IoT Cloud System Based Dual Axis Solar Tracker Using Arduino

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Abstract

Because of the urgent need for electricity and the shortage of it, humanity has searched for the most environmentally friendly and well-available types of energy. From the different types of energy that comes from the sun, wind, tides, hydro and thermal energy that emanates from the earth and is spontaneously replenished naturally, the focus has been on solar energy. Which represents the best source of energy as it is naturally available in life and does not cause any damage or pollution in particular to nature and life. Not to mention after-math effects. This project led to the development of a two-axis solar tracker with the Internet of Things (IoT) or cloud platform. The solar system improves the performance of the solar panels due to following and the sun's mobility. Four light-dependent resistors (LDRs) were used to detect sunlight and the maximum intensity of the light, two servo motors have been utilized to rotate the panels based on sunlight detection by the LDR, after that, we use the WiFi as an intermediary between the Arduino device and the cloud platform. The cloud represents the final destination for the data to be stored, manipulated and processed.

Keywords: Dual Axis; Solar Panels; Renewable Energy; IoT; Cloud Computing; Tracking Systems.

1 Introduction

The Solar energy is one type of emerging renewable energy source that has attracted interest from various sectors including industry, academia, and the government. In particular, the methods that are used to produce energy, the amount of energy that is produced, and the effects that this has on the surrounding natural environment (Jaafar & Maarof, 2022).

Some resources such as fossil and water, in addition to the various forms of energy sources are not permanent and shall eventually run out. These types of energy include solar, wind, and geothermal. The vast majority of the energy that the world uses originates from fossil fuels. The crisis that we are

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currently facing due to global warming is significantly exacerbated by the widespread use of fossil fuels as primary sources of energy. The climate is in a precarious state as a result of natural and human-caused factors such as global warming and emissions of greenhouse gases. These factors have contributed to the state in which the climate is currently in (Devan et al., 2020), (Rajesh et al., 2021).The challenges that are associated with fossil fuels as well as the severe environmental concerns have been a driving force behind the efforts to promote green energy. Within the next 20 years, global energy demand is expected to double. As a result, fossil fuels are depleting at a quicker rate than ever before. Furthermore, global warming and the attendant climatic change are becoming important issues for governments all over the world. As a result, there is a pressing need for more efficient and ecologically friendly energy supplies to be mined globally (Muneer et al., 2003). Furthermore, the net effects of the interaction between renewable energy and CO_2 emissions are positive, i.e. renewable energy lessens the consequences of CO_2 emissions on human development and economic progress (Omri & Belaïd, 2021). To achieve such a goal, researchers investigated different ways in which solar energy can be utilized as a source of renewable energy to overcome these challenges. Solar power is at the top of the list of recommendations when looking for a sustainable solution to the problem of meeting increasing demands for electrical energy (Pavithra et al., 2021).

The days and nights are caused by the rotation of earth around the polar axis, which takes about 24 hours, the seasons are caused by the earth's tilt of 23.45 degrees away from the ecliptic plane. These two things don't always happen the same way, which makes it hard to design solar tracking systems. From any point on Earth, vertical and horizontal planes show where the sun is in relation to a coordinate system. There are two angles, azimuth and altitude angles can be used to describe where the sun is on this coordinate. To use a dual-axis solar tracking system to follow the sun's rays, these angles must be set in relation to the sun and constantly optimized (Tchao et al., 2022). This requires new simplified system that is based on tracking no matter where the sun to appear.

The efficiency of solar power is increased by the solar tracking system. Power generation wasn't as good as it is now until a wide variety of nonrenewable and renewable energy sources were put into use, including nuclear power plants, hydroelectric power plants, geothermal power plants, and others. Pollution and emissions are eliminated entirely during solar power generation, unlike traditional energy sources (Kaur et al., 2016), (Hu et al., 2018).

