Microcontroller Based Dual Axis Solar Tracking System

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Abstract: Renewable energy solutions are becoming increasingly popular. Photovoltaic (solar) systems are but one example. Maximizing power output from a solar system is desirable to increase efficiency. In order to maximize power output from solar panels, one needs to keep the panels aligned with the sun. As such, a means of tracking the sun is required. This is definitely a more cost effective solution than purchasing additional solar panels. It has been estimated that the yield from solar panels can be increased by 30 to 60 percent by utilizing a tracking system instead of a stationary array. The solar panel perpendicular to the sun throughout the year is more efficient. In this paper, a new micro-controller based solar-tracking system is proposed, implemented and tested. Here the dual axis solar panel takes astronomical data as reference and the tracking system has the capability to always point the solar array toward the sun and can be installed in various regions with minor modifications. The vertical and horizontal motion of the panel is obtained by taking altitude angle and azimuth angle as reference. The micro - controller has been used to control the position of DC motors. The mathematical simulation control of dual axis Photovoltaic solar tracking system ensures the point to point motion of the DC motors.

Keywords: Solar panel; LDR; Microcontroller; Stepper motor; Dual beam tracker.

1 Introduction

The world population is increasing day by day and the demand for energy is increasing accordingly. Oil and coal as the main source of energy nowadays, is expected to end up from the world during the recent century which explores a serious problem in providing the humanity with an affordable and reliable source of energy. The need of the hour is renewable energy resources with cheap running costs. Solar energy is considered as one of the main energy resources in warm countries. In general, India has a relatively long sunny day for more than ten months and partly cloudy sky for most of the days of the rest two months. This makes our country, especially the desert sides in the west, which include Rajasthan, Gujarat, Madhya Pradesh etc. very rich is solar energy. Many projects have been done on using photovoltaic cells in collecting solar radiation and converting it into electrical energy but most of these projects did not take into account the difference of the sun angle of incidence by installing the panels in a fixed orientation which influences very highly the solar energy collected by the panel.

The aim is to keep the solar panel perpendicular to the sun throughout the year in order to make it more efficient. The dual axis solar panel takes astronomical data as reference and the tracking

ISSN: 2222-7059 (print), ISSN: 2222-7067 (online), http://www.aspbs.com/aiem
DOI: 10.7508/aiem.2016.02.010

system has the capability to always point the solar array toward the sun and can be installed in various regions with minor modifications. The vertical and horizontal motion of the panel is obtained by taking altitude angle and azimuth angle as reference. Through the ARDUINO Board using the microcontroller programming the position of DC motor is controlled to control the dual axis solar tracking system for tracking the sun.

2 DISTRIBUTION OF SOLAR RADIATION ON EARTH SURFACE

Sunlight has two components, the direct beam and diffuse beam. Direct radiation (also called beam radiation) is the solar radiation of the sun that has not been scattered (causes shadow). Direct beam carries about 90% of the solar energy, and the "diffuse sunlight" that carries the remainder. As the majority of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible.

2.1 Declination Angle-

The declination of the sun is the angle between the equator and a line drawn from the centre of the Earth to the centre of the sun. The declination angle, denoted by δ, varies seasonally due to the tilt of the Earth on its axis of rotation and the rotation of the Earth around the sun.

However, the Earth is tilted by 23.45° and the declination angle varies plus or minus this amount. Only at the spring and fall equinoxes is the declination angle equal to 0°.

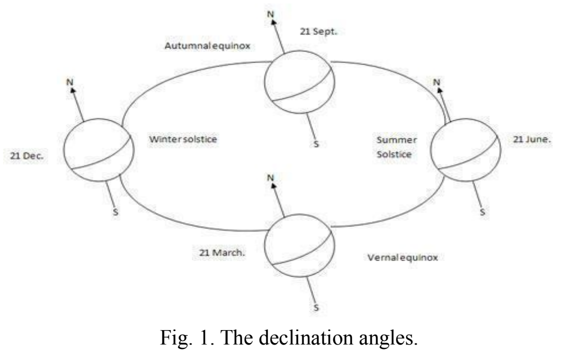

Fig. 1. The declination angles.

