Design and Fabrication of Periodic Tracking System for Solar Collectors

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Abstract - *A periodic tracking system for single axis motion gives the motion of angular lift to the collector. As the sun travels from east to west the trajectory of the sun changes every day by tilting towards the south direction. The tracking system is used to tilt the collector facing the south direction to keep it perpendicular to the sun by changing the tilt angle. This system will increase the efficiency of the collectors and will take the utmost use of solar energy. This system uses a chain sprocket mechanism to convert the rotational motion of the motor to angular lift motion to the frame. This tracking system can be used for any collector which requires an angular periodic lift to increase efficiency. The angular lift motion takes place as the frame is attached to hinges at one end and the other end is attached to a chain which has linear motion but as it is hinged at one end angular lift takes place. The tilt angle given to the system depends upon the latitude and date at which the collector is located.*

Key Words: *Tracking system, tilt angle, chain sprocket, Angular lift motion.*

1. INTRODUCTION

The sun travels from east to west but actually the trajectory of the sun changes every day by slightly tilting towards the south direction which is for Pune. So, to make our solar collectors more effective the idea of a tracking mechanism is used.

A periodic tracking system is a mechanism that is used to track the periodic motion of the sun and accordingly lift the frame. The main motive of this project is to give a single-axis motion to the collector by converting rotational motion to angular lift motion. This is achieved with the help of a Chain sprocket mechanism controlled by a stepper motor.

The tracking system is used for angular lift motions, we are considering solar collectors as an example but this mechanism can be used for any collector in use of the periodic angular lift. India has the advantage of abandoning sunlight so to take utmost use of solar energy this tracking system is needed. As renewable sources are in need this will help in generating more energy in less time. Industries use large-scale solar collectors so to make manual systems automated this system is needed to save human efforts and time.

2. AIMS AND OBJECTIVES

Our aim is to design an automated tracking system which can lift the collector and keep it in the perpendicular direction of the sun which has a maximum intensity between 9am to 3 pm to gain the utmost use of solar energy. Our objective is to use advanced technology yet simple techniques to save human time and efforts by using knowledge gained so far.

To save human time as well as unnecessary human efforts which would have been invested in trial-and-error methods, while optimizing the design and increasing the efficiency of collectors we are designing this tracking system with 1o accuracy from the required results.

A ready-to-use system is made for industries to test different dates and according to the accuracy of the lift. By considering all the analytical aspects, this mechanism is quite simple yet durable.

3. LITERATURE REVIEW

Solar energy is renewable energy used everywhere, in this paper explanation of solar trackers and fixed PV solar systems and a comparison of the efficiency of single-axis solar trackers and fixed solar PV panels. Solar trackers produce electricity in large amounts because of their tracking technology, solar panels always track the sun as compared to the fixed mount PV system. The solar system produces more energy when the sun is perpendicular to the PV panel. At a perfect angle, the solar system consumes a large number of solar rays and produces electrical energy. Solar trackers can adjust their angle towards the sun automatically, therefore they produce more energy. Fix mount PV panels are constructed at a fixed angle so they cannot consume sun rays all day.

Previously there were many projects related to solar tracking systems that improved the efficiency of the system. The following is the review paper on single-axis solar tracking systems based on their mode of rotation.

Mayank Kumar Lokhande [1] presented an automatic solar tracking system. He designed a solar panel tracking system based on a microcontroller and observed that a single axis tracker increases efficiency by 30% compared to the fixed module.

Guiha Li, Runsheng Tang, Hao Zhong [2] investigated horizontal single-axis tracker solar panels. They obtained results as east-west axis tracking was poor to improve the energy while tracking the sun about north-south was best. The efficiency increased for east-west.

Chaiko and Rizk [3] developed a tracking system using solar panels efficiently. They designed a simple single-axis tracking system using a stepper motor and light sensor. They observed that this system stretches the efficiency of power collection by keeping a solar panel perpendicular to the sun's rays. And they also found that the power gain was increased by 30% over a static PV system.

