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Arduino Based Solar Tracking System as a Step towards Efficient Utilization of Clean Energy: A Review

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Abstract: Solar energy is a form of renewable energy that is generated through the use of solar panels. However, since solar panels are usually stationary, they don't always align with the sun's position as it changes throughout the day. This can result in lower energy output. To address this issue, a solar tracking system has been developed. A solar tracker is a system that automatically adjusts the position of the solar panel to track the sun's movement and maximize the power output. This paper reviews different types of tracking mechanisms used in solar tracking systems. There are two main types of solar trackers: single-axis and dual-axis trackers. Single-axis trackers are suitable for areas around the equator where there is less variation in the sun's position. On the other hand, dual-axis trackers are better suited for regions where the sun's movement is tracked from east to west throughout the day and from east to north or south throughout the seasons. This paper aims to review various tracking mechanisms used in solar tracking systems. The objective is to explore different types of mechanisms that can improve the efficiency of solar panels by enabling them to constantly align with the sun's position.
Keywords: solar, tracker, Arduino, clean energy, sun, LDR.

I. INTRODUCTION

Solar energy is becoming an increasingly popular alternative to traditional forms of energy, and for good reason. It's renewable, sustainable, and has a much smaller carbon footprint than fossil fuels. However, in order to maximize the energy output of solar panels, it's important to ensure that they are always facing the sun. This is where a solar tracker comes in - it's a device that automatically adjusts the position of the solar panels to follow the sun as it moves across the sky. In this paper, a discussion is done on the previous works done on the topic of Arduino-controlled solar tracker. The Arduino microcontroller will be used to read sensor data and control the movement of the solar panel. The system will use two light-dependent resistors (LDRs) to determine the position of the sun, and will adjust the position of the panel using a servo motor. The result will be a solar panel that is always facing the sun, maximizing its energy output. This scheme is an excellent introduction to the world of robotics and automation. It combines elements of programming, electronics, and mechanics to create a system that can intelligently respond to changes in its environment.

II. LITERATURE REVIEW

Tarlochan Kaur [1] et al. (2016) presented the design and construction of a low-cost active Arduino based Dual Axis Solar Tracker which follows the solar path for the day during different seasons of the year. This tracking system uses five Light Dependent Resistors (LDR) to detect the position of the sun and thus align the solar panels at right angles to the sun rays for maximum power extraction. The LDRs are placed in the X and Y direction of the tracker, positioning them in the centre, left, right, up and down. The LDR sends input analog signal to the Arduino uno single-board micro-controller, which then sends PWM pulse to the two servo motors causing their motion and aligning of the solar panels. There are three points of motor rotation: 0, 90 and 180 degrees. Instead of stepper motor, servo motor has been used. The servo motor consumers power only during its rotation to the commanded position, but after that it rests; whereas stepper motors continue to consume power to lock in and hold the commanded position. A servomotor thus, uses less energy for the same functionality and hence, preferred. For the validation of the solar tracker, an automated light source was developed which would act as a prototype to the sun’s actual trajectory and compare between the solar tracker and the immobile solar panel.

The light rays from the automated light source was made to fall on the dual axis solar tracker and then on the immobile solar panel, and its results were plotted using LabVIEW and compared. It is observed that the voltage, current and power v/s time plots for the dual axis solar tracker is limited between very small range of values and is almost constant. Whereas in case of immobile solar PV panel, a parabolic type of output is obtained due to variation of light intensity with change in angle. Results show a 13.44% power gain in the developed system compared to the immobile solar PV system.