The harvesting of light gained from the sun to electrical energy has been known as the photoelectric process. Such a process is used nowadays to produce green energy that is environmentally friendly because it is generated from natural resources.

However, carbon emissions in the global economy continue to rise, making it critical to understand the variables that drive them. Whereas large amounts of information have emerged on the influence of economic expansion on carbon emissions, empirical research on the impact of renewable energy on environmental quality in developing nations has been limited. Renewable energy has recently been considered to be crucial in coping with substandard electric energy in poor locations and climate change challenges since renewable energy technologies provide appealing environmentally sound technology options for electricity. Because solar has a low carbon content, it is predicted to pollute the environment less than nonrenewable energy sources. As a result, any renewable energy will cut carbon emissions (Adams & Acheampong, 2019).

Attention must be put to what is happening in the world as the need for electric energy is increasing to sustain the global population. In this research, we focused on a specific solution method, which is the use of the dual tracking design, where this system contains two axes, the first fixed relative to the Earth, the primary one, while another axis can be considered as referring to the primary axis, also called secondary axis (Mishra et al., 2017).

The tracker helps reduce the waste angle, so the performance of the photovoltaic panels will be greater. In this research, we have used a light-dependent resistor (LDR), as they are two motors controlled by an Arduino to rotate the sun panels towards the sunlight. The focus of the researcher here is on the establishment of a two-axis solar tracking system using a control unit that uses logic in its work and is Arduino circuit that depends on the automatic tracking system in the performance of its work. The function of Arduino is to control the movement of the photovoltaic energy tracking device from the sun (Zolkapli et al., 2013).

An LDR is a light-sensitive electrical element consisting of a variable resistance made of ceramic and semiconductors, the value of its impedance changes with the change in the intensity of the illumination applied to it in an inverse proportion, that is, when the light intensity in the surrounding environment increases, the value of the electrical resistance of the element decreases, and vice versa (Mohanapriya et al., 2021), (Gaeid et al., 2020). This allows them to be used in light-sensing circuits. Above a certain frequency, the photons that are absorbed by a semiconductor photoresistor release energy that is tied up in electrons, which then makes it possible for the electrons to reach the conduction band. They give off free electrons and holes, which ultimately leads to a reduction in the amount of resistance they provide (Awad et al., 2020),(Pawar et al., 2021). LDR can be connected to the Arduino board via a simple voltage divider circuit and then reads the voltage on the divider output. By processing the value of the voltage signal that has been read, it is possible to know the value of the luminous intensity that is sensed by the photoresistor. The LDR output voltage $V_{out}=V_{in}\ Rx/(LDR+Rx)$. Where V_{in} is the input voltage and Rx is the resistor that is compared to the LDR. The latter can be symbolized as LDR1, LDR2, LDR3 or LDR4.

These LDRs are connected to the servo motors, these later have three wires: signal, DC power and ground. The power cable should be connected to the 5V pin on the Arduino board. The ground wire is attached to the pin on the board that serves as the board's ground. The signal is carried by the D9 and D10 pins on the board.as shown in Fig (1).

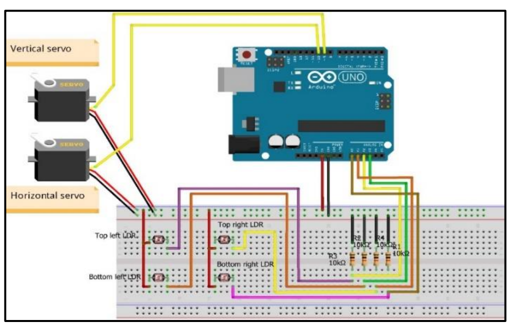

Figure 1: Block Diagram of the Tracking System

The design of a solar system is to track the sunlight and to ensure and improve the energy conversion gained from the sun to electricity by moving and converting the photovoltaic panel correctly until we reach the optimum situation of sunlight. Hence, the objective of our proposal is to experimentally establish a two-axes panel tracking circuit, which is done using sensors, where the mobility of the panel is monitored according to the light intensity. In addition to the development of the unique tracking circuit that monitors the process via a WiFi unit, last but not least, the performance of solar system has been connected to the cloud IoT platform for extra processing, manipulation and development (John Samuel Babu, G., 2023).