2.2 Hour Angle-

The Hour Angle is the angular distance that the earth has rotated in a day. It is equal to 15 degrees multiplied by the number of hours from local solar noon. This is based on the nominal time, 24 hours, required for the earth to rotate once Solar hour angle is zero when sun is straight over head, negative before noon, and positive after noon.(here noon means 12.00 hour

2.4 Solar Altitude (θz)-

The solar altitude is the vertical angle between the horizontal and the line connecting to the sun. At sunset/sunrise altitude is 0 and is 90 degrees when the sun is at the zenith. The altitude relates to the latitude of the site, the declination angle and the hour angle.

Solar Azimuth (θA)- The azimuth angle is the angle within the horizontal plane measured from true South or North. The azimuth angle is measured clockwise from the zero azimuth. For example, if you're in the Northern Hemisphere and the zero azimuth is set to South, the azimuth angle value will be negative before solar noon, and positive after solar noon.

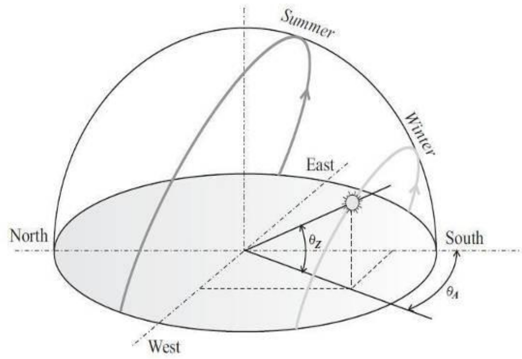

Fig. 2. Solar altitudes and azimuths typical behavior of sun path.

2.5 Insolation

Insolation is a measure of solar radiation energy received on a given surface area and recorded during a given time. It is also called solar irradiation and expressed as hourly irradiation if recorded during an hour. The unit recommended by the World Meteorological Organization is MJ/m^2 (mega joules per square meter) or J/cm^2

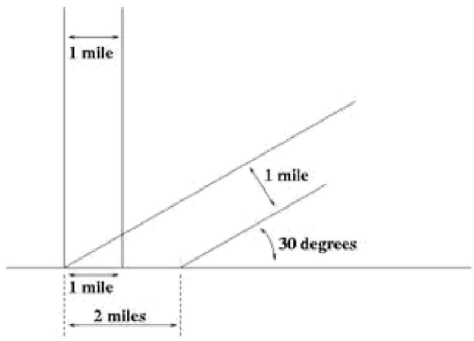

Fig. 3. One beam one mile wide shines on the ground at a 90° angle, and another at a 30° angle. The one at a shallower angle distributes the same amount of light energy over twice as much area.

3 PROJECTION EFFECT

The insolation into a surface is largest when the surface directly faces the Sun. As the angle increases between the direction at a right angle to the surface and the direction of the rays of sunlight, the insolation is reduced in proportion to cosine of the angle; Due to this 'projection effect' the Polar Regions are much colder than equatorial regions on Earth.

4 DESIGN OF SOLAR TRACKER

4.1 Panel Design

The solar tracker consists LDR(Light depended resister) array along with the azimuth-altitude dual axis tracker system . In flat-panel solar applications trackers are used to minimize the angle of incidence between the incoming light and a solar panel. This increases the amount of energy produced by the array.

Here we can use azimuth-altitude dual axis trackers (AADAT). Dual axis trackers extract the maximum solar energy levels due to their ability to follow the sun vertically and horizontally. No matter where the sun is in the sky, dual axis trackers are able to angle themselves to be in direction toward the sun. Here Two DC motors are used to drive the two rotational degrees of freedom.

Each LDR is connected to power supply forming a potential divider. Thus any change in light density is proportional to the change in voltage across the LDR's.

4.2 Servo System

The tracking systems would need to consist of two motors, which control the position of the array, and a control circuit (either analog or digital) to direct these motors. The following sections discuss some possible types of motors that could be used for this type of application.

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4.3 Controller sections

Input Module:

Arduino has an inbuilt 10-bit Analog to Digital converter(ADC), hence itcan provide Digital values from 0-1023.(since 2^10=1024). We can also set the

ADC reference voltage in arduino, but here we'll let it use default value. LDR's has two pins, and to get voltage value from it we use potential divider circuit. In potential divider we get V_{out} corresponding to resistance of LDR which in turn is a function of Light falling on LDR. The higher the intensity of light, lower the LDR resistance and hence lower the Output voltage (V_{out}) And lower the light intensity, higher the LDR resistance and hence higher the V_{out}.