Fatima Zohra Baouche [2] et al. (2022) proposed the necessity of using a solar tracker connected with a photovoltaic system to obtain the maximum efficiency from such panels. Depending on the control type and the sensitivity of the sensors or the positioning system they incorporate, solar trackers can be classified by two tracking techniques: the MPPT (maximum power point tracking) method or the sun tracking system. The MPPT method is based on an algorithm to find the maximum power curve of the PV panel and the solar tracker tracks the sun's path throughout the day for better exploitation of PV cells. The authors reported that a single-axis sun tracking system can increase the energy output by 20% whereas a dual-axis tracking system can increase the output by 40%. In recent research studies, 42.57% of the studies have discussed and presented single-axis solar tracking system whereas 41.58% studies reported on dual-axis tracking system. In this paper the author has presented a very simple logic for single-axis tracking which needs only two LDRs. The tracking algorithm is based on the comparison of the irradiance of two LDR, which not only reduces the number of LDR required but also reduces the system complexity. The servomotor moves the panel towards the brightest position by very small steps by comparing the two light intensities of the two LDR. This process can accurately track the sunlight by using two LDR only. In this paper the author also has shown the PV characteristics which are dependent on temperature and solar irradiance. The MATLAB Simulink model shows the tracking in different condition where according to the sun angle, the motor angle is changing. Byregowda K. C [3] et al. (2020) studied different tracking methods and analysed the increment of power output due to tracking. By using different tracking methods, power output of the panel can be increased up to 30 to 60%. Single axis tracking system can be implemented by sensing the light intensity of two LDRs installed in East-West direction. A linear actuator is used to move the panel angle. Dual axis tracker can be installed between a particular region which is between 10^0S to 10^0N. Dual axis tracking system can track the change of the sunlight throughout the year. Active solar tracking involves a continuous monitoring and tracking process throughout the day and when it detects a dark condition then it sleeps according to its design. Passive solar tracking involves the use of a low boiling gas fluid in a tube. The tracking process is done by observing the imbalance in pressure of two ends by the sun irradiance. Chronological solar tracker uses the artificial relative movement between the earth and sun which can ensure about the determination of sun angle changes. The authors have made several numerical analysis of solar tracking. They have also determined the tracking efficiency and the maximum power output of the panel. A tracking method has been implemented by using two LDR. The light intensity is sensed through a voltage divider network. By supplying the pulse of 1.5ms to the motor the angle changes by 90^0. They have shown the different irradiance of the LDRs at different times throughout the day. Clean energy comprises all zero-carbon emission energy sources [4]. Among all energy sources solar energy is considered best as it is a renewable resource and available lavishly. As solar energy is free from pollution it is also known as a green source of energy. Depending on the location of different countries intensity of sun's energy extraction varies during day time. Therefore target is to increase the efficiency which is achieved by solar tracking system. Solar tracking is of two types: Single axis tracker and dual axis tracker. The movement of sun is tracked from east to west during day time and from east to north or south throughout the season. Conversion of sun's energy into electricity is done by using PV cell [2019]. Maximum efficiency of PV cell studied is 24.5%. Research going on to increase this efficiency. Solar tracking becomes efficient using two types of tracking algorithms. Astronomical Algorithm and real time light intensity algorithm. Installation of a tracking system needs 4 to 5 acres per MW [2019]. Due to lack of constant energy supply in different countries, PV cell getting high demand.

Now maximum energy is produced by a solar cell when it is placed at right angle to the sun. Therefore aim of many researches is to build Arduino based solar tracking system to increase efficiency. Heliostat is used to reflect the sun's energy to a fixed location. Concentrators are used to direct sunlight to the powered device which is close to focal point of lens.

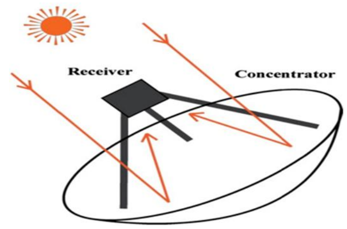

Fig. 1 Concentrator of solar tracking

It is found that without tracking, concentrators will not work [2020]. LDR are the sensors to detect intensity of sunlight entering solar panel. Analog input values are received from LDRs.LDR sends information to Arduino Microcontroller where analog values of LDR are processed and analog to digital conversion taken place internally [2021]. Using this digital value, microcontroller computes average voltage of LDR pairs. Depending on average value calculated servo motor receives control signals. Next analog point of microcontroller is connected to data point of Servo Motor [5]. Servo motor is moved by using digital PWM pulses.SG90 servo motor has been tested for this purpose as it is very cheap & can be controlled using PWM pulses. Servomotor changes the direction of solar panel to the position of LDR so as to receive maximum intensity of sunlight. A potentiometer is used to regulate the speed of servo motor. The block diagram is shown below.

