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Automatic Solar Tracking System: A Comprehensive Overview of an advanced Automatic Solar Tracking system using ESP8266

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ABSTRACT

This study focuses on developing a Solar Tracking System using ESP866 microcontrollers and Light Dependent Resistors (LDRs) to enhance the efficiency of solar panels. Solar panels work most effectively when directly facing the sun, and this system adjusts the panel orientation throughout the day to achieve optimal sunlight exposure. The ESP866 acts as the system's controller, processing data from strategically placed LDRs that detect the sun's position. This data drives servo motors to adjust the panels for maximum solar exposure, ensuring continuous and efficient energy generation.

By implementing this solar tracking system in which the study offers a cost-effective and practical solution to improve energy output from solar panels. The system leverages the programmability of the ESP866 and the light sensitivity of LDRs for real-time adjustments, reducing reliance on fixed panel setups. Its adaptability and affordability make it is useful for various applications, contributing to the wider goal of sustainable energy use. Ultimately, this study advances solar energy technology by providing a scalable, accessible way to maximize solar energy capture, supporting the shift toward more eco-friendly, renewable energy solutions.

Keywords: Light dependent resistors; ESP8266; Servo motor; Eco-friendly; Renewable energy; Sun's position; Technology; Solar energy.

1. Introduction

1.1. Overview

A sun-tracking solar panel system powered by an ESP8266 microcontroller offers an effective way to maximize the solar energy capture. The system uses the light-dependent resistors (LDRs) to measure sunlight intensity, adjusting the solar panel's orientation with a servo motor to follow the sun's movement throughout the day. The ESP8266 microcontroller controls the tracking mechanism and also provides Wi-Fi connectivity for real-time monitoring and data logging.

To further enhance its performance and durability, the system can be integrated with additional sensors, such as weather, dust, and rain sensors, ensuring efficient operation under varying environmental conditions. This setup provides a sustainable and adaptable solution for modern solar energy applications.

1.2. Study Objectives

The use of an ESP8266 in a sun-tracking solar panel system aims to improve energy efficiency and automate the process of solar energy harvesting. The system integrates the Light Dependent Resistors for detecting light and the servo motor which is used to adjust the panel's position, ensuring optimal alignment with the sun throughout the day. The ESP8266 microcontroller controls the tracking mechanism while also enabling real-time monitoring and data logging of system performance, such as voltage output. To further enhance energy generation, additional sensors, including weather, dust, and rain sensors, can be added to account for varying environmental conditions. This study showcases the integration of IoT technology with renewable energy systems, contributing to enhanced sustainability and smarter energy solutions.

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2. Hardware Components

2.1. ESP8266

The ESP8266 Wi-Fi module is a highly integrated, versatile, and cost-effective device commonly used in Internet of Things (IoT) applications. It is compact and includes built-in TCP/IP stack support, making it ideal for providing Wi-Fi connectivity to microcontroller-based systems. Powered by a low-power Ten silica L106 32-bit microprocessor, the ESP8266 operates at clock speeds up to 160 MHz and supports a variety of communication protocols such as UART, SPI, and I2C. Its onboard 2.4 GHz Wi-Fi transceiver is compatible with IEEE 802.11 b/g/n standards, allowing for wireless communication over significant distances with routers and other Wi-Fi devices.

The module can function both as a standalone microcontroller and as a slave device when paired with other systems like Arduino or Raspberry Pi. Its flexibility also allows for custom firmware programming, including popular options like Node MCU, which simplifies the development process.

Figure 1. ESP8266

The ESP8266 offers an easy-to-use Lua scripting environment and supports Over-the-Air (OTA) updates, allowing firmware to be wirelessly updated without needing a physical connection. Its low power consumption makes it is ideal for all the battery-powered devices, broadening its application in areas such as automation device which are used in home, wireless sensor networks, and industrial control systems. With its affordability, strong community support, and extensive documentation, the ESP8266 Wifi module is a popular choice for both hobbyists and professionals. Whether used for basic wireless data transfer or more advanced IoT projects like smart homes, weather monitoring, or solar-powered systems, the ESP8266 remains a key component in modern embedded systems design.

2.2. LDR

A Light Dependent Resistor (LDR), also called a photoresistor or photoconductive cell, is a type of resistor in which the resistance varies with respect to the intensity of light that falls on it. Made from semiconductor materials, LDRs exhibit photoconductivity, which means their conductivity increases when exposed to light. This unique property makes LDRs ideal for applications where detecting and measuring light intensity is essential.