Output Module:

Arduino has a 8-bit PWM generator, so we can get up to 256 distinct PWM signal. To drive a servo we need to get a PWM signal from the board, this is usually accomplished using timer function of the microcontroller but arduino makes it very easy. Arduino provides a servo library in which we have to only assign servo angle (0-1800) and the servo rotates by that angle, all the PWM calculations are handled by the servo library and we get a neat PWM signal according to the desired angle.

Controller Module:

The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

4.4 SYSTEM DESIGN

The purpose of a solar tracker is to accurately determine the position of the sun. This enables solar panels to interface to the tracker to obtain the maximum solar radiation. With this particular solar tracker a closed loop system was made.

The electrical system consists of five LDR sensors which provide feedback to a micro controller. This micro controller processes the sensor input and provides two PWM signals for the movement of servo motors.

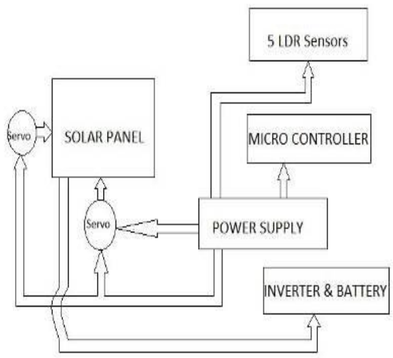

Fig. 3. Block diagram of overall system.

This servo motor moves the solar panel towards the higher density of solar light. The entire electrical system is powered by a 12 volt source power supply.

Initially five different analog values are obtained from LDR's, and then they are feed to micro controller. Micro controller gives two different PWM signal for the movement of solar panel through servo motor.

4.5 Program Segment:

```
include <servo.h>
Servo servo1;
Servo servo2;
int pos1=0;
int pos2=0;
int up=0;
int down=0;
int right=0;
int left=0;
int centre=0;
int ldr1=0;
int ldr2=0;
int ldr3=0;
int ldr4=0;
int ldr5=0;

void setup ()
{
    servo1.attach(10);
    servo1.write(90);
    servo2.attach(9);
    servo2.write(90);
    pinMode(ldr1, INPUT);
    pinMode(ldr2,INPUT);
    pinMode(ldr3, INPUT);
    pinMode(ldr4, INPUT);
    pinMode(ldr5, INPUT);
}
void loop ()

{
pos1=servo1.read();
pos2=servo2.read();

int up= analogRead(ldr1);
int down= analogRead(ldr2);
int centre= analogRead(ldr3);
int right= analogRead(ldr4);
int left= analogRead(ldr5);
//for conrol of vertical i.e. up-down(east-west)
position

if (up>centre << down<centre)

{
servo1.write(pos1+1);
delay(10);
}
else if (down>centre << up<centre)
{
servo1.write(pos1-1); delay(10);
}
else
{
servo1.write(pos1);
delay(10);

}
//for control of horizontal i.e.right-left (south-
north) position
if (right>centre << left<centre)
{
servo2.write(pos2+1);
delay(10);
}
else if (left>centre << right<centre)
{servo2.write(pos2-1);
delay(10);}
```

5 CONCLUSIONS

The paper has presented a novel and a simple control implementation of a Sun tracker that employed a single dual-axis Stepper motor to follow the Sun and used a stand-alone PV inverter to power the entire system. The proposed motor design was simple and self-contained, and through microcontroller programming its movement can be easily controlled. A laboratory prototype has been successfully built and tested to verify the effectiveness of the control implementation. Experiment results shows that the developed system increased the energy gain up to 28.31% for a partly cloudy day. The proposed methodology is an innovation so far. It achieves the following attractive features: (1) a simple and cost-effective control implementation, (2) a stand-alone PV inverter to power the entire system, (3) ability to move the two axes simultaneously within their respective ranges, (4) ability to adjust the tracking accuracy, and (5) applicable to moving platforms with the Sun tracker. The empirical findings lead us to believe that the research work may provide some contributions to the development of solar energy applications.

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