Dual Axis Solar Tracking System Using Arduino

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CERTIFICATE

This is to certify that the report titled **DUAL AXIS SOLAR TRACKING SYSTEM USING ARDUINO** submitted by **POKALA JAGAN MOHAN REDDY,** to the Electrical Engineering Department, Indian Institue of Technology, Patna, is a bona fide record of the work done by him under my supervision.

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Abstract:

The use of solar energy is increasing rapidly in the present scenario due to its environmental friendliness and abundance. Building a solar plant and arranging it to face the maximum amount of solar energy is an easy, fast, cheap, and everlasting way of producing energy. Dual axis solar tracker will be made by the combination of some mechanical and electronic components which will adjust itself to face the sun over the course of time with the help of sensors attached to it. A comparative analysis shows that a dual axis solar tracker is 10-15% more effective than a stationary solar panel and about 8-10% more effective than a single axis solar tracker. The goal of this project is to build a prototype of dual axis solar tracker to enhance solar panel efficiency by automatically adjusting its angle for optimal sunlight exposure. This uses sensors to detect the position of the sun and transmits this information to an Arduino microcontroller that controls the motor for adjusting the solar panel's angle.

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Introduction:

As we run out of fossil fuels nearly in the future, people are looking at renewable energies like solar and wind energy instead. Because of their renewability, they are considered as favourable replacements for fossil fuels. Among those types of energies, solar photovoltaic (PV) energy is one of the most available resources. Nowadays solar energy is widely used in residential areas for generating electricity, thanks to research and development activities to improve solar cell's performance and lower the cost. According to the International Energy Agency (IEA), worldwide PV capacity has grown at 49% per year on average since early 2000s. Solar energy is highly expected to become a major source of power in the future.

Solar PV energy has many benefits but it's not yet ready to fully replace traditional sources. In places with less sunlight, getting the most power from PV systems is hard. We need better tech from manufacturers, but we can also improve how systems are designed and built. The project aims to enhance energy output by dynamically aligning panels with the sun's position throughout the day, offering substantial gains over fixed panel setups

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Objective:

The objective of this project is to design and implement a solar tracking system using servo motors controlled by an Arduino IDE for optimizing the orientation of solar panels to maximize the duration of exposure to the sun. By using light-dependent resistors (LDRs), which indirectly convert light into voltage by varying their resistance the system adjusts panel angles throughout the day to ensure optimal sunlight incidence, thus enhancing the efficiency of solar energy generation.

Motivation :

The motivation of this project is to improve how solar energy is captured using a solar tracking system. With fossil fuels being limited and contributing to pollution and global warming, there's an urgent need to shift towards renewable energy options like solar power. Despite solar energy's potential, there's room for improvement in harnessing it efficiently, which can be achieved through the development of solar tracking systems. By designing a system that tracks the sun's movement and optimizes solar panel orientation, we aim to increase energy generation and reduce reliance on fossil fuels. Additionally, by minimizing operation costs and maximizing reliability, we can make solar tracking systems more accessible and practical for widespread adoption.

Theory:

The solar tracking mechanism ensures that a solar panel consistently aligns with the sun's position. This alignment optimizes sunlight absorption by positioning the panels perpendicular to the sun's rays. When the solar panels face the sun directly, they can generate more energy efficiently. Solar trackers find widespread use in orienting solar photovoltaic panels towards the sun, enhancing their energy production capabilities. Additionally, they serve in positioning space telescopes for optimal observation.

Solar trackers can be categorized based on their method of operation into Passive Tracking Devices, Active Tracking Devices, and Open Loop Trackers. Open Loop Trackers, in turn, are subdivided into Timed Trackers and Altitude/Azimuth Trackers. Additionally, solar trackers can be classified based on their motion or directional flexibility as Single-Axis Solar Trackers or Dual-Axis Solar Trackers.

