A REVIEW ON SOLAR WATER HEATING SYSTEMS

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ABSTRACT

The current review study examines the existing solar water heating (SWH) systems and their uses. Nowadays, there is always sufficient of hot water available for home, industrial, and commercial uses. Coal, diesel, gas, and other fuels are used to heat water and occasionally to produce steam. The primary substitute for traditional energy sources is solar energy. The method to capture a large amount of unrestricted free sun thermal energy is solar thermal water heating system. The solar thermal system is made to supply the necessary energy. The size of the systems is determined by the amount of solar radiation available, the customer's preferred temperature, the location of the system, and other factors.

I. INTRODUCTION

The most capable substitute of source of energy is solar energy.Solar energy is viewed as an appealing form of renewable energy that may be utilized for water heating in both households and industries due to increased energy demand and the expense of fossil fuels (such as gas or oil). Nearly 20% of a typical family's energy use goes toward heating water. The least expensive and most accessible sustainable energy option for households, solar water heating systems may provide the majority of the hot water a family need.

A solar heater is a device that utilises solar energy to heat water and generate steam for residential and industrial applications. Solar energy is the energy that comes from the sun in the form of solar radiations in an endless amount; when these solar radiations fall on an absorbing surface, they are turned into heat, which is then utilised to heat water. Heat losses due to radiation and convection occur in this sort of thermal collector. As the temperature of the working fluid rises, so do such losses.

II. SOLAR WATER HEATING (SWH) SYSTEM

SWH systems are often quite basic and rely solely on sunlight to heat water. When a working fluid comes into touch with a dark surface exposed to sunlight, the temperature of the fluid rises. This fluid might be the water being heated directly, which is known as a direct system, or it could be a heat transfer fluid, such as a glycol/water combination, which is known as an indirect system. These systems can be classified into three categories:

A. Active Systems

Active solar thermal systems, which are used to collect solar energy through solar collectors and transfer it to water or other heat-transfer fluids. These active systems use electric pumps, valves, and controls to circulate the fluid through the collectors and transfer the thermal energy to a storage tank or distribution system. The active system is further classified into open loop and closed loop.

In an open-loop system, the solar thermal fluid is pumped through the collectors and then directly into the potable water supply or heating/cooling system. This means that the solar thermal fluid is in direct contact with the water or heating/cooling system, which can be more efficient since there is no heat exchanger required. However, this type of system is more prone to corrosion and scaling in areas with hard or acidic water, and it is not suitable for freezing climates since the water in the system can freeze and cause damage.

In a closed-loop system, the solar thermal fluid circulates through the collectors and then through a heat exchanger. The heat exchanger transfers the thermal energy from the solar thermal fluid to the potable water supply or heating/cooling system without direct contact, which makes it more reliable and suitable for areas with harsh water conditions. In addition, closed-loop systems can be used in freezing climates by using an antifreeze solution as the solar thermal fluid, which prevents the water from freezing.

B. Passive Systems

Passive solar thermal systems, which are used to collect solar energy using solar collectors and transfer it to water or other heat-transfer fluids without the use of el other active components.

In a passive system, the fluid circulates between the collector and an elevated storage tank via natural convection. When the fluid heats up, its density decreases, causing it to rise and flow to the storage tank located above the collector. Cooler fluid from the bottom of the storage tank then flows back to the collector to repeat the cycle. The concept is straightforward and relies on the principles of thermodynamics.

Passive systems are less costly than active systems, as they do not require any electric pumps or other active components. However, they are also less efficient since they rely solely on natural convection to circulate the fluid. As a result, they may not be suitable for larger-scale heating or cooling applications.

Thermosiphon Systems

The operation and efficiency of a thermosiphon system, which is a type of passive solar thermal system that uses natural convection to circulate water between a collector and an elevated storage tank.

In a thermosiphon system, water flows naturally from the overhead storage tank to the bottom of the solar collector, where it is heated by the sun's rays. The heated water then rises to the top of the collector and flows into the insulated storage tank, where it is stored for later use. The cold water at the bottom of the storage tank then flows back into the collector to repeat the cycle. This circulation process continues as long as the absorber continues to absorb heat from the sun and water heats up in the collector.

