SciWaveBulletin
Vol. 1, No. 1, 27-33, 2023
https://sciwavebulletin.com/
DOI: 10.61925/SWB.2023.1105

Intelligent Cross-axis Solar Power Tracking System

Nithya Satish[1], Swathi M[2], Benita Roy M[3]

[1]*Master of Computer Applications, Atria Institute of Technology, Bangalore, India.*
[2]*Assistant Professor, Atria Institute of Technology, Bangalore, India.*
[3]*University Lecturer, Atria University, Bangalore, India.*
[1]nithyasatish228@gmail.com, [2]swathi.m@atria.edu, [3]benitaroym@gmail.com,

Abstract

The sun is an abundant and powerful renewable energy resource that plays a crucial role in sustainable energy production. With efficient power generation in mind, here is a system designed to make intelligent judgements based on a condition so that the solar panel is always tilted towards the maximum sunlight. The hybrid intelligent cross-axis solar power tracking system is built using the microcontroller, light sensors, solar panel, and motors. Here, there are two methods used namely, the Sun Position Algorithm and the other is using the sensors. The algorithm uses the azimuth angle and the sun's altitude to identify the position of the sun depending on the geo location. For maximum power generation from the solar panel, we use the sensor-based technique to come into picture whenever the output voltage is less than the fixed threshold voltage using the Sun Position Algorithm.

Keywords: Cross-Axis Solar Power Tracking, Microcontroller, Light Sensors, Solar Panel, Sun Position Algorithm, Azimuth Angle.

I. INTRODUCTION

Solar power is a clean and better energy source. It is an energy that produces no carbon dioxide or other heat trapping greenhouse gases. For a solar panel that is fixed at a position, say static solar panel, there is no movement and only when the sun's rays are perpendicular to the panel, there is maximum power generated. This condition is not possible throughout the day, with the sun moving from east to west. This presents a problem in tracking the maximum power at the static position. Hence, a dual axis system was proposed so that the solar panel can move both horizontally and vertically to capture the maximum sunlight at any given point of time [6].

Here is a model that is developed to track solar energy in an effective manner for maximum utilization. The Internet of Things (IoT) platform powers this system. It is a hybrid of sensor-less algorithmic tracking and sensor-based solar tracking. We are attempting to construct an intelligent system that not only calculates the position of the sun but also continuously monitors the output power, depending on which a choice is made to switch to the sensor-based tracking system as needed.

The sun position algorithm is used to ensure that the solar panel is always tilted in the direction of the sun. If a tree, clouds, or birds cast a shadow on the panel, the model switches to the LDR based system, which identifies the direction of maximum sunlight and tilts the panel to that direction. We call this model an intelligent system because it takes the decision on its own if it must follow the sun position algorithm or the LDR sensor [7].

The main objective of our intelligent decision maker algorithm is to increase the efficiency of tracking the solar power throughout the day, despite the disadvantageous shade situations that reduces the output.

II. PROBLEM STATEMENT

Humans are under pressure to conserve resources and utilize natural resources properly. We need a clever solar tracking system to harvest the greatest power from the sun to use solar energy efficiently. With the sun moving around the clock, we need to design an effective solar power tracking system that tilts the solar panel in the direction of the most sunlight for maximum efficiency.

III. LITERATURE SURVEY

[1] presents a result comparing the power outputs of static and dual axis setup of the tracking system which shows how the latter is more effective in harnessing maximum solar power. Also employing stepper motors instead of linear actuators helps to improve the overall performance of the system. In [2], the author compares the power outputs of the dual axis tracking system over single axis and static setups which shows a solid rise of 25.62% over the static system. The system tracking the sun's daily movement and the annual movement uses a stepper motor that can save 44.44% power compared to the continuous tracking system.

[3] also discusses about the LDR based dual axis tracking system which uses four LDRs (two for azimuth position sensor and two for altitude position sensor) can improve the efficiency by 30-45% when compared to static systems. The research in [4] presents a cadmium sulfide light dependent resistor (CdS-LDR) sensor which focusses on optimizing the performance of the LDR based on the intensity of sunlight.

