

Fabrication and Experimental Analysis on Single-Axis Solar Tracking System for a Parabolic Trough

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Abstract— With increase in our ease to do day-to-day jobs the consumption of electricity has increased. Even then our way of producing electricity is mostly depended on coal or non-renewable resources. Solar energy is a suitable alternative to this way of electricity. Sun's radiation a renewable resource can be used to help in meeting some percentage of electricity demands. To track the sun's radiation a solar tracking device is to be made. The main objective of this work is to present the performance analysis of an automatic solar tracking system which helps the solar parabolic trough to track the sun's position with respect to radiations. It may help in knowing the best position for maximum efficiency. Solar modules now days cleanly convert sun's radiation into electricity and give a practical solution of the problem of power generation in remote areas. Automatic Solar Tracking System is a hardware and software prototype, which will provide alignment of solar panels with the sun, for getting maximum output

Index Terms— Solar Parabolic Trough, Solar-Tracking Device, Electronic Circuit (Depend on the H-bridge & Wheat-stone bridge concept), DC Motor, Balancing System.

I. INTRODUCTION

Green energy consists of hydro power, solar energy, wind energy, biomass energy, tidal energy etc. The renewable energy will help in reducing the use of non-renewable resources. But the power generation from solar energy is to be increased so that it can increase its contribution in meeting up the demands for the current requirement. Solar energy can become a reliable resource of power for small and medium scale industries and many household applications. In achieving this solar tracking system is one of the important criteria to be studied and developed. The various solar tracking systems available can be classified on the basis of:

- Kinematic motion
- Type of solar collector
- Concentration ratio
- Indicative temperature range

These systems can further be summarized as: Stationary, Single-axis tracking, Two-axis tracking, and Multi axis tracking. Mostly solar panels are installed on a fixed surface like roof. Due to source-sun constantly changing its position a system that tracks the position of the sun will improve [1-2] the efficiency of the solar panels. This system at small scale version can be used to produce heat at temperature of 150°C. Small factories like food canning, air-conditioning, sterilization, paper production etc can use these small scale

versions of solar parabolic trough. The efficiency of these SPT can be improved by adopting an appropriate tracking technique. The operation of SPT is dependent on the collection of solar beams on the focal line [3] receiver from the different points of the PT-reflecting surface. The efficiency of SPTC can be explained or determined [4] as it is a function of intercept factor and the accuracy of the tracking system to collect sun rays. With this idea an Automatic solar tracking system is designed and discussed here. A commercial solar PV has 15-19% energy conversion efficiency when fixed. The overall increase of the total energy can be 20% if single axis tracker is used [6]. Solar trackers can be based on horizontal or vertical axis. Vertical axis is adopted where summer days are long. For applications parabolic or linear Fresnel mirror can be used. For accurate tracking various angles are to be kept in mind [7] like azimuth angle, zenith angle, elevation angle. These angles are important when control mode is through an algorithm. Optical efficiency of collector is a function of: intercept factor, mirror surface reflectance, incidence angle, transmittance, absorptions.

The errors in the assembly are: errors in operation and construction of the parabolic trough, misalignment of receiver and reflector, tracking error, parabolic profile error etc. The intercept factor is the basic factor for calculating optical efficiency, whereas intercept factor depends on tracking error [8] which controls thermal efficiency. There are three types of tracking modes for solar panels: active tracker, passive tracker, chronological tracker. Passive tracker involves low b.p. compressed gas fluid. Chronological tracker uses a tracker that counteracts the earth's rotation by turning at approximately the same rate as the earth but in opposite direction. For the concerned assembly here [9] we have used active tracker method i.e. motors and gear chain drives are used to direct the tracker as the circuit gives its signal.

