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Low Cost Solar Tracker Using Gearbox and Timer Circuit

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ABSTRACT: Solar technology has great potential in terms of supplying the world's energy demands. The effective way of using sunlight with solar energy concentration technology and solar tracking system is discussed in this paper. The present status of application and the ongoing research and development work suggest that parabolic dish solar concentrators coupled with solar trackers will bring a breakthrough of commercial solar energy concentration application technology in the coming years. The paper is focused on increasing the efficiency of parabolic dish concentrator using solar tracker. This paper will provide an up-to-date review of solar parabolic dish concentrators and their benefits to make solar technology affordable.
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KEYWORDS: Solar tracker, Parabolic dish.

I. INTRODUCTION

Solar energy is a dilute form of energy, but the amount of solar energy that is incident on earth's surface is capable of solving our energy demands. It is thus required to utilize maximum energy incident on earth. Parabolic trough is a device which concentrates sun's rays at its focal point, it is possible for it to concentrate the rays towards its focal point due to the geometric properties, but it can only happen when the sun's rays are perpendicular to the surface of the concentrator. As the earth rotates the position of sun changes according to the time and this changes the focal point position. To overcome this problem it is necessary to track the path of the sun which will continuously keep the concentrator perpendicular to sun's rays. The sunlight incidence angle constantly varies, not only during the daytime, but it also changes drastically during the different seasons of the year. Moving the concentrator in order to track the sun can significantly improve the energy output. Tracking sun will help keeping the focal point at the same position due to which the temperature obtained will me maximum and the efficiency of the unit will increase. Also it has to be taken into consideration that the amount of energy the tracker will utilize to track the sun should be minimum, otherwise it will be of no use if the tracker utilizes more energy than the increased energy in concentrator. Another point which has an impact is the cost consideration, already the solar equipment are costlier compared to devices working on conventional sources. Hence the tracker system which is an additional unit should not cost much. In this paper we have focused on developing a solar tracker which will have less initial cost also it will have very less running cost compared to the trackers that are available.

In this paper we have designed solar tracker for parabolic dish which can be used for process heating, thus with the use of this solar tracker we can have a fully automated unit which will require no human operator to change the concentrator position according to the position of the sun.

II. LITERATURE REVIEW

2.1 Need of Solar Tracker

Sunlight has two components, the "direct beam" that carries about 90% of the solar energy, and the "diffuse sunlight" that carries the remaining - the diffuse portion is the blue sky on a clear day and increases proportionately on cloudy days. As the major part of the energy is in the direct beam, maximizing the collection requires the Sun to be visible to

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the panels as much as possible. The energy contributed by the direct beam decreases with the cosine of the angle between the incoming light and the panel. Also, the reflectance (averaged across all polarizations) is almost constant for angles of incidence up to around 50°, beyond which reflectance decreases rapidly. For example, trackers that have accuracies of ± 5° can obtain greater than 99.6% of the energy delivered by the direct beam plus 100% of the diffuse light. As a result, high accuracy tracking is not typically used in non-concentrating PV applications. The Sun travels through 360 degrees east to west per day, but from the perspective of any fixed location the visible portion is 180 degrees during an average 1/2 day period (more in spring and summer; less, in fall and winter). Local horizon effects reduce this somewhat, making the effective motion about 150 degrees. A solar panel in a fixed orientation between the dawn and sunset extremes will see a motion of 75degrees to either side, and thus, according to the table above, will lose 75% of the energy in the morning and evening. Rotating the panels to the east and west can help recapture those losses. A tracker rotating in the east–west direction is known as a single-axis tracker. The Sun also moves through 46 degrees north and south during a year. The same set of panels set at the midpoint between the two local extremes will thus see the Sun move 23 degrees on either side, causing losses of 8.3% A tracker that accounts for both the daily and seasonal motions is known as a dual-axis tracker. Generally, the losses due to seasonal angle changes is complicated by changes in the length of the day, increasing collection in the summer in northern or southern latitudes. This oblique collection toward the summer, so if the panels are tilted closer to the average summer angles, the total yearly losses are reduced compared to a system tilted at the spring/fall solstice angle (which is the same as the site's latitude).There is considerable argument within the industry whether the small difference in yearly collection between single and dual-axis trackers makes the added complexity of a two-axis tracker worthwhile. A recent review of actual production statistics from southern Ontario suggested the difference was about 4% in total, which was far less than the added costs of the dual-axis systems. This compares unfavourably with the 24-32% improvement between a fixed-array and single-axis tracker. [1]

