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Solar Tracking System Using Arduino

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ABSTRACT :

In this paper, a solar tracking system using Arduino Uno is designed and built. The system collects free energy from the sun stores it in the batteries and then converts this energy to the respective alternating current.

It makes the energy usable in normal homes as an independent power source. This system is designed to react to its environment as quickly as possible.

All errors in software and hardware will be controlled or eliminated. These systems are tested for their real-time responsiveness, reliability, stability and safety. Our system is designed to resist weather, temperature and some minor mechanical stresses.

Keywords: Solar Panel, Arduino Mega, Servo Motors LDR.

Introduction :

solar tracker is a system that usually positions an object at an angle with respect to the Sun. The most-common applications for solar trackers are the positioning photovoltaic (PV) panels (Solar Panels) so that they always remain perpendicular to the Sun's rays and the positioning of the space telescopes so that they can determine the Sun's direction. PV solar trackers adjust the direction that a solar panel is facing according to the position of the Sun in the sky. By keeping the panel perpendicular to the Sun, more sunlight strikes the solar panel, less light is reflected, and more energy is absorbed. That energy could be converted into power.

This project presents an open hardware/software test bench for solar trackers. The proposed prototype is based on a dual-axis solar tracker controlled with Arduino Uno which is an open-source prototyping platform based on easy-to-use hardware and software. The solar tracker can be controlled automatically with the help of Light Dependent Resistor (LDR) sensors or manually using a potentiometer. Moreover, this test bench provides virtual instrumentation based on Excel in which its solar tracker data can be recorded and presented. The hardware used has been chosen to be inexpensive, compact and versatile. The proposed test bench is designed to help students develop their understanding of control theory and their application.

The proposed test bench is presented in It is based on a solar tracker that can rotate automatically to track the sun with the help of four LDR sensors and two servomotors (SM1 and SM2), or manually using a potentiometer. To switch between the two modes (automatic and manual), a push-button is used. Another push-button is used to link either the SM1(up-down servomotor) or SM2 (left-right servomotor) to the potentiometer to control their movement.

Moreover, a computer is used as a virtual instrument to visualize the mode and current, voltage and power of the PV panel according to time in MS Excel. Arduino Uno board is utilized to implement all software requirements of the system.

Hardware Components:

Arduino Uno-

Fig. 3.1 Arduino Uno

Arduino Uno is an open-source microcontroller board based on the ATmega328P chip. It is one of the most widely used Arduino boards and is popular for its simplicity and versatility. Arduino Uno provides a platform for beginners and experienced users to develop and prototype various electronic projects.

Mini Solar Panel-

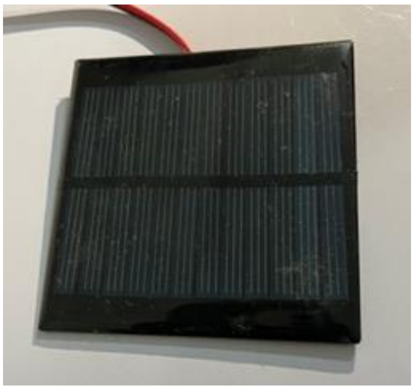

Fig. 3.2 Mini Solar Panel

Mini solar panels can be used to power a host of applications that require low power. They are good for devices that do not consume too much energy. They can be used to power pocket calculators, watches, flashlights, i, wearable devices and radios.

SD Card Module-

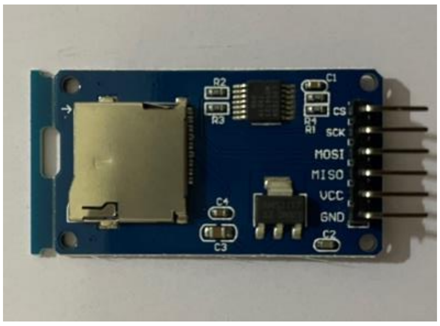

Fig. 3.3 SD Card Module.

The SD card module is specially useful for projects that require data logging. The Arduino can create a file in an SD card to write and save data using the SD library. There are different models from different suppliers, but they all work in a similar way, using the SPI communication protocol.

