Experimentally Investigating the Flat Plate Solar Water Heating System (FPSWHS) for South Indian Climate

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Abstract. The heat transfer performance of a flat plate solar water heating system was investigated experimentally in this paper (FPSWHS). The main objective of this investigation is to analyze the behaviour of FPSWHS with a 1.5 m² receiver surface area in South Indian weather conditions and to calculate the heat energy created by the receiver for residential usages, which lessens electricity usage and assists the nation in conserving energy acquired from carbon fuels. Water was employed as the working medium in this investigation. The trials have been conducted in the first week of March 2021 at 13.0827° North, 80.2707° East. The findings confirmed that the solar thermal system's estimated average efficacy remained 44.3%, and the system's maximum output temperature of water was 67°C.

Keywords: FPC; SWH; energy efficiency; hot water; domestic solar water heater.

1. Introduction

Solar energy systems are devices which utilize the solar heat provided by the sunrays to boil water for residential and industrial usage. Solar water heating systems provide boiled water with a wide range of temperature [1, 2]. Additionally, they have the benefit of reducing reliance on electricity generated, minimize ecological degradation, producing higher power than solar cells, and achieving the requisite financial viability. Solar collectors are intended to transform solar energy striking the opening surface into thermal energy in the absorbing section and transport that energy to the coolants via the working medium [3, 4]. Solar heating systems are primarily composed of a collecting component, a heat exchange mechanism (which includes a circulating medium and circulating mechanism), and a water tank.

There are various varieties of solar heating system, but perhaps the most common seems to be the flat plate type collecting system, which is inexpensive, readily available locally, and simple to set up and manage [5, 6]. It is utilized in a variety of purposes, both residential as well as business, that need
mild to high temperature range [7, 8]. Solar collecting system performance is influenced by the collecting component structure, the kind of heat transfer fluid used, and the seasonal changes. As a result, several attempts are being made to enhance FPSWHS performance using a variety of technologies. The researchers examined ways to improve the absorbing surface's capacity to catch solar irradiance, to reduce heat dissipation from the collecting device, to improve the thermal characteristics of circulating fluids, and to influence the meteorological patterns at various points on the collecting surface [9, 10]. Lastly, several academics are examining the financial potential of extended use of these collecting components [11, 12].

Ever since the seventeenth century, pioneering development on solar water heating devices had also been conducted. Numerous studies had been conducted since then, with the goal of enhancing present solar system's performance, which employs a flat plate as well as evacuated tube systems to harvest solar heat and transfer energy to the liquid to rise their temperature. When comparing the two aforementioned collectors, the evacuated tubes were considered to be more efficient than the flat plate systems because of its efficient construction [13, 14], which minimizes excessive solar losses, caused by radiation. The flat plate systems, on the other hand, are more advantageous due to its simple design, minimal maintenance requirements, and cost-effectiveness [15, 16]. Solar water heating systems are accessible in direct and indirect circulation configurations, with indirect circulation systems utilizing the change in density of the liquid and direct circulating systems utilizing the pumping systems [17, 18].

Hobbi and Siddiqui [19] investigated the effectiveness of FPSWHS used for heating water for household use in a small family's residence in North America. The analysis has been done through simulating environment utilizing a simulation package in order to find the absorber's optimal solution for all important architectural characteristics, incorporating the sunlight portion was indeed the optimizing variable. The mathematical findings indicated that enhancing the circulating velocity significantly increases both the solar component and collecting efficacy. The systems could meet around 60% of cold season hot water's demands and around 86% of hot season's hot water's requirements. Ultimately, the collecting arrangements with a selectively protective film could save up to 50% of yearly hot water energy bills. Serale et al. [20] premediated a study to enhance the heating behavior of FPSWHS. Heat optimization demands the use of latent heat contained in the sludge based phase shifting substances in addition to the freshwater and cleansers. The research recommended that solar energy systems be integrated with sludge type phase shifting substances, with the current design method being implemented on an organic phase shifting substances. The findings indicated that the device's thermophysical qualities were enhanced as comparing to utilizing a conventional solar collecting system. Sami et al. [21] assessed the economic and environmental implications of integrating the flat plate systems with high-performance dwellings. Three residences were selected for this inquiry in various areas around Algerian climatic zones. This survey's inquiry was based on the use of a new approach utilizing weather information for certain period. The research concentrated on lowering the space requirement for FPSWHS installation in order to minimize the deployment price in terms of energy and economics. The findings indicated that solar water heaters amounted to efficiency gains of around 60% and 40% in the different areas. As well as the yearly operational cost savings for FPSWHS reached 70 percent in the south parts and 50 percent in the north parts of the country, correspondingly. Yousefi et al. [22] had tried to increase the effectiveness of the FPSWHS through the mixing of an alumina based nano-fluid with the water. The nano-fluid employed in the studies had a mass fraction of between around 0.3% The nanoparticles was around 20 nm in size and had a changeable operating flow rate of liquid. The findings indicated that whenever a 0.3 percent nano-fluid fraction was utilized instead of water, the collecting medium efficiency increased by 29 percent, whereas the largest increase in efficacy was around 16 percent when the surfactants had been utilized.

