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Implementation and Analysis of a Dual-Axis Solar Tracker Using Arduino

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ABSTRACT- The ever-increasing need for renewable energy sources has academics and engineers focusing their attention on developing more efficient methods to capture the power of the sun. Utilising solar trackers has shown to be one of the most effective methods of maximising the use of solar energy, among the many other approaches that are now accessible. The purpose of this paper is to present the design, implementation, and analysis of a dual-axis solar tracker system that makes use of an Arduino microcontroller, DC motors for two-axis movement, Light Dependent Resistor (LDR) sensors for determining the direction in which the sun is shining, a solar inverter for powering AC loads, and an LCD display for measuring voltage. By continually detecting the sun's position, converting the produced DC power to AC, and showing the system's status in real time, the system that has been presented offers an efficient method for increasing the conversion efficiency of solar panels.

KEYWORDS- Dual axis solar tracker, Arduino, DC motors, LDR sensor, Solar inverter, LCD display, Renewable energy, Solar power, System design and implementation.

I. INTRODUCTION

In recent years, there has been a significant increase in the use of solar energy, which is usually seen as a renewable energy source that is not only clean but also sustainable and easy to obtain. This is because climate change and energy shortages are two of the most pressing problems facing the world today. This is as a result of the general realisation that solar energy is a source of renewable energy that is not only clean but also sustainable and easily accessible. However, due of the temporal and geographical unpredictability of sunlight, it is not possible to capture the full potential of solar energy. This is because solar energy is dependent on the angle of the sun. Because of this, there is a one-of-a-kind challenge set that has to be completed. The use of solar tracker systems is one possible solution to this problem that may be implemented. These systems can automatically adjust the orientation of solar panels so that they face the sun. Because of this, they are able to significantly boost the amount of solar radiation that is captured and, therefore, the amount of energy that is generated as a consequence of this improvement.

Traditional solar installations often make use of permanent, fixed-tilt systems that are only able to catch the sun at its optimal angle for a brief period of time at various times throughout the day. As a direct result of this, the quantity of usable energy that can be extracted from these installations is far lower than what would be ideal. In contrast, dual-axis solar trackers, which are capable of adjusting both the azimuthal and the polar angle of the solar panel, have shown the potential to increase the quantity of solar energy gathered by anywhere between 30 and 45 percent when compared to their fixed counterparts.

This study will investigate the design and implementation of a dual-axis solar tracker system that makes use of an Arduino microcontroller, DC motors for two-axis movement, Light Dependent Resistor (LDR) sensors for sun direction detection, a solar inverter for conversion of generated DC power to AC power that is suitable for common electrical loads, and a 16x2 LCD display for system status monitoring and voltage measurement. The purpose of this study is to investigate the design and implementation of the system.

The Arduino microcontroller is the component of choice for the job of carrying out the work of coordinating the operation of the system. Because of its versatility and user-friendliness, the Arduino microcontroller is the component of choice. DC motors were used to control the movement of the solar panel along both axes. This decision was made due to the precision, reliability, and overall efficacy of DC motors. In the process of detecting the azimuth of the sun and, as a consequence, providing the Arduino microcontroller with the appropriate input, LDR sensors, which have a resistance that changes in proportion to the amount of light they are exposed to, are used. An essential function of the system is performed by a solar inverter, which is to change the direct current (DC) that is generated by the solar panels



into an alternating current (AC). The solar panels create DC, and the inverter converts DC into AC. Direct current may be employed for a limited set of goods and systems, while alternating current can be used in a greater variety of settings. A 16x2 LCD display has also been included into the product in order to offer information on the operation of the system in real time and in a way that is simply understandable. This information may include voltage measurements, updates to the system status, and any error reports.

The fundamental purpose of this research project is to build a dual-axis solar tracker that is long-lasting, effective, and easily reproducible. This tracker will contribute to the improvement of the utilisation of solar energy to generate electricity. It will be described in great depth how to design the tracker, how to choose which components to use, how to put it together, how to put it through its paces, and how to evaluate how well it performs. Our research and findings, it is hoped, will make a contribution to the greater body of knowledge on the subject of environmentally friendly energy solutions and stimulate further breakthroughs in this very vital area of research.

II. PREVIOUS WORK

A considerable amount of study has been conducted over the course of the last few years [1-4] on the significance of solar energy as well as the advantages of solar tracking systems. The research that has been carried out up to this point demonstrates not only the viability of solar power as a source of renewable energy but also the need to develop novel approaches in order to improve the efficiency with which solar power is collected. This is a conclusion that can be drawn from the findings of the research. These investigations were the first to conceive and develop the concept of a dual-axis solar tracker, which has the ability to monitor the movement of the sun in both azimuth and elevation. [5-7] These studies also made an important contribution to the formation of this idea.

Keeping tabs on where the sun is at any one moment during the course of the day may be performed in a variety of different ways. When using some of these methodologies, determining the precise position of the sun necessitates the use of intricate algorithms, in addition to the collection of data from GPS devices and precise date and time information [8]. On the other hand, these methods often need a substantial amount of computational resources; hence, they may not be appropriate for all applications. On the other hand, light-dependent resistor (LDR) sensors have been effectively used in a number of investigations to provide a solution that is both simple and efficient [8-10]. A microcontroller receives data from these sensors, which determine the direction in which the greatest amount of sunlight is shining and transmit that information on. After then, the information obtained from the sensors is input into the microcontroller, which directs the movement of the solar panel accordingly.