A single-axis tracker operates by rotating solar panels around a single axis, typically oriented in the North-South direction. This movement allows the panels to track the sun from East to West throughout the day, maximizing sunlight absorption. Implementing a single-axis tracking system enhances the efficiency of a solar setup without the need for additional PV modules. Ideal for installation in sunny and dry areas with flat terrain, despite its initial high installation cost, a single-axis solar tracking system can significantly boost the productivity of a solar system, enabling a swift return on investment. A dual-axis tracker facilitates solar panel rotation on two axes, both horizontally and vertically, ensuring adjustment in all directions—North, South, East, and West. This versatility makes it ideal for various commercial applications. Its design aims to maximize solar energy generation throughout the year, utilizing algorithms and sensors to track seasonal changes and variations in the sun's height, along with its daily movement. By dynamically aligning panels with the sun's position, a dual-axis tracker enhances energy production efficiency. Its comprehensive tracking capabilities enable optimal sunlight absorption, resulting in increased power output compared to fixed-panel configurations. This system offers a versatile solution for locations with varying solar conditions, providing consistent energy generation benefits across different seasons and times of the day.

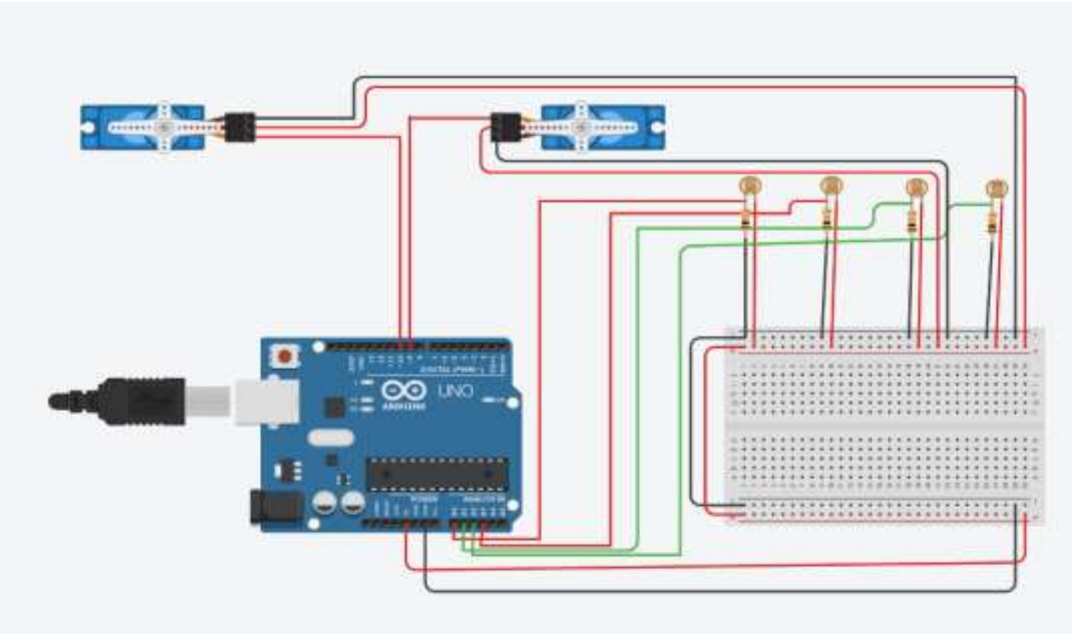
Components Required:

- Arduino UNO
- SG90 Micro-servo motor
- 3D parts
- Solar panel
- LDRs(5M ohm)
- Basic electrical components
- Multimeter

Softwares Used:

- Arduino IDE
- Tinkercard

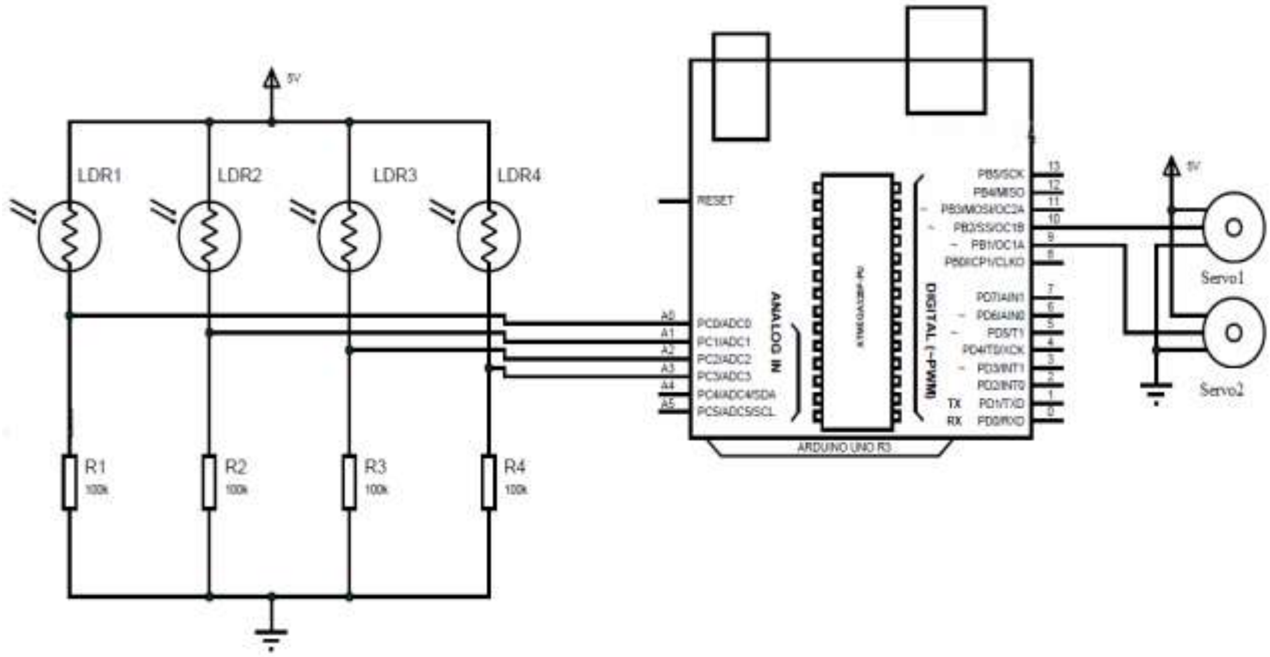
Design Methodology:



We used LDRs to measure the intensity of the sunlight and two servo motors to regulate the position of the solar panels in our system. The Arduino code was created to determine the sun's location based on data from the LDRs. The code then sends signals to the servo motors, causing the solar panels' position to be adjusted correspondingly. To ensure correctness and efficiency, the code was tested and debugged multiple times.

Resistance of LDR depends on the intensity of the light, and it varies according to it. The higher the intensity of light, the lower the LDR resistance, and due to this, the output voltage lowers when the light intensity is low, the higher the LDR resistance, and thus, a higher output voltage is obtained.The LDR senses the analog input in voltages between 0 to 5 volts and provides a digital number at the output which generally ranges from 0 to 1023.Now, this will give feedback to the microcontroller using the Arduino software(IDE) , which will control the position of the servo motor.The tracker finally adjusts its position sensing the maximum intensity of light falling perpendicular to it and stays there till it notices any further change.