A LDR which consists of a thin layer of semiconductor material, such as cadmium sulfide (CDS) or cadmium selenide, which is deposited in a zigzag pattern on an insulating base. Electrodes are placed at both ends to enable the flow of current. When the light hits the top surface on which the LDR, photons with enough energy excite electrons which present in the semiconductors material, creating free charge carriers. This process lowers the material's resistance, allowing more current to pass through. The relationship between the light intensity and the resistance is inversely proportional: as the light intensity increases, the resistance decreases, and vice versa.

Figure 2. LDR

The response of an LDR is not immediate; it experiences a slight delay when light conditions change. This delay, referred to as the rise and fall time, varies depending on the specific type and design of the LDR. With the rise of smart technology, LDRs are increasingly being integrated into IoT (Internet of Things) systems for advanced applications. For example, LDRs can be combined with microcontrollers like Arduino and ESP8266 modules to create smart lighting systems, sun trackers, or environmental monitoring devices. This process reduces the material's resistance, allowing more amount of current to flow through. The relationship between light intensity and resistance is inversely proportional. As materials science continues to advance, future LDR designs may become more sensitive and versatile.

2.3. Solar Panel

The solar panel it is a device designed to capture sunlight and convert it into energy for electricity generation or heating. Photovoltaic modules utilize light energy (photons) from the Sun to produce electricity through the photovoltaic effect. Most of these modules are made with wafer-based crystalline silicon cells or thin-film cells. The structural component of a module, which bears the load, can either be the top or back layer. To ensure durability, the cells must have protected from the mechanical damages which occurs and moisture. While most of the modules are rigid, some semi-flexible ones, made with thin-film cells, are also available. The cells are electrically connected in series. Externally, photovoltaic modules typically use MC4 connectors for weatherproof connections to the rest of the system.

Figure 3. Solar Panel

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The electrical connections between the modules are made in series to achieve the desired output voltage and/or in parallel to provide the required current. The conducting wires which is used to carry the current from the modules are typically made from the silver, copper, or the other non-magnetic conductive metals. Bypass diodes, either incorporated within the module or used externally, are employed to optimize the module's output when parts of it are shaded.

2.4. Servo Motor

As our innovation propels, the utilization of robots and other independent applications in our day by day lives increments as well. Whereas cheaper robots utilize stepper or brushed DC engines, more progressed mechanical autonomy require the utilization of servo engines. But what is characterized as a servo engine and why are they utilized in most industrial applications?

Figure 4. Servo Motor

The servo motor which is a compact electrical device which moves machine components with high accuracy and efficiency. Simply put, a servo motors which is a BLDC (brushless DC) motor equipped with a sensor used for positional feedback. This enables the output which is shaft to be adjusted to a specific angle, and the position, or speed, something a regular used motor cannot achieve. However, the servo motor is just one component of a closed-loop of motion of a control system. A full motion system also includes an amplifier, the control circuit, the drive gears, potentiometer, shaft used, and either an encoder or resolver, in addition to the servo motor.

2.5. Connecting Wires

Connecting wires enable electrical current to flow from one point in a circuit to another circuit, as electricity requires a medium to travel through. Typically, these wires are made up of copper or aluminum.

Figure 5. Connecting Wires

3. Proposed Work

3.1. Block Diagram

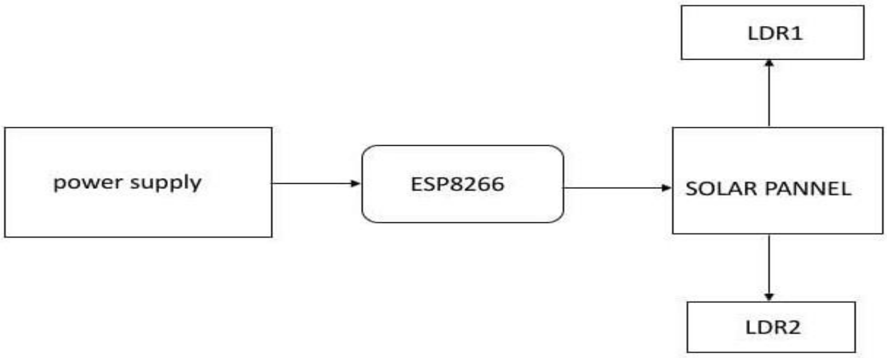

Figure 6. Block Diagram

3.2. Working

A sun-tracking solar panel system is designed to maximize the efficiency of a solar panel by orienting it toward the sun by observing throughout the day. By adjusting the angle of the solar panel to follow the sun position which has been observed in the sky, the system can capture more sunlight, increasing the amount of energy generated compared to a fixed solar panel. This process is achieved through a combination of light dependent resistors (LDRs), motors, and a microcontroller. In this setup, the ESP8266 microcontroller is often used due to its integrated Wi-Fi capabilities, which allow for remote monitoring and control of the system.

