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Design and Fabrication of Sun Tracking Solar Panel with Automatic Panel Cleaning System

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ABSTRACT

Sun is a low cost source of electricity and instead of using the generators; solar panel can convert direct sun rays to electricity. Conventional solar panel, fixed with a certain angle, limits there area of exposure from sun due to rotation of Earth. In pursuing to get the maximum energy converted from the sun, an automatic system is required which should be capable to constantly rotate the solar panel. The automatic solar tracking system solves this problem. A microcontroller is used as the hardware along with the comparison unit of LDR values for detecting the ray strength and shift the panel towards the maximum output from the sun.Servo motor is used to rotate the panel to the desired position. The system tracks by comparing the intensity of light falling on the sensors. Based on the sensors output the motor can rotate the solar panel to meet the sun's maximum position.This system also connected with cleaning arm, which cleans the panel in suitable rotation with the help of the servo motor.This cleaning feature helps to increase the efficiency of the solar power.

I. INTRODUCTION

As the range of applications for solar energy increases, so does the need for improved materials and methods used to harness this power source. There are several factors that affect the efficiency of the collection process. Major influences on overall efficiency include solar cell efficiency, intensity of source radiation and storage techniques. The materials used in solar cell manufacturing limit the efficiency of a solar cell. This makes it particularly difficult to make considerable improvements in the performance of the cell, and hence restricts the efficiency of the overall collection process. Therefore, the most attainable method of improving the performance of solar power collection is to increase the mean intensity of radiation received from the source. There are three major approaches for maximizing power extraction in medium and large scale systems. They are sun tracking, maximum power point tracking or both. The solar tracker, a device that keeps photo voltaic or photo thermal panel in an optimum position perpendicularly to the solar radiation during daylight hours, can increase the collected energy from the sun by up to 40%.

Usually the fixed PV panels cannot follow the sun movement. Sun tracking systems have been studied with different applications to improve the efficiency of solar systems by adding the tracking equipment to these systems through various methods. A tracking system must be able to follow the sun with a certain degree of accuracy and returns the panel to its original position at the end of the day. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on the way they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limits the amount of solar energy that we can acquire.

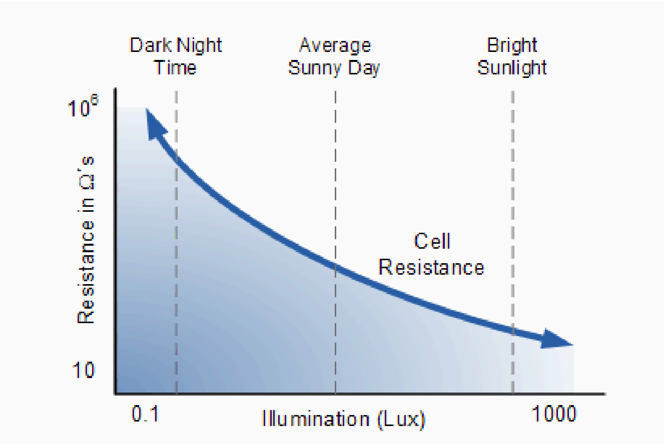
II. REGULATING SOLAR TRACKER

Light Dependent Resistor

To sense the light intensity, among many sensing device light sensors Light Dependent Resistor (LDR) has been chosen. An LDR is basically a resistor whose resistance depends on the intensity of light; Increase in the intensity of light decreases the resistance. LDRs are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes it is 1000000 ohms, but when they are illuminated with sun rays resistance falls dramatically. Some important features of an LDR is that its low in cost, simple to connect, it has moderate response time when exposed to light, it is bidirectional and it lasts long in the environment.

LDRs are connected to the controller circuit. When the sun moves from right to left, the incident light on the left LDR is more. Hence, the resistance of the left LDR decreases and vice versa. When the resistance of any particular LDR decreases, the controller circuit responses so that the panel is moved to the position of that particular LDR. Therefore, panel is always kept at the position where the light intensity is maximum and making the dual axis solar tracker to be more efficient. Below figure shows the block diagram of regulating a solar tracker.

