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Design Parameters of Parabolic Solar Water Heater with Inbuilt Automatic Solar Tracking System

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Abstract: This paper 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 exchange. 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.

I. INTRODUCTION

Energy manifests itself in many forms, for instance heat, light, electricity radiations and matter. Energy is required to sustain and improve the quality of life. Energy grows food and keeps people lively. It transports them, fuels the machine and keeps the economic system going. Primitive men use their own muscles to help him convert energy into useful work. In course of time he trained animals. Further, he began to use wind energy for sailing ships or driving windmills and waterfalls to turn water-wheels.

Solar energy is the most important form of energy for this planet. This is because all life on this planet depends on the energy received from the sun. Power from the sun comes to the Earth as heat and light. Solar energy is simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650, 000,000 tons of hydrogen to helium every second. This process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultraviolet radiation) streams out into space in all directions. Only a very small fraction of the total radiation produced reaches the Earth. The radiation that does reach the Earth is the indirect source of nearly every type of energy used today. The average amount of energy that contacts the Earth's surface in a day is 200 W/m2.This means that the average home has more than enough space to produce enough electricity to supply all of its power needs. In fact ,each day, more energy reaches the Earth from the sun than would be consumed by the global population in 27 years. We get solar energy from the sun and this energy is in unlimited form from thousands of years and the main problem was how to utilize or use this energy. The average distance between

The Sun is 150 million kilometers away, and amazingly powerful. Just the tiny fraction of the Sun's energy that hits the Earth (around a hundredth of a millionth of a percent) is enough to meet all our power needs many times over. In fact, every minute, enough energy arrives at the Earth to meet our demands for a whole year – if only we could harness it properly. Energy from the sun travels to the earth in the form of electromagnetic radiation similar to radio waves, but in a different frequency range. Available solar energy is often expressed in units of energy per time per unit area, such as watts per square meter (W/m 2). The amount of energy available from the sun outside the Earth's atmosphere is approximately 1367 W/m 2 ; that's nearly the same as a high power hair dryer for every square meter of sunlight! Some of the solar energy is absorbed as it passes through the Earth's atmosphere. As a result, on a clear day the amount of solar energy available at the Earth's surface in the direction of the sun is typically 1000 W/m 2.

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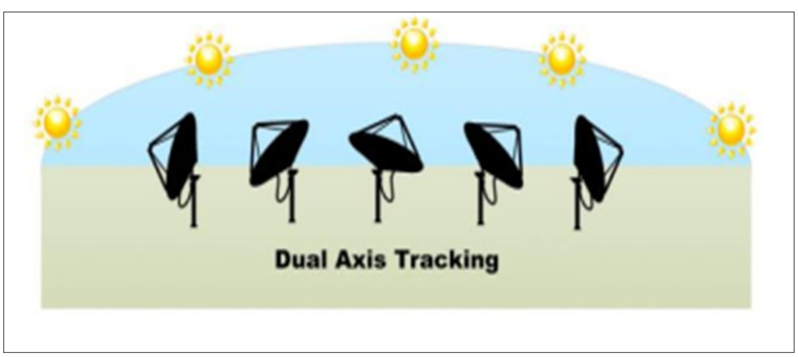
At any particular time, the available solar energy is primarily dependent upon how high the sun is in the sky and current cloud conditions. On a monthly or annual basis, the amount of solar energy available also depends upon the location. Furthermore, usable solar energy depends upon available solar energy, other weather conditions, the technology used, and the application.
There are many ways that solar energy can be used effectively. Applications of solar energy use can be grouped into there are three primary categories: heating/cooling, electricity production, and chemical processes. The most widely used applications are for water and space heating. Ventilation solar air heating is also growing in popularity. Uptake of electricity producing solar technologies are increasing for the applications in picture voltaic (primarily) and concentrating solar thermal-electric technologies. Due to recent advances in solar detoxification technologies for cleaning water and air, these applications hold promise to be competitive with conventional technologies

II. APPLICATIONS OF SOLAR ENERGY

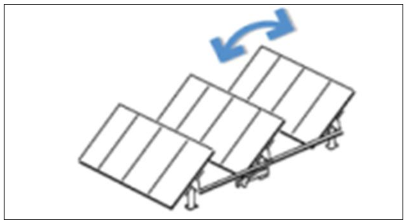
1) Heating and cooling of buildings.
2) Solar water heating.
3) Salt production by evaporation of sea water or inland brines.
4) Solar distillation on a small community scale.
5) Solar drying of agricultural and animal products.
6) Solar cooker
7) Solar engine for water pumping.
8) Food refrigeration
9) Photovoltaic conversion.
10) Solar furnace.

