DEVELOPMENT OF MECHANICAL TRACKING SYSTEM FOR SOLAR WATER HEATER

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Abstract - *Sun is one of the oldest, greatest and everlasting sources of energy. Solar energy is unlimited, has no negative environmental effects, and can be converted into a variety of other kinds of energy. Solar energy acquired can be processed and used in many applications such as solar heating process, thermal energy, generation of electricity etc. This paper presents the experiment of solar water heating with Mechanical tracking system. It focuses on the performance of dual axis tracking system with the application of water heater. Unlike electrical system of Arduinos, the tracking system applied is fully based on a mechanical simple machine. The efficiency of the solar water heater with and without tracking was tested in the experimental analysis. The experimental setup has been put to test, and the results have been drawn. The results of water heater with tracking have been proven to be more effective and beneficial than of without tracking.*

Key Words: *Mechanical tracking, solar heating, solar tracking, PV panels, efficiency, water heating.*

1.INTRODUCTION

Solar energy over the last two to three decades have arisen as a sustainable source of renewable energy and are now used on a wide scale in both industrial and residential applications. Many applications of solar energy include solar cookers, solar water heater, solar energy converted to electrical energy, solar ventilation, etc. Water heaters are now common in most countries for almost every day use. Traditional heaters, such as geysers and boilers, are environmentally damaging because the heating phase necessitates the combustion of fossil fuels and the release of greenhouse gases. Solar water heating is an alternative technology that can be used to heat water without damaging the atmosphere. Tracking system is used for accurate positioning and maximum efficiency. Solar tracking captures the movement sun moving in the sky in both axis and collects the solar energy. There are mainly two types of tracking systems yet discovered which includes Electrical/sensor operated tracking system and mechanical tracking system. The tracking system which requires no sensors or electric supply for movement for tracking are named as mechanical tracking system. This type of tracking mechanical system using gears, pulleys and belts are used to achieve the tracking of sun which absorbs maximum solar energy throughout the sun time in a day. A modified version of mechanical solar tracking system can be used for water heating. Dual axis tracking system includes azimuth and elevation angels, considering the angels the dual axis tracking system tracks the sun's movement. Among all the 15 types of collectors used for solar water heating process, flat plate collectors also known as water heating panels have advantages in solar water heating applications. Modified version of solar tracking system comprises of a dual axis rotation, spiral shaped tubing, flat plate collector and solar panels for Solar Tracking System. In Mechanical Solar Tracking System for water Heating absorbs maximum energy from sun throughout the day to heat the water flowing through the spiral copper tube. Construction of Mechanical Solar Tracking System comprises of heating panel which contains copper tube in spiral shape and aluminium frame; frame contains main bar and supporting bar of aluminium, belt drive mechanism for rotation of the assembly, geared DC motor and Photo Voltaic panels. Using mechanical tracking system for water heating increases efficiency buy increase in water heating time and increased quantity of water being heated as it accurately tracks the sun. Hence efficiency of solar tracking system is more than that of the non-tracking system.

2. LITERATURE REVIEW

2.1 Jignesh A. Patel, Tejendra B. Patel, Dr. Sadanand Namjoshi [1]:

Researchers presented work that involves a comparative analysis of the straight tube solar water heater's thermal efficiency with the proposed experimental set-up of the spiral tube solar heater. The experimental setup presented consists of a spiral-shaped copper tube, a flat plate collector and a thermocouple of type K for the change in water temperature for 100 liters per day of water power. In the clear days of May at Navsari (21 07 N, 73 40 E) in Gujarat, experiments on solar water heaters were carried out. Around 9:00 AM to 3:00 PM solar time, experiments were performed. In every 60 minutes interval times, the water inlet and outlet water temperatures were taken and data was logged to the data logger and respective graphs were plotted. Thermocouples have been used to calculate the various temperatures of solar water heaters at different sites. A maximum temperature difference of 16 C was observed between the solar water heater inlet and the outlet. The output of the spiral tube solar water heater was then measured as 47.63 percent, which was more than the straight tube solar water heater and was found to have the highest value during the experimental phase. In the case of a spiral tube solar water heater, the analysis concludes that there is a higher thermal efficiency and outlet temperature compared to a straight tube solar water heater.