The efficiency of the collector in a thermosiphon system depends on several factors. First, it is related to the temperature difference between the collector and the ambient temperature. The greater the temperature difference, the more efficient the collector will be at converting solar energy into usable heat. Second, the efficiency is inversely proportional to the intensity of solar radiation. This means that as the solar radiation increases, the efficiency of the collector decreases.

Thermosiphon systems are simple and require no controls or instrumentation, which makes them easy to maintain. However, their efficiency may not be as high as that of active solar thermal systems since they rely solely on natural convection to circulate the water.

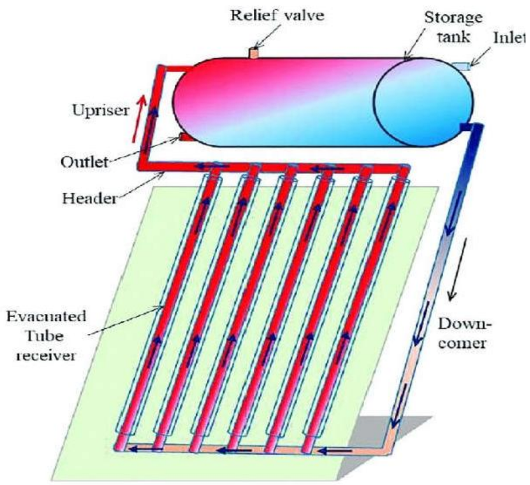

Fig. 1 Thermosiphon system [10]

C. Batch Systems

Batch systems (also known as integrated collector storage systems) are basic passive systems that consist of one or more storage tanks in an insulated box with a glass side facing the sun. Collection and storage tasks are merged in batch systems. Depending on the system, no pumps or moving parts are required, therefore they are affordable and have few components, resulting in less maintenance and fewer failures.

III. COMPONENTS OF SWHSYSTEMS

A solar radiation collecting panel, a storage tank, a pump, a heat exchanger, piping units, and an auxiliary heating unit are all common components of SWH. The following sections discuss some of the most critical components.

(A) Solar Collectors

The collector selected is influenced by the heating requirements as well as the climatic circumstances in which it will be used. Solar collectors are classified into plate solar collectors, evacuated tube solar collectors, and concentrated solar collectors.

(1) Flat Plate Collectors

Flat-plate collectors are commonly utilised in-home water heating applications. It is designed simply and has no moving components, so it requires minimum maintenance. It's an insulated, weatherproofed box with a dark absorber plate hidden under one or more transparent coverings. They can collect both direct and diffuse radiation. Their ease of building minimises the system's initial cost and upkeep. A more thorough image of these systems is of interest, and it is shown below.

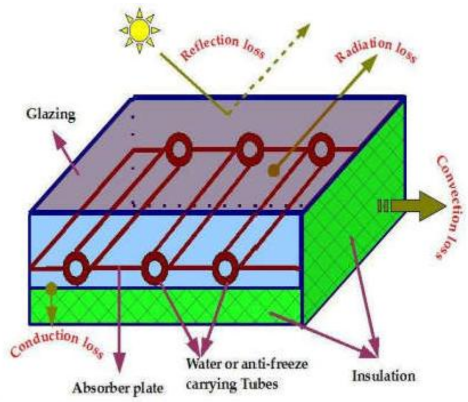

Fig. 2 Flat plate collectors [12]

(2) Evacuated-Tube Collectors

Evacuated-Tube Collectors are made up of parallel rows of clear glass tubes. Each tube is made up of a glass outer tube and an inner tube, or absorber, that is coated with a selective coating that effectively absorbs solar energy while preventing radiative heat loss. The air in the area between the tubes is removed ("evacuated") to create a vacuum, which reduces conductive and convective heat loss. They are best suited to extremely frigid ambient temperatures or persistently low-light environments. They are also employed in industrial applications where high-water temperatures or steam must be created since they are less expensive. Figure for the same is represented below.

