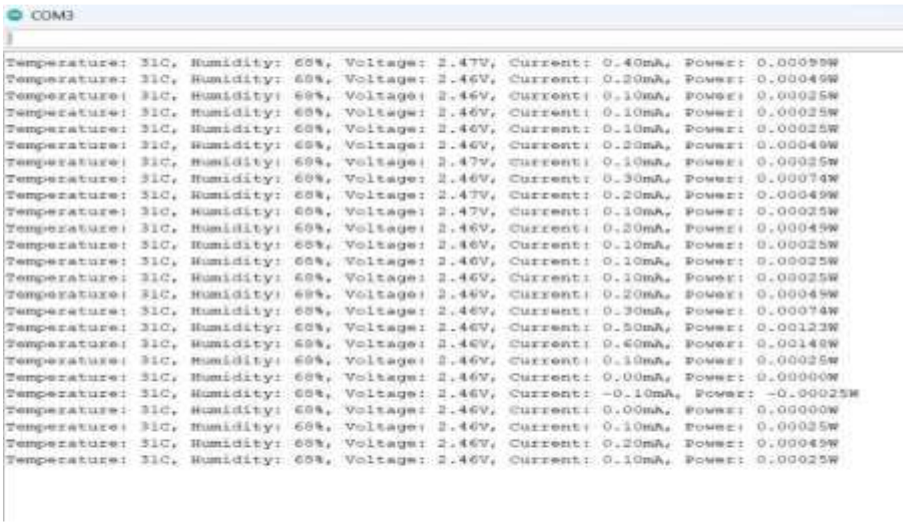

Figure 11:Output of the serial monitor

3.2.Blynk App:

Blynk App Free is a mobile application that creates a wireless connection and engages with an ssArduino board using your smartphone or tablet.

Purpose:

*Encouraging communication between the Arduino microcontroller board and mobile devices via 444 Wi-Fi or Bluetooth.

*Allowing for remote supervision and management of Arduino projects and prototypes.

Functions:

*User-friendly interface for transmitting commands and data to Arduino.

*Obtain sensor data and responses from Arduino in real time.

*E/A - Sets PIN modes (input, output, etc.) and digital/analog values.

*Accessible on iOS and Android mobile devices.

This app bridges the gap between tangible Arduino projects and the virtual control/monitoring of mobile devices. It can prove beneficial where remote interaction with Arduino is desired, such as in

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IoT projects, robotics, and prototypes for home automation. The free version likely includes basic features, whereas the paid version may provide additional functionalities.

Blynk

Figure 12:Blynk App

4.WORKING

The solar panel attached to a structure within the dual axis solar tracking system rotates in accordance with the sun's position as identified by the sensor. Four resistors and four LDRs are connected to the Arduino's four analog pins, A1, A2, A3, and A4, respectively. These elements are internally arranged in a voltage divider configuration, as illustrated in Figure 3. As shown in Fig. 3, the Arduino's digital pins 9 and 10 send PWM signals to the two servo motors. Essentially, LDRs act as the main light sensors. Two solar panels affixed to the structure assist the servo motor. The microcontroller receives an upload of the Arduino program. The system operates in the following manner: each LDR detects light in the directions of top, bottom, left, and right. It also measures the intensity of sunlight hitting each LDR. When comparing the analog readings from two top and two bottom LDRs for north-south tracking, the vertical servo will shift in the direction where the bottom pair of LDRs captures more light. The servo motor will move in that direction if the upper LDRs register more light. For angular deviation, the analog values from two left and two right LDRs are assessed. The horizontal servo will shift towards the direction indicated if the right pair of LDRs captures more light than the left pair.