The sun-tracking by using solar panel the system operates by using the two Light Dependent Resistors which is (LDRs) positioned on either side of the solar panel. These LDRs serve as sensors to measure the light intensity striking them. The resistance of the LDRs varies with the amount of light they receive. When the solar panel is correctly aligned with the sun, both LDRs receive an equal amount of light, causing their resistance values to be nearly identical. As the sun moves, however, one LDR will receive which is lighter than the other, leading to a difference in resistance. This change is then detected by the ESP8266 microcontroller.

The ESP8266 processes the data from the LDRs, compares the difference in light intensity, and sends a signal to the servo motor, which then adjusts the position of the solar panel. For instance, if one LDR which receives more light than the other, the system will rotate the panel towards the LDR that is receiving less light. This continuous adjustment throughout the day ensures that the solar panel stays at the optimal angle for maximum sunlight exposure.

The servo motor is responsible for physically tilting the solar panel. Typically, a 5V servo motor is used, powered either directly by the ESP8266 or by an external power source. The servo motor can adjust the panel's tilt on one or two axes, depending on the system's design. In simpler systems, the panel might only rotate on a single axis (east to west), while more advanced systems can adjust both the tilt (north to south) and azimuth (east to west), allowing the panel to track the sun in two dimensions.

In addition to the core tracking system, various environmental sensors can be integrated to enhance performance and provide extra data. Weather sensors, such as those measuring temperature, humidity, and barometric pressure,

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can offer real-time insights that help predict solar panel efficiency based on environmental factors. Rain sensors can detect when the panel is covered by rain, while dust sensors can signal when cleaning is necessary to maintain optimal performance. These sensors can be linked to the ESP8266, and their data can be transmitted wirelessly to a remote monitoring system, enabling users to monitor both system performance and environmental conditions.

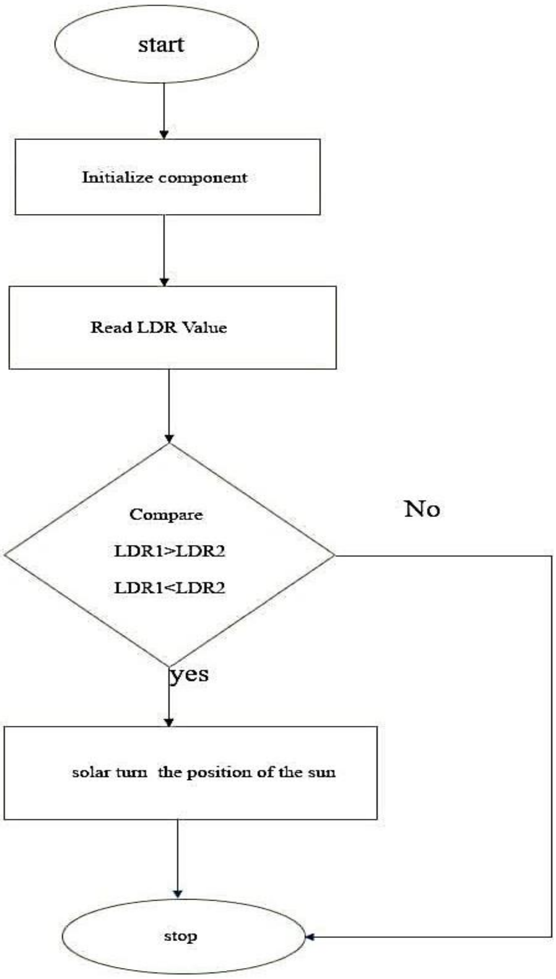

Figure 7. Flow Chart

Table 1. Result obtained voltage during hour calculation

HOUR	VOLTAGE (V)	CURRENT (mA)	POWER
10:00	15.7	1.14	18.046
11:00	16.0	1.17	18.742
12:00	16.7	1.23	20.632
13:00	18.3	1.33	24.518
14:00	18.9	2.12	26.158

