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# IOT Enabled Dual-Axis Solar Tracker: A Comprehensive Review

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***Abstract*—The purpose of this research is to present a solar global positioning system model that incorporates IoT technology to enhance the performance of photovoltaic modules in a solar energy system. The system's primary function is to keep the photovoltaic modules continuously aligned with the sun's rays, thereby maximizing the solar charger's exposure to the Sun's radiation and increasing the output power generated by the solar panel.**

**The project involved designing and implementing the hardware, as well as programming the microcontroller unit of the solar tracker. The system utilized an ATmega328P microcontroller to control the movement of two servo motors, which rotate the solar panel in two axes. The microcontroller was not solely responsible for controlling the solar tracker, as inputs from four photo sensors located near the solar panel were also used.**

**After the completion of the project, a fully functional solar global positioning system was designed and implemented. It was able to continuously align the solar charger with the sun or any other light source. Additionally, the solar tracker design from this project serves as a reference and a starting point for the development of more advanced systems in the future.**

***Keywords*—Solar tracker, IoT, Microcontroller, Solar radiation**

## I. Introduction

**R**ENEWABLE energy has gained significant attention worldwide due to the inevitable depletion of fossil fuel sources. Hydroelectricity, bioenergy, solar, wind, geothermal energy, tidal power, and wave power are among the renewable energy sources that have been receiving considerable interest from researchers, technicians, investors, and decision-makers. These energy sources are considered favourable substitutes for traditional fossil fuels because of their renewability. Among them, solar photovoltaic (PV) energy is one of the most accessible resources. Thanks to research and development activities, solar PV technology has become more widely adopted for residential use, with the worldwide PV capacity growing at an average rate of 49% per year since the early 2000s, according to the International Energy Agency (IEA). Solar PV energy is highly anticipated to become a major source of power in the future. Despite its benefits, solar PV energy still faces challenges in maximizing power output in areas with low solar radiation. However, improving system design and module construction is a practical approach to enhance the efficiency of solar PV power, making it a reliable choice for customers. Manufacturers need to develop more advanced technologies to improve the capability of PV materials, but this project aims to support the development of this promising technology. Despite the challenges, the potential benefits of solar PV energy make it a compelling choice for a sustainable and cleaner energy future.

Efficiency can be increased by maximizing the duration of exposure to sunlight, which can be achieved through the use of tracking systems that keep PV solar panels aligned with the sun's rays at all times. The aim of this project is to create a prototype of a light tracking system on a smaller scale that can be applied to any solar energy system. Additionally, the project aims to provide a quantitative measure of the tracking system's performance compared to a system with a fixed mounting method.

The solar project implemented two servo engines due to their speed, high power support, precise turn within a restricted angle, and noiseless operation. The coding was done using the Arduino IDE. The sun's position in Kolkata, which has coordinates of 22.5726°N, 88.3639°E, changes significantly throughout the year, especially in the jungles during specific seasons. An information platform that converts light into voltage using light-dependent resistors (LDRs) is included in the design. The microcontroller calculates the difference between the two voltages and uses the servo engine to adjust the solar panel's position until the LDR voltage outputs are equal. The difference between the LDR voltages is measured as an analogue reading.

The servo engine receives communication about the important factor, and then moves to ensure that the two LDRs have the same inclination. This guarantees equal light reception, and the solar charger receives sunlight at a 90° angle (the PV panel's plane is positioned at 90° to the Sun, with the opposite point at 0° to ensure maximum illumination using Lambert's cosine law). This process is repeated throughout the day. Tracker systems operate based on two simple principles. The first principle is the usual principle of rate and reflection on which our tracker works, and the second principle is the principle on which the solar (PV) panel works, generating power. Combining both principles results in nearly double the output typically achieved by the panel.

## II. LITERATURE REVIEW

In a study published in the Diary of Solar Energy Engineering, Vol. 133 in 2011, Hossein Mousazadeh et al. investigated the potential for increasing the energy output of a solar assist plug-in hybrid electric tractor (SAPHT) by incorporating an on-board PV system. They designed and evaluated a mobile sun tracking system using four light-dependent resistive sensors. Experimental tests utilizing the sun-tracking system demonstrated that the system collected 30% more energy compared to a horizontally fixed mode. To detect direct light emissions, four LDR sensors were utilized and separated by an obstruction as a shading device. A microcontroller-based electronic drive board was used as an interface between the hardware and software, while power MOSFETs were used to control the actuators for driving each engine. The results of the experiment indicated that the designed system was highly robust and effective.