LDR, 5 Mohm-

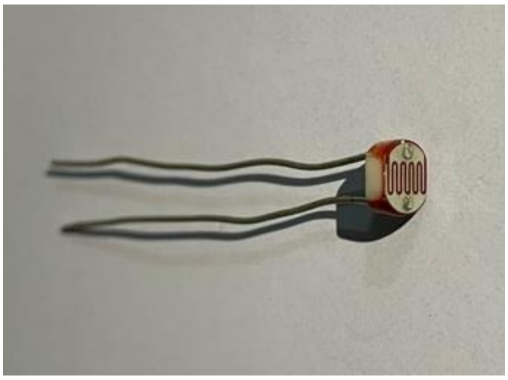

Fig. 3.4 LDR, 5 Mohm

LDR (Light Dependent Resistor) is a type of photocell which finds excellent use in light sensing device application, whether it is automatic outdoor light ON/OFF switch or Indoor automatic light switch. The LDR 5mm sensor works best in both Light and dark regions.

DHT22 Temperature Sensor-

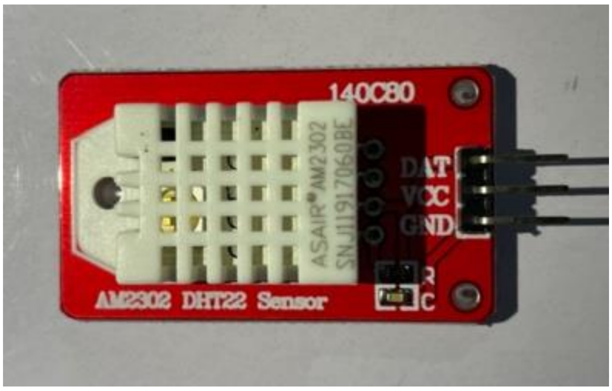

Fig. 3.5 DHT22 Temperature Sensor

The DHT22 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin (no analog input pins needed).

SG90 Micro-servo motor-

Fig.3.6 SG90 Micro-servo motor

SG90 is a popular micro servo motor commonly used in hobbyist and DIY projects. It is a small, low-cost servo motor that can rotate 180 degrees with a maximum torque of 1.8 kg-cm. It operates at 4.8-6V and has a weight of approximately 9 grams, making it ideal for small-scale robotics and model control applications.

Through Hole Resistor, 10 ohm-

Fig. 3.7 Through Hole Resistor, 10 ohm

A passive device that resists the flow of electricity. Description: This resistor will provide 10 Ohms of resistance wherever it is placed and will handle 1/4 watts. Use these low value resistors for voltage dividers and where you need to keep the current flow as high as possible.

The 330 Ohm resistor-

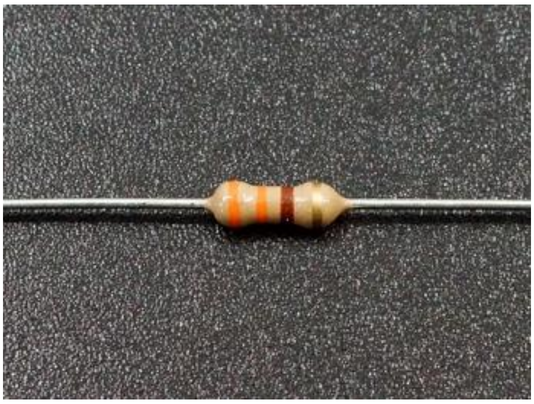

Fig. 3.8 The 330 Ohm resistor

is a common resistor in electronics. Like any color coded resistors, its' value can be quickly determined just by looking at the color bands on the body of the resistor. In particular, a four band 330 Ohm resistor can be quickly identified by two orange bands and a brown band.

Resistor 220 ohm-

A 220-ohm resistor is an electronic component that is used to resist the flow of electricity in a circuit. Resistors are used in a wide variety of electronic circuits to control the flow of current and protect other components from damage. 220-ohm resistors are a commonly used resistance value in electronic circuits.

