Design and Fabrication of Parabolic Solar Water Heater with Inbuilt Automatic Solar Tracking System

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Abstract - This project focuses on developing novel technique for a solar water heating system. The novel solar system comprises a parabolic dish concentrator, conical absorber and water heater. In this system, the conical absorber tube directly absorbs solar radiation from the sun and the parabolic dish concentrator reflects the solar radiations towards the conical absorber tube from all directions, therefore both radiations would significantly improve the thermal collector efficiency. The working fluid water is stored at the bottom of the absorber tubes. The absorber tubes get heated and increases the temperature of the working fluid inside of the absorber tube and causes the working fluid to partially evaporate. The partially vaporized working fluid moves in the upward direction due to buoyancy effect and enters the heat exchanger. When fresh water passes through the heat exchanger, temperature of the vapour decreases through heat exchanger. This leads to condensation of the vapour and forms liquid phase. The working fluid returns to the bottom of the collector absorber tube by gravity. Hence, this will continue as a cyclic process inside the system. The proposed investigation shows an improvement of collector efficiency, enhanced heat transfer and a quality water heating system.

1. INTRODUCTION

Solar parabolic systems have emerged as a promising solution for sustainable energy generation. They harness the power of the sun to generate electricity or heat water through the use of a parabolic reflector that concentrates sunlight onto a single point. This technology has gained popularity in recent years due to the growing demand for clean, renewable energy sources that can provide reliable power without contributing to greenhouse gas emissions. With several types of solar parabolic systems available, each with a unique design and application, the use of this technology is expected to play an increasingly important role in meeting our energy needs as technology continues to advance. The increasing concern about climate change and the need for sustainable energy sources has led to the emergence of solar parabolic systems as a promising solution for clean energy generation.

These systems harness the power of the sun to generate electricity or heat water through the use of a parabolic reflector that concentrates sunlight onto a single point. The reflector is designed in such a way that it tracks the movement of the sun, ensuring that maximum sunlight is captured throughout the day. Solar parabolic systems have gained popularity in recent years due to their high efficiency in capturing and converting solar energy. They offer a clean, renewable energy source that can provide reliable power without contributing to greenhouse gas emissions. With the growing demand for clean energy sources, solar parabolic systems are becoming increasingly important in meeting the world's energy needs.

Due to its connections to security, economic growth, and the eradication of poverty, energy plays a significant role in how a nation is represented. A significant need for electricity, which is met by coal, gas, and diesel fuel to generate electricity. The primary energy source is natural gas, which is rapidly running out. Just using natural gas or other non-renewable energy sources for household needs isn't a positive indicator for the future, and the vast use of reactive energy over the past century has contributed significantly to environmental pollution and climate change through the greenhouse effect. A future extreme is undoubtedly created by the enormous energy demand and reliance on natural gas.

Solar energy is the most appropriate renewable energy source for this nation out of the many others. Solar photovoltaic and solar thermal energy have allowed solar energy to enter the homes of millions of people all over the world. Solar energy systems are becoming more and more common as a result of improved materials and technologies that are becoming more affordable. While solar thermal energy systems are used to provide hot water, food, and other uses, solar PV systems generate electricity for use in the home or in commercial settings. However many commercial locations and hospitals require a substantial amount of hot water continuously. For this reason, using solar thermal energy might be a fantastic activity for conserving conventional energy and protecting the environment. The main component of every solar system is the solar collector. The energy from solar radiation is transformed into heat via solar collectors, an unique type of heat exchanger that transfers this heat to a fluid (often air, water, etc.) flowing through the collector.

There are several types of solar parabolic systems, each with a unique design and application. Solar parabolic troughs are one of the most common types of systems, and they are used for generating electricity and heating water. Solar power towers are another type of system that uses a central receiver to collect sunlight from a field of mirrors. Dish/engine systems, on the other hand, use a parabolic dish to concentrate sunlight onto a receiver, which is then used to generate electricity.

The choice of solar parabolic system depends on the specific application and the available resources. For instance, solar parabolic troughs are ideal for large-scale electricity generation, while dish/engine systems are better suited for smaller-scale applications. With advancements in technology and increased investment in renewable energy, solar parabolic systems are expected to play an increasingly important role in meeting the world's energy needs.

