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Design And Development Of Time-Based Solar Tracker

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Abstract
Conventional solar panels are statically installed, which leads to decrease in the amount of solar energy absorbed. Intensity of the incident sunlight and the temperature of the solar cell decides the efficiency. Tracking the incident sunlight on a regular basis is necessary for increasing the efficiency of the solar panel. A remunerative solution is required to install the panels in rural areas and farmlands. In smart city development usage of time-based solar tracker is inevitable. 3D modelling and simulation were done using PTC Creo parametric 6.0. Geometry and simulation data was perceived for electronic circuit. Circuit design and simulation was carried out using Autodesk Tinker cad to ensure the functionality of the program. The prototype consisting of servo motor, ambient light sensor, domestic solar panel and an Arduino R3 board was fabricated. Prototype was tested under the sun for a day and the values were recorded.
Keywords: solar tracker, prototype, simulation, efficiency

1. Introduction

People have been developing methods to use renewable energy as a result of the negative impacts of fuel-based electricity. This renewable energy source is derived from a variety of sources, including wind farms, hydropower facilities, and solar panels. As the globe shifts toward greater renewable energy production, innovations to make goods smoother and less obtrusive in daily life are emerging [1]. One of these developments is a solar panel that can spin in accordance with the sun's trajectory/movement. Solar energy is created by photovoltaic solar cells, which collect sunlight and convert it to usable power for a range of applications ranging from personal to industrial. A solar tracker is a solar panel setup that automatically tracks the sun to increase light intensity. Mechanism required for changing the position of the panel as per the sun in the sky changes. The heliostat, a moveable mirror that reflects the moving sun to a fixed point, is a well-known form of solar tracker, although many other techniques are employed as well. Active trackers utilize motors and gear trains to steer the tracker in the direction specified by a controller in response to the sun direction. Solar trackers may be utilized in a variety of applications, including solar lighting systems, and solar thermal arrays [4]. The solar cells and solar panels are primary beneficiary which uses solar tracking. Many of the solar panels were mounted to a permanent surface, such as a roof. Because the sun is a moving object, this strategy is not the best. One approach is to actively monitor the sun by moving the solar panel to follow the Sun using sun tracking system. When the Sun is continuously facing the panel, the maximum amount of energy may be absorbed because the panel is functioning at optimum efficiency. The primary goal of this research is to maximize the efficiency of solar cells. Although there are numerous solar trackers on the market, the prices are high and prohibitive since the industry for solar trackers is still young and only a few nations, such as the United States and South Korea, use them. The large-scale solar tracker that is often employed is not appropriate for home use. Low cost solar tracker is required for tracking the sun intensity. This project will create a sun tracking system for a low-cost solar cell that is specifically suited for home and other domestic application [3]. The primary goal of this project is to create a model of a sun tracking solar system, which is a device that follows the movement of the Sun independent of motor speed. Furthermore, it aims to enhance total power generation utilizing a single axis sun tracking system and to create a design for residential/ domestic application. The entire process entails reading several sensor data and then digitally comparing them to establish the exact location of the sun in the east-west direction. Again, certain predetermined parameters are supplied to the system depending on the sun's geographical location in the north-south direction. The entire system is split into mechanical and electrical systems to ease the design and implementation process. Solar panels must be oriented orthogonally to the sun in order to collect the most energy from it. We can get 40% more electricity from each panel by using a dual-axis tracking solar system. This decreases the project's initial expenses and, to a large degree, balances the increased cost for tracking devices. By using a dual-axis tracking solar system to generate energy, one may use the same number of panels as initially planned but generating 40% more power and money [8]. The additional energy generated by using The Novel Low-Cost Automatic Solar Tracking System is around 25% to 30%. When compared to a static panel, a hybrid dual axis solar tracking system can generate more electricity. The results reveal that the hybrid dual axis tracking system outperforms the continuous tracking system by 25.62 percent. The current panel is subjected to harsh environmental conditions, which reduces efficiency and causes deterioration. Existing panel designs are fastened to the surface, and the panel is also set at a single angle, resulting in a very low energy absorption rate. After drawing a few conceptual sketches, the conceptual design was developed using PTC Creo Parametric 6.0.2.0. Software. Fig.1 shows the bottom and top view of the solar tracker. The final design was improvised from the conceptual sketch and CAD model. Based on the requirements obtained from research several factors like cost, ease of manufacturing, low maintenance and requirement & availability of components were fixed as the datum.

