NATIONAL INSTITUTE OF TECHNOLOGY , AGARTALA

INDUSTRIAL INSTRUMENTATION PROJECT

Project:- **Solar Plates automated positioning system**

GROUP :-04

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AIM OF THE PROJECT:-

To design and implement a Sun Tracking Solar Panel System that optimizes the efficiency of solar energy capture by continuously adjusting the orientation of a solar panel to follow the sun's path using Light-Dependent Resistor (LDR) sensors and Arduino Uno control, thereby increasing the overall energy generation from solar panels.

OBJECTIVE OF PROJECT:-

- Design and construct an Arduino-based Solar Tracker using Light-Dependent Resistor (LDR) sensors and a Servo Motor.
- Enhance solar panel efficiency by ensuring maximum light intensity consistently hits the solar panel surface.
- Create a single-axis solar tracking system capable of precisely following the sun's movement throughout the day.

COMPONENTS REQUIRED:-

sl.no	Component's Name	Description	Quantity
01	Arduino Uno Board	-	01
02	Servo Motor	SG90	01
03	Resistors	10KΩ	02
04	LDR(Light dependent resistor)	-	02
05	Breadboard	-	01
06	Connecting wires	Jumper wires	As req.

INTRODUCTION:-

Solar energy is a clean and renewable source of power. To harness solar energy effectively, solar panels need to be aligned with the sun's position to maximize energy conversion. The Sun Tracking Solar Panel System aims to automatically adjust the orientation of solar panels to follow the sun's path, optimizing energy capture.

Our project centers on the development of a single-axis solar tracking system, where the entire solar panel seamlessly follows the sun's trajectory from east to west throughout the day. The integration of this solar tracker circuit in energy production holds the promise of substantially boosting efficiency. Furthermore, we envision the adaptability of this system in various solar energy-driven applications, such as optimizing performance in water heaters and enhancing output in steam turbines.

THEORY:-

Typically, a solar tracking system adjusts the face of the solar panel or reflective surfaces to follow the movement of the Sun. The movement of solar trackers increases the solar energy output by up to 40% than standard panels. Solar trackers are increasingly used in both residential and commercial-grade solar panels due to improved and more efficient solar trapping technology. Based on mode their motion solar trackers can be classified as:-

1. Single axis trackers
2. dual axis trackers

With respect to earth, the sun has two rotational movements, one is daily rotation from east to west and second is annual rotation in north and south direction. Daily rotation is tracked by single axis trackers which have one axis of rotation and track the movement of the sun from east to west. It increases the energy efficiency by up to 30%, and the dual axis trackers have another axis of tracking for the annual north-south of the sun. Panels are usually installed at a tilt to provide optimal irradiation. The direction and angle of this tilt is based on the location of the site, primarily based on the longitude of the installation. Installations in the northern hemisphere should be tilted facing south, and installations in the southern hemisphere should be tilted facing north. The degree of tilt varies according to longitude, generally the longitude of the installation site is a good reference for the angle of tilt.

Single axis trackers are further classified as:-

1. Horizontal Single-Axis Solar Tracker (HSAT)
2. Horizontal Tilted Single-Axis Solar Tracker (HTSAT)
3. Vertical Single-Axis Solar Tracker (VSAT)

4. Vertical-Tilted Single-Axis Solar Tracker (VTSAT)

HSAT rotates from east to west throughout the day on a fixed axis which is parallel to the ground. This type of tracker is considered the most cost-effective tracker geometry in many applications. An HSAT structure may be supported at many points along the rotating axis and therefore requires less complexity and less material for construction than other tracking geometries.

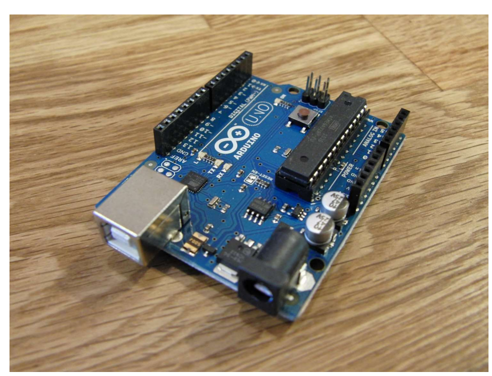
HTSATs is similar to the HSAT. However, the device is installed at a certain tilt. Tilted-axis tracking systems are relatively more complex than horizontal single-axis trackers and usually require a concrete foundation. These trackers require a special mechanical system for installation which increases the cost of installation, that's why these are not scalable.

VSAT are often installed in high-altitude or mountainous locations. The profile of VSATs is not parallel to the ground, because of which it is easier for these trackers to maintain a consistent angle of solar incidence when the Sun is lower in the sky. These are particularly used in northern altitudes for ex- latitudes between 40 to 45 degrees.