2. APPLICATIONS OF SOLAR ENERGY

- Heating and cooling of buildings.
- Solar water heating.
- Salt production by evaporation of sea water or inland brines.
- Solar distillation on a small community scale.
- Solar drying of agricultural and animal products.
- Solar cooker.
- Solar engine for water pumping.
- Food refrigeration
- Photovoltaic conversion.
- Solar furnace

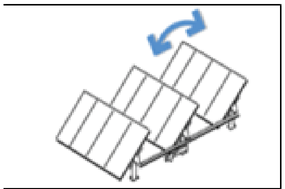
3. SUN TRACKING

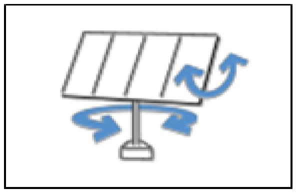
Nowadays the development of the solar radiation conversion system is focused mainly on aspects related to materials development and solar energy conversion processes. In the design process of the solar trackers the input data is the direct solar radiation that may be converted into thermal energy (by using solar collectors) or electrical energy (by use of the picture voltaic panels). The competitiveness of the solar energy conversion system on the market deals with their efficiency and an alternative solution for improving their efficiency is the use of the tracking systems so called ―solar trackers or sun - tracking systems‖. According to the scientific literature, by increasing the incident radiation rate with solar trackers, in order to maximize the degree of direct (and diffuse) solar radiation collection, the efficiency of the solar radiation conversion systems may be increased up to 50%. The sun – tracking systems are, most of them, mechatronics devices used for the orientation of the solar energy conversion systems. The input data that determines the orientation principle is provided by the position of the Sun on the celestial sphere. In order to reach the highest conversion degree the sunrays has to fall perpendicularly onto the receiver surface. The periodic adjustment of the receiver is determined by the astronomical information related to the Sun position on the sky dome.

Observing the geometrical relation Sun-Earth there are identified two motions that has to be considered:

The Earth describes along one year a rotational motion on an elliptical trajectory around the Sun; combined with the precession motion this rotation generates the seasons.

But the Earth has also a daily motion around its own axes that is responsible for the succession of the days and the nights and more concluding for the east – west daily path of the Sun.





Single Axis Tracking Dual Axis Tracking

4. REVIEW OF LITERATURE

Soteris A. Kalogirou (2004) Thomson gave a paper on solar thermal collectors and applications and he presented an introduction into the uses of solar energy followed by a description of the various types of collectors including flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors. This followed by an optical, thermal and thermodynamic analysis of the collectors and a description of the methods used to evaluate their performance. Typical applications of the various types of collectors presented in order to show the extent of their applicability.

Another person named Joshua Folaranmi (2009) had designed, made and tested a parabolic dish collector system, a black absorbent material focused heat from the radiation that fastened within the reflector focus purpose. The water was converted to steam as a result of it heating to awfully warmth. To tilt the parabolic dish reflector to completely different angles, it fastened on a hinged frame supported with a slotted lever, therefore the radiation forever directed to the collector at completely different periods of the day. In the sunny days, the results of the check gave temperature on top of (200 ^{0}C).

Lifang Li and Steven Dubowsky(2010) made and developed a replacement style approach for a solar concentrating parabolic dish. From skinny flat metal petals with an extremely reflective surface, the mirror is dish shaped. Hooked up to the rear surface of the mirror petals were many skinny layers, whose shape optimized to own reflective petals kind into a parabola, once their ends force toward one another by cables or rods, the parabola system redoubled the temperature of water up to 120 ^{0}C.

As mentioned by Vinayak Sakhare (2014) & V. N. Kapatkar in the paper presented that dish was used for water heating & cooking applications. But, in this case less energy extraction due to single axis rotation.

As mentioned by Dr.Nitin Shrivastava (2015), Praween Kumar Patel, Shiyasharan Patel in the paper presented that they track the path of the sun with help of hydraulic actuator arrangement. But in this case the automation problem arises with the initial setting.