When it comes to the control system, a lot of studies have advised the use of systems that are based on microcontrollers for the purpose of controlling the motion of solar trackers. Particularly, the Arduino platform has been lauded for the ease with which it can be used, the versatility with which it can be utilised, and the accessibility with which it can be obtained, traits that combine to make it a great choice for both hobbyists and researchers [11-14]. It has been shown that making use of DC motors as a means of controlling the movement of a solar tracker along both axes is a way that is both effective and economical [15, 16].

Solar inverters are a means of converting the direct current (DC) electricity that is produced by solar panels into alternating current (AC) power, which is better suited for the majority of the appliances and machinery used in industrial and domestic settings [17]. Previous research has investigated the use of solar inverters as a means of accomplishing this conversion. In addition, research has been done on the measurement of voltage and the display of the system's present condition; LCD panels have emerged as a favoured alternative because to the accessibility and readability they give [18]. This is because LCD panels provide both of these features.

In spite of these advancements, there is still a significant opportunity for optimising the design and implementation of dual-axis solar trackers, with a special focus on boosting the efficiency of energy conversion as well as the durability of the system. The current work intends to make a contribution to this ever-expanding area of inquiry [19-20].

III. IMPLEMENTATION

The assembly of the various pieces of hardware is the first stage in the process of putting together the dual-axis solar tracker system. A microcontroller based on the Arduino Uno platform acts as the primary command and processing unit

for the whole system. Because all of the components are linked to it, the Arduino is able to interpret the information that it receives from the sensors, operate the motors in accordance with what it learns, and so on.

The set of four LDR sensors is the next essential component in the system. These sensors are installed on the perimeter of the solar panel in such a manner that they are able to detect sunlight coming from any of the conceivable directions. LDRs are chosen because of their intrinsic trait of exhibiting a change in resistance in response to changes in the amount of light present. The amount of sunshine that strikes each of these photocells causes them to generate a unique voltage value, which is then read by the Arduino.

Two DC motors are used so that the solar panel may be moved along two different axes simultaneously. Adjustment of the azimuth angle (on the horizontal axis) is handled by the first DC motor, while adjustment of the elevation angle (on the vertical axis) is handled by the second DC motor. Because of its movement along both axes, the solar panel will always be facing the direction that receives the most light, which will result in the creation of the most possible electricity. Motor driver circuits are used to link these motors with the Arduino Uno. These circuits work by amplifying the signals that are sent from the Arduino to a level that is sufficient to operate the motors. Figure 1 shows the circuit diagram.

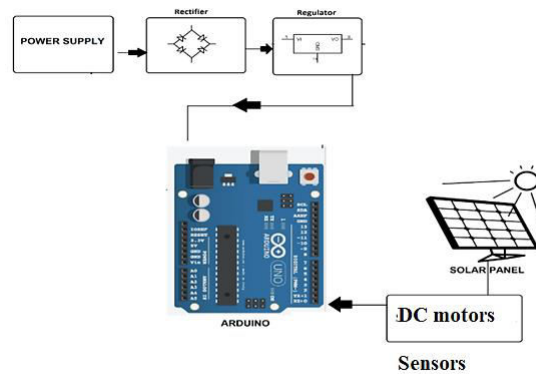


Fig. 1 Circuit Diagram

Solar energy is converted using an inverter that is linked to the solar panel. The electricity that is produced by the solar panel is in the form of DC, which is incompatible with the majority of the equipment in a home. In order to transform this DC electricity into AC power, a solar inverter is required to be used. It is essential to keep in mind that the power rating of the solar panel and the anticipated AC loads should serve as the basis for selecting the appropriate inverter.

The system comes with a 16x2 LCD display that can be interfaced with the Arduino Uno. This is the last component. The LCD display fulfils two roles in the system. Not only does it display the actual voltage that is being produced by the solar panel in real time, but it also indicates the current operating condition of the solar tracking system. Users are able to monitor the operation of the system and take remedial steps if they deem it essential thanks to this feature.

Now that all of the hardware components have been installed, the attention is being shifted to the portion of the implementation that involves the creation of software. The software, which was developed using the Arduino IDE, is responsible for coordinating the activities of all of the system's components.

The LDR sensor values are received by the software code, which then uses those readings to determine the direction that receives the most sunshine. Following the completion of this computation, it then sends control signals to the DC motors in order to position the solar panels in the most effective manner possible. The movement of the DC motors is managed by a PID control algorithm, which has been implemented into the software code in order to achieve higher levels of precision and functionality. This method guarantees that the motors will move exactly and smoothly, with no overshoot occurring at any point.

The programme also reads the power output from the solar panel, transforms it into a voltage value, and shows this information on the LCD screen. In addition to this, the software also displays the information. In addition to this, it monitors the operational state of the system and shows error warnings in the event that any problems are found.