Dual-axis trackers have two rotation axis degrees, which are called the "primary axis" and the "secondary axis." The rotational axis can move downwards or upwards to adjust with the angles of the Sun throughout the day.   Dual-axis tracking allows for the most accurate orientation of the solar device and is said to provide 40% more output through energy absorption. However, these solar trackers are more complex and expensive. These trackers continually face the Sun as they can move in two different directions. There are two types of altitude-based dual-axis trackers — tip-tilt and azimuth-altitude. Typically, dual-axis tracking is used to orient a mirror and redirect sunlight along a fixed axis towards a stationary receiver. As these trackers track the sun's path vertically and horizontally, they help obtain maximum solar energy. Azimuth-altitude dual-axis trackers can solve both issues. However, these trackers can be expensive and add nearly $3,500–$6,500 to the solar installation cost.

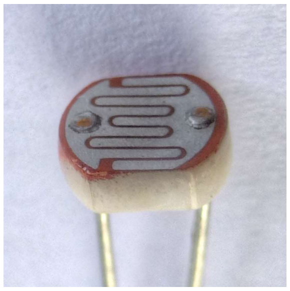
In this project, we built a prototype of single axis trackers with horizontal axis of rotation. This tracker is able to track daily movement of the sun from morning to evening. We used **two LDR** sensors to sense the position of the sun based on the difference of intensity of light on these LDR , **arduino uno** as a **controller** which controls the particular position of the **servo motor** with respect to the position of the sun. Some thoughts about components used are following : -

- **Arduino Uno Board**:- The Arduino Uno serves as the central control unit in our project, orchestrating the precise movement of the solar panel. Its versatility and ease of use make it an ideal choice for managing the Sun Tracking Solar Panel System. With the ability to read data from Light-Dependent Resistor



(LDR) sensors and send signals to the servo motor, the Arduino Uno efficiently executes the control algorithm, ensuring that the solar panel continuously tracks the sun's position. Its adaptability and open-source nature allow for easy customization and integration, making it an indispensable component in our project's success.

- **LDR (Light Dependent Resistor):-**



The Light-Dependent Resistor (LDR) is a pivotal component within our Sun Tracking Solar Panel System, operating on the principle of varying resistance in response to ambient light levels. These semiconductor devices change their resistance as the intensity of incident light fluctuates. In our project, two strategically positioned LDR sensors, one oriented eastward and the other westward, continuously measure the sunlight's intensity. This real-time data forms the basis for determining the sun's precise position. As the sun's angle in the sky shifts during the day, the LDRs communicate this information to the Arduino Uno controller. The Arduino Uno interprets these signals and orchestrates the servo motor's movement, ensuring that the solar panel continually aligns itself with the sun.

- **Servo Motor:-**

The servo motor, at the heart of our project, operates on a closed-loop control system, specifically designed for accurate angular positioning. Comprising a motor, a feedback sensor (commonly a potentiometer or encoder), and a control circuit, it functions by continuously comparing the desired position with the real-time feedback from the sensor. Any deviation between the desired and actual positions generates an error signal, which is then amplified and used to drive the motor. This motor movement reduces the error until the desired position is reached. The feedback sensor maintains a continuous feedback loop, allowing the control circuit to make instantaneous adjustments, ensuring precise and accurate positioning. The servo motor's intrinsic ability for high-precision control makes it an indispensable component in applications demanding exactitude, including our solar panel tracking system.