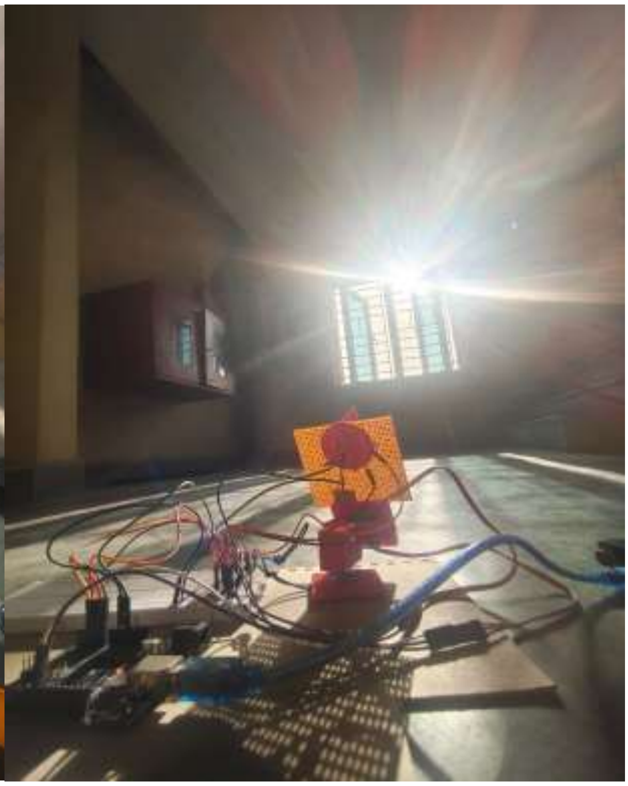
Circuit Diagram:



Images of solar tracker:

Images of the tracker taken simultaneously with different orientations:

Images of solar tracker taken at different times and different places:

In all the above cases we can see that the solar tracker points to the sunlight, this makes sure that the panel is aligned perpendicularly to the light, which increases the exposure to the sunlight of the panel which increases the efficiency. of panel

Code for an Arduino-based dual-axis solar tracker system :

```
#include <Servo.h>

// intialising servo motor limits
Servo horizontal; // horizontal servo
int servoh = 180;
int servohLimitHigh = 240;
int servohLimitLow = 2;
// 65 degrees MAX

Servo vertical; // vertical servo
int servov = 180;
int servovLimitHigh = 240;
int servovLimitLow = 2;

// LDR pin connections ie which ldr is connedted to which
pin
// name = analogpin;
int ldrlt = A0; // LDR top left - BOTTOM LEFT <--- BDG
int ldrrt = A3; // LDR top rigt - BOTTOM RIGHT
int ldrld = A1; // LDR down left - TOP LEFT
int ldrrd = A2; // ldr down rigt - TOP RIGHT

void setup()
{
    // These two lines attaches the horizontal,vertical
servo motors
    // to pin 9,10 of the Arduino board respectively.It
initializes
    // communication between the Arduino and the servo
motors connected
    //  to pin 9 and 10 respectively.
    horizontal.attach(9);
    vertical.attach(10);
```

```
    // This line sets the initial position of the horizontal
servo motor
    // to 180 degrees,vertical servo motor to 45
degrees.This angles
    //represent a specific starting position for the
horizontal and vertical
    //movement of the solar panels.
    horizontal.write(90);
    vertical.write(180);

    // This line introduces a delay of 2500 milliseconds (or
2.5 seconds) after
    // setting the initial positions of the servo motors.
This delay allows time
    // for the servo motors to move to their initial
positions before the program
    // continues execution.
    delay(2500);
}

void loop()
{
    // these variables stores the analog value read by the
LDR connected to the
    // respective analogpins
    int lt = analogRead(ldrlt); // top left
    int rt = analogRead(ldrrt); // top right
    int ld = analogRead(ldrld); // down left
    int rd = analogRead(ldrrd); // down right

    int dtime = 50;
    int tol = 20;

    int avt = (lt + rt) / 2; // average value top
    int avd = (ld + rd) / 2; // average value down
    int avl = (lt + ld) / 2; // average value left
    int avr = (rt + rd) / 2; // average value right
```

```
    // Calculates the average light intensity value for the
vertical direction by
    // averaging the readings from the LDRs positioned at
the top right (rt) and
    // bottom right (rd).
    int dvert = avt - avd;

    // Calculates the difference in light intensity between
the left and right
    // directions by subtracting the average light intensity
value of the right
    // direction (avr) from the average light intensity
value of the left
    // direction (avl).
    int dhoriz = avl - avr;

    // this dynamically adjusts the vertical angle of the
solar panels to maximize
    // sunlight absorption based on the difference in light
intensity between the top
    // and bottom directions.
    if (-1 * tol > dvert || dvert > tol)
    {
        if (avt > avd)
        {
            servov = ++servov;
            if (servov > servovLimitHigh)
            {
                servov = servovLimitHigh;
            }
        }
        else if (avt < avd)
        {
            servov = --servov;
            if (servov < servovLimitLow)
            {
                servov = servovLimitLow;
            }
```

```
        }
        vertical.write(servov);
    }

    // this dynamically adjusts the horizantal angle of the
solar panels to maximize
    // sunlight absorption based on the difference in light
intensity between the left
    // and right directions.
    if (-1 * tol > dhoriz || dhoriz > tol)
    {
        if (avl > avr)
        {
            servoh = --servoh;
            if (servoh < servohLimitLow)
            {
                servoh = servohLimitLow;
            }
        }
        else if (avl < avr)
        {
            servoh = ++servoh;
            if (servoh > servohLimitHigh)
            {
                servoh = servohLimitHigh;
            }
        }
        else if (avl = avr)
        {
            delay(5000);
        }
        horizontal.write(servoh);
    }

    delay(dtime);
}
```

