Report

Solar Tracking System Using Arduino

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.

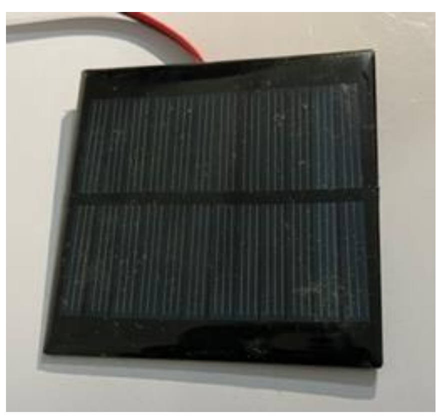
Hardware Components:

Arduino Uno-

Fig. 3.1 Arduino Uno

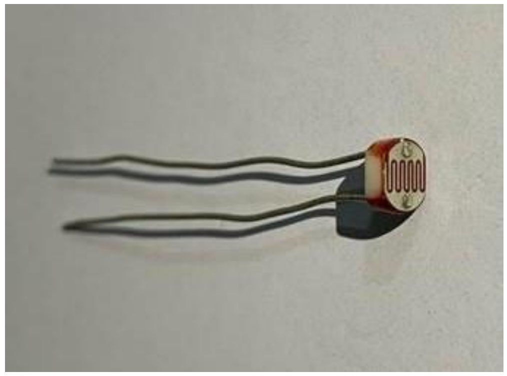
Arduino Uno is an open-source microcontroller board based on the ATmega328P chip. It is one of the most widely used Arduino boards and is popular for its simplicity and versatility. Arduino Uno provides a platform for beginners and experienced users to develop and prototype various electronic projects.

Mini Solar Panel-



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.

LDR –



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.

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

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

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 briefsummary of the software components:

a. **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.

b. **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/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.

d. **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.

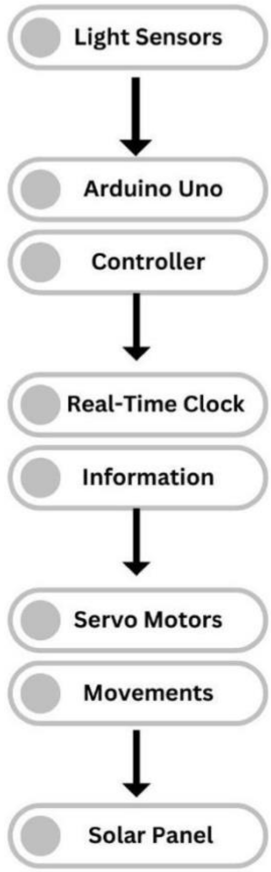
a. **Calibration and Calibration Tools:** Calibration is an essential aspect of the software components. It involves fine-tuning the system parameters, such as the sensitivity of the light sensors and the movement range of the servo motors, to ensure accurate tracking and precise adjustments. Calibration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

b. **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.

c. **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.

d. **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.

e. **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.



Working Principle :

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.

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.

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.

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.

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.

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.

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

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.

Future scope

1. Improved Energy Efficiency in Solar Power Generation

- **Increased Power Output**: By using Arduino-based solar tracking systems, solar panels can be kept aligned with the sun's position throughout the day, maximizing energy absorption. This can improve energy efficiency by up to 30-40% compared to fixed solar panels.
- **Lowering Costs**: As technology becomes more affordable, integrating smart tracking systems can reduce the cost-per-watt of solar energy, making solar power more competitive with other energy sources.

2. Smart Integration with IoT and AI

- **Automation and AI**: Future systems could integrate AI to optimize tracking based on real-time weather forecasts, cloud cover, and even predictive maintenance. This would make the system smarter and more responsive, further enhancing its efficiency.
- **IoT Integration**: Combining the system with the Internet of Things (IoT) would allow for remote monitoring and control. This is useful for large solar farms, where data from many trackers can be collected and managed from a central hub.

3. Sustainability and Climate Goals

- **Contributing to Green Energy Initiatives**: As governments and industries push towards sustainable energy sources, solar tracking systems will be an important tool in achieving higher solar power yields and meeting renewable energy targets.
- **Reduced Carbon Footprint**: Efficient solar tracking can contribute to reduced dependence on fossil fuels, helping to mitigate climate change.