IV. EXISTING SYSTEM

There are many solar power tracking systems that either use only the LDR sensors or the sun position algorithm. LDR sensor-based systems track the maximum light intensity by continuously comparing the resistances to move the panel in the direction of maximum sunlight. On the other hand, sun position algorithm-based systems move the panel depending on the geographic location of the sun.

V. PROPOSED SYSTEM

In the sun position algorithm-based systems, when there is a shade, there is no choice for the system to track the maximum solar power. The idea proposed is a smart system which utilizes both the sensor-less and sensor-based methodologies so that there is an opportunity to harness most light at any given shade situations. We aim to design an intelligent decision-making algorithm which helps switch to the system which offers maximum output at a given point of time. Additional feature like WhatsApp message regarding the power output, the methodology that is being chosen and any other data required for further analysis or monitoring is to be incorporated.

VI. BLOCK DIAGRAM

Here is the block diagram of the solar power tracking system.

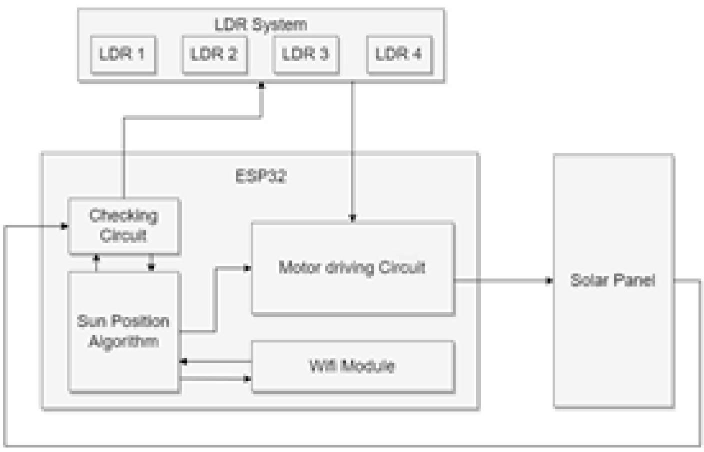

Figure 1: ***Block Diagram of Intelligent Cross-axis Solar Power Tracking System***

In this block diagram, the sun position algorithm runs first and then checks the power output with the threshold. If the output power is lesser than the threshold, then it shifts to the LDR methodology, else the solar panel remains tilted towards the direction of the sunlight.

Here, there are four LDRs, one on the North of the panel, one on the south of the panel, one on the west of the panel and one on the east of the panel. All these sensors are the LDR system.

Next, we have the microcontroller that is ESP32. It does two operations. One, checks if the voltage output is less than the threshold. If it is less than the threshold, then it shifts to the LDR system. Another operation is that, if the voltage output is more than the threshold, then it stays in the sun position itself.

Once, the checking is done, it sends input to the motors directing them to either move towards the maximum sunlight using the sensor-based system or tilt the panel towards the direction of the sun using the azimuth and the altitude angle of the sun at that geolocation [7].

VII. ALGORITHM BASED SYSTEM

The algorithm used here is the sun position algorithm. The sun position algorithm used in solar power tracking system is based on astronomical calculations that take into account the date, time and location (latitude and longitude) of the system. The "Solar Position Algorithm" (SPA) is developed by the National Renewable Energy Laboratory (NREL) of the United States.

The sun position algorithm calculates the position of the sun in the sky. In this system we are using the sun azimuth angle and the altitude angle to find the exact position of the sun.

The flow of the algorithm is this way: Get the current time to get the solar time

Calculate the day of the year (N)

Getting the heliocentric latitude (B): $B = (n-1)\frac{360}{365}$

Finding the equation of time(E):

$$E = 229.2(0.000075 + 0.001868\, cosB\, -\, 0.032077\, sinB -\, 0.014615\cos 2B -\, 0.04089\sin 2B$$

Calculating the solar time: $Solar\ Time = (4 * (longitute - STD\ longitude) + E) + timenow$

The solar declination is calculated using the day of the year and a fixed value of 23.45 degrees, representing the tilt of the earth's axis:

$$\delta = 23.45\sin(M\_PI\ \times \frac{360}{365.0} \times \frac{284\ +\ N}{180})$$