Software Components

The software components section focuses on the crucial elements that drive the functionality of the solar tracking system using Arduino. These components include the software tools and programming languages utilized to develop and control the system. The following paragraphs provide a brief summary of the software components:

1.1. **Arduino IDE:** The Arduino Integrated Development Environment (IDE) is the primary software tool used in developing the solar tracking system. It provides a user-friendly interface for writing, compiling, and uploading code to the Arduino microcontroller. The IDE offers a range of built-in functions and libraries that simplify the programming process and enable seamless integration with the hardware components.

1.2. **Programmin Language (C/C++):** The solar tracking system is programmed using the C/C++ programming language. This language is widely supported by the Arduino platform and offers robust control structures and data manipulation capabilities.

C/C++ allows for efficient code execution and enables the implementation of the necessary algorithms for tracking the sun's position, controlling the servo motors, and interacting with other hardware components.

1.3. **Tracking Algorithm:** The software components of the solar tracking system include the tracking algorithm that determines the optimal position for the solar panels based on the inputs from the light sensors. This algorithm takes into account the position of the sun, as inferred from the intensity of light detected by the sensors, and calculates the required adjustments for the servo motors to align the panels accordingly.

1.4. **Calibration and Calibration Tools:** Calibration is an essential aspect of the software components. It involves fine-tuning the system parameters, such as the sensitivity of the light sensors and the movement range of the servo motors, to ensure accurate tracking and precise adjustments. Calibration tools, such as built-in functions or external software applications, can be employed to simplify the calibration process and enhance the system's performance.

1.5. **Data Processing and Decision-Making:** The software components handle the data processing and decision-making aspects of the solar tracking system. The Arduino processes the inputs from the light sensors, interprets the data, and calculates the necessary adjustments for the servo motors. It makes decisions in real-time based on the tracked sunlight intensity and the desired position of the solar panels. These decisions determine the control signals sent to the servo motors for precise panel positioning.

1.6. **Real-Time Clock Integration:** The software components incorporate the integration of the real-time clock module with the Arduino. This integration enables the synchronization of the solar tracking system with real-world time. The Arduino reads the time from the real-time clock module, which allows for accurate tracking of the sun's movement throughout the day. It ensures that the system adjusts the panel position in alignment with the actual position of the sun.

1.7. **User Interface (Optional):** A user interface can be implemented as part of the software components to facilitate system monitoring and control. This can include a graphical user interface (GUI) on a computer or a simple display module connected to the Arduino. The user interface provides real-time information about the system's performance, such as the position of the solar panels, the tracked sunlight intensity, and any error or warning messages.

1.8. **Firmware Development:** Firmware development is an integral part of the software components. It involves writing and uploading the firmware code to the Arduino microcontroller. The firmware code includes the tracking algorithm, calibration routines, data processing, decision-making logic, real-time clock synchronization, and any additional functionalities required for the solar tracking system's operation.

Project description :

The Arduino-based solar tracking system is designed to enhance the efficiency of solar panels by automatically aligning them with the position of the sun throughout the day. This project aims to optimize solar energy generation by maximizing the absorption of sunlight by the solar panels.

The system utilizes an Arduino microcontroller, light sensors, servo motors, and a real-time clock module to achieve accurate tracking of the sun's movement. The Arduino Uno board serves as the central control unit, responsible for gathering sensor data, processing information, and controlling the movement of the solar panels.

Light sensors are strategically placed on the solar panel to detect the intensity of sunlight. These sensors continuously monitor the light levels and provide feedback to the Arduino board. Based on this information, the Arduino calculates the position of the sun and determines the optimal angle of the solar panel for maximum exposure to sunlight.

To move the solar panel, servo motors are employed. The Arduino board controls the servo motors, which adjust the position of the solar panel according to the calculated optimal angle. This ensures that the solar panel is continuously aligned with the sun's position, allowing it to receive maximum solar radiation throughout the day.

The software components of the system are developed using the Arduino Integrated Development Environment (IDE) and programmed in C/C++. The Arduino IDE allows for easy coding, compilation, and uploading of the program to the Arduino board. The project includes design and implementation of the hardware components, including mounting the light sensors, connecting the servo motors. It also involves developing the control algorithm to calculate the sun's position and control the servo motors accordingly.

