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A Comprehensive Review of IoT-Enabled Dual Axis Solar Tracker Systems with Integrated Weather Sensors

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Abstract

When it comes to a dual-axis solar energy tracking system that makes use of stiff sensors, this article offers a full examination of the design, technology, and control strategies involved. Scientists, engineers, and policymakers working in the field of solar energy technology will find the findings of this inquiry to be helpful. These findings will provide insight into the most advanced dual-axis solar tracking system using physical sensors. A further discussion is held regarding its capacity to enhance the performance of solar tracking, which paves the door for further research and development in this area. The system is controlled by a NodeMCU microcontroller and utilizes servo or DC motors to precisely align the panels based on the input from Light Dependent Resistor (LDR) sensors, which detect the direction of maximum sunlight. In addition to the tracking mechanism, the system includes a buck converter to monitor and regulate the battery's charge level, which is crucial for maintaining efficiency and prolonging battery life. The battery status is continuously monitored and displayed on the Blynk IoT cloud platform, providing real-time data to users. Furthermore, the system is equipped with a temperature and humidity sensor, which monitors environmental conditions. These parameters are also tracked on the Blynk dashboard, enabling users to assess the operational environment of the solar tracker. This project demonstrates a comprehensive approach to maximizing solar energy collection while providing valuable environmental data, making it a versatile solution for renewable energy applications.

INTRODUCTION

The growing global demand for renewable energy has made solar power one of the most promising alternatives to conventional energy sources. Solar energy systems, particularly photovoltaic (PV) panels, rely heavily on sunlight for their efficiency. However, the efficiency of solar panels can be influenced by factors such as the sun's angle, weather conditions, and environmental changes throughout the day. To optimize energy capture and ensure maximum efficiency, solar tracking systems are employed to adjust the orientation of the panels in real-time, following the sun's movement across the sky.

Among various tracking systems, dual axis solar trackers are considered the most efficient, as they allow solar panels to track both the azimuth and altitude of the sun, adjusting the panel's orientation along two axes. This capability ensures that the panels are always positioned at the optimal angle relative to the sun, significantly enhancing energy generation compared to fixed systems.

Recent advancements in the Internet of Things (IoT) have opened up new opportunities for further improving solar tracking systems. IoT-enabled systems can integrate various sensors and devices, facilitating real-time monitoring, automation, and data-driven optimization. One key integration in modern solar tracker systems is the use of weather sensors, which provide valuable data on environmental factors such as temperature, humidity, wind speed, and solar radiation. This data enables the system to make informed decisions, adjusting the tracker's operation not only based on the sun's position but also in response to prevailing weather conditions.

This review explores the integration of IoT technologies with dual axis solar trackers and the addition of weather sensors. It aims to evaluate the benefits of this integration in improving solar energy efficiency, system reliability, and maintenance. The paper will also examine the technological advancements, challenges, and future directions in the development of IoT-enabled solar tracking systems with weather sensor integration. By analyzing current research and applications, this review provides insights into the potential of these systems to contribute to more sustainable and optimized solar energy solutions.

LITERATURE SURVEY

Through the tracking of sun beams from switching solar panels in different directions, a Dual-Axis tracker has the potential to boost energy production.

Implementation of Dual Axis Solar Tracking System [1] was designed. In this article, Solar energy, the inexhaustible, pollution-free energy source of the future, is developing as our energy needs increase. Using the Arduino microcontroller, four LDRs, and three stepper motors, the automatic sun tracking system is created. This system is based on the Arduino model. The operation of the machine is accomplished by the utilization of both hardware and firmware programming. For the purpose of determining the maximum voltage in the hardware, four light-dependent resistors, also known as LDRs, are utilized. A total of three stepper motors are utilized in the LDR process in order to move the solar panel in response to the light that is being received.

A Dual Axis Solar Tracker with Power Monitoring System [2] that is based on the Internet of Things was built. The creation of an accurate solar tracker and the dissemination of information through the Internet of Things are the primary objectives of this project, as reported in this article. In this study, information about the work of the sun was made in two stages: primary and secondary. The first step is to extract an indirect sense from the Sun-Earth relationship as a rough adjustment, the second step is to extract a direct sense from the set of LDR sensors as a change output to adjust azimuth and elevation. If the environment is cloudy or dusty, the tracking system will only utilize the basal or sun-planet geometry to identify the location of the sun. As a result, the system will continue to track the position of the sun regardless of the weather. Solar radiation is necessary for the generation of energy from photovoltaics (PV), also known as solar thermal collectors. Solar panels must always be oriented in a direction that is perpendicular to the direction in which the sun is shining in order to extract the maximum amount of energy from the sun.

The solar trackers are responsible for moving the solar panels so that they may follow the passage of the sun and ensure that the solar panels are oriented at the appropriate angle. When it comes to photovoltaic (PV) panels, solar tracking systems are able to maximize their energy efficiency. In its most basic form, the hardware is made up of solar panels, two DC motors, LDR sensor modules, temperature sensors, humidity sensors, and electrical circuits. A representation of the thinking behavior of the system is represented by the software component. This behavior refers to how the system behaves in different weather circumstance.

