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Dual- Axis Sun Tracking Solar System

Abhishek Paliwal[1], Ayushi Saxena[2], Sabitha Gauni[3]
Department of ECE, SRM University, Kattankulathur

Abstract— In recent times, the availability of non-renewable resources is depleting at an alarming rate. To add to the murk, the pollution caused by the exploitation of these resources, is also on the rise. In wake of this, science has focussed its attention towards forming more efficient and sustainable sources of energy. One of the popular methods used these days, is Solar Energy, because of its abundance in nature.

The photonic energy from the sun is trapped using solar panels and converted to a usable form of energy, which is used to aid several applications. Though an efficient method, it comes with its set of drawbacks. The efficiency of the solar panels depends largely on the angle of incidence between the panels and rays.

Therefore in this project, we have created a method of varying the position of the solar panel using an arduino code controlling a set of stepper motors, which alternate using the analog data provided by four LDRs, in order to tilt the solar panel in the direction of the sun rays, so as to produce maximum efficiency of power generation.

Keywords:

I. Introduction

The current paradigm of nature has time and again proved the abundance of solar radiations and the prospects of generating highly efficient and inexhaustible supply of energy. Solar energy is readily available and thus scientists and engineers seek to utilize solar radiation by converting it into useful form of energy. Solar energy is largely segmented into two types, namely passive solar energy and active solar energy depending on how it is trapped and channelized into various applications. Photo-voltaic system, concentrated solar power and solar water heating finds its application are classified as active solar techniques, while passive solar techniques include orienting buildings to towards the sun, selecting materials with light dispersing properties. According to the reports of UNDP in its 2000 World Energy Assessment, the annual potential of solar energy was found out to be 1575-49837 exajoules (EJ), which is quite larger compared to the conventional world energy consumption (559.8 EJ)

However, the efficiency of the solar panels depend greatly on the orientation of the system with the direct incoming rays, therefore creating a need for a movable system, wherein the position of the panels vary according to the different position of the sun, throughout the day. Concentrated applications like concentrated photo-voltaic panels and concentrated solar power, demand a high degree of accuracy to ensure that the orientation of the focal point of the reflectors and the lenses is in synchronization with the incoming sun rays.

Our project concentrates on developing a prototype to demonstrate the extraction of maximum efficiency of the solar panel system, where we can have many customized types of varying costs, sophistication and performance.

The tracking can be achieved using a Single Axis or a Dual Axis prototype. In a single axis model, we can either have a horizontal or a vertical axis. Horizontal type is used in tropical areas where sun is high at noon and days are comparatively shorter. The vertical model is used in temperate regions were the sun is not very high and the day lasts longer. Dual axis model is a combination of the horizontal and the vertical axis system, wherein it can detect the position of the sun, practically anywhere at any latitude/longitude. It is a more efficient model, having several applications such as solar power towers and dish applications.

Both models have their own set of benefits and deficits, depending upon the area of application. Our prototype involves a dual axis, since this system orients itself directly in line with the centre of the sun, which is the brightest spot in the sky. Sky clarity is the measure of how much pollution is absorbed by the clouds in a particular weather condition. Low clarity is “diffused light” like on a hazy day with slight overcast. High clarity (0.7-0.8)

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is a sunny day, with minimal pollution or atmosphere with high particle content.

Therefore keeping the aforementioned facts in mind, we created an environment for testing, wherein our dual axis system was tested in a high clarity zone, effectively producing an efficiency of 40-45% more than a fixed solar panel mounted on rooftop that is tilted ideally for the latitude.

The above facts are implemented using an arudino uno 32, which controls a set of stepper motors, where one controls the horizontal axis movement of the solar panel and the other controls the vertical position. The data of the angle of incidence is obtained using 4 LDRs, which provides an analog signal, which is converted into a digital signal (accepted by the arduino board) using line drivers. This signal provides a command to the stepper motors, which in turn vary the position, thereby shifting the axis of the solar panels, therefore creating a situation of maximum efficiency of power generation. Therefore, the dual axis model is implemented, and tested in a zone of high clarity environment, testifying all the theory, which is mentioned above.

II. SYSTEM WORKING

The system consists of four LDRs, four 100 kilo ohm resisters, which are connected in a voltage divider circuit. The output of the connection is given to the four analog input terminals of the arduino. The Pulse width modulation inputs of the two servo motors are given from digital pins 9 and 10 of the arduino. LDRs are used as light detectors in the circuitry. A stable structure acts as a holding backbone to hold the panels upright. The arduino board is loaded with the program, which governs the movement of the solar panels based on the input provided at the pins.