(a) Bottom view (b) Top view

Fig.1 Design developed from conceptual sketches

This datum was used to compare the existing design and the developed designs using concept screening technique and the final design was considered ideal and thus it was for proceeding further. In the final design the opening and closing mechanism was not included because of cost factors and complexity in the mechanism that was to be used. The material was also changed from aluminum to PVC material to reduce cost and to make it lighter to reduce the load given to the motor. Thus, the final design makes the product more economical as shown in fig 2.

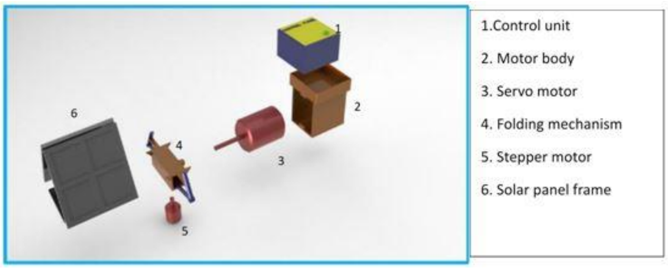


Fig. 2 Final design of solar tracker

2. Experiment and Simulation

The brightness or amount of light generated by a given light source is referred to as its intensity. It is a measurement of the wavelength-weighted power of a light source. Important primary factor in solar energy usage is solar intensity. Intensity is not constant throughout the day. Dependable parameters are angle of the sun, geographic location and season. The angle created by solar rays striking the Earth is known technically as the angle of incidence. The most powerful rays are those that strike the planet's surface straight overhead, which is, at a 90-degree angle measured from the horizon. Most of the time and in most places, the sun makes a less than 90-degree angle with the horizonontal plane, indicating that the sun is lower in the sky [4]. The bigger the surface area over which the sun's rays extend, the smaller the angle. This impact decreases the intensity of the sun at any given location. Solar radiation, for example, covers a 40% larger area and is 30% less intense at a 45 degree angle of incidence than at the maximum angle of incidence of 90 degrees [5]. This Experiment was mainly conducted to record the intensity of sunlight at a particular time in a day. The experiment was started at 9.00 am in the morning on 20.3. 2021. The setup for the experiment consisted of an ambient light sensor connected to a bread board which was then connected to a multimeter forming a closed circuit. The voltage readings were recorded one hour once from 9.00 am till 4.00 pm. Table 1 presents the voltage readings with time.

Table 1: Recorded Voltage

TIME	VOLTAGE
9:00 AM	9.92V
10:00 AM	9.98V
11:00 AM	9.99V
12:00 AM	9.99V
1:00 PM	10.01V
2:00 PM	9.99V
3:00 PM	9.96V
4:00 PM	9.95V

Using these readings, a range was for formed for all the time frames in the above table. These readings were then mapped to a percentage value (say: if the voltage reading is 9.95V then the percentage of intensity of sunlight is 70%). Thus, the aim of the experiment was to change the light intensity to percentage values which were successfully implemented. This study was conducted to

know when and at which angle does the sun rise and sets in a particular Sunrise and sunset times in Coimbatore, Tamilnadu, India. Online data available at website which approximately shows the rise and set timings of the sun in the locality. This website was monitored for more than a month to accurately predict the angle and time. After observation for a month, the average rise and set angle was taken and was introduced in the program. Table 2 shows the sunrise and sunset data taken for the month March 2021. Many online free access tools are available to perform programming work and embedding the software against electronic components. Tinkercad.com, an online tool for Arduino Programming and Simulation, was used for program development and simulation. In this work and effective program is performed to reduce the cost of the hardware requirements without compromising the intended purpose. The Above program is the most effective software solution for a solar tracker. This program when simulated, can live track the movement of the sun using 3 ambient light sensors. Working principle of the proposed model is given below. When the light intensity reading in the first sensor is between ranges the frame will rotate in a certain angle. Figure 3 shows the optimized program for effective simulation of electronic control. Similarly fig 4 shows the simulation of the same. Actual circuit setup was planned as shown in fig 5. Likewise, the same concept is used for the other two sensors. Website link to see the live changes is given below.
https://www.tinkercad.com/things/gXqEdm61CSy-mightyhillarbruticus/editel?sharecode=wnNl1Fl9UDd851zCla_qUHIiFNsL93pBIMhq5306Yw0