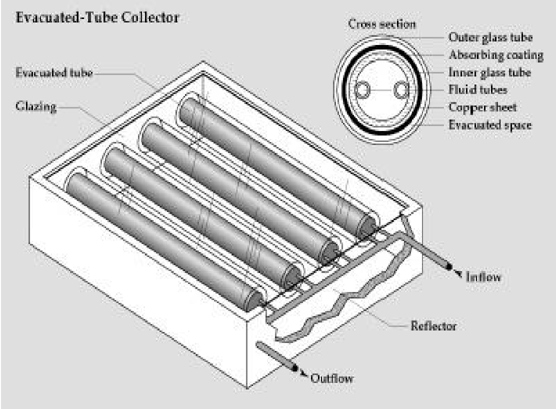

Fig. 3 Evacuated-Tube Collectors [11]

(3) Concentrating Collectors

Concentrating collectors employ mirrored surfaces to focus the sun's energy on an absorber known as a receiver. A heat-transfer fluid travels through the receiver and absorbs heat. These collectors may achieve significantly greater temperatures than flat-plate collectors and evacuated-tube collectors, but only when direct sunshine is available. However, concentrators can only focus straight sun energy, therefore their effectiveness is low on foggy or cloudy days.

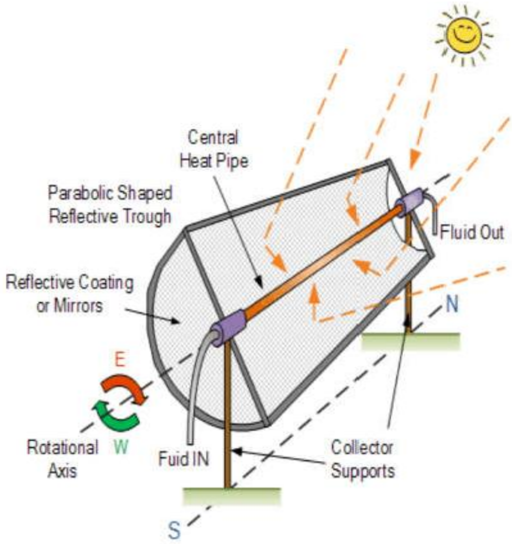

Fig. 4 Concentrating Collectors[12]

(B) Storage Tank

Most commercially available solar water heaters need the use of a well-insulated storage tank. The thermal storage tank is built of high-pressure-resistant stainless steel that is wrapped with insulat aluminium foil. Pumps are used in certain solar water heaters to recirculate heated water from storage tanks via collectors and exposed pipes. This is usually done to keep the pipes from freezing when the ambient temperature drops to freezing or below.

(C)Heat Transfer Fluid

A heat transfer fluid is used to capture heat from the collector and transmit it directly or via a heat exchanger to the storage tank. To have an efficient SHW setup, the fluid should have a high specific heat capacity, a high thermal conductivity, a low viscosity and thermal expansion coefficient, anti-corrosive properties, and, most importantly, a cheap cost. Water is the best heat transfer fluid among popular heat transfer fluids such as water, glycol, silicon oils, and hydrocarbon oils. Water is the most affordable, widely accessible, and thermally efficient fluid, although it freezes and can cause corrosion.

IV. REVIEW

Solar water heater systems are classified into two types: passive and active. Active systems are relatively expensive since they include pumps and rotating elements.

Natural water circulation, gravity, and/or pressurised water systems are used in passive systems. Passive solar water heater systems are significantly less expensive than active systems and are simpler to maintain and repair.

(Hussain Al-Madani, 2006 [1])reviewed a batch solar water heater in Bahrain that was made of a glass tube that had been evacuated. Copper coils inside the glass tube serve as collectors through which water flows. A cylindrical batch system with a maximum efficiency of 41.8% and a maximum temperature difference between the inlet and outflow of 27.8°C was tested side by side. Al-Madani calculated that the cylindrical batch system would cost $318 to produce, which is a little less than the $358 average cost of flat plate collectors.

(H.P.Garg, R.K.Agarwal, 2000 [2])the two basic ways to use solar energy are thermal and electrical. Two distinct systems produce two types of energy. The research of a system that integrates thermal and photovoltaic systems into one unit is the subject of the current effort. In essence, the system is a standard forced circulation water heater. The absorber plate is covered in solar cells, transforming the system into a combined one. A finitedifference approach is used to solve the system equations. Different solar cell areas, mass flow rates, and water masses are considered in the simulations. Pump-off and pump-on, sometimes known as the differential temperature controller, are employed.