CIRCUIT DIAGRAM:-

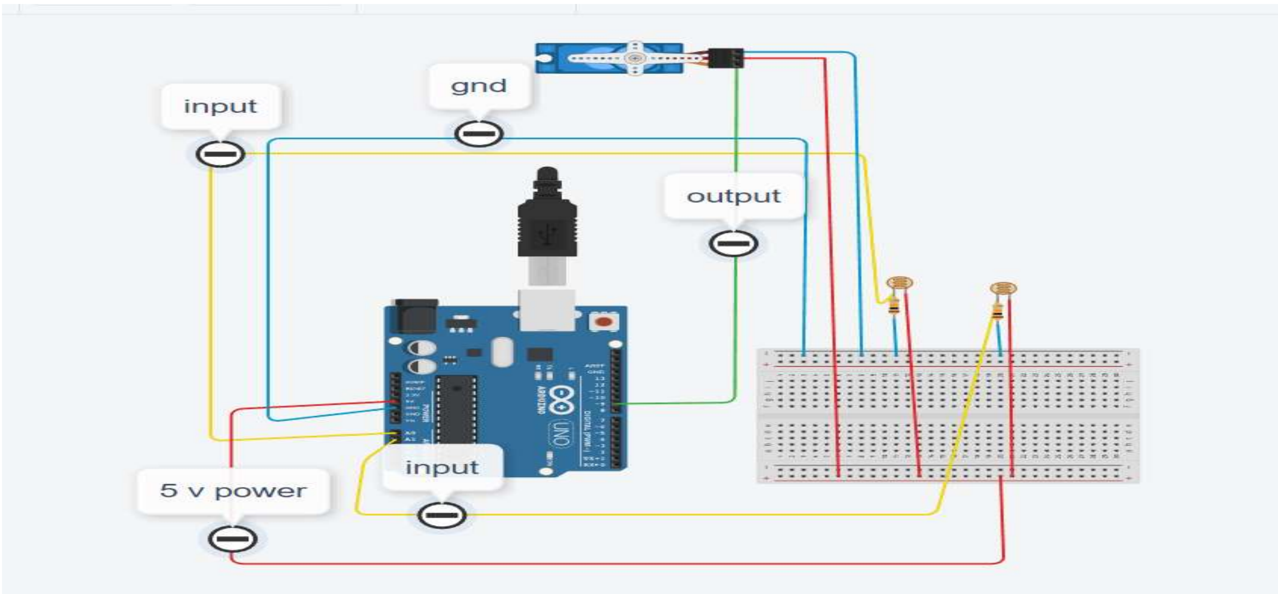


fig-01 :- circuit diagram

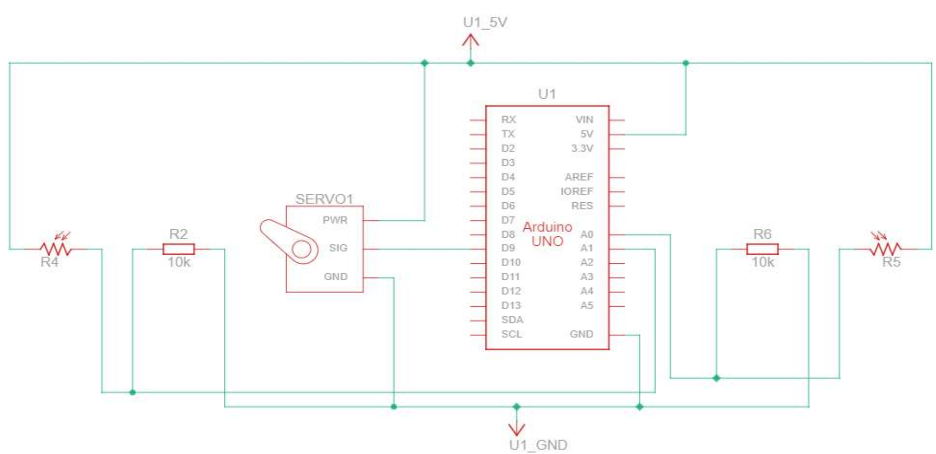


fig2:- schematic view

WORKING OF THE PROJECT :-

The Sun Tracking Solar Panel System operates on the principle of dynamic solar panel orientation to maximize exposure to sunlight. Two Light Dependent Resistors (LDRs), LDR1 and LDR2, are strategically placed on the solar panel itself. The system continually monitors the light intensity received by these sensors.

➔ **LDR Connections and Functions:**

Two LDRs (R4 and R5) are strategically placed on the solar panel assembly. These LDRs act as light sensors that detect variations in light intensity caused by the sun's movement across the sky.

Each LDR is connected in a voltage divider configuration with a fixed resistor (R2 and R6, respectively). The varying resistance of the LDR due to changing light conditions affects the voltage at the junction of the LDR and the resistor.

The analog output of each LDR is connected to analog input pins of the Arduino (A0 and A1). The Arduino reads the analog values from the LDRs to determine the relative intensity of light falling on them.

➔ **Arduino Connections and Functions:**

The Arduino (U1) serves as the central control unit. It reads the analog values from the LDRs and processes this information to calculate the sun's position relative to the solar panel.

Based on the LDR readings, the Arduino determines whether one LDR is receiving more light than the other. This imbalance indicates the sun's direction, as per following cases:-

Case 1: Sun on the Left Side :-

- When the sun is positioned to the left of the solar panel, LDR1 detects a higher light intensity as the shadow of a barrier falls on LDR2.
- This prompts the system to send a signal to the servo motor, causing it to rotate the solar panel clockwise to align with the sun's direction.