Results:

Reading taken on 14/4/2024:

→Without solar tracker:

Time	Voltage(v)	Current(A)	Power(W)
9 am	5.5	0.11	0.605
10 am	9	0.19	1.71
11 am	10.5	0.2	2.1
12 pm	12.5	0.28	3.5
1 pm	14	0.32	4.48
2 pm	13	0.3	3.9
3 pm	11	0.26	2.86
4 pm	8	0.16	1.28
5 pm	4.8	0.12	0.72

P_{avg} =2.36W

→With solar tracker:

Time	Voltage(v)	Current(A)	Power(W)
9 am	8.5	0.16	1.7
10 am	11	0.25	2.75
11 am	11.5	0.28	3.22
12 pm	13	0.3	3.9
1 pm	14	0.33	4.78
2 pm	13.5	0.31	4.185
3 pm	12	0.32	3.84
4 pm	10	0.24	2.4
5 pm	6.2	0.13	1.14

P_{avg} =3.11W

The results obtained from our experiments indicate that the solar tracker significantly outperforms fixed-panel configurations with approximately 25 % more efficiency , resulting in a notable increase in energy output over the course of the day. By dynamically adjusting the orientation of the solar panels to track the sun's movement, our system effectively maximizes sunlight absorption and energy generation potential.

Conclusion:

The prototype of the dual axis solar tracker was successfully made and The output of the project was as per the expectation. The solar panel moved itself in the direction of maximum intensity of light. It remained unmoved when equal intensity of light was focused on the LDRs. Solar trackers fully utilize the sun peak hours and, in turn, increase the efficiency and increase the yield of the PV project .Though it has many advantages, trackers are expensive and need constant Maintenance. It is highly recommended to use a fixed tilt system for smaller projects , but for bigger projects, despite the initial higher cost, the long-term benefits of solar tracker project are substantial.

Future scope of extension:

Solar energy is a rapidly growing industry and its use is expected to continue to increase in the coming years. As the price of solar technology continues to fall and the environmental benefits of solar energy become more widely recognized, it is likely that more and more individuals and businesses will turn to solar as a source of electricity.

Solar trackers are devices that help solar panels to remain aligned with the sun throughout the day. These Solar tracking systems are becoming increasingly popular due to their ability to increase the efficiency of the solar power systems.Increasing the output of each panel means that fewer panels are needed to provide the same amount of power. This indirectly reduces space for the production of the same amount of power. These are especially useful in areas where sunlight is not uniform throughout the day, such as areas with a significant amount of cloud cover, panels can track the sun and produce more energy .

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