CONSTRUCTION AND PERFORMANCE TEST OF FLAT PLATE SOLAR COLLECTOR USING WATER HEATING SYSTEM

A Thesis
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Of

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LETTER OF TRANSMITTAL

January, 2025

To

Shahinur Rahman

Lecturer & Coordinator

Department of Mechanical Engineering.

Sonargaon University

Subject: Submission of Project Report**.**

Dear Sir,

We are pleased to submit the project report on **"Flat Plate Solar Collector Using Water Heating System.".** It was a great pleasure to work on such an important topic. This project has been done as per instruction of your supervision and according to the requirements of the Sonargaon University.

We expect that the project will be accepted by the concerned authority we will remain happy to further explanation that you may feel necessary in this regard.

Thank You

Sincerely yours,

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DECLARATION

We do hereby solemnly declare that, the work presented here in this project report has been carried out by us and has not been previously submitted to any University/ Organization for award of any degree or certificate

We hereby ensure that the works that has been prevented here does not breach any existing copyright.

We further undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligation.

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ABSTARCT

The flat plate solar collector (FPSC) is an effective and sustainable solution for water heating, utilizing solar energy to reduce dependency on conventional energy sources. Comprised of an insulated box, an absorber plate, and tubes for water circulation, FPSCs efficiently capture sunlight and convert it into heat. The solar energy heats the absorber plate, transferring the heat to the water flowing through the tubes. This technology offers several advantages, including cost savings, minimal maintenance, and environmental benefits by lowering greenhouse gas emissions. FPSCs are widely used in both residential and commercial applications for hot water production, making them an accessible and eco-friendly alternative to conventional water heating systems. Their ability to utilize renewable solar energy promotes sustainable development and supports energy conservation efforts.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Solar energy is a provider of clean and green energy, which can be used to fulfill global energy needs [1,2]. The solar energy is very important which is coming from the sun as a form of the solar radiation, this can be an alternative energy source. The solar radiation can be useful for our life to the heating building, heated water in order to produce steam and used it in any way such as in industrial and domestic. The system of solar water heating is consumed and cheapest about 20% of the family total energy consumption [3]. Kabeel et al. [4] show considerable improvement in the daily solar collector efficiency is obtained with increasing the nano-particle concentration up to 11% for concentration 3% with; this increase in efficiency is bounded by ± 10% uncertainty and the outlet water temperature was increased with increasing of nano-particle concentration by 5.46% for concentration 2%. El-Said and Abou Al-Sood [5] displayed experiments for investigation of air injection into the shell side of shell-and-multi-tube heat exchanger aims to augment the thermal performance and the obtain significant impact on the heat exchanger performance enhancement. Liu et al. [6] show that the maximum value of the system efficiency are 62% under small different temperatures between ambient air temperature and the collectors' temperature. The increase difference temperature between the temperature of collectors and the water temperature increased the heat gain by collectors. Kabeel and El-Said [7] demonstrate hybrid solar desalination system consisting of a humidification dehumidification unit and single stage flashing evaporation unit and they studied hybrid desalination system give a significant operational compatibility between the air humidification dehumidification method and flash evaporation desalination. Weitbrecht et al. [8] saw that experimentally study in the water solar collector of a flat plate with laminar flow



Figure 1.1 Solar power Hotsell Water Heating

condition and observed the distribution of the flow through the collector. The higher collector's efficiency factor was observed at a higher rate of water flow [8,9]. Vendramin et al. [10] shows that the maximum outlet temperature was recorded in flat plate collector was 55 °C, while total loss of the heat to feed tube solar water heating systems was 3.2 MJ/d, corresponded to 16.4% of energy collected by flat plate collector and 19.8% of energy supplied to hot water tank. Sontake and Kalamkar [11] noted that the maximum efficiency of the collector at an inclined angle of 45° from the horizontal surface [12]. Kabeel et al. [13] were enhance the heat transfer in a solar water heater by using Cu nano-particles dispersed in water for various concentrations ranging from 0% to 5%. The water flow by the gravity of the reservoir, the discharge of water selected from 0.1 to 0.2 litter per minute, with accuracy of 0.005 L. Bhowmik and Amin obtained from an observation that the collector efficiency and heat transfer rate are strongly depended on solar radiation. The radiation sent out by the collector absorber plate thus maximized the efficiency of the collector. The collector efficiency is recorded without and with reflector is 51–61% respectively. Prasad et al. [14] divided the solar collector energy into two types: air-type, used air as working fluid to transfer the heat. Another type, water (hydraulic), take the water as a heat transfers fluid. They show that the coefficient of heat transfers was low and thermal efficiency was low when used air-type, while when used watertype collector having high thermal performance. The solar water heater with circulating water through

the tube of aluminum was tested and designed by Mongre and Gupta [15]. The efficiency was increased by fifty-five percent by increasing the area of glazing. Hernández and Guzmán [16] studies two flat plates' collector with the coil of different material, one of them is copper and the other coil stainless steel [17]. The objective of this article is to investigate the heating of water to use in many porpoises, as well as low cost.