The working of the above components is as follows – LDRs sense the amount of sunlight falling on them. 4 LDRs are divided into Top, Bottom, Left and Right. For east – west tracking, the analog values from two top LDRs and two bottom LDRs are compared and if the top set of LDRs receive more light, the vertical servo will move in that direction. If the bottom LDRs receives more light, the servo moves in that direction. For angular deflection of the solar panel, the analog values from two left LDRs and two right LDRs are compared. If the left set of LDRs receives more light than the right set, the horizontal servo will move in that direction. If the right set of LDRs receives more light, the servo moves in that direction.

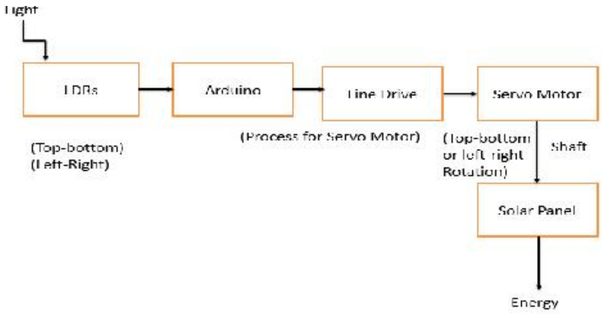

Fig.1. Block Diagram of Dual Axis Sun Tracking Solar Panel

In the tracking operation, the quadruple of LDRs detect the sunlight intensity as a reference voltage signal which is input at the terminals of the arduino board, creating an unbalance in the voltages, thereby creating a feedback error in the loop. The difference between the sunlight location and the panel location creates a proportional error voltage, which is compared with a specified threshold (tolerance). For a high output signal, the motor driver is activated so as to rotate the dual axis tracking motor (elevation and azimuth), bringing the PV panel in the line of the sun

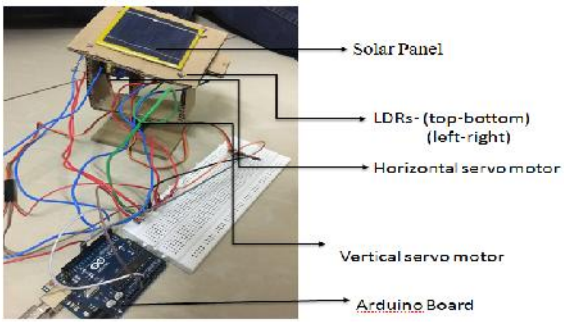

Fig.2.Descriptive Model of Dual Axis Sun Tracking Solar Panel

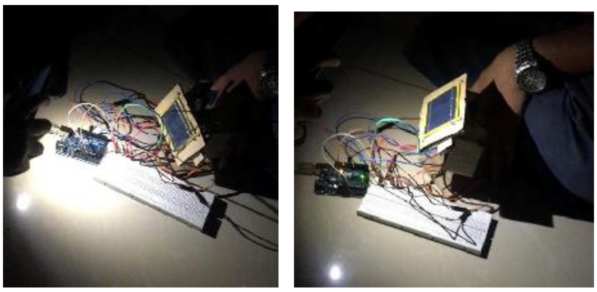

Fig.3. Working Demonstration of the prototype in a stimulated environment

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The stimulus used to demonstrate the effect of sun rays so as to create the necessary environment for the model to function, is a flashlight.

All the components used are very cost-effective, enabling an easy and economical approach to the problems stated.

III. SPECIFICATION OF THE COMPONENTS

A) ATmega 32S

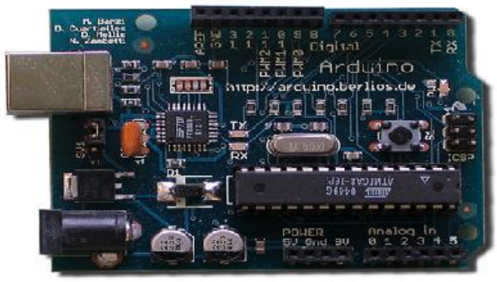

Fig.4. Atmel ATMega 328

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It has a 6-channel 10 bit A-D converter, programmable watchdog timer and five software selectable power saving modes. The device operates between 1.8 to 5.5V. The throughput is 1 MPS per MHz.