In general, the process of putting into action the dual-axis solar tracker system requires a deft combination of hardware assembly and software development, the two of which must operate in perfect harmony in order to produce a solar power generating system that is highly effective.

IV. RESULTS

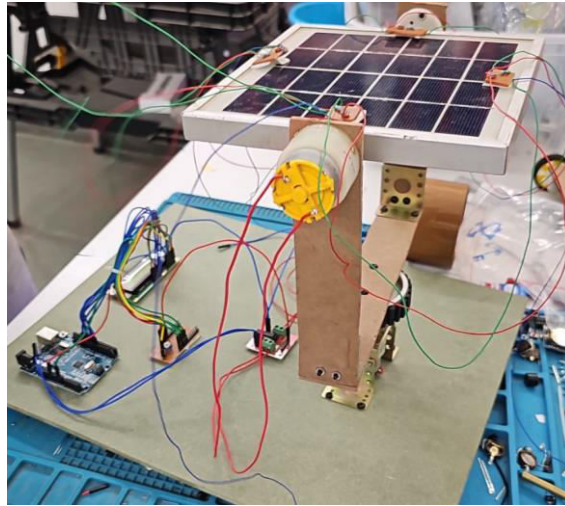


Fig. 2 Project image

Figure 2 illustrate the physical setup of the system with all hardware components in place. This includes the Arduino Uno microcontroller as the central hub, four LDR sensors at the edges of the solar panel, two DC motors attached to the solar panel for dual-axis movement, the solar inverter, and the 16x2 LCD display connected to the Arduino Uno. The figure might provide a clear visual of how these components are interconnected, forming a fully assembled dual-axis solar tracker system.

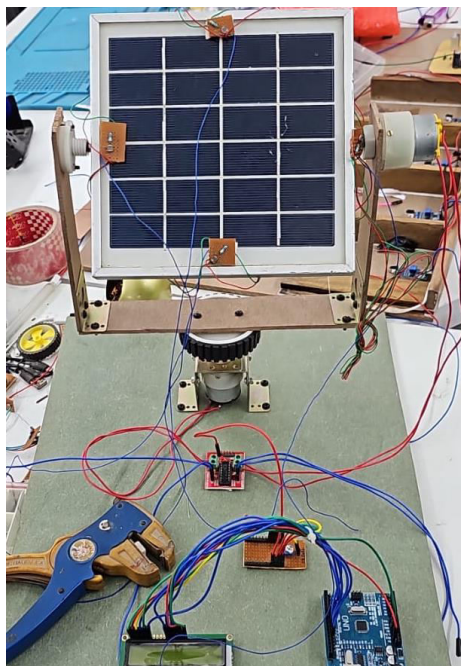


Fig. 3. Prototype Image

Figure 3 an image of the software interface or the Arduino IDE, showing the code used to control the solar tracker system. This could include snippets of the code where the values from the LDR sensors are read, the direction of maximum sunlight is calculated, and the signals to control the DC motors are sent. It might also show sections of the code where the power output from the solar panel is read and displayed on the LCD screen, as well as error messages in case of system issues.

V. CONCLUSION

In conclusion, the design and installation of the dual-axis solar tracker system is a novel way to enhancing the efficiency of solar energy production. It offers an ideal solution for catching the greatest possible quantity of sunshine by combining various components of hardware with thoughtfully developed software. This allows for the most possible amount of sunlight to be captured.

The Arduino Uno microcontroller, which acts as the principal control unit, is located deep inside the system and serves as its nerve centre. It does this by interacting with a number of the system's components, including LDR sensors, DC motors, a solar inverter, and an LCD display, in order to guarantee that the system runs smoothly. The hardware configuration has been deliberately constructed in order to make optimum use of these components for the dual-axis movement of the solar panel. This will ensure that the panel is always oriented in such a way that it receives the greatest amount of light.

When it comes to the software, controlling the system may be done in a manner that is both thorough and adaptable when the Arduino IDE is used. By guaranteeing that the motors move in a precise and smooth manner, the deployment of a PID control algorithm contributes significantly to an increase in the performance of the system. In addition, the software not only maintains the operational aspect, but it also monitors the performance of the system, showing essential data such as real-time voltage generation and system status. This allows the programme to manage both aspects.

However, it is essential to point out that the planning and installation of a dual-axis solar tracker system, despite the fact that it has the potential to significantly boost the production of solar electricity, comes with its own unique set of obstacles. These include the difficulty of integrating the hardware and software, the possibility of experiencing mechanical troubles due to the dual-axis movement, and the need of performing routine maintenance and calibration. In spite of these possible obstacles, the advantages given by such a system much exceed the potential drawbacks. These benefits include greater energy efficiency as well as increased power production.

In the not too distant future, developments in sensor technology, motor control, and software algorithms may be able to considerably enhance the performance and dependability of solar tracker systems. The continued worldwide drive for renewable energy sources will only continue to enhance the significance and relevance of projects like the dual-axis solar tracker system. This will be the case since the importance and relevance of these projects will continue to rise. As a result, the completion of this project marks a baby step—albeit a major one—toward the usage of solar energy that is more effective and environmentally responsible.

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