Table 2: Sunrise and Sunset data

2021	Sunrise/Sunset	
Mar	Sunrise	Sunset
1	06:36 → (98°)	18:32 ← (263°)
2	06:36 → (97°)	18:32 ← (263°)
3	06:35 → (97°)	18:32 ← (263°)
4	06:35 → (96°)	18:32 ← (264°)
5	06:34 → (96°)	18:32 ← (264°)
6	06:34 → (96°)	18:32 ← (265°)
7	06:33 → (95°)	18:32 ← (265°)
8	06:33 → (95°)	18:32 ← (265°)
9	06:32 → (94°)	18:32 ← (266°)
10	06:32 → (94°)	18:32 ← (266°)
11	06:31 → (94°)	18:32 ← (267°)
12	06:31 → (93°)	18:32 ← (267°)
13	06:30 → (93°)	18:32 ← (267°)
14	06:29 → (92°)	18:32 ← (268°)
15	06:29 → (92°)	18:32 ← (268°)
16	06:28 → (92°)	18:32 ← (269°)
17	06:28 → (91°)	18:32 ← (269°)
18	06:27 → (91°)	18:32 ← (269°)
19	06:26 → (90°)	18:32 ← (270°)
20	06:26 → (90°)	18:32 ← (270°)
21	06:25 → (90°)	18:32 ← (271°)
22	06:25 → (89°)	18:32 ← (271°)
23	06:24 → (89°)	18:32 ← (271°)
24	06:23 → (88°)	18:32 ← (272°)
25	06:23 → (88°)	18:32 ← (272°)
26	06:22 → (88°)	18:32 ← (273°)
27	06:22 → (87°)	18:32 ← (273°)
28	06:21 → (87°)	18:32 ← (273°)
29	06:20 → (86°)	18:32 ← (274°)
30	06:20 → (86°)	18:32 ← (274°)
31	06:19 → (86°)	18:32 ← (275°)