Zenith angle, the angle between the vertical and the line to the sun, the angle of incidence of beam radiation on a horizontal surface.

$$\delta = \mathrm{acos}\Bigg(cos\left(latitude\ \times \frac{M\_PI}{180.0}\right) \times cos\left(solar\ Declinaton \times \frac{M\_PI}{180.0}\right) \times cos\left(\left(solar\ Time - 12 \times 60 \times \frac{15.0}{60}\right) \times \frac{M\_PI}{180}\right) + sin\left(latitude \times \frac{M\_PI}{180.0}\right) \times sin\left(solar\ Declination \times \frac{M\_PI}{180.0}\right)\Bigg)$$

Hour angle, the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15 degrees per hour; The hour angle is usually negative in the morning and positive in the afternoon. The hour angle is as follows:

$$\omega = \left(solar\ Time - 12 \times 60 \times \frac{15.0}{60}\right) \times \frac{M\_PI}{180}$$

Solar azimuth angle, the angular displacement from south of the projection of beam radiation:

$$\gamma = abs\left(\left(acos\left(\frac{\cos(solarZenth) \times sin\left(latitude \times \frac{M\_PI}{180.0}\right) - sin\left(solar\ Declination \times \frac{M\_PI}{180.0}\right)}{\sin(solarZenith)} \times \cos\left(latitude \times \frac{M\_PI}{180.0}\right)\right)\right)\right)$$

The degree of the azimuth and altitude angles are calculated using the map function.

Then changing the azimuth angle according, the angle hour.

Then the servo motors are adjusted according to the azimuth degree and the altitude degree that were calculated.

In the sensor-less based system, we use the sun position algorithm which will run by default until and unless the output power is lesser that the threshold.

VIII. SENSOR BASED SYSTEM

In the sensor-based system, we are using the LDR sensors which is the Light Dependent Resistor sensor. It is an electronic component that changes its resistance depending on the intensity of light. The primary function of the sensor is to detect and measure light levels [8].

In the solar power tracking system, we are using four LDR sensors placed on the north, south, west and east directions. North and south are the y-axis and west and east are the x-axis.

The following is the flow to using LDR sensor:

Read the values or resistance of the sensors

Calculate the x-axis and y-axis position:

Calculate the difference in resistance

Check if it is positive or negative

If the difference is positive, then tilt the motor towards the left.

If the difference is negative, then tilt the motor towards the right.

8.1. Working of the LDR sensor:

It is dependent on the intensity of the light that falls on the sensor. In the LDR system, the motors use output of the sensor to rotate accordingly. Below is the circuit diagram of the LDR sensor.

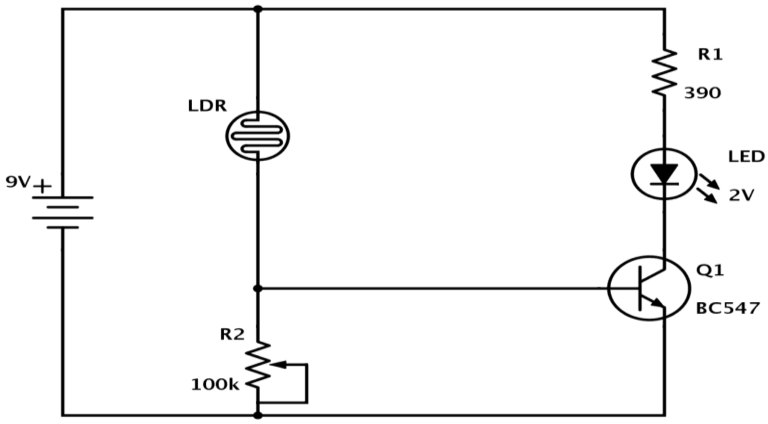

Figure 2: ***LDR Sensor***

The idea behind employing a sensor-based system is that, should clouds block the sun's beams and light originate from another direction, the sensor-based system will activate and tilt the panel in the direction of greatest light.