However, solar panels can be generated electrical energy through the use of sunlight and in addition charges a battery or by the switch to the power system directly. So the LDRs, that is connected to the Arduino, will measure the area intensity of light in their surroundings. Thus, the resistance of the LDRs will be changed that depends on the amount of light it receives and influences it. Moreover, the Arduino board reads the varying resistance values from the LDRs using analog input pins. Thus, it converts the resistance values into digital data that represents the light intensity so easy to read. Therefore, by using WiFi connectivity, the Arduino board can transmit the light intensity data to another device connected to the same network. Hence the receiving end can be, analyze the data, and store it. Moreover, it could be visualized on a web interface and sent the data to the mobile application.

2 Method

There are many components of the solar tracking system, as shown in Fig (2), have been used in the proposed experiment:

1.Arduino: Two of the most significant advantages provided by the Arduino Board are a fast turnaround time and an intuitive user interface. These open-source boards provide dependable technology that is reasonably priced and are also very easy to get your hands on. The analog pins received signals from the various components, which were sent from those components. It was also possible to upload the necessary code to the Uno board by connecting it to a computer via USB, and then using the Arduino Integrated Development Environment to perform the upload. Although the board can only support a voltage of 5V across all of its I/O pins (Badamasi, 2014), it is possible to make the board operational by loading it with a voltage that falls between 9 and 20V.

2.LDRs: There are many different types of semiconductors, but the most common ones are germanium, silicon, cadmium sulfide, gallium arsenide and lead sulfide (Nasrudin et al., 2011). The light-dependent resistor, also known as an LDR for short, is a type of semi-conductive device that reacts to alterations in the amount of light present. Once a change occurs in the intensity of the light, the LDR resistance changes too (Silva & Acosta-Avalos, 2006).

Servomotor: When it comes to precise control of motion, a servomotor is your best bet. Servomotors have the versatility to either rotate or linearly move. It can turn about 120 degrees and carry around 5 kilograms (Hoffmann et al., 2018), (Žarko et al., 2006), (Liu et al., 2020). As a result of having fewer turns per coil, less overall mass, and less moment of inertia, as well as a lower manufacturing cost, the motor heat generated by this design is less for the same torque output. You can describe it as having these characteristics.

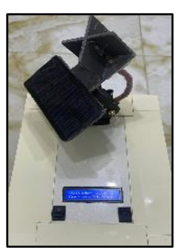

Figure 2: The Experimental Setup of the Proposed Tracking System

LDRs are often referred to as the system's eyes, as shown in Fig (3). Because of how well LDR sensors work and how much radiation the solar panel gets. The mission was to determine where in sky the sun is located. On either sides of the panel, the LDRs lying down. The signal that is received first from LDRs is transferred to the Arduino board, and the latter determines the amount of variation that exists in the new value of the signal with already existed value. When the difference be greater than indicated value of the Arduino code, the Arduino transmits a signal towards the motor instructing for necessary movement. Then, new value is sent via the WiFi to cloud platform. The new value will also come towards the same operation to obtain another new value, and so on.

This project aims to monitoring the performance of a solar energy tracking system using the IoT, where this project is divided into two phases, first one tackles the software, while the other focuses on hardware, where the system detects sensors for the sun's position and transfer the data to the Arduino, then Arduino processes the coming information from the sensor until a servo axis is controlled at a 180-degree angle which carries the panel to move towards the sun. Prefabricated by photovoltaic cells to the WiFi unit and sent to an IoT platform to record, then the IoT system updates the data each 5 seconds.