The present study has been planned to investigate the performance of a low capacity flat plate water heating system (FPSWHS) for the residential application under the South Indian Climatic conditions. The experimentation was conducted a FPSWHS under thermosyphonic flow situation
without the assistance of any external pumping devices. The efficiency and maximum water temperature were determined for a 100 litre capacity FPSWHS.

2. Experimental
The FPSWHS is composed of various critical components as illustrated in Figure 1, which might have an effect on their own heat transfer efficacy. A transparent top cover, housing, a receiver surface, the risers, and thermal insulating cover are included. The absorbing surface (coated with the black paint) was designed as 1.5 m² total exposed area to receive the radiant energy from the sun and the stowing capacity of 100 litres per day. The top glass wall admits the solar heat to penetrate into the collecting surface, thereby, the water inside the risers get heated and had risen to the top through thermosyphonic action [23, 24]. These riser tubes serve as a heat transferring medium, whilst the solar collector enhances the system's thermal performance. The sides and base portions of the FPSWHS are protected with insulating material to limit energy losses to the external environment via radiative and conductive mode of transfer, hence increasing the FPSWHS's performance. The most prevalent issue that degrades the FPSWHS effectiveness is dirt deposition, which necessitates cleanup to preserve efficiency [25, 26]. A further typical dependability concern in FPSWHS, according to Hawwash et al. [27], is scorching owing to stagnant temperatures. Excessive heating would degrade the materials, resulting in leakage and interruption of system functioning, lowering the FPSWHSs dependability. The FPSWHS was erected towards south as per the guidelines from the literature to achieve the maximum possible efficacy [28, 29].

![Figure 1. Schematic of FPSWHS.](image)

3. Results and discussion
The investigations were performed from dawn to sunset in early March of 2021 at 13.0827° North, 80.2707° East. Six days of evaluations have been conducted to ensure the convergent validity. The temperature of the water and ambience were recorded with the aid of temperature sensors (±0.2°C accuracy) and the average water temperature was determined by taking average at all the point of measurement. The solar irradiance was assessed using a high precision solar meter (accuracy of ±10 W/m²) [30]. The following paragraphs examine and report the average values in even more detail. By dawn, all trial situations had experienced a new fill-up of the tank's water. Then, each trial day at sunset, water was emptied as well as refilled with almost the similar quantity of water.
The environmental measurements had been recorded and charted, as seen in Figure 2 and Figure 3. The instantaneous sun irradiation for the testing sessions is depicted in Figure 2. Solar irradiation recorded on experimentation sessions averaged as 25.7 kJ/day. It was about the yearly average level of radiation at the site in which the testing got managed. Figure 3 depicts the variance in air temperature throughout the course of the monitoring periods, which showed gradual variations from dawn to sunset owing to the radiant heat from the sun and wind current.

![Figure 2. Instantaneous solar irradiation.](image1)

![Figure 3. Temperature of the atmosphere during the examination.](image2)
The water temperature’s temporal fluctuations are depicted in Figure 4. The water temperature was recorded at different points inside the storage tank and their values were averaged to obtain their overall view. The temperature of the water improved steadily from morning to evening and reached a temperature of 67°C at the evening, acquiring the radiant heat from the sun with the aid of flat plate conducting arrangements.

![Figure 4. Mean water temperature during investigations.](image)

The instantaneous energy efficacy of the FPSWHS system is demonstrated in Figure 5. The efficacy was low during the morning hours and reached the peak in the afternoon owing to the excess
availability of energy during those times and once again started declined till the evening. The maximum efficacy recorded was 60% during the late noon. The average daily efficacy was calculated as the 44.3% at this location and environmental conditions.

4. Conclusion

The thermosyphonic driven flat plate solar water heating system (FPSWHS) was installed and assessed for the South Indian climatic conditions at the location of 13.0827° North, 80.2707° East to find it performance and suitability. The collecting area was 1.5 m² and the storage capacity was 100 litres per day. The experiments were continuously run for the six days during the trial period and the average value of the findings were examined and presented. The water temperature was reached up to 67°C at the sunset and the instantaneous efficacy was reached up to 60% in the late noon. The daily mean efficacy was determined to be 44.3%, which is good enough to use the proposed FPSWHS in the assessed location.

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