The Contrast of LDR and Other Sensors: As light sensing components instead of LDR other light sensors such as, photodiode or phototransistors could also be used. Photo-diodes have quicker response time than an LDR, but that quicker response time would be unnecessary tracking sunlight. Besides, connection of LDR is simple since it is bidirectional whereas photodiodes are unidirectional. Moreover, photodiodes are digital in nature and would make the circuit more sophisticated. Some other drawbacks of photo-diodes in the solar tracking devices are that the photo-diodes are temperature sensitive and costly than LDRs. On the other hand, a photo-transistor is slower in response time. Phototransistors are basically used where one needs amplification of the light signal. In a solar tracker light amplification would also be unnecessary. Besides, phototransistors are temperature sensitive, unidirectional and needs sophisticated circuit design. The Characteristics of LDR with respect to solar radiation is shown in figure.



III. SERVO MOTOR

A servo motor is a rotary actuator that allows for precise control of angular position. It consists of a motor and a sensor for feedback position. A drive is used to collect the feedback from the sensor to precisely control the position of the motor. There are two kinds of servo motor, standard and continuous. The former is a geared down motor that has limited range of rotation. It uses internal electronics to identify the current angle of the motor and Arduino and the Continusousservo.h library can be utilized to turn the motor. Continuous servo motor does not have a limit on its range of motion, so instead of the having the input signal determine which position the servo should rotate to, it relates the input to the rotary speed and direction. The control is performed using a pulse train signal, typically with pulses that vary from 1 to 2 milliseconds, sent every 20 milliseconds (50 Hz). A one millisecond pulse corresponds to full speed in one direction, while a two millisecond pulse is full speed in the other direction. These pulses are easy to generate using the pulse-width-modulation hardware on a modest microcontroller. Halfway between those extremes, a 1.5 millisecond pulse should cause the motor to stop.

We are using MG995 continuous servo motor.

Below are examples of how the library function works:

servo.step(100); // Gives the servo 100 pulses, a 2ms pulse every 20ms. The servo turns right for approx 2sec.

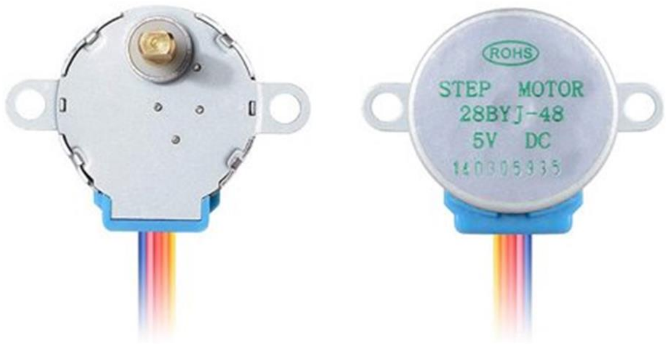
servo.step(-100); // Gives the servo 100 1ms pulses, making it turn left instead

IV. CLEANING MECHANISM

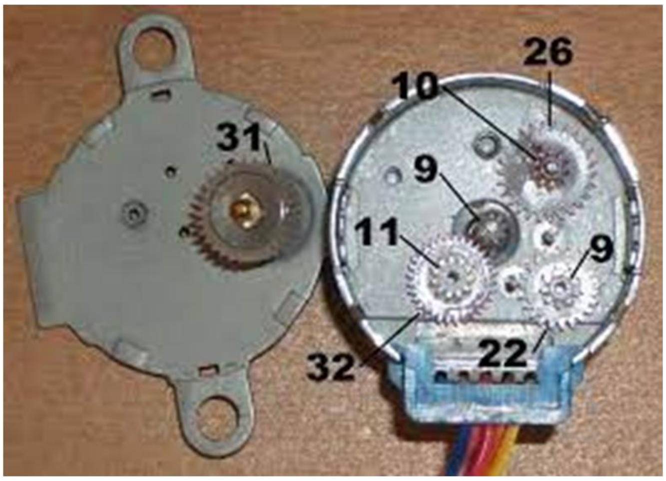
Stepper Motor

A stepper motor is a brushless DC motor that can be commanded to move and hold its position in particular angle. Basically, this motor divides a full rotation into equal steps, therefore, they are called stepper. They are usually found in desktop printers, 3D printers, CNC milling machines, and anything else that requires precise positioning control. These stepper motors use a cogged wheel (having 32 teeth) and four electromagnets to rotate the wheel one 'step' at a time. Each HIGH pulse sent, energizes the coil, attracts the nearest teeth of the cogged wheel and drives the motor one step.