2.2 Types of Solar Tracker

- Single-axis solar tracker
- Dual-axis solar tracker

2.2.1 Single axis solar tracker

Single axis trackers have one degree of freedom that acts as an axis of rotation. The axis of rotation of single axis trackers is typically aligned along a true North meridian. It is possible to align them in any cardinal direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), horizontal single axis tracker with tilted modules (HTSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT). The orientation of the module with respect to the tracker axis is important when modelling performance. [2][3]

2.2.2 Dual axis solar tracker

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis. There are several common implementations of dual axis trackers. They are classified by the orientation of their primary axes with respect to the ground. Two common implementations are tip-tilt dual axis trackers (TTDAT) and azimuth-altitude dual axis trackers (AADAT). The orientation of the module with respect to the tracker axis is important when modelling performance. Dual axis trackers typically have modules oriented parallel to the secondary axis of rotation. Dual axis trackers allow for optimum 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 direct contact with the Sun. [3]

2.3 Reduction gearbox

Number of gears are used and brought in mesh with each other in pair to reduce the input speed as per the required output speed. The reduction in speed increases the torque. As per the cost consideration and market survey the calculations were done according to the availability of the gear.

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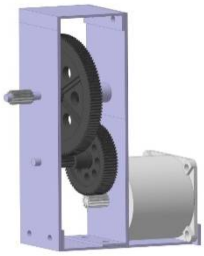

Fig 1: CATIA model of reduction gearbox

Fig. 1 Has the 3 dimensional view of the reduction gearbox that we have used for the tracker system which has been made using CATIA software, this figure shows how the gearbox has been assembled along with the position of motor and gears.

III. TRACKER DESIGN

- Motor Specifications
- Gearbox Calculations
- Timer Circuit

3.1 Motor Specifications:
Type: 2 phase synchronous motor
Input: 240 V AC
Torque: 10 kg-cm
Speed: 60 RPM
Line amps: 0.15 A
Wattage: 34.5 W
As the motor output speed is higher than the rotation speed of the earth a reduction gearbox is required.

3.2 Gearbox calculations**:**
Motor output speed**-** 60RPM
Shaft 1, which is connected to motor carries a 12teeth gear.
Shaft 2, carries a 72 teeth gear which is in mesh with 12teeth gear on shaft 1, hence the output speed of shaft 2,

$$\frac{72}{12} = \frac{60}{?}$$

Therefore, the speed of shaft 2 i.e. stage 1 = 10rpm
Further shaft 2 carries a 12 teeth gear
Shaft 3, carries a 120 teeth gear which is in mesh with 12 teeth gear on shaft 2, hence output speed of shaft 3,

$$\frac{120}{12} = \frac{10}{?}$$

Therefore, the speed of shaft 3 i.e. stage 2 = 1rpm

Further shaft 3 carries a 12 teeth gear
Shaft 4, which carries a 120 teeth gear which is in mesh with 12 teeth gear on shaft 3, hence output speed of shaft 4,

$$\frac{120}{12} = \frac{1}{?}$$

Therefore, the speed of shaft 4 i.e. stage 3 = 0.1rpm
1rpm = 360°
Therefore 0.1rpm = 0.1 × 360°
0.1rpm = 36°

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For 60 seconds 36°
Therefore for 1 second = 36 ÷ 60 = 0.6°
Hence for 1 second the shaft 4 will rotate by 0.6°
But the earth's rotation speed is 0.25°/min
Within 12 minutes earth rotates by 3°
To match this amount of rotation the motor should run for 5seconds
Therefore after 5 seconds rotation of shaft 4 = 0.6° × 5 = 3°
If earth rotates by 3° in 12minutes also the reflector which is connected to shaft 4 should rotate by 3° in 12 minutes
Hence this condition can be satisfied if motor is switched off for 715 seconds and after completion of 715 seconds the motor is switched on and kept on for next 5 seconds. Hence at the end of 12 minutes the earth's rotation will be 3° and also the reflector will be moved by 3°.

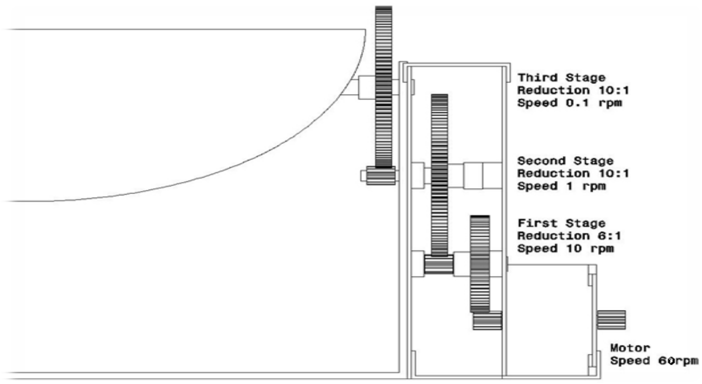

Fig 2: Gearbox stage wise speed reduction

Fig. 2 schematically shows speed reductions achieved at different stages in the gearbox using various gear ratios at each stage to attain the required speed at the final stage i.e. at the parabolic dish.