Case 2: Sun on the Right Side

- Conversely, when the sun is on the right side, LDR2 senses a higher light intensity due to the shadow of the barrier falling on LDR1.
- The system responds by instructing the servo motor to move the solar panel counterclockwise to track the sun's position.

Case 3: Sun on the Center

- When the sun is directly in front of the solar panel, both LDRs receive equal light intensity. In this case, the solar panel remains stationary, as it is already aligned with the sun's path.

➔ **Servo Motor Connections and Functions:-**

The servo motor (SERVO1) is connected to the Arduino using digital pins. Servo motors are commonly used for precise angular control.

The Arduino generates Pulse Width Modulation (PWM) signals to control the servo motor's angle. By changing the duty cycle of the PWM signal, the Arduino instructs the servo motor to rotate to a specific position.

As the Arduino receives data from the LDRs, it calculates the required angle of adjustment based on the sun's position. It then sends the appropriate PWM signal to the servo motor, causing it to rotate the solar panel to face the sun.

SOFTWARE DEVELOPMENT:-

We have used arduino uno code editor to write and upload the code in the controller. Codebse of the software used in the project is written here.

```
#include <Servo.h>

#define LDR1 A0
#define LDR2 A1
#define setpoint 1.0 // Setpoint for the desired ratio
#define KpLow 30.0 // Low Kp for angles < 160
#define KpHigh 60.0 // High Kp for angles >= 160
#define Ki 0.07 // Adjust Ki as needed
#define Kd 0.2 // Adjust Kd as needed
#define integralLimit 100.0 // Limit for the integral term

Servo servo;
int servoStep = 3; // Increase step size for faster movement

void setup() {
  servo.attach(9);
  // Read initial LDR values
  int ldr1 = analogRead(LDR1);
  int ldr2 = analogRead(LDR2);

  // Calculate the current ratio of LDR values
  float currentRatio = (float)ldr1 / ldr2;

  // Check if LDR values are balanced (within a tolerance)
  if (abs(ldr1 - ldr2) < 10) { // Adjust the tolerance value as needed
```

```
    servo.write(120); // Initialize the servo angle to 120 degrees when 
balanced
  } else if (ldr1 > ldr2) {
    servo.write(90); // Default to 90 degrees if LDR1 is greater
  } else {
    servo.write(150); // Default to 150 degrees if LDR2 is greater
  }
  Serial.begin(9600);
  delay(1000);
}

void loop() {
  int ldr1 = analogRead(LDR1);
  int ldr2 = analogRead(LDR2);

  // Calculate the current ratio of LDR values
  float currentRatio = (float)ldr1 / ldr2;

  // Compute the error
  float error = setpoint - currentRatio;

  // Initialize PID variables
  static float integral = 0;
  static float previousError = 0;

  // Calculate PID terms with different Kp values
  float Kp = (servo.read() < 145) ? KpLow : KpHigh;
  float proportionalTerm = Kp * error;

  // Anti-windup logic: Limit the integral term
  integral += Ki * error;
  integral = constrain(integral, -integralLimit, integralLimit);

  float derivativeTerm = Kd * (error - previousError);

  // Calculate the servo angle
  int Spoint = 120 + proportionalTerm + integral + derivativeTerm;

  // Constrain the servo angle within the range
  Spoint = constrain(Spoint, 80, 220);

  // Update previous error
  previousError = error;

  // Set the servo angle
  servo.write(Spoint);
```

```
  // Print the values for debugging
  Serial.print("Current Ratio: ");
  Serial.print(currentRatio);
  Serial.print(" Error: ");
  Serial.print(error);
  Serial.print(" Servo Angle: ");
  Serial.println(Spoint);

  delay(100); // Add a delay for stability (adjust as needed)
}
```

RESULTS :-

The Sun Tracking Solar Panel System successfully tracked the sun's movement throughout the day, optimizing the solar panel's orientation. This resulted in a noticeable increase in energy efficiency compared to a fixed solar panel.

CONCLUSION:-

The Sun Tracking Solar Panel System is an effective solution for improving the efficiency of solar panels. By using LDR sensors and an Arduino Uno board to control a servo motor, the system can continuously adjust the solar panel's orientation to follow the sun's path. This project highlights the potential for renewable energy systems to be more efficient and reliable, making solar energy a more practical and sustainable option.

FUTURE ENHANCEMENTS:-

To further improve this system, future enhancements could include:

- Integration with a solar tracking algorithm that accounts for latitude and longitude to optimize tracking accuracy.
- Remote monitoring and control capabilities for system maintenance and performance analysis.
- Implementation of a feedback control system to fine-tune the tracking process for even better results.

- The Sun Tracking Solar Panel System is a step towards harnessing solar energy more effectively and making it a viable and sustainable energy source for the future.

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