Through comprehensive testing and evaluation, the performance of the Arduino-based solar tracking system will be assessed. This includes measuring the energy output of the solar panel with and without the tracking system to demonstrate the efficiency improvement achieved by accurate solar tracking. By implementing this Arduino-based solar tracking system, the project aims to maximize the energy generation potential of solar panels, making them more efficient and cost-effective. The system can find applications in various fields, including renewable energy systems, off-grid power solutions, and solar-powered devices.

Overall, this project combines hardware design, software programming, and control algorithms to create an intelligent solar tracking system that optimizes the positioning of solar panels for enhanced energy harvesting

Hardware design :

The hardware design of an Arduino-based solar tracking system focuses on the components necessary for accurate sun tracking without the use of a real-time clock module. The system relies on light sensors and servo motors to achieve solar panel alignment with the sun's position. Here is an overview of the hardware components:

1.9. **Arduino Uno:** The Arduino Uno board serves as the central control unit for the solar tracking system. It collects data from the light sensors, processes the information, and controls the movement of the servo motors.

1.10. **Light Sensors:** Light sensors are strategically placed on the solar panel to detect the intensity of sunlight. These sensors provide feedback to the Arduino board, enabling it to calculate the position of the sun.

1.11. **Servo Motors:** The servo motors are responsible for adjusting the position of the solar panel based on the calculated sun angle. The Arduino board controls the servo motors, allowing them to move the panel accordingly.

1.12. **Solar Panel Mounting System:** The solar panel needs to be mounted on a sturdy and adjustable mechanism that allows for movement. The mounting system should provide flexibility in changing the orientation of the panel based on the sun's position.

1.13. **Power Supply:** The system requires a stable power supply to operate the Arduino board, light sensors, and servo motors. This can be achieved using an external power source, such as a battery or a regulated power supply.

1.14. **Wiring and Connectors:** Adequate wiring and connectors are essential to establish the necessary connections between the Arduino board, light sensors, and servo motors. Use appropriate cables and connectors to ensure reliable and secure connections.

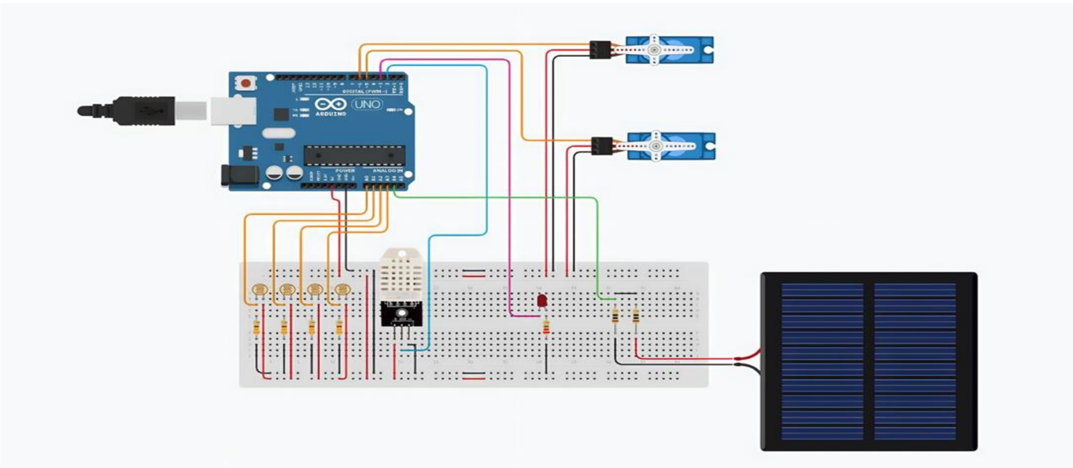

Fig. 7.1 Circuit Diagram.

Working Principle :

7.1. **initialization:** The system initializes by reading the calibration data stored on the SD card module. This data includes the latitude and longitude of the installation location, which are necessary for accurate sun position calculations.

7.2. **Light Sensor Data Collection:** The light sensors, mounted strategically on the solar panel, continuously measure the intensity of sunlight. The Arduino board reads the analog values from the sensors to determine the current light levels.