III. ABOUT SUN TRACKING

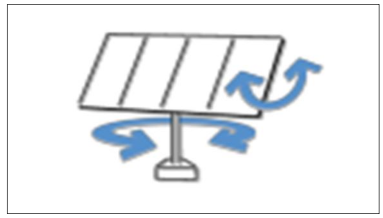
Nowadays the development of the solar radiation conversion system is focused mainly on aspects related to materials development and solar energy conversion processes. In the design process of the solar trackers the input data is the direct solar radiation that may be converted into thermal energy (by 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



Axis Tracking



Dual Axis Tracking

IV. 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).

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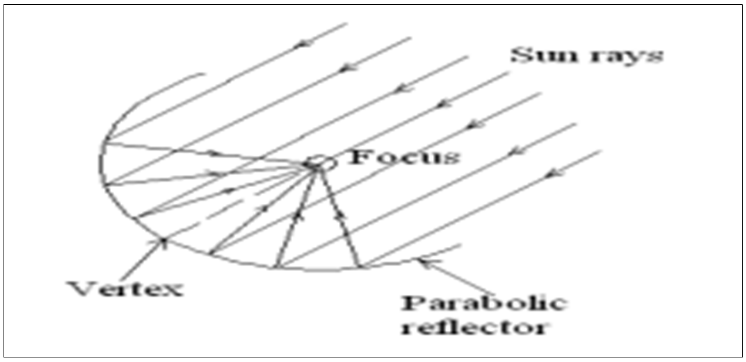
V. DESIGN ASPECTS

Parabolic Trough Solar Collector (PTSC) which is also called cylindrical parabolic collector employs linear imaging concentration. These collectors are comprised of a cylindrical concentrator of parabolic cross – sectional shape, and a circular cylindrical receiver located along the focal line of the parabola. Basically it consists of (i) a parabolic reflector of about 1-6 m aperture width, (ii) an absorber tube made of steel or copper with diameter 1-5 cm and coated with selective coating, and (iii) a concentric tubular glass cover surrounding receiver with a gap of about 1- 2 cm.The cylindrical parabolic reflector focuses all the incident sunlight onto a metallic tubular receiver placed along its length in the focal plane. The heat transfer fluid is allowed to flow through the receiver.
Parabolic troughs have a focal line, which consists of the focal points of the parabolic cross sections. Radiation that enters in a plane parallel to the optical plane is reflected in such a way that it passes through the focal line.



VI. THE RELATIONSHIP BETWEEN SUN AND TRACKING SYSTEM

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

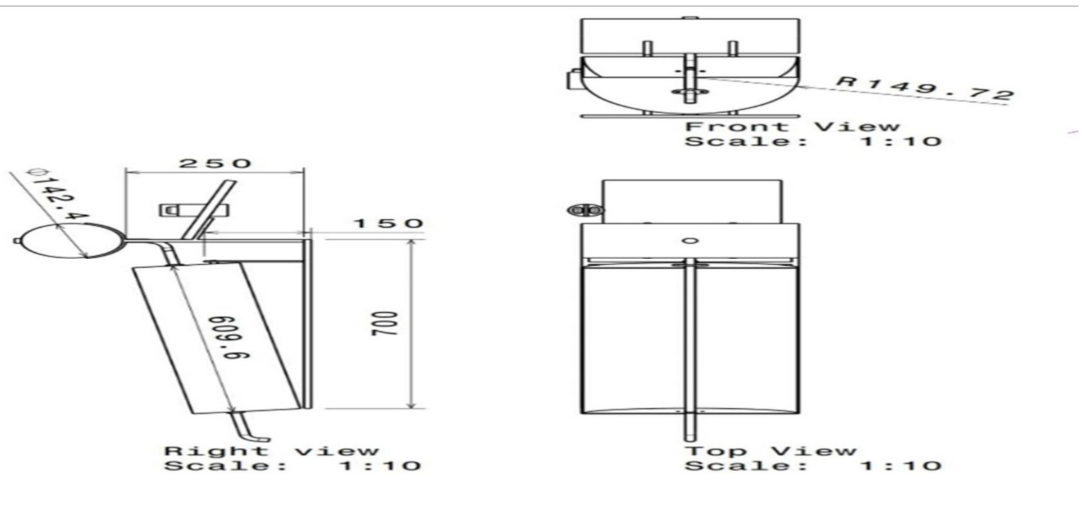
$$24 \text{ hr.} = 1 \text{ rev.}$$
$$N = 1/24\times60 \text{ rev. /min.}$$
$$N = 6.94\times10^{-4} \text{rpm.}$$

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.

