

Optimizing Solar Energy: A Study on Dynamic Panel Systems

Ranjeeta Susan Avinash

Grade 12, Indian Community School, Kuwait

Abstract- The greatest challenge in the upcoming decades is to switch from using fossil fuels to a greener form of energy. Solar energy is of the highest priority. However, the frequent change in the sun's position with respect to the Earth makes it nearly impossible to collect a hundred percent heat energy from the sun. Therefore, the need to improve the energy efficiency of photovoltaic solar panels by building a solar tracking system must be considered. To get maximum energy, PV panels must be perpendicular to the sun's position. The methodology includes the implementation of an Arduino-based solar tracking system consisting of Light-dependent resistors (LDRs), a PV solar panel, and a servo motor to control the movement of the solar panel based on the position of the sun. The result of this work has clearly shown that the tracking solar panel produces more energy than a fixed panel.

Index Terms- PV panels, Solar energy, LDR

I. INTRODUCTION

Nearly 85 percent of energy is produced by fossil fuels. As we know, fossil fuels are limited, and the increasing amount of their usage and consumption is raising the Earth's temperature, which, in turn, creates issues of global warming. Hence, the realization of the importance of switching to renewable energy sources has become apparent in creating a sustainable environment for generations to come. Thus, the demand for solar, geothermal, ocean tidal, and wave energy has increased.

Solar energy being obtained from the sun remains the cleanest source of energy. This green energy does not pollute the environment due to its zero-carbon footprint. On average, the energy from the sun received at the top of the Earth's atmosphere amounts to 175 petawatts (PW) (or 175 quadrillion watts), of which close to 31 percent is reflected by clouds and from the surface. The atmosphere, land, or ocean absorbs the rest (120 PW).

Maximum power is generated when the panel faces the sun directly. For a fixed panel, maximum radiation collection will happen only at midday when the sun is above the panel, efficiently working only for a few hours each day. To harness maximum power output from solar panels, the angle of incidence between the panel and sun radiation needs to be aligned. By automating the panels to face the sun continuously, we can accomplish the required efficiency.

In this paper, I explore how to convert solar energy into electrical energy using a single-axis solar tracking system. The

construction of this system includes the physical design of the module, the control system, and the processing/monitoring system.

Photovoltaics - Sunlight is made up of photons that contain varying amounts of energy corresponding to different wavelengths of the solar spectrum. When photons fall on a PV cell, they will reflect off, pass through, or be absorbed by the PV cells' semiconductor material. The most popular material for PV cells is silicon. Only the absorbed photons provide energy to generate electricity. Electrons are ejected from the silicon atom when enough solar energy (sunlight) is absorbed by the semiconductor. The PV cells are manufactured to make the front surface of the cell more receptive to the free electrons so that the electrons naturally migrate to the surface of the cell. An imbalance of electric charge between the cell's front and back surfaces is created due to the movement of all the negatively charged electrons toward the front surface of the PV cell. This imbalance creates a voltage potential similar to the negative and positive terminals of a battery. Electrical conductors on the PV cell absorb the electrons. When the conductors are connected to a positive and negative side, forming an electrical circuit, the electrons can be captured in the form of an electric current called electricity.

II. EXPERIMENT MODEL

1. Materials Needed

Hardware

Solar panel: to convert sunlight into electrical energy

Arduino UNO microcontroller: to process inputs from the LDR to send signals to the servo motor
 Servo Motor: to control the movement of the solar panel

Light-dependent resistors: to detect light intensity to identify the sun's direction
 Power Supply: to provide the necessary electrical power to the other components

Software

Arduino IDE for program TinkerCad for Circuit design

Component specification

Arduino UNO microcontroller board
 Microcontroller: ATmega328P
 Operating voltage: 5V
 Input voltage: 7-12V
 Digital I/O pins: 14
 Analog input pins: 6

Servo motor

Type: Rotary actuator with position control
 Torque: 2.5 kg•cm (at 4.8V)
 Operating voltage: 4.8V to 6V
 Operating temperature range: -30°C to 60°C
 Rotation angle: up to 180°
 Light-dependent resistor (LDR):
 Type: Cadmium sulfide (CdS) photoresistor
 Resistance range: 1 kΩ to 10 MΩ
 Operating temperature range: -40°C to 70°C
 Spectral response range: 400 nm to 700 nm