Ashwin R, Varun A.K et al. [4] presented a sensor-based single-axis solar tracker to achieve the highest degree of energy through solar panels. It keeps tracking continuously for the maximum strength of light.

4. METHODOLOGY

A. Design and Manufacturing-based project:

First, we found out our common grounds and decided to do a self–sponsored project in design and manufacturing.

B. Literature review:

We started finding out new ideas, and different research papers related to new age topics and shortlisted some topics, after various brainstorming sessions we decided to proceed with the tracking system project.

C. Calculations:

To find the mechanism we assume certain data to carry out the calculations to finalize the chain sprocket mechanism. After that we did all the necessary calculations for the mechanism dimension and material specifications.

D. Simulation:

We did a 1:3 scale prototype to simulate our system and to confirm if the calculations are correct. The fig. below shows the prototype model of our system

Figure 1: Prototype

E. Design Process:

After simulating our system, we made some changes to the formation and designed it according to the calculated data. We did our design on SOLIDWORKS 2019.

F. Manufacturing process:

After fixing the design and conforming all the dimensions and material used, we started our manufacturing process which includes welding, laser cutting, laser engraving Etc.

5. EXPERIMENTAL SETUP

A. Module 2 Tracking System:

A solar collector is oriented with its focal axis pointed either in the east-west or the north-south direction. In the east-west orientation, the focal axis is horizontal, while in the north-south orientation, the focal axis may be horizontal or inclined.

Mode II

The focal axis is east-west and horizontal. The collector is rotated about a horizontal E-W axis and adjusted continuously so that the solar beam makes the minimum angle of incidence with the aperture plane at all times.

In this mode also, the aperture plane is an imaginary surface with either $\gamma=0°$ or $\gamma=180°$. In order to find the condition to be satisfied for θ to be a minimum, we differentiate the right-hand side of the resulting equation with respect to β and equate it to zero. Thus, we get

$\tan(\phi - \beta) = [\tan\delta / \cos\omega]$ for $\gamma=0°$………….. (1)

And $\tan(\phi + \beta) = [\tan\delta / \cos\omega]$ for $\gamma=180°$……… (2)

Equations (1) and (2) can be used for finding the slope of the aperture plane. Eq. (1) corresponding to $\gamma=0°$ is used if the magnitude of the solar azimuth angle is less than 90°, while eq. (2) corresponding to $\gamma=180°$ is used if the magnitude of the solar azimuth angle is greater than 90°.

The expression for the corresponding minimum angle of incidence is obtained by subtracting Eq (1) and (2) in the appropriate version. For both cases, we obtain

$$\cos\theta = (1 - \cos^2\delta \sin^2\omega)^{1/2} \ldots\ldots\ldots\ldots\ldots (3)$$

B. Parts:

The main parts used in this system are as follows:

1. Frame: The frame is the main part of this mechanism. It consists of many sub-parts.

Details- Length=2m
Breadth=1m
Section- 50mmX50mmX3mm angle
Material- Mild steel

2. Sprocket: A total of 2 sprockets are used in this mechanism.

Details- PCD: 156mm
Number of teeth: 76
Thickness: 7mm
Material: Mild Steel

3. Chain: The chain used in this mechanism is a standard chain manufactured by the brand diamond.

Details- Pitch: 12.7 mm

4. Sprocket Stand: A stand is used to hold the sprockets in place. This stand is also fabricated as per the need of the mechanism. It has a base at the bottom, for sturdiness.

C. Mechanism Calculations:

1. Torque Calculation:

Torque on the sprocket is equal to the torque of the motor required as the weight of the chain is negligible.

The Stepper motor used for this system must have torque equal to 13.66 N.m or 140 Kg.cm

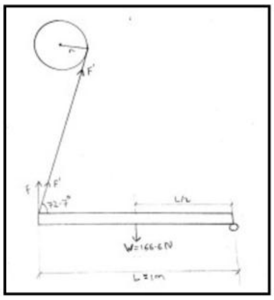

Fig. 2. FBD for torque calculations

2. Shaft Calculation:

Considering the data from the PSG Design data book we assumed certain data like the length of the shaft to be 120mm. l = 120 mm.