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To enhance the intelligence of the sun-tracking system, the ESP8266 can be programmed to adjust the panel's orientation not only based on the LDR inputs but also using data from weather and environmental sensors. For instance, if the system detects cloudy skies or rain, it could stop tracking the sun and reposition the panel for easier maintenance or protection from the weather. Additionally, the ESP8266's Wi-Fi capabilities allow data to be transmitted to the cloud, where it can be analyzed and monitored in real time. This enables users to access performance data from anywhere, keeping them informed about the status of their solar panel system.

A major benefit of using the ESP8266 in a sun-tracking solar panel system is its affordability and ease of use. As a popular microcontroller in the IoT community, the ESP8266 is known for its low cost, compact size, and robust Wi-Fi capabilities. This makes it easy to integrate remote monitoring features into a solar panel system, making the ESP8266 an ideal choice for DIY solar tracking projects.

In conclusion, a sun-tracking solar panel system powered by an ESP8266 offers an efficient and affordable method to optimize solar energy performance. By automatically adjusting the panel's position to follow the sun throughout the day, the system can greatly enhance energy production. The addition of environmental sensors and Wi-Fi connectivity further enhances functionality, enabling real-time monitoring and data analysis. With these improvements, solar tracking systems are becoming more intelligent and accessible, driving the development of more efficient renewable energy solutions.

4. Proposed Model

4.1. Prototype

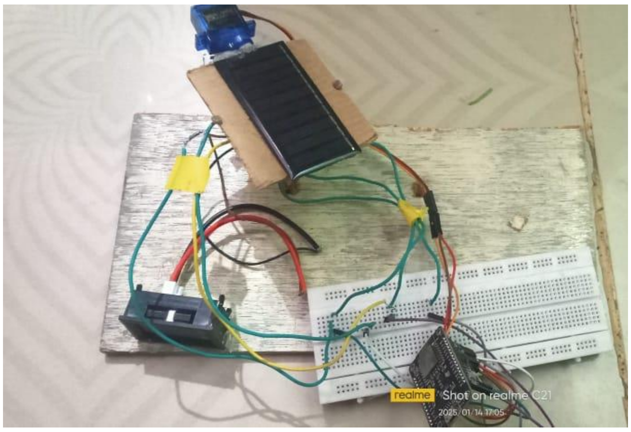

Figure 8. Hardware Model

4.2. Advantages

The main benefit of a sun tracking system is the enhanced energy capture. Solar panels that remain in a fixed position receive sunlight at different angles throughout the day, leading to less efficient energy conversion. A tracking system which can increase energy output by 20-50%, depending on the geographical location and weather conditions.

The ESP8266 is an inexpensive and widely accessible microcontroller with integrated Wi-Fi capabilities. Its low cost makes it an appealing choice for DIY enthusiasts and researchers who want to implement smart solar tracking systems without a large financial investment.

With its Wi-Fi capability, the ESP8266 enables remote monitoring and control of the solar tracking system. Users can view real-time data on energy production, panel orientation, and system performance through a web interface or mobile app. This feature allows for proactive maintenance and troubleshooting.

The ESP8266's compatibility with the Internet of Things (IoT) makes it easy to integrate solar tracking systems into larger smart home or energy management setups. Users can automate and optimize energy usage based on solar production data, improving overall energy efficiency. The ESP8266 is also compatible with various programming environments, including Arduino IDE and Node MCU.

4.3. Applications

Sun tracking solar panels, when integrated with IoT technology like the ESP8266, offer numerous advantages over traditional fixed solar panels, primarily by maximizing solar energy capture throughout the day. A key application of sun tracking systems is in improving the efficiency of solar panels. Solar panels typically generate the most energy when they are positioned directly facing the sun. Since the sun's position changes throughout the day due to the Earth's rotation, a fixed solar panel loses efficiency as it deviates from the optimal angle. Sun tracking systems, which adjust the angle of the panels in real-time, allow the panels to remain aligned with the sun's path, ensuring they capture the maximum amount of the sunlight. With the use of the ESP8266, a popular Wi-Fi microcontroller.