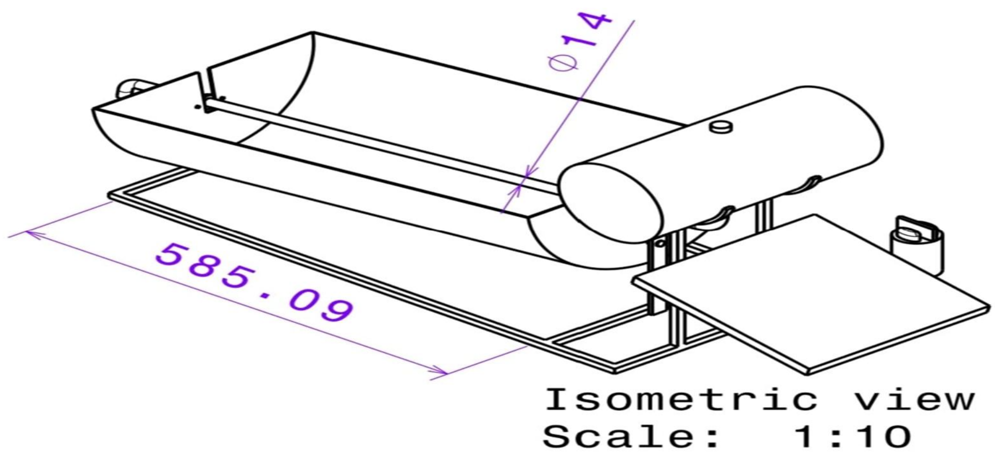
$$1 \text{ hour} = 15^0$$

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.

VII. CAD DESIGN(2D)



VIII. CAD DESIGN(3D)



IX. CONCLUSION

This paper presents and approach which could be used for designing parabolic solar water heater with inbuilt automatic solar tracking system to improve the thermal efficiency of parabolic solar water heater without utilizing fossil fuels to get maximum output temperature throughout the day.

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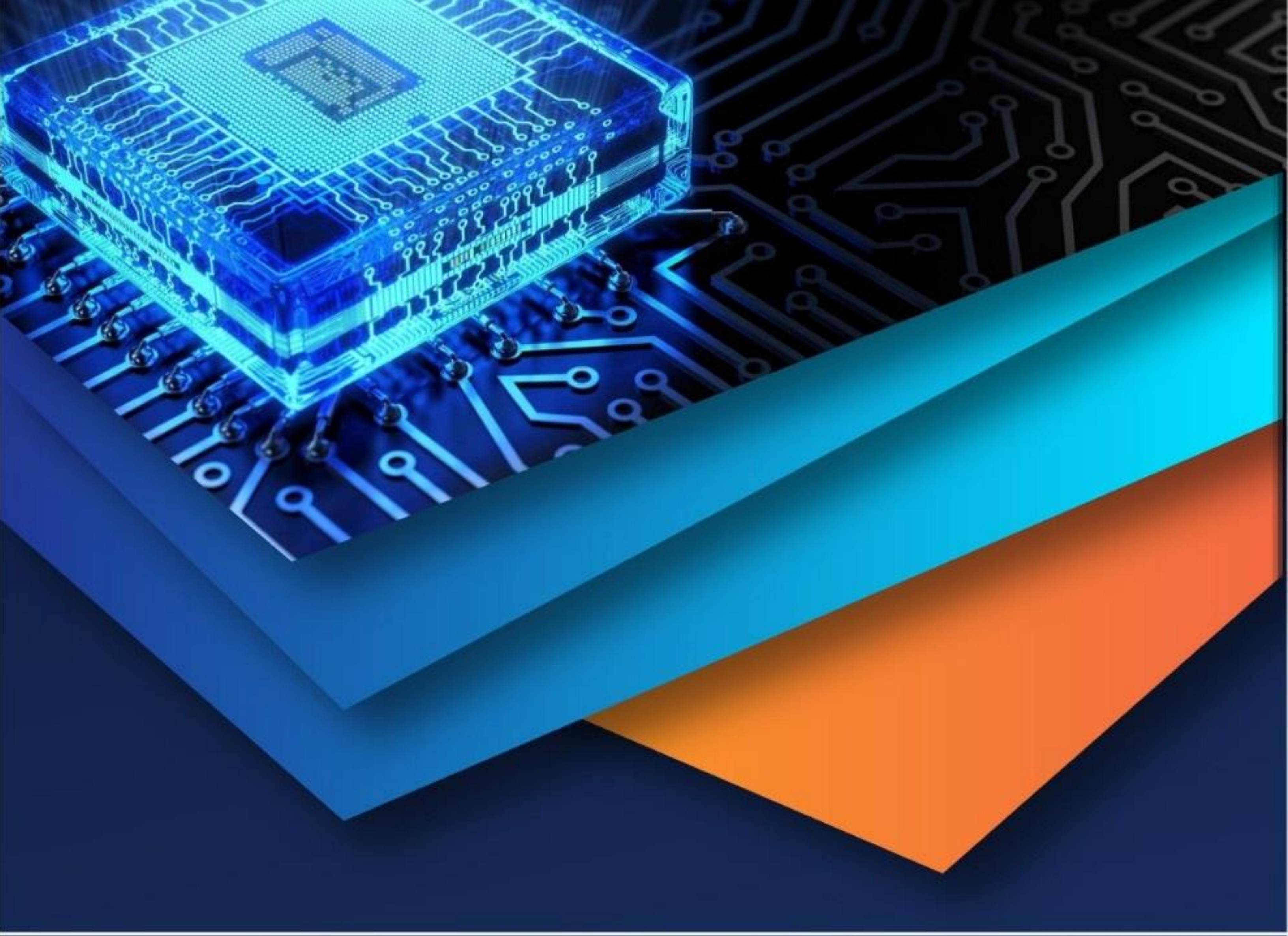

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