B) Servo Motor

Fig.5. Servo Motor

The Servo motor acts as a rotary/linear actuator, allowing it to precisely control the angular and linear position, velocity and acceleration. It also consists of a motor, which is coupled with a sensor to get a position feedback signal. Its closed loop servo mechanism uses position feedback to control its motion and final position. The motor is generally paired with an encoder to provide position and speed feedback. The measured position of the output is compared with the command position and if it differs from the required one, an error signal is generated which causes the motor to re-rotate in the required direction. As it reaches the required direction, the error signal is reduced to zero, stopping the motor.

C) Light Dependent Resisters

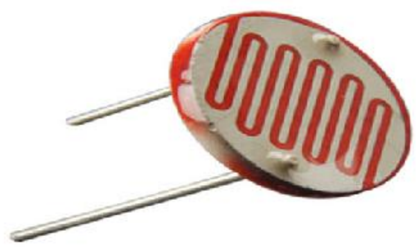

Fig.6. LDR

A light-dependent resisters, also known as photo detectors are light controlled variable resisters. Their resistance decreases with the increasing light intensity which falls on it. This phenomena depicting inverse relation between light and resistance is called photoconductivity. These photo resistors are composed of a high resistance semiconductor. They can have a resistance as high as few mega ohms, while s low as hundred in daylight. When the incident light exceeds a particular frequency, the electrons in the bounded region get enough energy to jump to the conduction band. The resulting electron-hole pairs conduct electricity.

CLASSIFICATION	SPECIFICATION
CPU Type	8-bit AVAR
Oscillating Frequency	16 MHz
Pin Count	14 digital pins, 6 analog pins
Flash Memory	32 KB
Ext Interrupts	2
EPROM	1KB
SRAM	2KB

IV. PROGRAM ALGORITHM

The algorithm is based on a comparison with reference values, and generation of an error signal, which is used to control the angle of the two servo motors.

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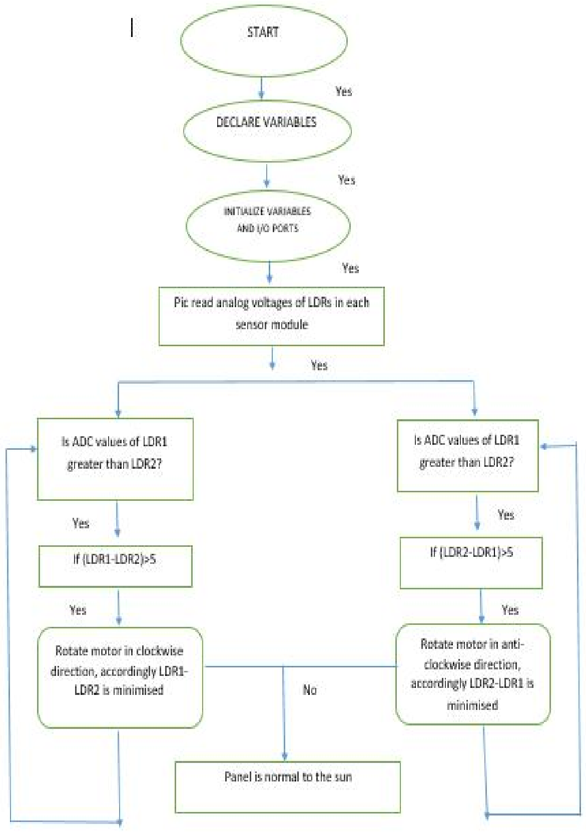

Fig.7. Program Flow Chart

In the code, horizontal and vertical servo motors are assigned to the variables – Servohori and Servoverti.

```
int servoh = 0;
int servohLimitHigh = 160;
int servohLimitLow = 20;

Servo servoverti;
int servov = 0;
int servovLimitHigh = 160;
int servovLimitLow = 20;
```

Fig.8.Servo Limits

The limits for the horizontal and the vertical angle is set as 20 and 160, so as to prevent collision between the solar panel backbone and horizontal plane, on which the setup is placed.

The top LDR 1 is assigned port 2 on the arduino, top LDR 2 is assigned port 1, bottom LDR 1 is assigned port 3 and bottom LDR 2 is assigned port 0. The analog values of the LDRs are taken using the analogRead() function. The input values of the respective LDRs are assigned to topl, topr, botl, botr.

```
int avgtop = (topl + topr) / 2; //average of top LDRs
int avgbot = (botl + botr) / 2; //average of bottom LDRs
int avgleft = (topl + botl) / 2; //average of left LDRs
int avgright = (topr + botr) / 2; //average of right LDRs
```

Fig.9.Calculating reference values (average)

The average intensity of the top quadrant of the system is calculated using the intensities of top left LDR and top right LDR.