Construction

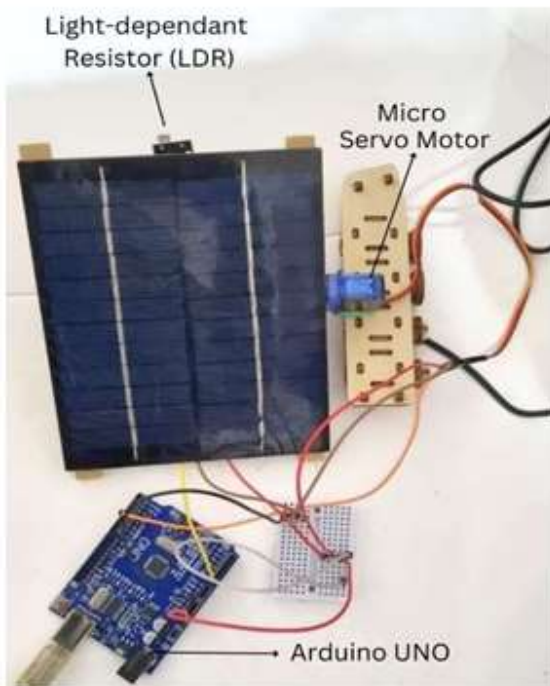


Fig 1: Photo of Arduino System

In this prototype, the solar panel is designed to follow the sun's path from east to west. To determine maximum solar energy absorption, two light-dependent resistors (LDRs) are placed at the ends of the solar panel. LDRs are resistors that increase or decrease in resistance value depending on the amount of light falling on the surface of the sensor. The higher the light, the higher the electron value, hence decreasing the resistance value, allowing the current to flow more easily. The difference in light intensities is monitored and processed by the Arduino Uno to determine the optimal position for maximum sunlight to fall on the panel, which is achieved by a servo motor that allows for precise control of the angular position.