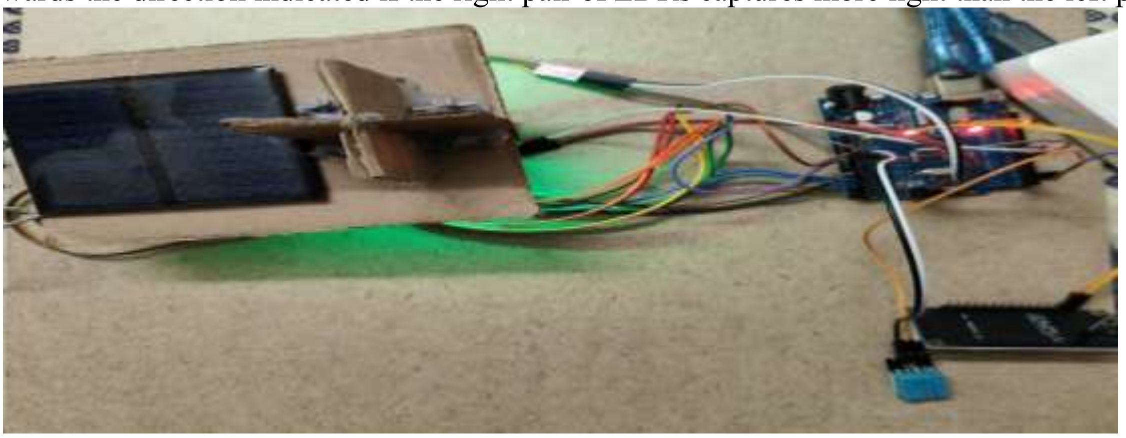

Figure 13:Real Time implementation of the device

5.Result

The dual-axis solar tracking system effectively enhances the effectiveness of solar energy collection by adjusting the orientation of the solar panel in response to the sun's position. The important findings and results of the project are:

Increased Solar Efficiency – The solar panel tracks the sun throughout the day, guaranteeing optimal exposure to sunlight, resulting in a 20-30% rise in energy production compared to stationary panels.

Accurate Sun Tracking – The LDR sensors accurately sense sunlight intensity, and the servo motors quickly react to real-time variations, ensuring precise tracking in both the north-south and east-west orientations.

Smooth and Reliable Movement – The servo motors provide exact adjustments, facilitating efficient tracking without sudden movements or mechanical issues.

Automated Operation – The system functions without human involvement once it is powered on, adjusting independently based on sunlight intensity.

Improved Performance in Variable Conditions – The system effectively adapts to changing light conditions, maximizing power generation even during partially cloudy weather.

Minimal Power Consumption – The energy usage of the Arduino and servo motors is minimal compared to the additional energy obtained through improved solar tracking.

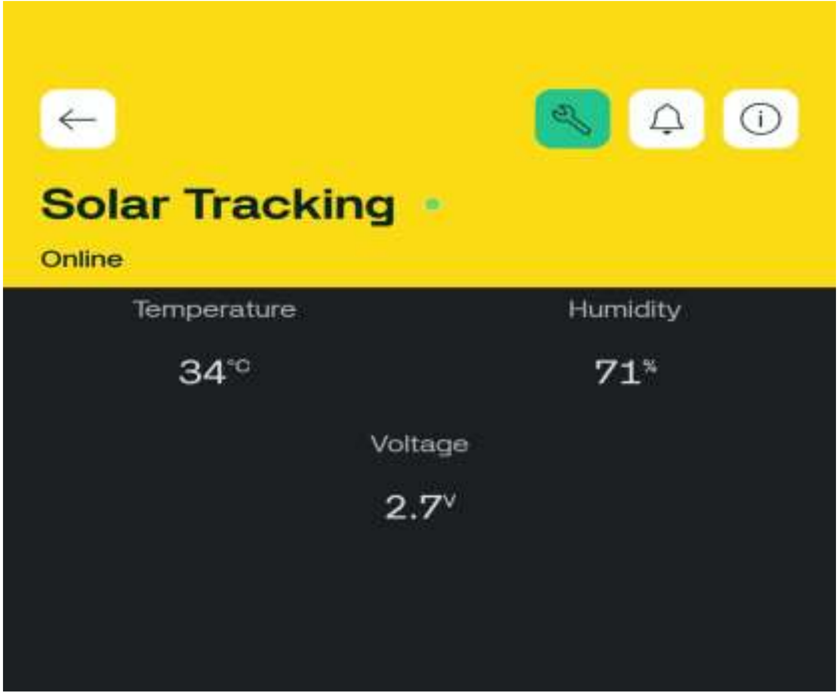

Figure 14:Output of the device

6.Conclusion

Weather Monitoring System and a two-axis solar tracking system offer a holistic method to optimize solar energy generation while ensuring reliability and operational efficiency. This type of system enhances energy collection, lessens adverse environmental effects, and boosts system durability by dynamically modifying the solar panels' alignment based on the sun's location and prevailing weather conditions. The synergistic impacts of monitoring weather and solar power utilization underscore the development of sustainable energy options across diverse environmental scenarios, paving the way for a more efficient and resilient 444 framework for renewable energy.

7.Reference

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