In our project we are using 28BYJ-48 stepper motor.



According to the data sheet, when the 28BYJ-48 motor runs in full step mode, each step corresponds to a rotation of 11.25°. That means there are 32 steps per revolution (360°/11.25° = 32).



In addition, the motor has a 1/64 reduction gear set. (Actually its 1/63.68395 but for most purposes 1/64 is a good enough approximation), what this means is that there are actually 32*63.68395 steps per revolution = 2048 steps.

Gear Ratios:

- 32 / 9
- 22 / 11
- 26 / 9
- 31 / 10

Multiplying the gear ratios:

$$\frac{32}{9} \times \frac{22}{11} \times \frac{26}{9} \times \frac{31}{10} = 63.68395$$

Round 63.68395 up: 64

To calculate steps per mm for linear motion with belts and pulleys:

$$\frac{s_{rev} \cdot f_m}{p \cdot N_t}$$

srev is the number of steps per revolution for the motor =2048

fm is the microstepping factor = 1

p is the pitch =2

Nt is the number of teeth on the pulley attached to the motor shaft.=16.

which gives the resolution of 64 steps per mm.

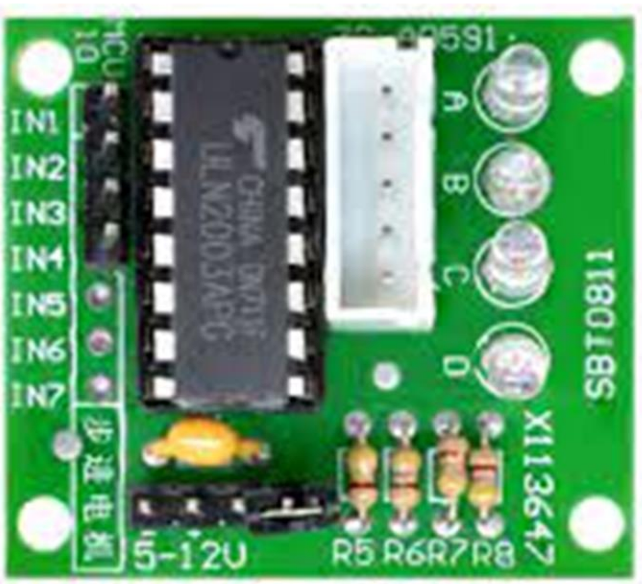
The distance brush should travel to reach other side= 260mm.

Number of steps required= distance x resolution= 16640.

Number of revolution = 8 (approx)

V. ULN2003 DRIVER BOARD

The ULN2003 is one of the most common motor driver ICs, consisting of an array of 7 Darlington transistor pairs, each pair is capable of driving loads of up to 500mA and 50V. Four out of seven pairs are used on this board.

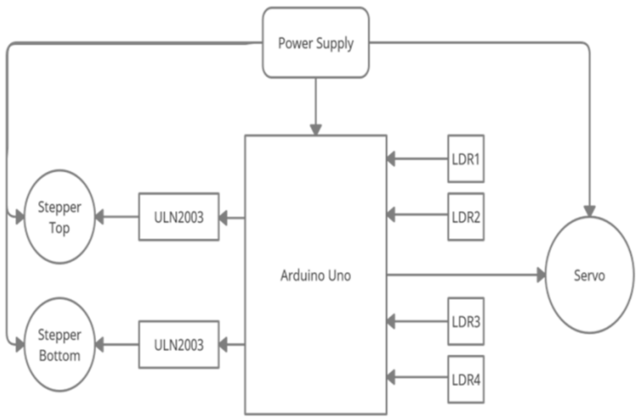


The board has a connector that mates the motor wires perfectly which makes it very easy to connect the motor to the board. There are also connections for four control inputs as well as power supply connections. The board has four LEDs that show activity on the four control input lines (to indicate stepping state). They provide a nice visual when stepping. The board also comes with an ON/OFF jumper to isolate power to the stepper Motor.