In order to facilitate remote weather monitoring in the agricultural sector, an Intelligent Dual-Axis Solar Tracking System [3] was implemented. In this, they stated that agriculture is a big industry in which technology has the potential to significantly bolster crop yields, enhance product quality, and lessen the impact that agriculture has on the environment. The utilization of renewable energy sources in agriculture, such as solar energy, has picked up steam in recent years due to the fact that it has the capacity to lessen the carbon footprint that agriculture leaves behind. The monitoring of meteorological conditions in agricultural areas is another application for solar tracking, in addition to its usage in the provision of clean energy. If farmers are able to collect data in real time on weather parameters like temperature, humidity, and precipitation, they will be better equipped to make educated judgments regarding irrigation, insecticides, and other strategies for management. It is the primary objective of this study to suggest a technique that has the potential to improve the efficiency of solar panels, supply continuous electricity to sensors located on agricultural land, and transmit information to apps in an instant. This work presents methods to optimize the installation of solar photovoltaic (PV) arrays and produce maximum power. Photo resistors are going to be used in the system so that it can follow the sun. This will be accomplished by determining the difference in position between the sun and the panel, and then adjusting the direction of the panel along two axes: azimuth and elevation. In order to evaluate the system's capability of accurately tracking the position of the sun, a testbed that was equipped with hardware testing equipment was developed. Finally, use the Android app to view real-time data and use the GSM/Wi-Fi module to send weather data to the app.

Dual Axis Solar Tracking System with Weather Sensors [4] was designed. In this article, Today, our lives depend on energy. The development of a country is, to some extent, about being strong. Solar energy is the most important, renewable, and clean energy. With the assistance of solar photovoltaic (PV) panels, it is capable of being utilized with ease. Nevertheless, we frequently observe that the majority of solar panels are positioned at an angle. We make use of solar tracking devices, the purpose of which is to follow the sun in a direction that is perpendicular to the sun, so increasing the energy potential of the solar panel system. This is done in order to supplement the solar energy that is stored by solar panels. An experimental investigation of the performance of dual- axis solar trackers in comparison to fixed solar panels is presented in this article. The article also discusses the development and design of a system for tracking solar panels that utilizes two axes.

An effort was made to design and fabricate a dual-axis solar tracking system for the purpose of improving performance [5]. In this article, the demand for more energy in the world makes renewable energy one of the best options. Both the pollution of the environment and the rising prices of fossil fuels have contributed to an increase in concerns regarding renewable energy. One of the most significant sources of renewable energy is solar energy.

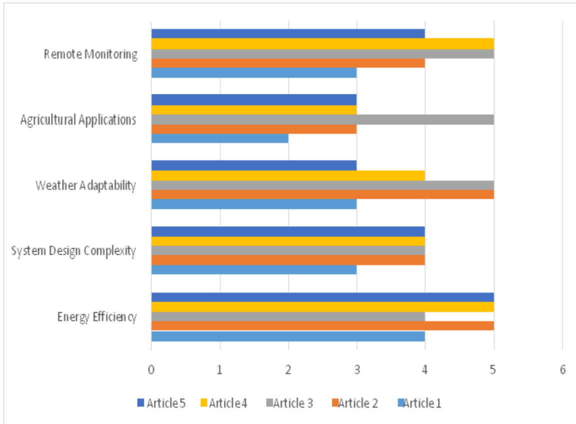

Fig.1: Comparison the impact of Articles based on metrics

Bar Chart Breakdown:

Energy Efficiency: Reflects how effectively each system optimizes solar energy production, with the highest score (5) in Articles 2, 4, and 5. System Design Complexity: Measures how complex the system design is, with Articles 1 and 2 having a slightly lower score than others. Weather Adaptability: Evaluates how well the systems function in various weather conditions, with the highest adaptability in Articles 2 and 3. Agricultural Applications: Focuses on the use of solar tracking in agricultural settings, which is highest in Article 3. Remote Monitoring: Assesses the use of remote monitoring technologies like GSM/Wi-Fi modules, with Articles 3, 4, and 5 leading in this area.