S.D. Kulal (2016) & S. R. Patil experimented using various reflecting materials such as stainless steel, silver foil and aluminium sheet and found that the overall efficiency of silver foil is high, and having a very good response to solar intensity as a reflecting material. The Reason behind this result is that silver foil has good reflectance as compared to other materials. As compared to the stainless steel and aluminium foil, the silver foil is cost effective and less material is required. So it is concluded that silver foil is economical to use as a reflector for parabolic dish collectors.

Asif Ahmed Rahimoon (2019) Paper presents the tracking scheme layout of parabolic dish PV system for enhancement of PV using Arduino. The research involves the designing of a CSP system with PV module to capture maximum solar irradiation in less brighten areas. Aluminium polished surface parabolic dish with twelve cross sectional view was developed with integration of PV panel to enhance the system output power. he dual axis closed loop tracking mechanism was installed with 4*4ft 2 parabolic dish, LDR sensor module, 12 V DC power motors, H-Bridge drive & Arduino Controller.

The 10 W polycrystalline solar panel was used as a payload receiver for a parabolic dish to generate optimum level of output power. The outdoor experiment was performed to analyse a solar PV tracker and proposed parabolic dish tracker. The results show that the average output power of solar PV panel was about 5.78 W while, for the prop0osed parabolic dish PV system was 9.2515 W. Hence, the output power of the designed parabolic dish PV system is 3.43% more improved than the compared solar PV panel.

Sattar Aljabair (2019) introduced three models of parabolic dish collectors with different dimensions to study the effect of change in diameter and depth of the dish on the position of focus point and concentration ratio and the temperature of outlet hot water or steam by using different receivers. Parabolic dish and receiver were made of three variants in terms of dimensions for testing and analysis to produce hot water and steam from solar energy. When the parabolic dish collector was operational, the temperature of water was 60 ^{0}C in the rectangular receiver tank, 75 ^{0}C within the copper coil and 125 ^{0}C in the radiator device receiver. For rectangular receiver tanks, hot water obtained within time (2 h), for copper coil receiver tank, hot water obtained within time (30 min) and for radiator heat exchanger receiver, steam obtained within time (20min).

5. THE RELATIONSHIP BETWEEN SUN AND TRACKING SYSTEM

Speed of earth
Earth completes its one revolution through 360 degrees in 24 hours.

24 hr. = 1 rev.

N = 1/24×60 rev. /min.

N = 6.94×10 $^{-4}$rpm.

These are required to rotate the parabolic dish collector using a solar tracking system.

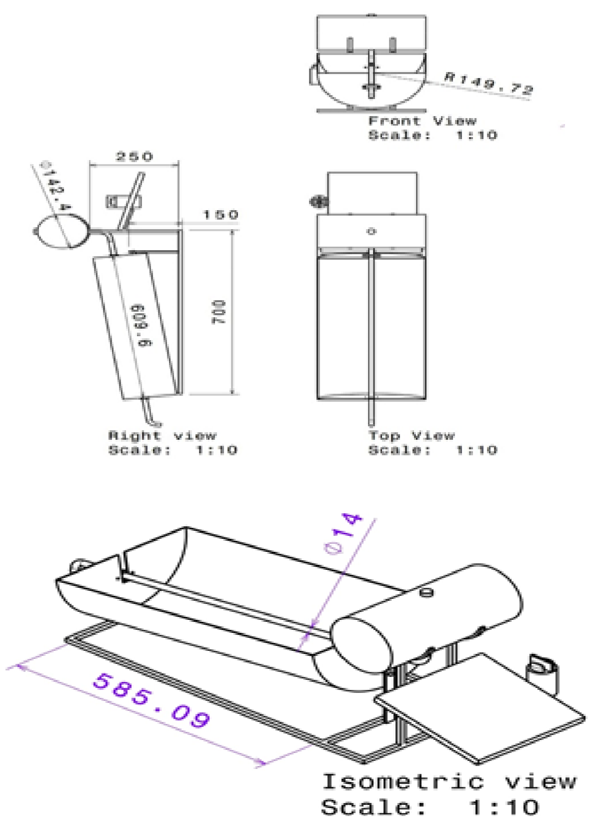
In 24 hours = 360 degrees

i.e. One revolution completed in 24 hours.