II. DESIGN OBJECTIVES

- I. To Design solar parabolic trough collectors for utilize renewable energy.
- II. For affordable to common people, Make cost effective solar parabolic trough collectors.
- III. To develop an automated sun tracking solar parabolic trough. (N-S horizontal).
- IV. To bring up a system that constantly works with intended mechanism.
- V. A system, which eliminates the human work considerably.

1. Methodology

- I. Find out the centre of gravity for Static balancing of the solar parabolic trough using by CRE-O .
- II. Designing and fabrication an single axis type of tracking system for solar parabolic trough.

2. Solar Parabolic Trough Collector Design

The Parabolic concentrating collector assembly was modelled by using CRE-O Modelling of solar parabolic trough is done with CRE-O.

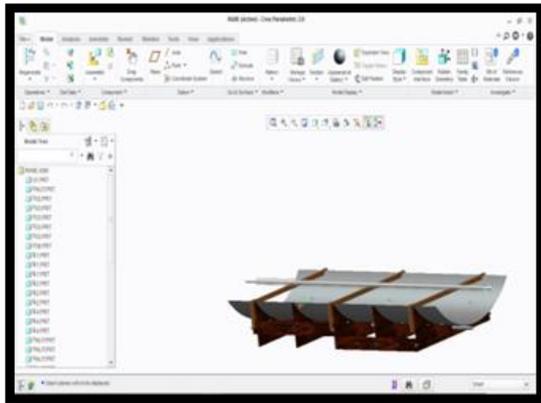


Figure 1: Design of SPTC

Centre of gravity has been calculated of the designed model to decrease the torque required. Substituting the density of the various materials incorporated in the design: After giving these values as input C.G. of the assembly came to be (from reference point).

X-axis=-2.7677e⁰⁰in.
Y-axis=-1.09538e⁰¹in.
Z-axis= 2.5443e⁰³ in

3. The geometry of Parabolic Trough:

The making of parabolic trough required great precision as it depends on the capability of the reflector to focus the radiation reflecting from the surface

MATERIAL	DENISITY (lbm/in ³)
Stainless Steel	0.27976
Iron	0.28432
Wood	0.2237
Glass	0.04335
Steel	0.28277

Table: 1

Determining the size of

- a. parabola
- b. Evaluation of position of focal point is done by mathematical relation:

$$y = \frac{x^2}{4f}$$

where f is the focal point of the parabola,
x is axial to parabolic curve,
y is centre line of focal,
f =30cm.

4. Support Stand of SPTC

The support stand is made of wood. It consist of rectangle shaped cross sectioned bars attached together and inner race of the two ball bearings is fixed with the supporting rod. The specifications of the support frame are:

Dimension	Value
Height of the support stand	650 mm
Distance between the two stands	2480mm
Width of the stand	300 mm

Table: 2



Figure 2: Support Stand of SPTC Supporting frame of SPTC

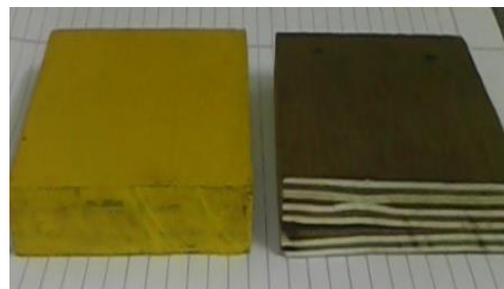


Figure 3: Model of supporting frame

Ply-wood specimens were taken in order to create a base for parabolic trough. They were painted respectively and submerged in water for 20-days and then exposed to sunlight. The changes in dimension of the specimen were negligible hence it was chosen to be as the base for parabolic trough.

5. Parabolic trough

Stainless steel-304 Trough:

To obtain the desired parabolic trough stainless steel sheet is used. Stainless steel-304 sheet dimensions are as follows:

- Length: 3110 mm
- Breadth: 1120 mm
- Thickness: 0.5mm



Figure 4: Stainless steel trough

In parabolic trough the most costly part is reflector. The life of reflector should be long and handling should be easy so that the maintenance cost and the system cost can be reduced. Stainless steel has a long life and low handling as compare to glass.