(Jay N Meegoda, Jason Jawidzik and Paul Rodriguez, 2019 [3])a solar collector with a 1.67m2 surface area, a 10.6L storage tank, and connection pipework are all included in the proposed solar water heater. A flat plate absorber made of black plastic sheet is part of the solar collector. Transparent plastic sheet with a 1.67m2 surface area and a 6.35mm thickness covers the collection. Plastic extrusions on the back and sides of this collector provide thermal insulation. The proposed solar water heater produced 34 litres of hot water per hour at a flow rate of 11.7 °C hotter than the water entering it. According to the trial findings, efficiency on sunny days is 68.03%. Black Plexiglas solar water heater costs substantially less than copper (13.7%) offers.

(Soteris A. Kalogirou, 2004 [4])overview of the various solar thermal collectors and uses is provided. The solar collectors employed in these systems, such as flat plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish, and heliostat field collectors, are essential to all solar systems that harness solar energy. Domestic, commercial, and industrial uses all encompass solar collectors.These include industrial process heat, refrigeration, solar water heating, which includes thermosyphon, integrated collector storage, direct and indirect systems, and air systems; space heating and cooling, which includes space heating and service hot water, air and water systems, and heat pumps; desalination; and thermal power systems, wh parabolic trough, power tower, and dish systems.

(B Sivaraman and N Krishna Mohan, 2005 [5])represents research on the impact of the heat pipe's L/d ratio on the heat pipe solar collector. Two solar collectors have been created, each with a distinct L/di.The solar collector's transport tubes are replaced by a heat pipe with a stainless-steel wick. Methanol served as the heat pipe's working fluid, while the container, wick material, and heat pipe were made of copper and stainless steel.

A heat transmission factor of between 194 and 260 W of thermal energy is what is intended for heat pipes. Summertime experiments were carried out using a collector tilt inclination of 13 degrees to the horizontal. It was discovered that the collector with the L/di ratio of 52.63 was more effective than the collector with the L/di ratio of 58.82. This increased efficiency is the result of the heat transport factor of the heat pipe increasing when the L/di ratio decreases.

(Dharamvir Mangal, Devander Kumar Lamba, Tarun Gupta, Kiran Jhamb, 2010 [6])presenting one of the newest solar water heaters, an evacuated solar water heater based on the thermos syphon principle that uses sun radiation to heat water for domestic uses in homes. Convective and conductive heat loss from the inside of the solar tube are significantly reduced as the air is drawn out of the tube to create a vacuum.

As a result, wind and cold weather have less of an impact on the efficiency of evacuated solar water heaters. As a result of less heat loss, water heats up faster than with a flat plate solar water heater/collector. The advantages of evacuated tube solar water heaters were discussed in this research. In India, there is still a new kind of solar water heater that may be used in our homes to combat the challenges of climate change, global warming, energy crisis, and so on. When comparing peak efficiency levels, it may appear that there is little difference between flat plate and evacuated tubes; nevertheless, flat plate may be higher under low heat loss conditions. When averaged over a year, evacuated tube collectors offer a distinct advantage.

(K. S. Ong and W. L. Tong, 2011 [7])presents a Solar water heater system performance is determined by collection and storage tank design and sizing, as well as meteorological conditions (solar radiation intensity and ambient temperature). Natural and force convection U-tube and heat pipe evacuated tube solar water heaters were subjected to short- and long-term performance tests. The test methodologies used allowed for comparisons of solar water heating system performances even when they were evaluated at different periods of the year. The experimental results revealed that the natural convection heat pipe system was capable of heating water to 100 degrees Celsius and outperformed the other systems examined.

(K. Sivakumar [8])represent the Elliptical Heat Pipe Flat Plate Solar Collector design and were tested at a tilt angle of the collector of 11° to the horizontal. Variable cooling water mass flow rates, different inlet cooling water temperatures, and the condenser length/evaporator length (Lc/Le) ratio of the heat pipe were all examined experimentally. The collector uses five different elliptical heat pipes with stainless steel wick as the transmission tubes. Methanol has been employed as the heat pipe's working fluid, and copper tube has been used as the container material. The performance of the elliptical heat pipe solar collector has been investigated, and findings have been compared. These heat pipes were fixed to the absorber plate of the solar collector.Using experimental trials, it was discovered that an elliptical heat pipe solar collector with a Lc/Le ratio of 0.1764 had a greater instantaneous efficiency.