The design is carried out by using the Maximum shear stress theory.

Therefore, the radius of the shaft is 20mm with a factor of safety 2.

3. Chain Length:

Considering the radial and linear parameters of the frame trajectory the total chain length is calculated.

Therefore, the total length of chain calculated as,

$$L = AD + EF + x1 + x4$$
$$= 2044.95\ mm$$

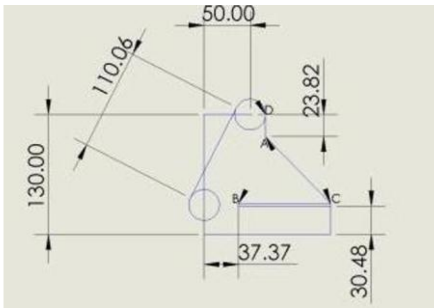

Fig. 3. Chain Length

D. 3D Model:

The final design of the tracking system is done on SOLIDWORKS 2019.

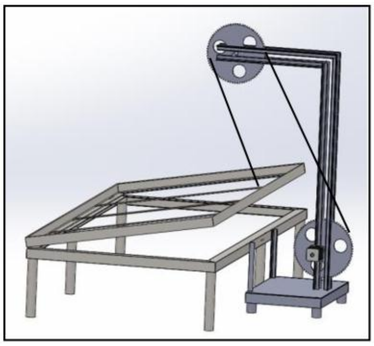

Fig. 4. Final Design of the Tracking System

6. EFFICIENCIES CALCULATION

The efficiency for collectors with tracking and without tracking is found and the comparison is given below

A. Fixed Plate Collector:

For calculating Efficiency without a tracking system i.e., for horizontal Flat Plate collector:

$\cos \theta z = \sin \emptyset \sin \delta + \cos \emptyset \cos \delta \cos \omega$

$\cos \theta z = -0.0022 + 0.9492 \cos \omega$

Ig = Ib + Id

Ib= Ibn $\cos\theta\ z$

B. Tilted Plate Collector:

As discussed earlier, we have used the Mode II, tracking model. Using this, the other parameters are calculated.

$$\tan(\phi - \beta) = [\tan \delta / \cos \omega]$$

For γ=0°

$$\cos \theta = \sqrt{}(1 - \cos 2\ \delta\ \sin 2\ \omega)$$

C. Comparison of both collectors:

The effective efficiency of with tracking system collector and without tracking system collector is calculated by comparing both flux values of collectors. The tilted plate collector is 11% more efficient than a fixed plate.

$$\eta = \frac{I_{T2} - I_{T1}}{I_{T1}} \times 100$$

$$\eta = \frac{971.8133 - 874.4831}{874.4831} \times 100$$

$$\eta = 0 \cdot 1113 \times 100$$

$$\underline{\eta = 11.13\ \%}$$

7. WORKING MODEL

The main objective of this project was to make a working model.

Fig. 5. Working Model of the system

8. COST ANALYSIS

This project is self-sponsored. Hence costing and spending was a huge part of it.

The total cost of the project is 10,087/-. This cost was divided equally among all the three group members while procurement.

The most amount was spent on chains and sprockets, followed by the frame.

Approximately in 216 days, the total cost of the project will be recovered.

9. ENERGY BALANCE

The final product of this project will have a stepper motor coupled to the driver shaft.

Power consumer by the motor = I*V
= 6.2*24
= 148.8 kWhr
= 0.148 kWhr

Extra electricity generated with collector
= 60 * 0.1113
= 6.678 kWhr

Total extra electricity available to be used
= 6.678 – 0.148
=6.53 kWhr

Therefore, use of this tilting mechanism results in more than 6.53 units per day.

10. CONCLUSION

The chain sprocket mechanism used for the tracking system does the work of angularly lifting the frame. This proves that the calculations, assumptions, and selection of the mechanism are right.

From the Efficiency calculations, we found out the collector with a tracking system has 11% more efficiency for a day than the collector without tracking. Hence, we conclude that this mechanism is helpful and efficient.

The payback period for the total cost of this system is projected to be 216 days.

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