3.3Timer circuit:

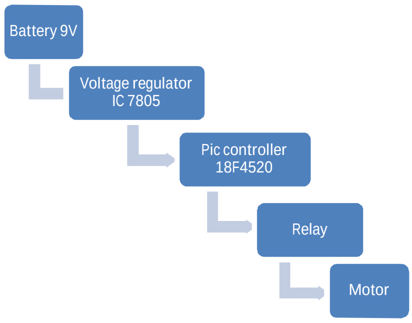

Fig 3: Block diagram of timer circuit

Fig. 3 shows different components used in the timer circuit so as to achieve the delay that is required for the tracker to work more efficiently and accurately

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3.3.1 Microcontroller

As it is required to generate pulse of 5 seconds after every 715 seconds, it is necessary to use delay circuit so that the motor will not consume energy when it is stationary and will consume energy only for 5 seconds when switched ON. Microcontroller is a programmable device which can be programmed to generate required delay.

Microcontroller 18F4520 has been used as it based suits our application

Software used: Proteus for simulation

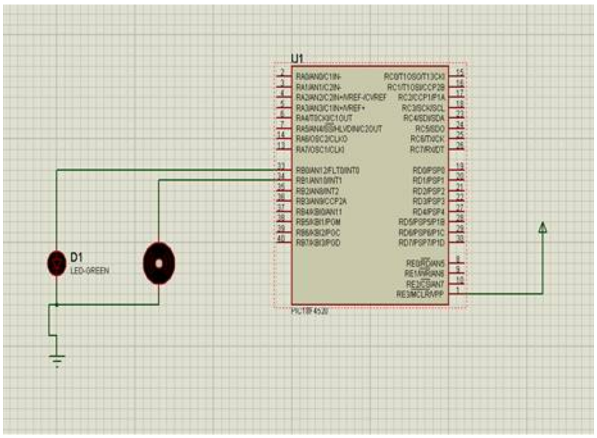

Fig 4: Interfacing diagram

Fig. 4 illustrates the successful simulation of microcontroller 18F4520 in Proteus.

Microcontroller Program (Software used: MPLAB X IDE for programming)

```
#include<stdio.h>
#include<conio.h>
#include"p18f4520.h"
#include"config.h"
void delay_5(void);
void delay_715(void);
void main()
{
   TRISB=0X00;
while(1)
   {
      PORTB=0xFF;
      delay_5();
      PORTB=0x00;
      delay_715();
   }
}
void delay_5()
{inti;
for(i=0;i<2;i++)
{
   INTCONbits.TMR0IE=1;
```

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```
   INTCONbits.TMR0IF=0;
   T0CON=0x07;
   TMR0L=0x68;
   TMR0H=0x67;
   T0CONbits.TMR0ON=1;
while(INTCONbits.TMR0IF==0)
   {}
}
}
void delay_715()
{inti;
for(i=0;i<357;i++)
{
   INTCONbits.TMR0IE=1;
   INTCONbits.TMR0IF=0;
   T0CON=0x07;
   TMR0L=0x68;
   TMR0H=0x67;
   T0CONbits.TMR0ON=1;
while(INTCONbits.TMR0IF==0)
   {}
}
}
```

IV. RESULTS

Motor consumption = 34.5 W
1 electric unit = 1 KW-hr
Number of hours required by motor to consume 1 electric unit = 29 hours
Because of timer circuit, motor runs for 5 seconds in every 12 minutes. Therefore it runs for 25 seconds in every hour.
Assuming 10 hours of working every day, motor will run for 250 seconds i.e. 4.16 minutes/day
29 hours = 1740 minutes
Therefore number of days tracker should work to complete 1 electric unit = $\frac{1740}{4.16}$ = 418 days 6 hours 27 minutes 21 sec.

V. CONCLUSION

Thus we have successfully designed a solar tracker using gearbox and timer circuit which has low initial cost as there are no sensors used and very less running cost, making it economical to use with a single parabolic dish. With the use of this tracker, we have been able to bring automation in solar technology at domestic level, as human interference is eliminated.

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