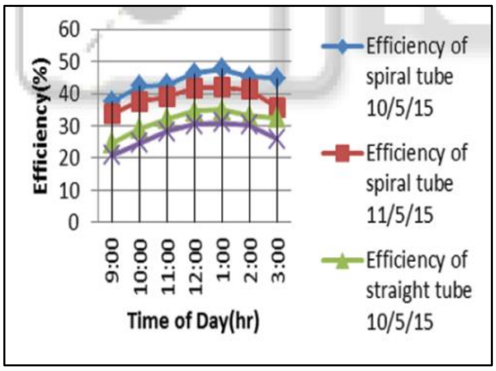

Fig.1 Efficiency vs Time graph [1]

2.2 M. Z. H. Khan, M. R. Al-Mamun, S. Sikdar, P. K. Halder, M. R. Hasan [2]:

This paper investigated a novel loop-heat-pipe based solar thermal heat-pump device for small-scale hot water production for household purposes. The effective use of solar energy is hindered by the intermittent nature of its availability, limiting its use and efficiency in domestic and industrial applications, particularly in the area of water heating. The easiest and most used method is the conversion of solar energy into thermal energy. In this review, a prototype was built for solar water heating systems for experimental testing. Observations show that the efficiency of solar thermal conversion is 29.24 percent in summer, 14.75 percent in winter and 15.53 percent in rainy season. This paper also discussed the DC heater for backup system and current by using a thermoelectric generator that is 3.20V in the summer, 2.120V in the winter, and 1.843V in the rainy season. This solar water heating system is primarily suitable for its ease of operation and simple maintenance. Such novel solar thermal technology is expected to further contribute to the development of heating and hot water services powered by renewable energy (solar) and contribute to significant environmental benefits.

2.3 Mr. M.V. Kulkarni, Dr. D. S Deshmukh [3]:

This paper explained how the performance of various solar water heating collector models under similar climate and operating conditions can be compared and calculated. The efficiency of solar heating systems largely depends on the performance of the solar collector used. The collector's potential is mainly determined by the optical properties of the surface of its cover and the absorbers. However, there are losses that can be known as input losses that occur when heat is transferred from the collector to the liquid. Flat plate collector performance can be improved by using the following methods.

1) Increase the heat transfer volume from the collector to the running fluid.
2) Reduces losses by reducing losses in conduction, convection and radiation.
3) Increase the coefficient of heat loss with the operating temperature of the collector and local wind speed.

The test system consisted of an under-test flat plate collector, a liquid pump, a cooling coil heat exchanger and a storage tank with electric emission heaters. The data was reported for fixed values of m and Ti under steady heat conditions and the effectiveness of the collector was determined. It was also concluded that, relative to flat plate collectors, evacuated tube collectors had lower thermal losses and were therefore less affected by environmental conditions. The tests were carried out for about fifteen days instead of performing tests for the whole year and the result was extrapolated to achieve annual results.

3. EXPERIMENTAL SETUP

Figure shows the experimental setup which comprises of total 8 main components starting with water heating panel whose purpose is to heat the water to required temperature. The next components are PV solar Panels whose sole purpose is to supply the power to DC motors by collecting energy from sun and converting it into electrical output. Other components are Supporting Guides in which Main bar, Side supports, Angle plates, Cross bar and Wooden disk, these are responsible for supporting the whole structure and movement. Another component is DC Motor which is use to drive the pulley and belt arrangement. Next components are Belt and Pulley mechanism which is use to move the entire setup in particular direction i.e., in 360° rotation and Up and Down direction. Last and important component is Dead weight whose purpose is to balance the whole assembly.

While setting up one pair of PV panel are connected to one of the motors for achieving upward and downward motion and another pair is connected to second motor for achieving circular motion. When one of the PV panel gets exposed to the sun, it gets charged by the solar energy and thus it starts providing electrical input to one of the motors causing it to run the motor and moving the assembly in particular direction. Same is the case for all four PV panels. When water is supplied into the copper tubes, it gets heated as the heating panel is directly perpendicular to the sun.

Fig.2 Experimental Setup

4. CALCULATIONS

4.1 Calculation of length of copper pipe required for heat transfer

By Energy balance equation

$$A_s \times q = \dot{m} \times C \times \Delta T$$

$\dot{m}$ - Mass flow rate of water (Kg/s)
C- Specific heat of water (KJ/Kg-K)
ΔT-Desired temperature difference (K)
A_s- Surface Area of copper tube (m^2)
q- Heat flux (W/m^2)
∴ Mass Flow Rate ($\dot{m}$) = 9.0909×10^{-3} (Kg/s)
C = 4.184 (KJ/Kg-K)
ΔT= 20°C
D = 6 mm= 0.006 m.
q = 5000 W/m^2 [4] ………… (Average solar power in India)

By Energy balance equation
$$A_s \times q = \dot{m} \times C \times \Delta T$$
L = 8.0714 m

4.2 Comparison of efficiency for solar collector (water heating panel)

The efficiency of the Solar Water Heater is calculated for the given period of heating time from 10:00am to 12:00pm