In the Global Journal of Scientific and Engineering Research, vol. 3, 2229-5518, K.S. Madhu et al. (2012) explain that a single-axis tracker follows the sun's movement from east to west, while a two-axis tracker follows the sun's day-to-day east to west motion and seasonal declination movement. Concentrated solar power systems use lenses or mirrors and tracking systems to concentrate a large area of sunlight into a small beam. Photovoltaics convert light into electrical current through the photoelectric effect. Solar power is the conversion of sunlight into electricity. Experimental results indicate that using a tracking solar panel in normal days increases power efficiency by 26 to 38% compared to a fixed panel. However, the efficiency varies during cloudy or windy days at any level.

## III. PROPOSED METHOD

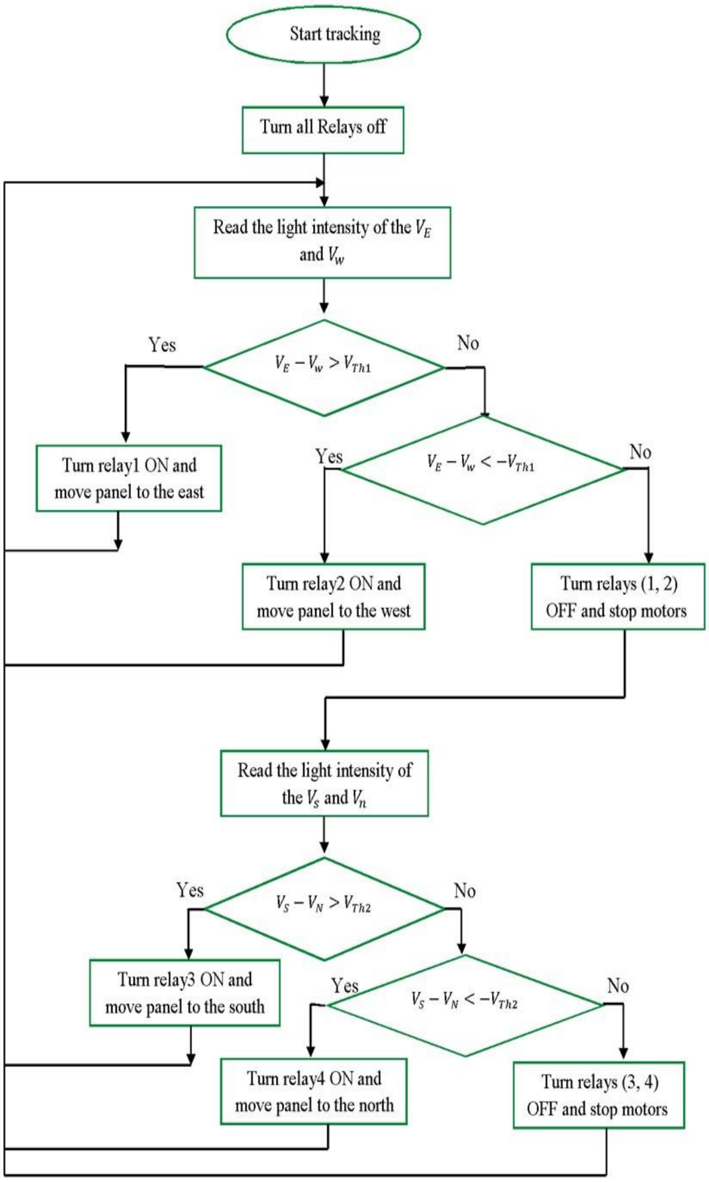


Fig.1. Architecture of the proposed method.