1.2 Background

Solar thermal water heating systems in buildings are well-established technologies in many countries around the world. It helps to protect the environment by eliminating the need for heat generated by the combustion of fossil fuels and mitigating greenhouse gas emissions. Solar energy is one of the key sources of renewable energy for building heating, cooling, hot water and generation of electricity. For decades, solar thermal energy has been used by ancient people to heat and dry solar energy. For several nations, it has become a big industry. It is well known that the construction sector contributes 40% of the total global primary energy consumption. In Spain, about 16% of total electricity consumption is related to the construction industry, which is why many of the energy policies and strategies for reducing CO2 emissions from climate change are targeted at reducing building energy consumption. A large amount of the overall energy production may be provided by solar thermal technologies at an acceptable price.

In recent times, solar energy has been developed in a broad range of thermal processes for power generation, water heating, and drying and water purification. There is a recent tendency in the construction industry to implement solar thermal systems with the idea of building-integrated solar thermal systems (BIST). The "multifunctional energy facade" is known as BIST, which differs from traditional solar panels in which it offers a broad range of architectural design solutions (i.e., colour, texture, and shape). In contrast to the configurations of building-added, BIST provides a range of advantages by higher esthetic benefit. It has versatile functions including heating/cooling of the building, the availability of hot water, energy generation as well as enhancing ventilation and the overall appearance of buildings as an ideal solution. However, this is a key element in the development of renewable energy that could cover, in whole or in part, the energy needs of a building . Designers take into consideration solely energetic roles and an excess of distinct qualities. A typical solar water heater (SWH) is made up of a glass cover to

encapsulate the absorber and the insulator for solar irradiation . The collector system often becomes a part of the facade, which is more about functionality than the aesthetic, an issue with conventional collectors. Because solar energy is typically not enough to satisfy demand, solar heat must also be stored in a thermal unit. These steps include coloured collectors, configurations that make it possible to achieve optimum inclinations of the solar collector on vertical facades, the inclusion of solar collection in cladding systems for the architecture, and the inclusion of solar collectors in fixed shading devices and glazing systems.

A few studies were based on overcoming the obstacles of conventional collectors of solar systems by evaluating the operating effectiveness, the practicality of construction, economic feasibility, and implementation opportunities of novel modern architecture interventions that easily incorporate solar thermal systems into buildings. It has resulted in greater lobbying power and an increasing impact of the solar water heater industry on policy-making and increased collaboration between SWH companies and the real estate market, allowing SWH systems to be more competitive in the building environment. It is incredibly challenging to identifying practical and appropriate design solutions for cost-effective solar thermal collectors and solar thermal systems that are highly desired. Therefore, the purpose of this study is to compare the performance of flat plate and evacuated tube collector's solar water heating systems in the facade of the building on thebasis of the urban house occupants.BIST is thus a promising option for enhancing energy efficiency and reducing maintenance costs in contemporary build environments with excellent applicability and building protection along with increased energy production.

1.3 Experimental Works

This solar thermal system work aims to emphasize key aspects of system architecture and the incorporation of collectors in the design and collector design of the building facade. The electrical heater backup is used to fulfil the hot water requirements in the system of both collectors with storage tank. The system performance measurement of collectors was conducted at an operational temperature of 65 °C and with a tilt angle of 40 ° by the process of F-chart and the T*SOL software simulation technique which is a dedicated software for solar thermal heating systems to determine the optimum solution to be used.

The F-chart model relates annual solar energy fraction to the heat output. In the context for advancing with the new SWH schemes, the restriction and feasibility review were also carried out with the principle of financial analysis using the same software module.

The solar thermal water heater needs to be integrated to determine the size of the storage tank. A solar thermal collector collects heat by direct absorption of sunlight that converts energy into a more usable form of energy. Depending on the occupancy and consumption profile of the chosen building, the number of collectors is needed. Fig. 1 displays the design simulation of the flat plate collector and the evacuated tube collector.