IX. FLOW CHART

Below is the flow chart for the working of the smart solar power tracker:

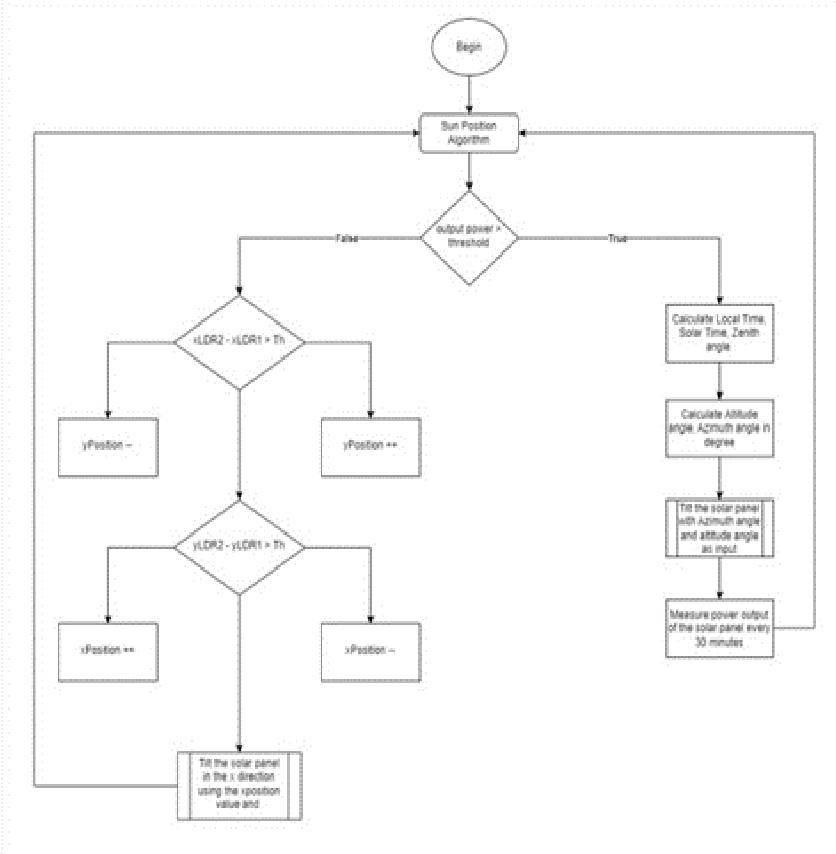

Figure 3: ***Flow Chart of Intelligent Cross xis Solar Power Tracking System***

X. IMPLEMENTATION

In order to build the prototype, we started with 6v solar panel which is driven by two SG90 motors, one for the horizontal axis and one for the vertical axis. When the system is switched on, it automatically steps into the sun position algorithm and tracks the maximum sunlight. After a particular set time interval, the system checks whether the output voltage generated is greater than a fixed threshold value. In which case, it continues to execute the sun position algorithm. Else the system enters the sensor-based technique where the solar power is tracked based on the LDR input. After a particular set time interval, the system again enters into sun position mod and the process repeats. Another feature in this system is that it sends WhatsApp message regarding the action taken by the solar power tracker [9].

Figure 4: ***Prototype of Intelligent Cross-axis Solar Power Tracking System***

XI. TESTING

The prototype was tested under the sunlight. The following are the test cases checked and the actions taken by the system:

Table 1: ***Data collected from test cases of prototype under sunlight***

Sl.No.	Test Case	Voltage Output (V)	Action taken
1.	Extreme light conditions	4095	Sun Position Algorithm
2.	Normal light conditions	3252	Sun Position Algorithm
3.	Cloudy (less light)	1231	LDR system
4.	Building shadow (less light)	2715	LDR system

Here, photons from the intense light source energise the electrons in the sensor by landing on it. Here, the LDR's conductivity rises and its resistance falls. This results in giving out most or maximum voltage and therefore uses the sun position algorithm. This follows the azimuth angle and the altitude angle of the sun.

When there are normal light conditions, it checks if the light is more than the threshold or less than the threshold, depending on that it uses the sun position algorithm or the LDR system. Here, in the test case 2, the voltage output was more than the threshold value, hence it is using the sun position algorithm and the panel is tilted toward the direction of the sun.