The efficiency improvements enabled by sun tracking with ESP8266 can also help reduce the overall cost of solar energy production. By ensuring that the solar panels always receive optimal sunlight exposure, the energy generated by the system is maximized. This translates into higher energy output and a shorter payback period for the initial investment. Additionally, such systems are scalable and adaptable to different applications, from small residential rooftops to large commercial solar farms. With the added benefits of data logging, weather forecasting integration, and long-term performance analysis, the use of ESP8266 in sun-tracking systems can be a game changer for the solar energy industry. Beyond energy efficiency, these systems can contribute to environmental sustainability by improving the adoption and efficiency of renewable energy sources

5. Result

5.1. Future Scope

The future scope of sun-tracking solar panels using the ESP8266 is vast, as it opens up numerous possibilities for optimization, sustainability, and integration with emerging technologies. In the coming years, solar energy systems are likely to become more efficient and intelligent, offering several areas for innovation. One promising avenue is the continuous enhancement of solar panel tracking systems, particularly with the use of the ESP8266, a low-cost, low-power Wi-Fi module, to improve real-time data analysis and remote monitoring. As solar technology advances, implementing AI and machine learning algorithms to predict the optimal angle for solar panel placement based on weather patterns, geographical location, and time of day will become a key trend. These systems could dynamically adjust based on weather forecasts, thereby increasing the overall energy capture throughout the day.

Incorporating of the Internet of Things which is (IoT) technology into sun-tracking solar panels using the ESP8266 can improve energy management and grid integration. IoT enables communication between solar systems and centralized platforms, allowing for the real-time monitoring of each individual panels, predictive maintenance, and optimized energy distribution. This approach could create a network of interconnected solar panels that not only track the sun but also relay performance data and adjust to environmental factors. These capabilities could support the development of a more intelligent, decentralized energy grid, reducing the dependence on the fossil fuels and promoting more sustainable energy production.

Another key area for future progress is the integration of environmental sensors into sun-tracking systems. By adding sensors that monitor factors like temperature, humidity, rainfall, and pollution, valuable data could be gathered to enhance the panel's positioning and performance. For instance, in regions prone to dust storms, the system could adjust the panel's angle to minimize dust accumulation, helping to maintain efficiency. Furthermore, integrating weather forecasting capabilities could enable the system to predict and respond to changes in environmental conditions.

5.2. Conclusion

In summary, the use of solar tracking systems that incorporate the ESP8266 and Light Dependent Resistors (LDRs) represents a major step forward in improving solar energy harvesting efficiency. The ESP8266 serves as the control unit, managing the precise movement of solar panels according to real-time data from the LDR sensors. This adaptive system enables the panels to constantly adjust their position to remain optimally aligned with the sun, thereby maximizing energy capture throughout the day. Additionally, the lower cost and widely availability of the ESP8266 make this solar tracking solution both technologically advanced and more affordable for a wide range of applications. The incorporation of LDRs adds a level of sensitivity to environmental changes, ensuring the system can adapt to fluctuating light conditions. This combination of ESP8266 and LDR technology enhances the performance of solar tracking systems, supporting the sustainability of solar energy as a practical and efficient renewable resource. In conclusion, the integration of ESP8266 and LDRs in solar tracking systems provides a practical and accessible way to optimize solar energy capture. This technology offers great potential for improving renewable energy efficiency, contributing to a more sustainable and environmentally friendly future.

Declarations

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

References

[1] Arsalan, S. (2013). Sun Tracking System with Microcontroller 8051. Intl. J. Sci & Eng. Research, 4: 2998.

[2] Anurag, A., & Gandhi R. (2014). Solar Tracking System Using Stepper Motor. Intl. J. Electronic & Electrical Eng., 7: 561.

[3] Chhatwani, P.K., & Somani, J.S. (2013). Intelligent Solar Tracker System Implemented On 8051 Micro controller. Intl. J. Eng. Trends Technol., 4: 4267.

[4] Saxena, A.K., & Dutta, V. (1990). A versatile microprocessor based controller for solar tracking. Photo volt Specialists Conf., IEEE.

[5] Ferdaus Rashid Ahammed, Mahir Asif Mohammed, Sanzidur Rahman, Sayedus Salehin & Mohammad Abdul Mannan (2014). Energy efficient hybrid dual axis solar tracking system. Journal of Renewable Energy.

[6] Vieira, R.G., et al. (2016). Comparative performance analysis between static solar panels and single-axis tracking system on a hot climate region near to the equator. Renewable and Sustainable Energy Reviews, 64: 672–681.