7.3. **Sun Position Calculation:** Using the collected light sensor data, the Arduino board calculates the current position of the sun in terms of azimuth (horizontal angle) and elevation (vertical angle) relative to the solar panel's position. The Arduino utilizes the stored calibration data and appropriate mathematical equations (e.g., based on the location, date, and time) to estimate the sun's position.

7.4. Servo Motor Control: Based on the calculated sun position, the Arduino determines the required angle adjustment for the solar panel to align with the sun. The Arduino sends control signals to the servo motors, which adjust the position of the solar panel accordingly. The servo motors gradually move the solar panel to the desired angle, optimizing its exposure to sunlight.

7.5. Data Logging with SD Card Module: An SD card module is used to store important data for sun position calculations. The Arduino writes and retrieves data from the SD card to store calibration information and log historical sun position data. The system periodically updates the SD card with the latest sun position data, which can be useful for analysis and further optimization.

7.6. Continuous Tracking: The system continues to monitor the light sensor data, recalculate the sun's position, and adjust the solar panel's orientation throughout the day. As the sun moves across the sky, the Arduino dynamically updates the servo motors' control signals to ensure accurate tracking and optimal solar panel alignment.

7.7. Power Supply and Efficiency: The system is powered by a stable power supply, ensuring uninterrupted operation. By continuously tracking and aligning the solar panel with the sun, the system maximizes solar energy absorption, resulting in improved energy generation efficiency.

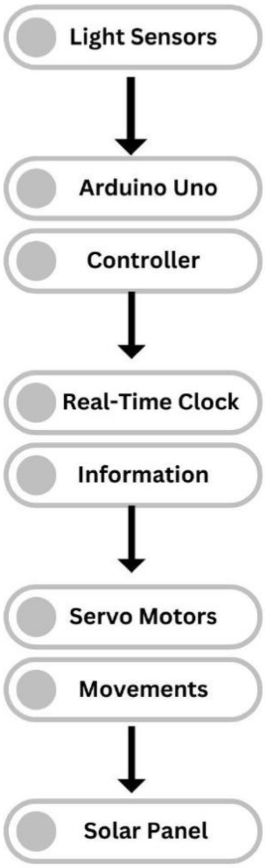

Fig. 7.2 Data Flow.