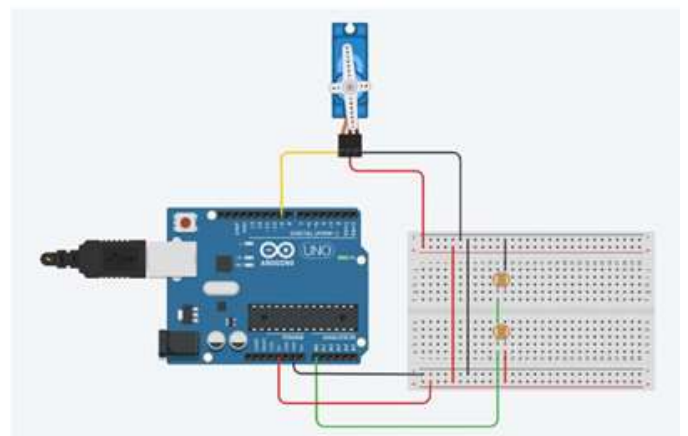


Fig 2: Arduino UNO Connections Diagram

Working Principle

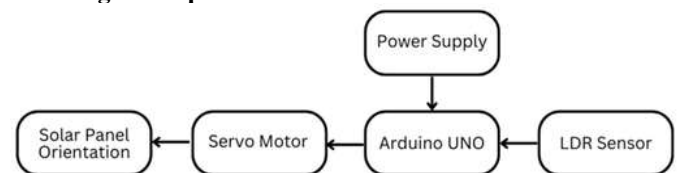


Fig 3: Block Diagram of Arduino UNO Signal Transmission

The basic working of this solar tracking system would need a sensor that would detect sunlight that falls on it, a microcontroller that could measure the intensity of the light and a solar panel that could face the direction of the sun using servo motors. For the construction of this Solar tracking prototype Light, light- dependent resistors were used as sensors to detect the intensity of light entering the solar panels. This information is sent to the Arduino microcontroller, which is programmed to compare and detect the direction of light intensities being maximum. The Arduino uses the inputs from the LDR and then forwards the digital results to the driving module and the servo motors, and thus, it rotates the solar panels at a desired angle in the direction of maximum intensity.

```

1 // C++ code
2 //
3 #include <Servo.h>
4
5 int sensorPin = A0;
6 int servoPin = 9;
7
8 int sensorValue = 0;
9 int servoGrad = 90;
10 int tolerance = 40;
11
12 Servo myservo;
13
14 void setup() {
15     pinMode( sensorPin, INPUT);
16     myservo.attach( servoPin );
17     myservo.write( servoGrad );
18 }
19
20 void loop() {
21     sensorValue = analogRead(sensorPin);
22     if ( sensorValue < (512-tolerance) )
23     {
24         if (servoGrad < 180) servoGrad++;
25     }
26
27     if ( sensorValue > (512+tolerance) )
28     {
29         if (servoGrad > 0) servoGrad--;
30     }
31
32     myservo.write( servoGrad );
33
34     delay(100);
35 }
36

```

Fig 4: Code for Arduino UNO System

III. RESULTS AND DISCUSSIONS

Mimicking plants' phototropism, solar tracking systems can harvest up to 400 percent more energy than static solar panels. Harvesting more power efficiently improves performance and results in a decrease in cost per watt, ensuring a more cost-effective solution than traditional fixed solar panels.

Scope of Improvement

Solar tracking systems significantly increase efficiency by optimizing the amount of sunlight they receive. The future is promising as more research is being conducted to improve design and functionality, making them more efficient, cost-effective, and environmentally friendly. This system would be crucial in fulfilling the energy needs of the world in a sustainable way. Innovative ideas to rotate the panels in a multidimensional workspace, water-free cleaning solutions for the panels, and self-maintaining hardware are a few of the enhancements that could further improve the efficiency of these tracking systems.

Applications

In residential and commercial settings, this system could enhance power output and reduce the reliance on traditional energy sources, leading to a more sustainable energy footprint. In industries with high demand needs, solar trackers could help reduce operational costs and environmental impact. Using solar tracking at electric vehicle charging stations would boost clean energy production and reduce grid reliance, leading to wider adoption of EVs. Additionally for military and disaster relief operations, these systems provide a portable, efficient power source that can be deployed rapidly in the field, powering essential equipment like communication devices and medical tools in remote or temporary setups.

V. CONCLUSION

From this study it is evident that by mimicking plant phototropism, dynamic solar systems are an advancement in optimizing energy capture. These systems enhance efficiency and lower greenhouse gas emissions, contributing to a more sustainable future. As technology continues to evolve, the potential for even greater efficiency becomes increasingly promising.

REFERENCES

1. Gulhane, Y. (2022). DUAL AXIS SOLAR PANEL USING ARDUINO. Indian Scientific Journal Of Research In Engineering And Management. <https://doi.org/10.55041/ijsrem12663>
2. Solar power arriving to earth from the sun (w - Biosphere - BNID 100943. BioNumbers. <https://bionumbers.hms.harvard.edu/bionumber.aspx?s=n&v=3&id=100943>
3. The Editors of EnergyTrend. (2019). Solar power arriving to earth from the sun. EnergyTrend. <https://www.energytrend.com/news/20191203-15790.html>
4. A Review Paper on Solar Tracking System for Photovoltaic Power Plant. (2023). ResearchGate. https://www.researchgate.net/publication/341872696_A_

Review_Paper_on_Solar_Tracking_System_for_Photovoltaic_Power_Plant

5. Solar Tracking Systems - A Review. (2023). ResearchGate.
https://www.researchgate.net/publication/377987176_Solar_Tracking_Systems_-_A_Review
6. Photovoltaic cells convert sunlight into electrical energy. (2023). Energy Information Administration.
<https://www.eia.gov/energyexplained/solar/photovoltaics-and-electricity.php#:~:text=Photovoltaic%20cells%20convert%20sunlight%20into,or%20particles%20of%20solar%20energy.>
7. NCBI. (2019). Impact of different angles of incidence on sunlight. National Center for Biotechnology Information.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6611928/#:~:text=So%2C%20it%20is%20concluded%20that,angle%20of%20incidence%20of%20sunlight.>