However, the Internet of Things (IoT) and cloud systems play a crucial role in tracking and monitoring solar systems, offering several advantages such as Real-Time-Monitoring where it's the Internet of Things devices integrated into solar systems enable real-time monitoring. Thus, this information can be accessed via remote connection through the cloud. Moreover, it can do fault detection and maintenance by using IoT sensors and detect anomalies in solar system parameters, such as equipment malfunction. So These issues can be as notifications the operators use for fixing the problem in any component of the solar system. whereby using the cloud systems, maintenance teams can remotely access the system's data and diagnose problems. Hence, data analytics and performance optimization in solar systems through IoT sensors are very important advantages. Where these advantages will help to optimize energy production and predict maintenance needs. In addition, there are other advantages such as remote control and automation and energy forecasting and grid integration and data security and backup. These technologies contribute to improved performance and increased operational efficiency and optimized energy management in solar installations.

Fig 4 shows the experimental design of the solar energy tracker motion. It consists, for start, of four sensors, all of which detect the sun's position. The received data from the sensor will be converted from analog into digital, then it will be noticed by the Arduino to make a comparison so that the panels are placed perpendicular in the direction of the sun's radiation. The system analyzes the information to estimate the sun's direction and make the servo motor horizontal and vertical so that it moves according to the information put into the Arduino.

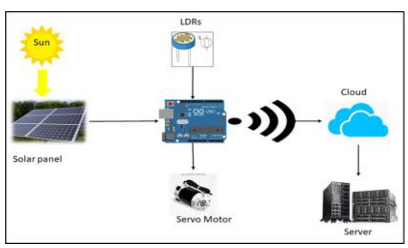

Figure 3: Tracking System Block Diagram

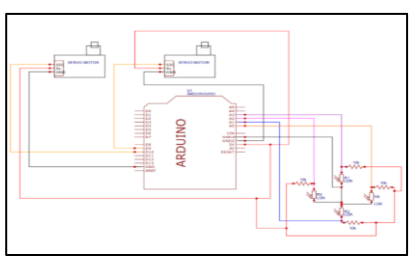

Figure 4: The Architecture of Dual Axis Arduino with LDRs and Motors

The Arduino is utilized as an important processor and a motor has been used as a hardware device to rotate the solar panel. In this work, we used a servo motor with a 180-degree angle in both vertical and horizontal axes. The motor works according to a sensor that senses the LDR that detects the light coming from sunlight. The sensor has five points that must be present to make the servo motor rotate. Firstly, when the LDR1 and LDR3 sensors detect more sunlight than LDR2 and LDR4, the vertical motor would switch from 0° to a 120°. Then, when LDR1 and LDR3 are lower than LDR2 and LDR4, the vertical motor rotates from 0° to 15°. After, when LDR1 and LDR2 sensors are more than the LDR3 and LDR4 sensors, the motor rotates horizontally at an angle of 65 degrees. Moreover, when the LDR1 and LDR2 sensors are less than LDR3 and LDR4 sensors, the horizontal motor turns to a 180°. Finally, when all sensors are equal, this means all sensors have detected the sunshine and the motor stops. These conditions depend upon the location of the sun and the weather. Moreover, the Arduino controller undergoes a loop to gain the best sun location, as shown in algorithm of Fig (5).

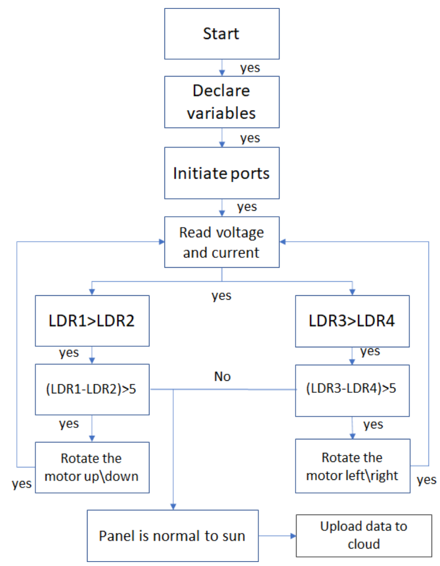

Figure 5: Flow Chart of Solar Tracker System

The Arduino is a board with the smallest dimensions that is designed to be compatible with breadboards. The Arduino is equipped with pins that facilitate breadboard attachment and a tiny USB port. That makes it an excellent choice for IoT projects of all kinds.