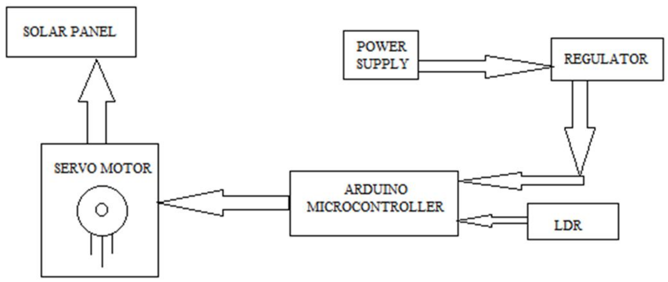

Fig. 2 Block diagram of Solar tracking with Arduino

Proteus software have been used to do the simulation [2020]. According to the block diagram simulation process and connections are carried out. A comparative study has been done also between fixed tilt panel and tracking solar panel [2020].
Power of solar panel is defined as P = VI, where P is electric power of solar panel, V is voltage output and I is solar current [2021]. Solar irradiance is calculated as

$E=\frac{P}{A}$ where E is solar irradiance and A is surface area of solar panel.

The efficiency of overall system is calculated as

$$\eta = \frac{Average\ Power(T) - Average\ Power(S)}{Average\ Power(S)}$$

where Average Power(T) is the average power of solar panel with tracking system and Average Power(S) is the average power of solar panel with static system.
Studied shows that two types of solar energy technologies are there in market [2021]. PV technology & Solar thermal technology. Among this Solar thermal technology is suitable for those countries where high solar irradiance level like in Malaysia has whereas PV solar technology is mostly used [2021].
Arjun Lande [6] et al. (2022) developed a prototype solar panel system that utilizes servo motors to automatically track the sun's movements. The system also incorporates an Arduino microcontroller that monitors the intensity of sunlight using an LDR sensor. All the required components are placed within the framework of the rotating solar panel. The system uses two servo motors and two LDRs to enable movement in both horizontal and vertical directions, with two degrees of spacing between the "main axis" and the "secondary axis". The solar panel can move up or down throughout the day to compensate for changes in the sun's position. This dual-axis tracking system provides the most accurate orientation of the solar panel and increases energy absorption by up to 40%. Although dual-axis trackers are more complex and expensive, they have the ability to track the sun in two directions, ensuring that the panel is always facing the sun. Two different types of altitude-based dual-axis trackers, tip-tilt and azimuth-altitude, are used, with the solar tracker requiring both vertical and horizontal pivots to function as a control system similar to solar telescopes. The proposed solar tracker system uses a microcontroller and stepper motor to enable the system to follow the sun's path, making it functional regardless of location or weather conditions. The tracker's threshold voltage can be modified to suit specific requirements, and the system can reset itself to the starting position once the sun has set. Moreover, at night, the solar panel faces the ground, which helps protect it from dust and extends its lifespan. However, the prototype design has some limitations as it is a miniature version of a larger system. For practical applications, the number of LDRs used would need to be increased.
Amaize Peter Aigboviosa [7] et al. (2016) proposed a solar tracking system that includes a solar panel, an Arduino microcontroller, and sensors.

The system relies on sunlight emission to function, and LDRs serve as sensors to detect the intensity of light that enters the solar panels. This information is then sent to the Arduino microcontroller. The system includes a servo motor circuit with three pins, one of which is connected to the +5v of the Arduino microcontroller. The negative side of the servo is connected to the ground, and the data point on the servo is connected to the analog point on the microcontroller. A potentiometer is also included to regulate the speed of the servo motor. The solar panel tracking system was simulated using Proteus software, and the simulation [7] process helped determine the exact circuit diagram and connection of the system.

Experimental observations were carried out to compare the performance enhancement of the implemented tracking solar panels and the fixed solar panels. The simulation and experiments were performed to verify if the designed and implemented system would perform as expected.

Pratik Pawar [8] et al. (2018) proposed a system that uses two LDRs, one for the East and the other for the West direction. Both sensors provide digital information about the presence or absence of light intensity to the microcontroller. Based on this information, the microcontroller determines the output signals for the motor driver, which drives the motor in either clockwise or anti-clockwise direction.

The motor driver module receives signals from the microcontroller and drives the motor in the specified direction with the specified speed. As a result, the motor controls the orientation of the solar panel mounting structure, ensuring constant exposure to sunlight throughout the day.

III.CONCLUSIONS

This type of work can be executed on industrial scale which will be beneficial for developing countries and where sunlight maximizes its intensity only for few hours in day time. More efficient sensors can be used which consume less power, so as to become cost effective. Many works are going on in this topic all over the world, which will surely enhance the utilization of solar energy for a better, cleaner future.

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