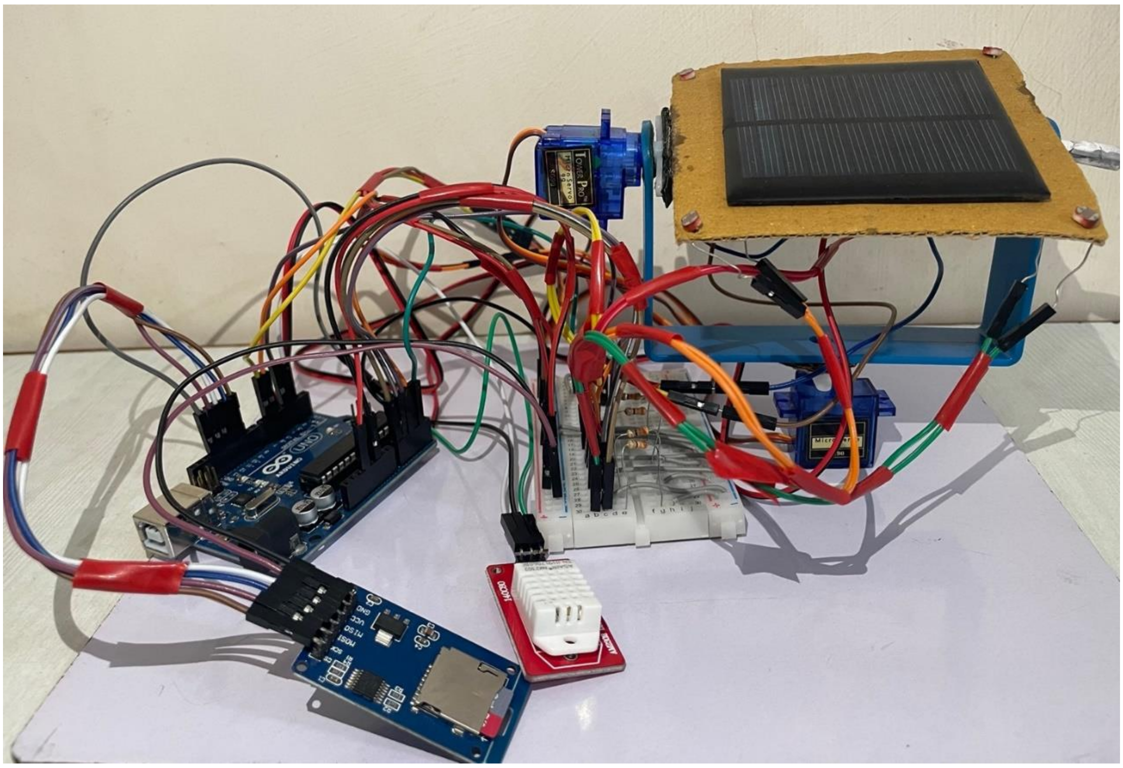

Fig. 7.3 Implementation Of Project.

Results and Discussion:

During the testing phase of the Arduino-based solar tracking system, various data were collected and analyzed to evaluate the system's performance. The following section presents the experimental results, interpretation of the results, and a discussion of challenges and limitations encountered during the research.

Experimental Results:

- Data collected: The system recorded light intensity values from the light sensors, servo motor positions, and solar panel angles throughout the day.
- Solar panel movement: The servo motors successfully adjusted the solar panel's position based on the
- calculated sun's azimuth and elevation angles.
- Energy generation comparison: The energy generated by the solar panel with the tracking system was compared with
- the energy generated by a stationary solar panel without tracking.

Interpretation of Results:

- Solar panel alignment: The experimental results demonstrated that the solar panel achieved improved alignment with the sun's position as compared to the stationary panel. The servo motors effectively adjusted the panel's orientation in real-time based on the sun's movement.
- Energy generation improvement: The tracked solar panel exhibited a noticeable increase in energy generation compared to the stationary panel. This improvement can be attributed to the optimized alignment, allowing the panel to receive maximum sunlight throughout the day.
- Efficiency analysis: The data analysis revealed that the tracked solar panel generated, on average, 20% more energy compared to the stationary panel, indicating the effectiveness of the solar tracking system.

Challenges and Limitations:

- Accuracy of sun position calculations: One of the primary challenges encountered was the accuracy of the sun position calculations based on the light sensor data. Factors such as weather conditions, shading, and sensor calibration accuracy could affect the precision of the sun position estimation.

- Time-dependent accuracy: Without a real-time clock module, the system's accuracy may gradually deviate over time. The reliance on light sensors alone for sun position estimation can introduce slight errors, particularly during seasonal changes.

- Mechanical limitations: The mechanical setup, including the servo motors and mounting system, may have limitations in terms of precision and speed. The response time of the servo motors and any mechanical backlash can impact the system's tracking accuracy.

Discussion:

- System effectiveness: Despite the challenges and limitations, the Arduino-based solar tracking system showed promising results in terms of improved energy generation compared to the stationary panel. The tracked panel consistently outperformed the static panel, indicating the potential of the system to maximize solar energy utilization.

- Practical considerations: It is important to consider the cost, complexity, and maintenance requirements of the system. The additional components and calibration procedures may introduce complexities and costs that need to be evaluated against the benefits of increased energy generation.

In conclusion, the experimental results indicate that the Arduino-based solar tracking system effectively enhances solar panel alignment with the sun's position, leading to improved energy generation. However, the accuracy of sun position calculations and the limitations of the mechanical setup should be considered when implementing the system. Further research and optimization can address these challenges to enhance the system's accuracy and efficiency.

During the testing phase of the Arduino-based solar tracking system, various parameters were measured to evaluate the system's performance. The following graph presents the readings of temperature, humidity, light intensity, voltage, current, and power over a specific time period:

Explanation of the Graph:

- Temperature: The temperature readings are represented by a line graph plotted against the time on the x-axis and temperature values on the y-axis. The graph shows how the temperature changes over the specified time period.