A) Without solar tracking system

Q heater= m × Cp ×ΔT = 502.08 KJ
Wattage heater= Q/t = 69.73 Watts
Average solar power in India is 5 KW/m^2 [4]
Surface area of the collector = $0.1508m^2$
So net solar power incident on collector surface = [5000 * 0.1508] =754 Watts
So, Efficiency of the collector without tracking = [W heater/W solar] * 100 = 9.25 %

B) With solar tracking system

Q heater= m × Cp ×ΔT = 920.48KJ
Wattage heater= Q/t = 127.84Watts
Average solar power in India is 5 KW/m^2 [4]
Surface area of the collector = $0.1508m^2$
So net solar power incident on collector surface = [5 * 0.1508] =754 Watts
So, Efficiency of collector with tracking = [W heater/W solar] * 100 = 16.96 %

∴Due to the application of solar tracking system the efficiency of solar collector (water heating panel) increases by 7.72 %.

5. RESULTS

5.1 Accuracy of Solar Tracker:

Testing Day 1: 3rd March, 2021, (**With Solar Tracking System)**

- Based on the recorded observations it can be noted that the average difference between the elevation angle of sun and panel is 2.23° and the average difference between azimuth angle of sun and panel is 2.14°.
- The maximum difference in elevation angle was observed at 4:00pm and it was 2.88° and minimum difference was observed at 12:00pm and was 1.31°.
- The maximum difference in azimuth angle was observed at 4:00pm and it was 3.4° and minimum difference was observed at 1:00pm and was 1.35°.

Day time	Elevation angle of sun [5]	Elevation angle of panel	Azimuth angle of sun [5]	Azimuth angle of panel
8:00 am	40.76	38.6	78.01	76.5
9:00 am	54.75	51.4	84.85	82.3
10:00 am	68.9	67.1	90.09	88.2
11:00 am	83.02	80.54	94.85	93.5

12:00 pm	97.29	96	99.76	97.9
1:00 pm	111.06	109.6	105.45	104.1
2:00 pm	124.45	122.2	112.82	109.3
3:00 pm	136.98	134.5	123.51	121.6
4:00 pm	167.58	164.7	140.8	137.4

Table -1: Comparison of Elevation and Azimuth Angle of Sun and Panel

5.2 Examination of Effectiveness of Tracking System in Terms of Heat Transferred to The Water

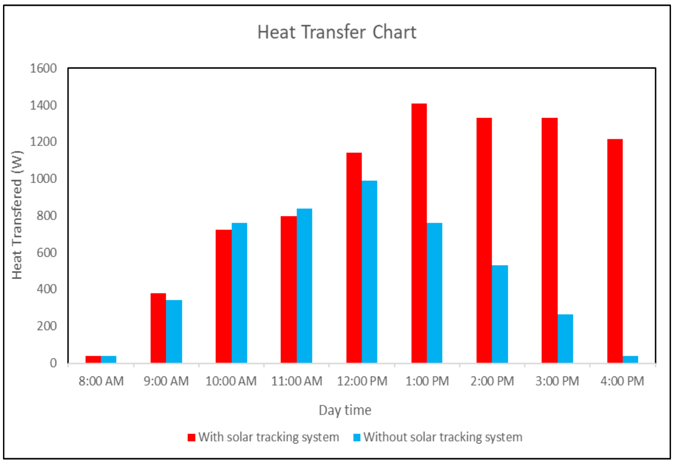

Chart -1: Heat Transfer Chart

- Based on the recorded observations it can be noted that the average difference in heat transferred was recorded as 439.2W.
- The maximum difference in heat transferred was observed at 4:00 pm and was 1179.1W.
- The minimum difference in heat transferred was observed at 8:00 am it was 0W.

5.3 Savings in Cost

DESCRIPTION	WITHOUT TRACKING	WITH TRACKING	UNIT
Quantity of water heated	250	291.68	Litre
Difference	41.67		Litre
Cost of hot water for 24 hours	8.681		INR
Saving per 24 hours	361.74		INR
Saving per month (30 days working)	10,852.12		INR
Saving per annum (12 Months)	1,30,225.44		INR
Savings during life of 10 years	13,02,254.4		INR

Table -2: Cost Savings

6. CONCLUSION

The mechanical solar tracking system is a best way for solar tracking because it is accurate and also eliminates the use of any external power source. When this tracking system is connected to a solar water heater, it improves the water heating time by almost 4 hours per day which provides an additional supply of hot water. This reduces the cost of water heating panel for the same quantity of water. Due to the application of solar tracker the average temperature of hot water increases by 11.12°C per day. Further while manufacturing a full-scale machine 16.67% of additional hot water is available due to increased heating time.

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