Similarly, average of the bottom quadrant is calculated using intensities at bottom left LDR and bottom right LDR. The average intensity at left quadrant is calculated using top left LDR and bottom left LDR and average intensity at right quadrant is calculated using top right and bottom right LDRs.

The averages are calculated, in order to generate a reference value, to which the input value would be compared, thus generating an error voltage, which would be used to move the motor appropriately.

```
if (avgtop < avgbot)
{
  servoverti.write(servov +1);
  if (servov > servovLimitHigh)
   {
    servov = servovLimitHigh;
   }
  delay(10);
}
else if (avgbot < avgtop)
{
  servoverti.write(servov -1);
  if (servov < servovLimitLow)
{
  servov = servovLimitLow;
}
  delay(10);
}
else
{
  servoverti.write(servov);
}
```

Fig.10.Comparing input and reference, generating error signal and moving motors accordingly

If average top intensity is greater than average bottom, it means that the intensity f light in the top half is greater. Therefore, servov is incremented by 1 degree, so as to move the servo motor shaft in the vertical direction upwards, so as to get max intensity. The movement continues, until servo becomes equal to the vertical limit (160 deg). After reaching that point, the motor is stopped using a delay() function.

If average bottom intensity is greater than average top, it means that the lower intensity is greater, therefore the servov is decremented so as to move the motor downwards, till the minimum limit (20).

Similarly, the average of left and right are compared, in order to move the shaft along the horizontal axis using the increment/decrement on the servoh variable, towards the highest intensity (left or right)

The above two comparisons happen simultaneously, making it a dual axis system, therefore creating a movement in 3D plane.

V. OUTPUT

The above algorithm was implemented on a sunny day, under supervised conditions, where the two solar panels (one with and one without the sun tracking algorithm) were exposed to the sun rays. The voltage output of both the panels was measured using a multimeter and a table was plotted to demonstrate different values of voltage from both the panels at different times in the day (different sun angles)

Table 1: Values of voltage at different time intervals for sun tracker and fixed solar panels

Time	Voltage Without Sun Tracker	Voltage With Sun Tracker
11 AM	19.57 V	21.4 V
12 noon	13.97 V	22.66 V
1 PM	13.68 V	20.23 V
2 PM	13.28 V	21.34 V
3 PM	12.80 V	20.25 V
4 PM	12.75 V	19.85 V

From the above information, a graph was plotted in order to provide a pictorial comparison of the voltages at different times in the day, for the solar panel with and without the sun tracking mechanism.

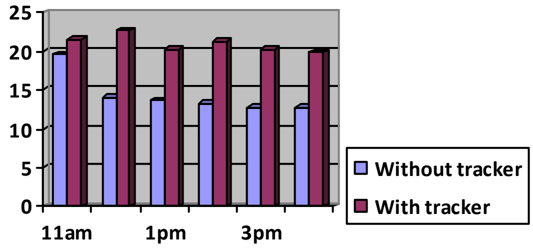

Fig.13. Relationship between Time Vs Voltage (V) for the two models.

From the above graph, it can be concluded that more voltage is generated by tracking solar panels which proves the better efficiency of trackers over fixed panels. More voltage is attributed to the fact that with changing time and availability of sunlight, the tracker keeps moving in such a way that the angle of incidence is always equal to 90 degrees, thus, making the efficiency greater than the fixed panels.

VI. CONCLUSIONS

This paper aims to give solutions to help people rely on a more energy efficient device which wouldn't exhaust like any other conventional source. The shortcoming of a fixed tracker is combated by using our prototype which points in a direction where the maximum energy can be extracted from the sun. The vital importance of a dual axis solar tracker lies in its better efficiency and sustainability to give a better output compared to a fixed solar panel or a single axis solar tracker. Through experimentation, we have also proved that we get 30-60% more efficiency from a tracking system as compared to fixed trackers.

This tracker finds its direct application in everyday households. They can be used as reliable backups and can be also very effective in remote areas where power lines are not accessible.

Above all, tracking systems can help in reducing emissions and contribute against global warming. They also enhance clean emission free production.

Some utilities offer the Time of Use (TOU) rate plans for solar power by few states, which implies that the utility will be purchased by the power generated during the peak time of the day at a higher rate. In this case, it is advantageous to generate a huge amount of electricity during the peak times of the day. Therefore, utilisation of a tracking system helps us in maximizing the energy which is gained during the peak time periods.

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