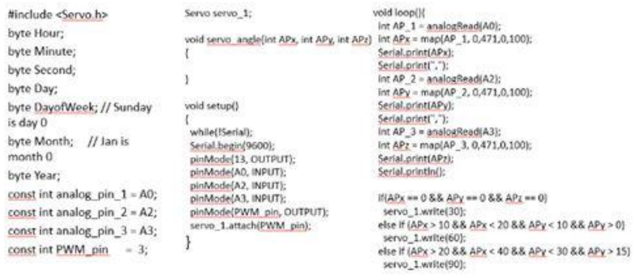
Program:

```
#include <Servo.h>
#include <TimeLib.h>
const int analog_pin_1 = A0;
const int PWM_pin        = 3;
unsigned long tlast = 0;
unsigned long ti;
Servo
servo_1;
void setup(){
while(!Serial);
```

```
Serial.begin(9600);
pinMode(13, OUTPUT);
pinMode(A0, INPUT);
pinMode(PWM_pin, OUTPUT);
servo_1.attach(PWM_pin);
tlast = millis();
}
int time_circuit()
{
unsigned long t = millis();
int t1 = 0;
if (t-tlast>100000)
{
tlast+=100000;
//Serial.println(ti);
if (++ti>=12)
{
ti = 0;
}}}
void loop(){
int AP_1 = analogRead(A0);
int APx = map(AP_1, 0,471,0,100);
Serial.print(APx);
Serial.print(",");
Serial.println();

digitalWrite(13, HIGH);
delay(1000);
digitalWrite(13, LOW);
int orientation = time_circuit();
switch(orientation)
{
case 0: servo_1.attach(PWM_pin);
//servo_1.write(14.4615); // angle value
case 1: servo_1.attach(PWM_pin);
//servo_1.write(28.923); // angle value
case 2: servo_1.attach(PWM_pin);
//servo_1.write(43.3845); // angle value
case 3: servo_1.attach(PWM_pin);
//servo_1.write(57.846); // angle value
case 4: servo_1.attach(PWM_pin);
//servo_1.write(72.3075); // angle value
case 5: servo_1.attach(PWM_pin);
//servo_1.write(86.769); // angle value
case 6: servo_1.attach(PWM_pin);
```

```
//servo_1.write(101.2305); // angle value
case 7: servo_1.attach(PWM_pin);
//servo_1.write(115.692); // angle value
case 8:servo_1.attach(PWM_pin);
//servo_1.write(130.1535); // angle value
case 9: servo_1.attach(PWM_pin);
//servo_1.write(144.615); // angle value
case 10: servo_1.attach(PWM_pin);
//servo_1.write(159.0765); // angle value
case 11: servo_1.attach(PWM_pin);
//servo_1.write(173.538); // angle value
case 12: servo_1.attach(PWM_pin);
//servo_1.write(187.9995); // angle value
default:
digitalWrite(13, LOW);
break;
}}
```



```
#include <Servo.h>
byte Hour;
byte Minute;
byte Second;
byte Day;
byte DayofWeek; // Sunday
is day 0
byte Month;    // Jan is
month 0
byte Year;
const int analog_pin_1 = A0;
const int analog_pin_2 = A2;
const int analog_pin_3 = A3;
const int PWM_pin     = 3;

Servo servo_1;

void servo_angle(int APx, int APy, int APz)
{

}

void setup()
{
 while(!Serial);
 Serial.begin(9600);
 pinMode(13, OUTPUT);
 pinMode(A0, INPUT);
 pinMode(A2, INPUT);
 pinMode(A3, INPUT);
 pinMode(PWM_pin, OUTPUT);
 servo_1.attach(PWM_pin);
}

void loop(){
 int AP_1 = analogRead(A0);
 int APx = map(AP_1, 0,471,0,100);
 Serial.print(APx);
 Serial.print(",");
 int AP_2 = analogRead(A2);
 int APy = map(AP_2, 0,471,0,100);
 Serial.print(APy);
 Serial.print(",");
 int AP_3 = analogRead(A3);
 int APz = map(AP_3, 0,471,0,100);
 Serial.print(APz);
 Serial.println();

 if(APx == 0 && APy == 0 && APz == 0)
  servo_1.write(30);
 else if (APx > 10 && APx < 20 && APy < 10 && APy > 0)
  servo_1.write(60);
 else if (APx > 20 && APx < 40 && APy < 30 && APy > 15)
  servo_1.write(90);
```

Fig 3. Program Simulation (Effective Solution)

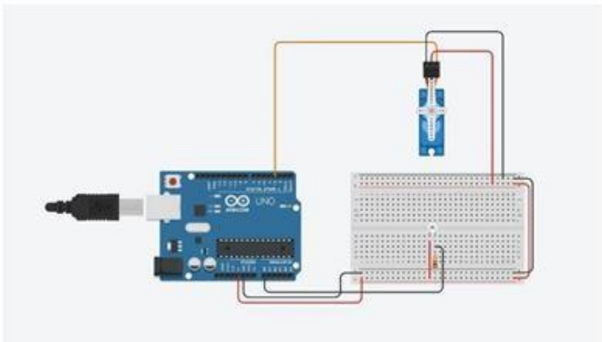


Fig 4. Circuit Simulation (Effective Solution)

According to the above program & Circuit setup, when the light sensor reads a certain intensity, the circuit starts working and aligns the frame according to the direction of the sun in different time frames automatically. The sun rises at 86 degrees east and sets at 274 degrees west, so the difference is 188 degrees. Bright Sun light will last for 12 hours in a day, so this 188degrees is split into 12 parts and the angles are calculated and set to rotate in a particular an hour once. By this way the absorption rate of sun light will increase thereby increasing efficiency. The CAD Model was for the product created using CREO 6.0.2.0 Parametric Software. To show the working of the model, a simulation was created using CREO 6.0.2.0 Parametric software. The frame is in home position, perpendicular to the axis of the motor as shown in fig 6 and fig 7.