VI. CONTROL CIRCUIT

In our model we used Arduino UNO (ATMEGA328p) for controlling the solar tracking system. In control circuit, PORTC (A0 to A4) is used for input where 4 LDRs are connected. Two LDRs are placed on top and other two are placed at bottom of panel to track sun on azimuth plane. The PWM pin of servo motor is connected to PORTD 6th pin (D6). PORTB (PB0-PB3), which are D8 to D11 of UNO board, are connected to the motor controller IC-ULN2003 of stepper motor.

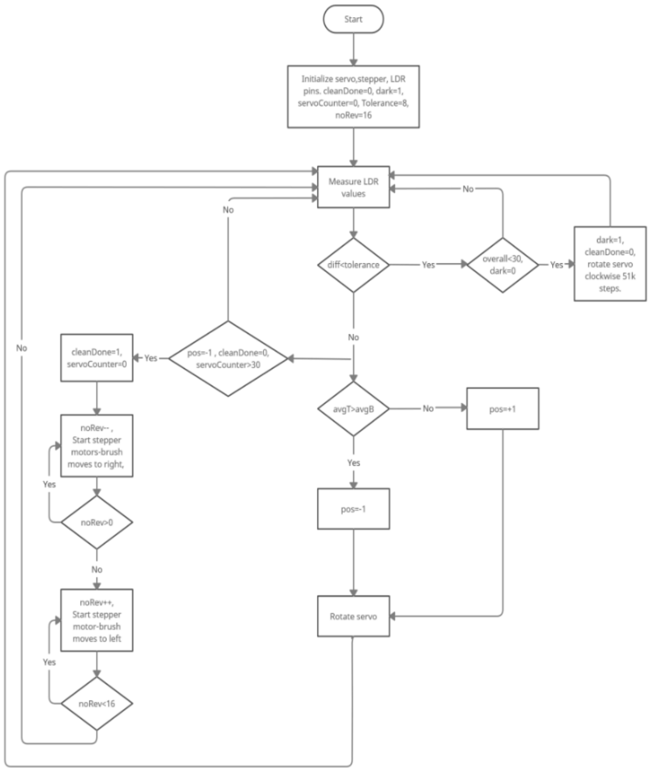
For Programming purpose we consider the voltage drop across LDRs as V1, V2, V3 and V4. ADC converter is needed for getting the actual analog value of voltages at LDRs. The tracking system will start with the comparison of running average of top and bottom LDR values after ADC conversion. The cleaning mechanism is done in a manner that it cleans the panel once a day. A belt and pulley system is attached to top and bottom of the panel so that the brush can slide from left to right when cleaning.



Block diagram

VII. ALGORITHM OF MICROCONTROLLER CIRCUIT

Upon powering the circuit, servo motor is initialised to stay at whichever position it has been placed .It will then start taking running average of LDR values after conversion and compare it. If the difference is less than 8(tolerance), the overall average is checked if it is greater than 100 and a variable named dark is set to indicate its day. But if its less than 30 and variable dark is zero(night), variable dark is set to 1, clean variable cleanDone is made 0(to allow cleaning the next day) and panel is rotated clockwise atleast 51k steps to east side so that it faces the sun upon sunrise. If the difference exceeds 8, then the servo motor is rotated in a manner that the side which receives least sun light moves counter clockwise (pos =-1) or clockwise (pos =+1) so that difference between top and bottom falls to tolerance value.The pos variable value is used by servo motor to decide to which direction it should rotate. Tolerance value was selected after testing against different situations. The cleaning mechanism activates when it is day time and servo motor has moved at least 30 times. The stepper motor is made to take 16384 steps to and fro to clean from left to right and back. In the program its designed to make 1024 step per every pos= +/-1 execution. Hence in total 16 times of previous statement is needed to be executed to achieve 8 revolution ot cover length of panel..



Flow chart

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