Furthermore, the solar tracker project has various types of data such as solar panel performance data where this data provides insights into the efficiency of each panel and helps identify any underperforming or faulty panels. However, the energy production data is important too because this type of data refers to the specific energy data production of the solar system and energy yield over specific time intervals. This data type is essential for monitoring the system's overall performance and analyzing the energy trends and evaluating the system's financial viability. While the environmental data type such as temperature and humidity and solar irradiance. This data type will help in assessing the system's performance under different weather conditions, moreover, optimizing energy generation. In addition, the maintenance and diagnostic data through which store data related to system maintenance where this information will help in diagnosing issues and scheduling maintenance activities. Thus, the cloud platforms play a vital role in the solar tracker project by collecting, manipulating, and processing various types of data. Through real-time monitoring and data analytics and predictive maintenance and energy forecasting and remote control and cloud systems optimize the performance and reliability and efficiency of the solar system.

3 Results and Discussion

The objective of this study is to compare the voltage, current, and power readings of fixed and traceable solar panels, then the proposed biaxial tracking method that is used to follow the most amount of light that shines in a straight line towards the solar panel during the day, month or year. We have made a comparison between the two-axis system with the fixed-angle system, the outcomes showed that the generated energy has a total increase of 8% and even to 25% more than the fixed solar tracking angle.

In this research, we focused is on the efficiency of solar panels, and there are several ways to increase this efficiency using a microcontroller chip. The solar light tracker is an electro-mechanical equipment that has several types of microprocessors, these are usually used to track energy derived from sunlight, the primary mission of the tracker is to boost the density of the sunlight, or that the density of light is preserved by controlling the system responsible for determining the position of the tracker. Fig (6) shows the voltage comparison of the tracking design with fixed angle. The maximum voltage of the prototype solar panel was 6V. This result shows the voltage in average about 5.1V in case of tracking system, and 4V without tracking. This means there is 1.1V improving in the voltage over time. The lost value of the voltage was expected due to the panel efficiency, semi-perfect sun, atmospheric dust and clouds. Note that the Arduino update the algorithm to obtain the perpendicular angle to the sun each 5 seconds.

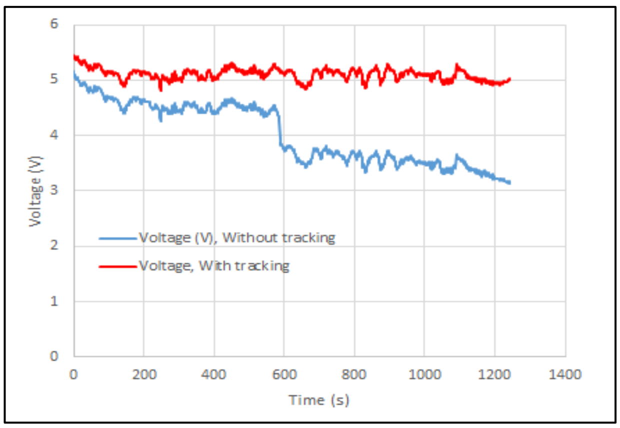

Figure 6: Voltage Comparison of the Dual with Fixed Angle Design

The following Fig (7) shows the current performance of dual-axis tracker in comparison with the single axis circuit. The average current value is about 85.83mA without tracking, while with tracking it is about 109.05mA, which means there is 23.21mA current gain in comparison.