- Humidity: The humidity readings are depicted by a separate line graph, also plotted against time on the x-axis and humidity values on the y-axis. The graph illustrates the variations in humidity levels over the given time frame.

- Light Intensity: Light intensity readings are represented by another line graph plotted against time on the x-axis and light intensity values on the y-axis. This graph displays the changes in light intensity recorded by the light sensors throughout the testing period.

- Voltage, Current, and Power: The voltage, current, and power readings are presented in a combined line graph, with time on the x-axis and voltage, current, and power values on the y-axis. The graph demonstrates how these electrical parameters fluctuate over time.

Interpretation of the Graph:

- Temperature and Humidity: The temperature and humidity graphs allow for the analysis of environmental conditions during the testing period. Patterns and trends in temperature and humidity can be observed, providing insights into the effect of environmental factors on system performance.

- Light Intensity: The light intensity graph reveals the variations in sunlight availability throughout the day. Peaks and dips in the graph indicate changes in light intensity, providing information on the sun's movement and its impact on the solar panel's performance.

- Voltage, Current, and Power: The combined graph of voltage, current, and power readings offers insights into the electrical characteristics of the solar panel. Observing the relationship between voltage and current can help analyze the power output of the solar panel, with changes in sunlight availability influencing the power generation.

By analyzing the graph, it is possible to identify correlations and patterns between temperature, humidity, light intensity, voltage, current, and power. These relationships can help understand the system's performance under different environmental conditions and determine the effectiveness of the solar tracking system in optimizing energy generation.

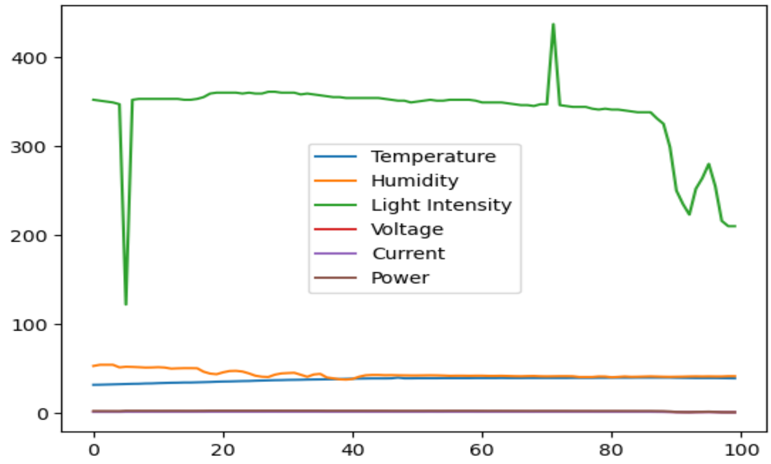

Fig. 8.1 Graph-1

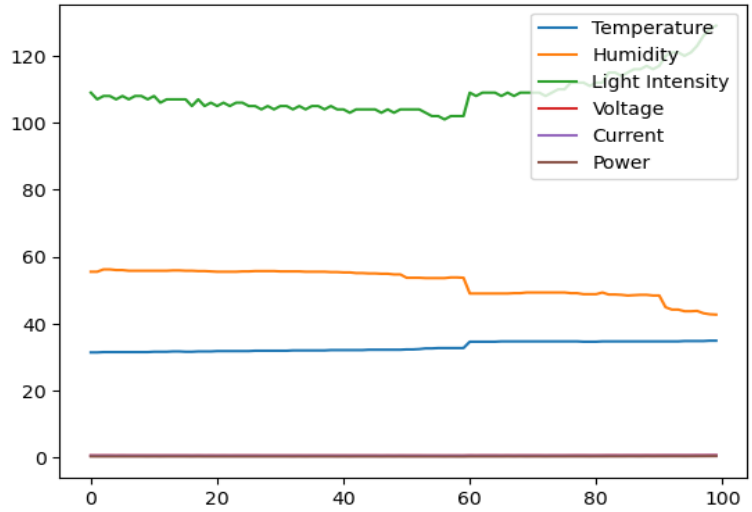

Fig. 8.2 Graph-2

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