## IV. MATHEMATICAL MODELING

The intensity of illumination on a surface is inversely proportional to the square of its distance from the source. For instance, if a surface is located 1 meter away from the source and the illumination on it is I units, then the illumination on a surface 2 meters away will be I/4, and I/9 on a surface 3 meters away, and so forth. It is important to note that the inverse square law only applies when the light rays emanate from a point source and fall perpendicularly on the surface.Thus, illumination in lamberts/m$^2$ on a normal plane = Candle power/ (Distance in metres)$^2$

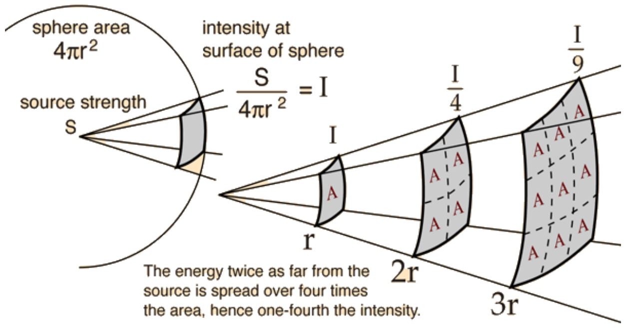


Fig.2. Solar radiation pattern.

The illumination received on a surface is proportional to the cosine of the angle between the direction of the incident light rays and normal to the surface at the point of incidence. This is mainly due to the reduction of the projected area as the angle of incidence increases.

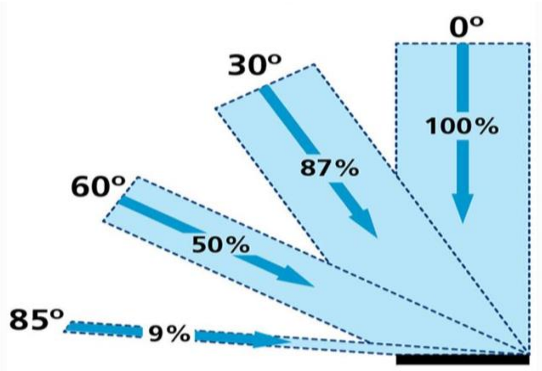


Fig.3. Cosine Law sequence

The equation for cosine law is

$$E_0 = E\cos\theta = \frac{I\cos\theta}{D^2} \quad (1)$$

where,
$E_\theta$ = illumination on horizontal plane
E= illumination due to light normally incident
Θ= the angle of incidence
D= distance from the surface

## V. BLOCK DIAGRAM FOR SOLAR TRACKER

In the block graph, there are three Light Dependent Resistors (LDRs) mounted on a plate along with a solar panel. These LDRs are exposed to varying amounts of light from a source, and their resistance values change accordingly due to their inherent property of photoconductivity. As a result, the resistance values of the LDRs are not constant over time. Each LDR sends its respective resistance value to the Microcontroller, which uses programmed logic to compare the values with a reference LDR.

Two dc servo motors are connected in such a way that the first one moves with the axis of the second one. The first servo motor drives the solar panel along the X-axis, and the second servo motor drives it along the Y-axis. The microcontroller receives input signals from the LDRs and sends appropriate messages to the servo motors to adjust the position of the solar panel. One servo motor is responsible for movement along the X-axis, and the other one is responsible for movement along the Y-axis.

In this way the solar tracking system is designed.

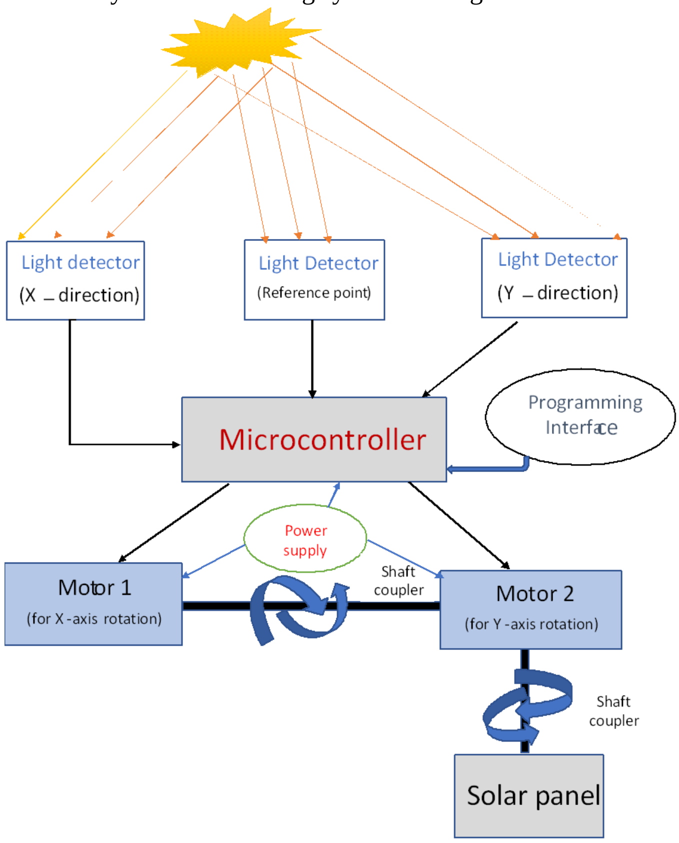


Fig.4. Block diagram for solar tracking system

## VI. PROGRAMMING AND RESULTS

The various steps for the program are shown as follows:

To control the servo engines, both servos are declared as important, and their reference positions are stored in the variables posx and posy. The ADC input pins of LDRs are selected for dual-direction movement and a reference pin. A resilient value is chosen to determine the engines' operation. The servos are attached to digital pins using the servo object, and the necessary input pins are set to the correct mode using pinMode(pin, mode). To locate the user, the servos are set to the mid-point or a unique position with a 1-second delay. Three variables are used to read and convert analog values to integers between 0 and 1023. If the difference between the two factors is not equal to the resistance value, the servos remain in their current position; otherwise, they move towards the direction of maximum light intensity by adjusting the values of posx and posy. Once the position is determined, it is written to the servo, and the process repeats until the input values change by an amount greater than the minimum tolerance. If the position exceeds 150˚, it is set to 150˚, and if it is below 30˚, it is kept at 30˚, as the limits are set to 30˚ and 150˚, respectively.

The basic programming is given as follows:

Void setup()

```
{
serial.begin(9600);
}
Void
Loop()
{
intsensorValue =
analogRead(A0);
serial.printin(sensorValue);
delay(10);
}
```

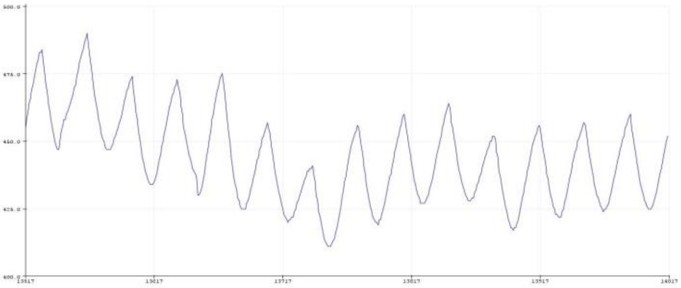

Fig.5. Output response.

In this paper, a dual-axis solar tracker is illustrated to optimize the amount of solar energy received by the solar panel. The tracker utilizes light sensors, specifically LDRs, to detect the intensity of sunlight reaching the panel. By comparing the values obtained from the LDRs, the board is moved using a servo motor to the position where it receives the most sunlight. The project consists of three stages or subsystems: an input stage that converts incident light to a voltage, a control stage that controls actuation and decision making, and a driver stage with the servo motor that is responsible for the actual movement of the panel. The input stage incorporates a voltage divider circuit that provides a desired range of illumination for different lighting conditions, while a potentiometer caters for changes in brightness. The control stage utilizes a microcontroller that receives voltage inputs from the LDRs and determines the appropriate action. The final stage comprises mainly of the servo motor, which is powerful enough to drive the board while being noise-free and affordable. This project demonstrates the effectiveness of LDRs as light sensors, which are readily available and cost-effective compared to other sensors like temperature sensors.

## VII. CONCLUSION

As we progress into the 21st century, our innovation, population, and development have led to a significant increase in energy consumption per capita, while our energy resources such as fossil fuels are rapidly declining. Therefore, to ensure sustainable development, we must consider alternative methods, such as the use of renewable energy sources, to meet our energy demand.

Our project, the Dual Axis Solar Tracker, involves the development of a demonstration model that tracks the optimal point of light source to maximize the voltage generated by the solar panel. Through numerous trials and errors, we have successfully completed the project and are proud to contribute to our society. However, like every experiment, our project has a few limitations.

Firstly, our panel can only sense the light within a particular sensing zone, beyond which it fails to respond. Additionally, if there are multiple sources of light, such as diffused light sources, the panel calculates the vector sum of the light sources and moves to that point. Despite these limitations, our team has implemented the project with minimal resources, keeping the circuitry simple, understandable, and user-friendly.

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