III. SCHEMATIC DIAGRAM OF ACTIVE TRACKING CONTROL SYSTEM.

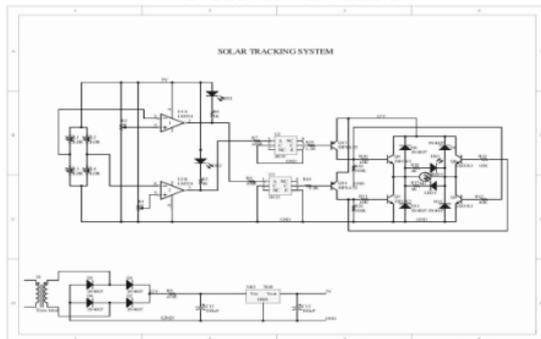


Figure 5: Tracking System

Working:

- It contains 4 LDR connected in wheat stone bridge concept. A part of bridge will be receiving more sunlight relatively.
- The output from that part will act as input to the respective op-amp (LM324) connected.
- LM324 IC consists of four independent operational amplifiers. The input to the negative terminal of the op-amp is connected to the respective part of the bridge and the input to the positive terminal of the op-amp is given by the variable resistor.
- Variable resistors help in giving differential input which is required for the working of op-amp.

- The output of both the op-amp is connected to optocoupler 4N35 (U2 &U3) respectively. DS1 and DS2 help us in knowing which op-amp is working.
- Optocoupler 4N35 is used to couple two circuits. Optocoupler is used in order to prevent the two section of the circuit from each other in case of short circuiting or any other electrical problems.
- Optocoupler is an integrated circuit in which an infrared emitter diode drives a phototransistor that is further connected to the pnp transistors.
- The output of the optocoupler 4N35 is connected to pnp-transistor MPSA92 and input of the optocoupler 4N35 is connected to op-amp LM324.
- PNP transistor MPSA92 general purpose is to switch and amplify. The output from the pnp-transistor goes to npn-transistor 2SD363 which is connected in H-Bridge format.
- An H-Bridge is an electronic circuit that enables a voltage to be applied across load in either direction.
- The circuit is connected to a DC motor that runs in clockwise and anticlockwise direction. H-Bridge arrangement is generally used to reverse the polarity direction of the motor and also to stop the motor.

The following table summarizes operation:

T1	T2	T3	T4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
1	0	1	0	Motor brakes
0	1	0	1	Motor brakes
1	1	1	1	Short power supply
1	1	0	0	Short power supply
0	0	1	1	Short power supply
0	0	0	0	Motor free runs

So the required current is supplied to let the motor run in desired way.



Figure 6: Actual tracking control Arrangement

Converting AC to DC:

- A step-down transformer is used to convert high voltage AC to low voltage AC.
- Electrical current enters the primary coil of the transformer and induces a current in the secondary coil resulting in a lower voltage.
- The low voltage AC is passed through a rectifier. It consists of 4 diodes. 2 diodes are used to pass the positive half of the current and the other 2 diodes to pass the negative half.
- The output of both sets is a current that climbs from 0 volt to Maximum positive voltage.
- Adding a capacitor to smoothens out the voltage. A capacitor stores an electrical charge for a short period of time and then releases it slowly.
- A 7805 IC is used. It is a 5V voltage regulator that restricts the voltage output to 5V and draws 5V regulated power supply.
- Again a capacitor is use to store electrical charge for a short time and then release it slowly.