In the next test condition where the sky is cloudy, the output voltage was less than the threshold value. Hence, the tracker uses the sensor-based system to detect the direction of the maximum light and tilts the panel towards the direction of the maximum light.

In the last test condition, we see that there was a building shadow falling on the panel which results in the less light rays falling on the panel in order to get maximum output. Which is why the tracker is using the sensor-based system to identify the direction from which there is maximum light towards the panel. Depending on that, the panel is tilted towards the maximum light in order to get the maximum voltage output.

The above test conditions are done for the cases where there are direct sunrays and when there are diffused sun rays. When the sky is clear, we get the direct sun rays whereas when there are clouds, we get the diffused sunrays.

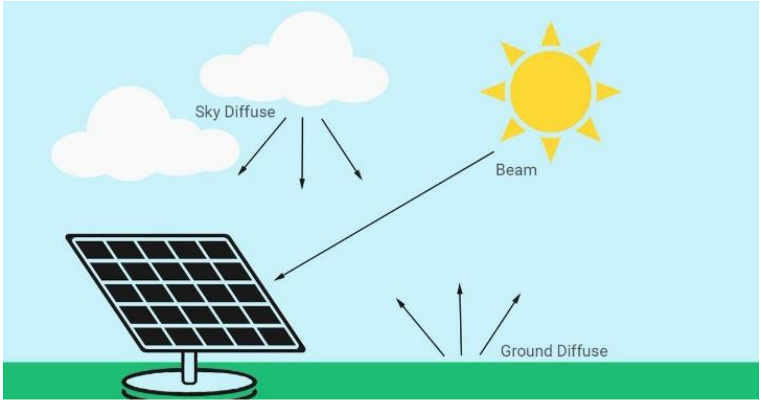

Figure 5: ***Test conditions under direct sunrays***

XII. FUTURE ENHANCEMENT

Periodically the tracker has to switch to the sun position algorithm to compare the output voltage and the threshold voltage. We can improve the efficiency by reducing the frequency of the system entering the sun position algorithm just for checking purposes.

There is a concept of reflectors that can be used to capture the direct and diffused sunrays towards the solar panel. This method helps in reducing the number of sensors used as well as the number of motors to be used. In this kind of system, the solar panel will remain static while the reflector alone will move accordingly.

XIII. CONCLUSION

This paper presents a smart and creative solution to implement Cross-axis Solar Power Tracking System using sun position algorithm and the LDR sensors in combination. The intelligent decision-making capability of this system helps maximizing the power output of the solar panel throughout the day.

Acknowledgement

Special appreciation to the amazing team for their assistance and guidance in successfully finishing the work.

Funding

This research received no external funding

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Mohanapriya, V., Manimegalai, V., Praveenkumar, V., & Sakthivel, P. (2019). Implementation of Dual Axis Solar Tracking System.
[2] Ferdaus, R. A. (2018). Energy Efficient Hybrid Dual Axis Solar Tracking System.
[3] Karthika, A., Jayanthi, S., & Deivamani, G. (2017). Dual Axis Solar Tracking System using Arduino.
[4] Duffie, J. A. (Deceased), & Beckman, W. A. (2013). Solar Engineering of Thermal Processes (4th ed.).
[5] Kumar, S., & Singh, M. K. (2016). Solar Tracking System: A Review. In 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT) (pp. 1-5).
[6] Ranjan, A., & Yadav, R. (2017). A Comprehensive Study on Solar Tracking System. International Journal of Engineering Research and Applications, 7(7), 29-35.
[7] Reddy, A. A., & Kumar, R. B. (2018). Design and Implementation of a Microcontroller-Based Solar Tracking System. International Journal of Computer Applications, 179(24), 16-19.
[8] Xu, Y., & Wei, W. (2019). Solar Tracking System Using Fuzzy Logic Control. In 2019 12th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI) (pp. 1-5).
[9] Khatib, T., Mohamed, A., & Mohan, B. K. (2020). Real-Time Implementation of Dual-Axis Solar Tracking System Using Microcontroller. In 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-6).