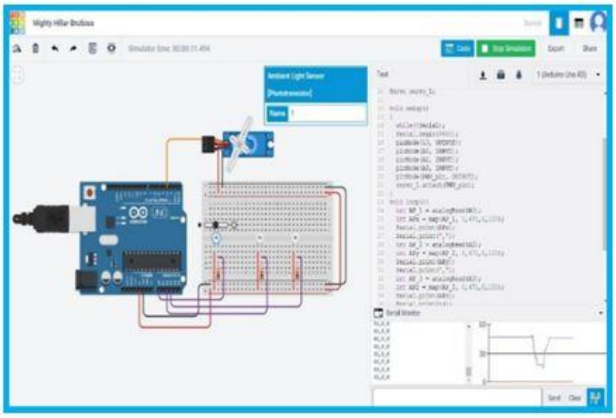


Fig 5. Actual Circuit Setup

When the program kick starts from the information collected from the ambient light sensor, the motor and frame setup rotates to an angle of 14.415 degree. Similarly the motor rotates based on the time.

Fig 6. Home Position

Fig 7. Model Simulation

The frame should have been designed using aluminium fame, but due to the ongoing pandemic, the aluminium frame cannot be welded together. Considering this issue, it was decided to use PVC material for frame design. After selecting the material the PVC material purchased was cut according to the dimensions mentioned in the blueprint.

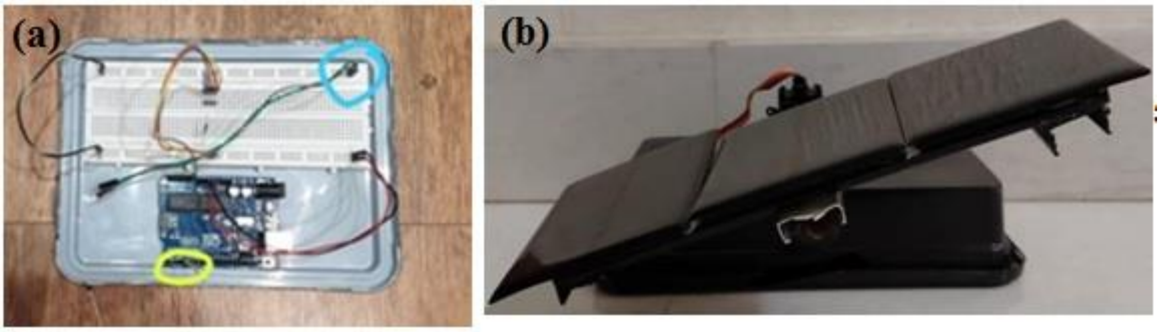


Fig. 8 (a) Circuit (b) Prototype

After cutting process, the one more PVC plank was placed on the chassis, to support the solar panels. Now hollow PVC pipe of was cut according to the blueprint for the shaft support hole as shown in fig 8. To reduce cost the casing was designed using plastic. A plastic box was taken and holes were drilled wherever required and was painted in black, as the sensor will be placed on top of the casing. The circuit diagram was designed using Tinker Cad software. The circuit connections were given according to the circuit diagram. The Code that was prepared was compiled and uploaded to the Arduino board using Arduino IDE software. The errors were checked before uploading. Finally, after frame design and circuit setup, the components were assembled according to the design as shown. The blue coloured circle shows the ground and power for motor connections, yellow coloured circle shows the pwm signal for motor and the red coloured circle shows the ambient light sensor connections. After setting up the prototype, it was tested on 01.04.2021 for the whole day. The motor and frame setup worked perfectly according to the instruction provided by the Arduino UNO board. It started from an angle of 14.415 degrees at 6.30 am then rotated one hour once and finally ended up in an angle of 188.9995 degrees, completing a full rotation according to the trajectory of the sun. The folding mechanism was not incorporated in the model as it involved complex mechanism, which can increase the cost of production.

3. Conclusion

This work would be useful in smart city development and useful for marine power requirement. Successful model and simulation was achieved through software. The cost effective simulation and prototype was done in this work. Folding mechanism can be inbuilt in future work.

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