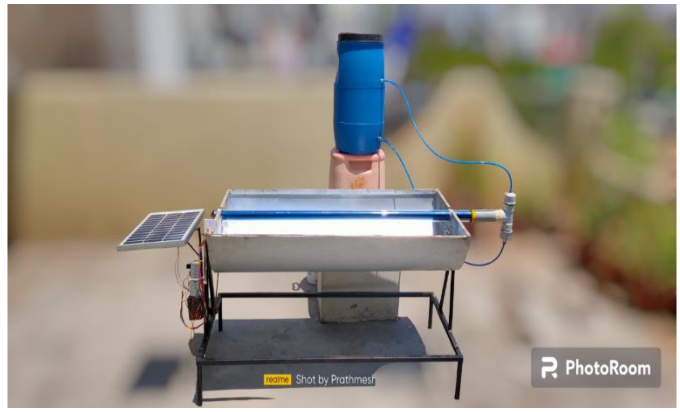
1 hour = 15^0

This is the angle through which the collector must turn per hour for continuously maintaining it directly in line with Sun rays throughout the day.

6. DIAGRAM OF PROTOTYPE



7. PHOTOGRAPH



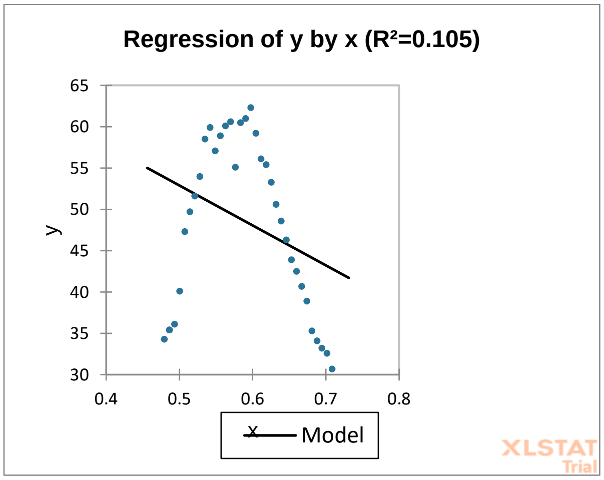
8. OBSERVATIONS

Sr. No.	Time(x) (HH.MM)	Temperature(y) In (°C)	Angle(z) In °(Degree)
1	11.30 AM	34.3	85
2	11.40 AM	35.4	87
3	11.50 AM	36.1	88
4	12.00 PM	40.1	90
5	12.10 PM	47.3	91
6	12.20 PM	49.7	93
7	12.30 PM	51.6	94
8	12.40 PM	54	96
9	12.50 PM	58.5	97
10	01.00 PM	59.9	99
11	01.10 PM	57.1	101
12	01.20 PM	58.9	103
13	01.30 PM	60.1	104
14	01.40 PM	60.6	106
15	01.50 PM	55.1	107
16	02.00 PM	60.5	109
17	02.10 PM	61	111
18	02.20 PM	62.3	112
19	02.30 PM	59.2	114
20	02.40 PM	56.1	115
21	02.50 PM	55.4	117
22	03.00 PM	53.3	118
23	03.10 PM	50.6	120
24	03.20 PM	48.6	121
25	03.30 PM	46.3	123
26	03.40 PM	43.9	125

27	03.50 PM	42.5	126
28	04.00 PM	40.7	128
29	04.10 PM	38.9	130
30	04.20 PM	35.3	131
31	04.30 PM	34.1	133
32	04.40 PM	33.2	134
33	04.50 PM	32.6	136
34	05.00 PM	30.7	138

Equation of Model:

y = 77.0463865546218-48.330756302521*x



9. CONCLUSION

This paper presents an approach which could be used for designing parabolic solar water heater with inbuilt automatic solar tracking system to align Collector in focal line to improve the thermal efficiency of parabolic solar water heater without utilizing fossil fuels (without releasing Green House Gases) to get maximum output temperature throughout the day.

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