(S.B. Joshi, A.R. Jani, 2015 [9]) Improved Small Scale Box Type Hybrid Solar Cooker (ISSBH), a revolutionary concept created especially for small families, demonstrates 38% efficiency. Five solar panels with a 75 W output capacity make up the solar panels. The SSBH (Small Scale Box type Hybrid solar cooker) and ISSBH solar cookers each have a 15 W component.

By combining the photovolt effects, the cooking time is significantly decreased. The innovative and user-friendly characteristics offered by ISSBH include the ability to cook at any time that is convenient for the user, quick cooking, the ability to prepare four to five meals per day, a cheap price, compact size and light weight, and unattended cooking. For customers who already own a solar emergency lighting system, the price drops from $120 to $15, and vice versa.

(GianlucaCoccia,Alessia Aquilanti, Sebastiano Tomassetti, AkikoIshibashi, GiovanniDi Nicola, 2021 [10])this studies, concentrating solar cooker was introduced and experimentally tested in order to characterise its lens-mirror system for directing solar energy directly to the bottom of a cooking pot. The suggested prototype is cheap, composed of recyclable materials, and simple to make. It also has a high geometrical concentration ratio (40.97).

The solar cooker was tested outside using a saucepan filled with water and silicone oil. According to the estimation of the key thermodynamic variables, the cooker can heat 3 kg of silicone oil from 40 °C to 170 °C in less than an hour and boil 3 kilograms of water in around 30 minutes.The study's cooker can reach high temperatures with good thermal efficiency, as demonstrated using silicon oil. After examining the efficiency curves from each test, it was feasible to compare the prototype's thermal and optical efficiency to that of other cookers that had been researched in the literature. The concentrating cooker's opto-thermal ratio is excellent and on par with other concentrating cookers. Due to all the aforementioned factors, we think that the proposed solar cooker could serve as a basis for further research into the subject of solar cookers. We specifically anticipate that other researchers will find the parameter values discovered through experimental analysis valuable for simpler comparison and evaluation.

V. BENEFITS OF SOLAR WATER HEATER

The household energy demand on power utilities is decreased because to the energy saved by installing a solar water heating system. After the system has paid for itself, a solar water heater is a long-term investment that will reduce the cost of heating water. There are various advantages to using the sun's energy to heat water, in addition to the reduced use of electrical energy and cost savings. Most solar water heaters include a second water tank that feeds the regular hot water tank. The increased hot water storage capacity and decreased risk of running out of hot water are advantageous to users.

Some solar water heaters can run without electricity. If there is enough sunshineto power the system, these systems' hot water supply is secure against power outages. Pool water can be heated directly using solar water heating systems, which has the added advantage of extending the swimming season for outdoor pools.

VI. APPLICATION OF SOLAR ENERGY

Most solar energy applications focus on storing solar energy as photovoltaic (PV) heat.

Because sunlight has a low energy density, the system will get more complex and expensive as the required temperature rises. Solar thermal applications are categorised into three main groups according to the temperature range used:

1) Low temperature uses (below 100°C), including cooking, solar drying, and hot water supply.

2) Applications requiring medium temperatures (less than 150 °C), such as industrial process heat, refrigeration, etc.

3) Applications involving high temperatures (over 150 °C), such as the production of electricity.

VII. CONCLUSION

Solar water heating (SWH) is a well-established and widely used technology that is considered one of the b converting solar energy into thermal energy. While modern SWH systems are available for sale, there is still room for improvement to enhance their reliability and effectiveness. The design elements and associated technological developments of SWH systems have been the focus of research to improve their energy efficiency and cost-effectiveness. Although there are several solar water heating systems available on the market, those designed for developing nations' tropical climates are more frequently used. Recent advancements in heat pipe-based solar collector technology have shown a promising design to use solar energy as a reliable heating source in solar-adverse locations, such as regions with limited sun exposure. However, due to environmental concerns, several factors, including the refrigerant type used, can affect the environmental impact of heat pipe-based solar water heating systems.

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