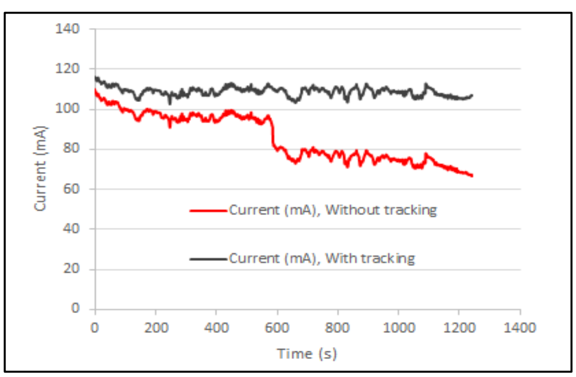

Figure 7: Current Performance of the Dual Axis Solar Panel Tracker in Comparison with the Single Axis Circuit

In addition, Fig (8) shows the power of the solar tracker circuit when compared to the single axis power performance. The tracking method average value was about 557.33mW, while without tracking power was 351.87mW, which spare about 204.46mW power gain from tracking the sun.

These results were recorded using IoT and cloud monitoring platform. Fig (9) presents this platform, which is used to save the resulting data. These latter are transferred from the Arduino to the cloud platform via the WiFi.

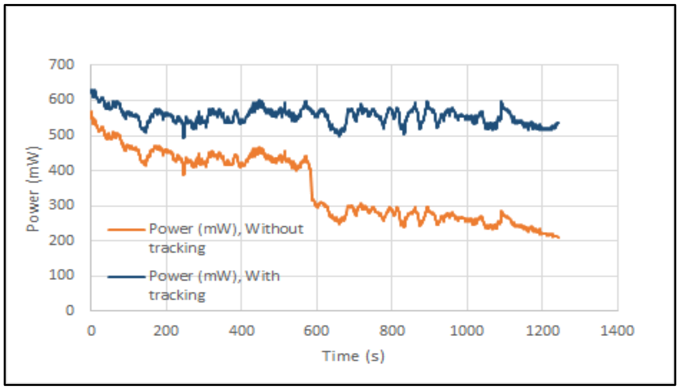

Figure 8: Power of the Solar Tracker Circuit Comparison with Single Axis Power Performance

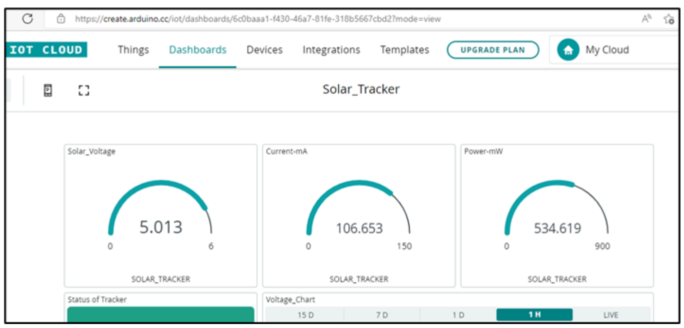

Figure 9: The Cloud Platform

4 Conclusion

In conclusion, dual-axis tracker circuit is established. This solar system has improved the harvested voltage, current and power of the solar panels via following and tracking the movement of the sun. Four LDRs have been used to detect the sunlight and obtain the maximum intensity of the light. Moreover, two motors have been placed to administer the solar panels based on the direction of the source of light detected using the LDRs. Arduino device is supported with WiFi unit for transmitting the resulting information from the solar panels to an IoT monitoring and cloud platform. There are two motions regarding the tracker, these are categorized as vertical and horizontal with 180-degree to select the function of the system at each specific time, in this work is equal to 5 sec. In addition, the output data was stored in the IoT system can be used for further improvement in the future.

Finally, a solar tracker could be a game changer for the future technologies and developed manufacturers. It is safe to be used as it helps to reduce the increased rate of world-wide pollution and its impact on the environment.

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