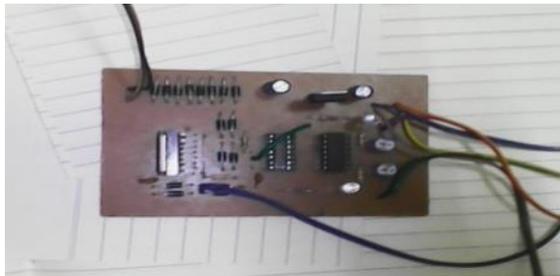


Figure 7: Actual Ac to Dc Converting Circuit

IV. STATICS BALANCING

To minimize the torque required by the parabolic trough static balancing is done. In this a lumped mass is hanged through the centre axis of parabolic trough.

The balancing of parabolic trough is explained by eqⁿ given below:

$$M_1R_1 + M_2R_2 = M_3R_3$$

M₁=weight of receiver tube and glass tube

M₂=weight or reflector sheet and frame

M₃=weight of applied load

R₁ and R₂= vertical length from the centre axis of upper side

R₃=vertical length below from the centre axis of parabolic trough

Calculation: $M_1R_1 + M_2R_2 = M_3R_3$

(M₁=10kg, M₂=25kg, M₃=14kg, R₁=40cm, R₂=12cm, R₃=50cm)

V. EXPERIMENT AND OBSERVATION:

The experimental setup used for testing the manufactured SPTC's is shown below. The water is filled from the one end of the SS absorber pipe with other end opened. The temperature of water was measured by using electronic thermometer and tabulated for every hour from 9:00 am to

4:00 pm. The SPTC was rotated using a DC motor and sprocket-chain mechanism to keep the sun perpendicular to the absorber pipe.



Figure 8: Final Setup of SPTC

Initial Observation: When conducting the experiments a jerk was noticed in the operation of the parabolic trough.

Control Measure: To overcome that jerk so that it may not cause problems to the electronic and mechanical components a shock absorbing material was added to the support stand of the parabolic trough.

Final Observation: After the application of damper the rotation of parabolic trough is smoothened and the readings and timings were stabilized. Variation of solar radiation throughout the day (Thermal Performance)

S.No.	Time	Solar Radiation(W/m ²)
1	12:15	960
2	12:19	920
3	12:48	984
4	01:19	930
5	01:55	1080
6	01:58	1010
7	02:04	1020

Average radiation coming from the sun (G)= 986W/m²



Figure 9: shock absorbing material

Observation on 4th April 2015:

The observation was made for receiver tube maintained at atmospheric pressure.

Performance Calculation:

Formula used: Energy collected = $m_{\text{water}} \times (h_{\text{out}} - h_{\text{in}})$
 $h = C_p T$

Mass flow rate of water (m) = 0.5 ml/sec

Specific heat of water (C_p) = 4.187 KJ/Kg

= $m \times (h_{\text{out}} - h_{\text{in}})$

Mass flow rate m = 0.5 ml/sec

Enthalpy at inlet - $h_{\text{in}} = C_p \times \Delta t$

= $4.187 \times (42^\circ - 0^\circ)$

= 175.85 kJ/kg

Enthalpy at outlet - $h_{\text{out}} = h_g + C_p (\text{superheated steam}) \times \Delta t$

= $2676 + 2.091 \times (116 - 100)$

= 2709.45 kJ/kg

= $0.0005 \times (2709.45 - 175.85) = 1.26 \text{ kW} = 1260 \text{ W}$

Average radiation coming from the sun (G) = 986 W/m^2 ,

Total heat input = $G \times A = 986 \times 3 = 2958 \text{ W}$

Efficiency of parabolic trough = heat output/heat input

= $1266.8 / 2958 = 42.6\%$

VI. CONCLUSION

The single axis tracking system is helpful in reducing the cost of the assembly. Here an electro-mechanical system is built with the basics like wheat-stone bridge and H-bridge concept. This also helps in reducing the maintenance cost and hence proving it useful for the application in small scale industries as the temperature of 150°C can be achieved with no difficulty.

Some improvement can be done in order to bring the assembly back to its initial system. The electro-mechanical system used for the tracking of the assembly can be more improved so that it can withstand the unknown weather condition of the area where installed.

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