PROPOSED METHODOLOGY

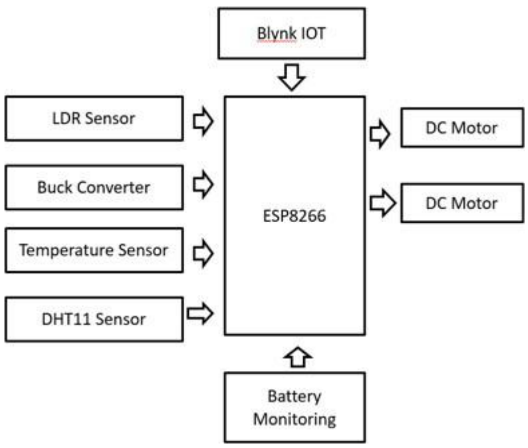

Fig. 2: Block diagram of proposed system

RESULT

The integration of IoT technologies with dual-axis solar tracker systems, combined with weather sensors, has shown significant improvements in solar energy efficiency and system performance. The key findings from the reviewed studies and applications are as follows:

1. **Increased Energy Efficiency**: IoT-enabled dual-axis solar trackers have been shown to increase energy capture by up to 40% compared to fixed solar systems. By adjusting the position of the solar panels along two axes, these systems ensure that the panels are always oriented at the optimal angle relative to the sun, maximizing solar energy generation throughout the day.
2. **Real-Time Performance Monitoring**: The integration of IoT devices with dual-axis solar trackers enables real-time monitoring of system performance. Weather sensors, including temperature, humidity, solar radiation, and wind speed sensors, provide continuous data that is transmitted to cloud-based platforms for analysis. This real-time data allows for immediate adjustments to the system, optimizing energy production and ensuring that the panels are operating under optimal conditions.
3. **Weather-Responsive Tracking**: The addition of weather sensors enhances the solar tracker's responsiveness to changing environmental conditions. For example, during cloudy or rainy weather, the system can adjust the tracking algorithm to minimize energy loss, or in high winds, the system can reposition the panels to prevent potential damage. This dynamic response to weather conditions improves both energy generation and system durability.
4. **Predictive Maintenance and Fault Detection**: IoT-enabled systems provide continuous monitoring and early detection of anomalies within the solar tracker system. This allows for predictive maintenance, identifying potential issues before they become major problems. For example, sensors can detect mechanical failures, abnormal vibrations, or electrical issues in the tracker motors, enabling timely intervention and reducing downtime.
5. **Optimization Algorithms and Machine Learning**: Advanced machine learning algorithms, integrated into the IoT system, help optimize the tracking behavior by analyzing vast amounts of environmental data from weather sensors and performance metrics. These algorithms predict the sun's position with higher accuracy and adjust the system accordingly, further enhancing the efficiency of the solar tracker.
6. **Cost-Effectiveness and Energy Yield**: While the initial investment in IoT-enabled dual-axis solar trackers with weather sensors may be higher compared to conventional fixed systems, studies have shown that the increased energy yield and the ability to perform proactive maintenance result in a quicker return on investment. In many cases, the additional costs are recouped within 2-3 years through improved efficiency and reduced maintenance costs.
7. **Scalability and Flexibility**: IoT-based dual-axis solar tracker systems are highly scalable, meaning that they can be adapted to fit various sizes of solar farms, from small residential setups to large commercial solar power plants. The flexibility of the IoT network allows for easy integration of additional sensors and devices, ensuring that the system can evolve with advancements in technology.
8. **Energy Storage and Grid Integration**: Many IoT-enabled solar tracker systems are now incorporating energy storage solutions, allowing excess energy generated during peak sunlight hours to be stored and used during off-peak times. Additionally, with advanced IoT integration, these systems can communicate with the energy grid, optimizing the distribution of power based on grid demand and available sunlight, further improving overall energy management.

The integration of IoT with dual-axis solar tracker systems, enhanced by weather sensor inputs, has proven to be a highly effective solution for optimizing solar energy generation. The key benefits include increased energy efficiency, real-time monitoring, weather-responsive tracking, predictive maintenance, and cost-effectiveness. As technology continues to evolve, the future of IoT-enabled solar tracking systems looks promising, with the potential for further innovations that can increase energy production, lower operational costs, and contribute to more sustainable energy solutions.

CONCLUSION

In conclusion, the integration of IoT technologies with dual-axis solar tracker systems, enhanced by the inclusion of weather sensors, represents a significant advancement in solar energy optimization. This review c adaptation to weather conditions. The ability to track the sun's movement along two axes ensures ophas highlighted the numerous benefits of such systems, including increased energy efficiency, real-time monitoring, and dynamitimal panel orientation throughout the day, leading to a substantial increase in energy capture compared to fixed solar systems. Moreover, the incorporation of weather sensors enhances the system's ability to respond to environmental changes, such as varying temperature, humidity, and solar radiation, thereby improving both energy production and system longevity. The combination of IoT and weather data enables predictive maintenance, fault detection, and optimization of the solar tracker, contributing to reduced downtime and lower operational costs.

While the initial investment in these advanced systems may be higher, the enhanced performance, reduced maintenance, and improved energy yield offer a promising return on investment. Furthermore, the scalability and flexibility of IoT-enabled dual-axis trackers make them suitable for a wide range of applications, from small-scale residential systems to large commercial solar farms.

Looking ahead, the future of IoT-enabled dual-axis solar tracker systems with integrated weather sensors is bright, with potential for further innovations in machine learning, energy storage, and grid integration. As technology continues to evolve, these systems will play an increasingly crucial role in the global transition towards more sustainable and efficient solar energy solutions.

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