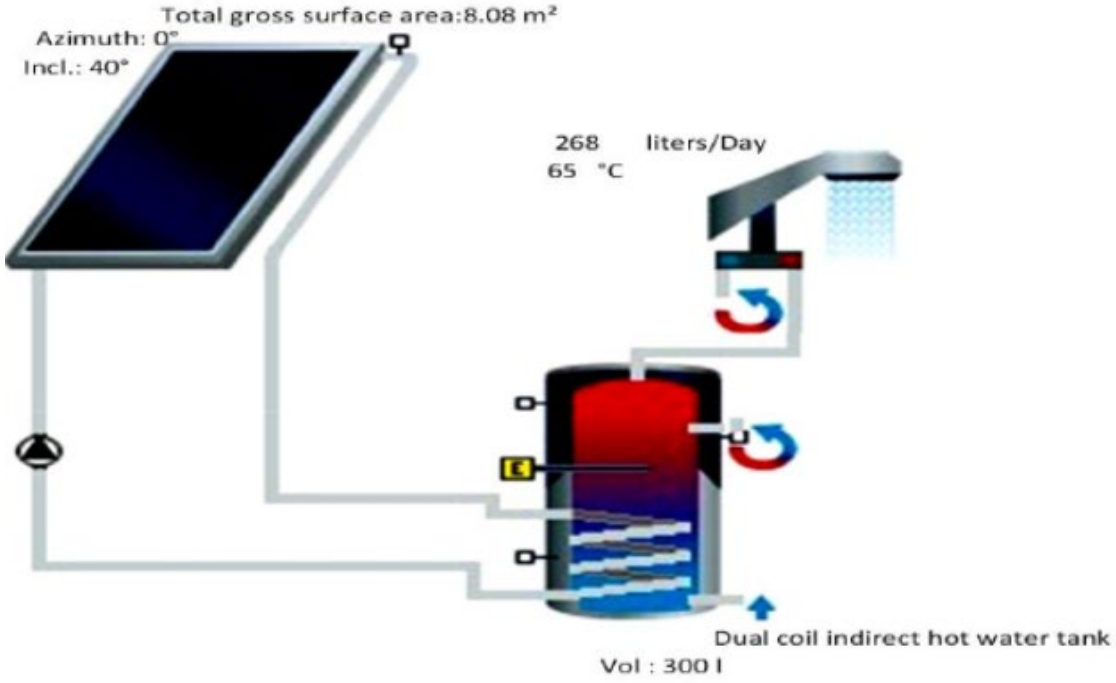


Figure 1.2 : Flat -Plate

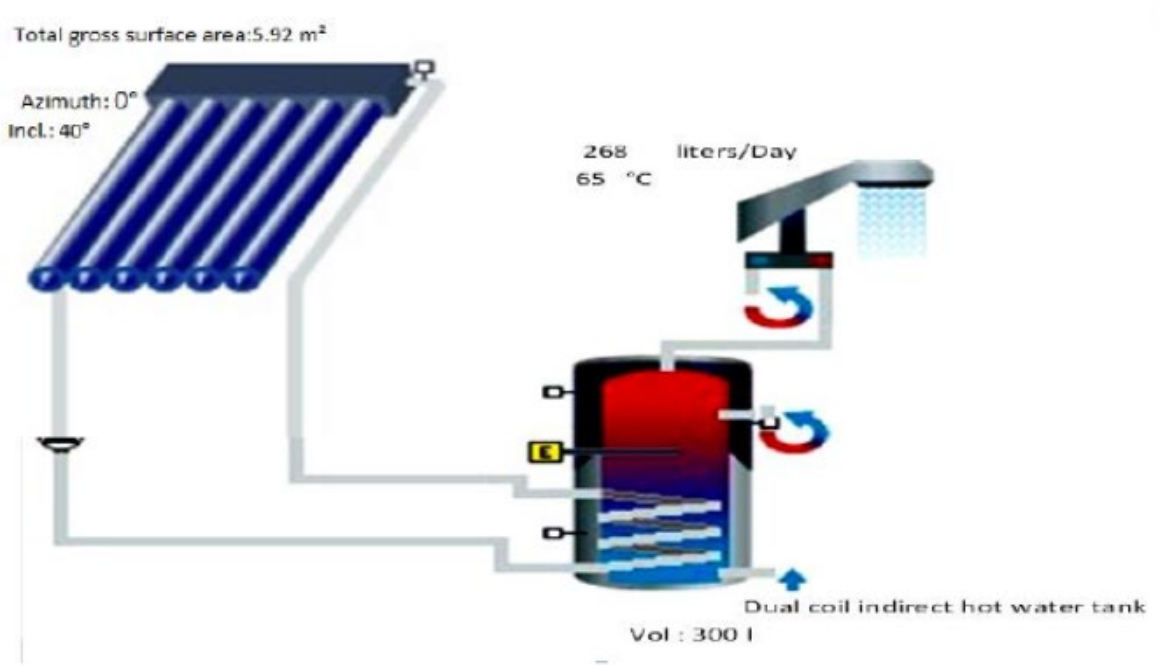


Figure 1.3 : Evacuated Tube Collector

1.4 Overview of solar Water Heating

Solar energy can be utilised as a form of heat, such as solar water heating and as electricity, such as solar photovoltaic. Solar water heating systems are commonly referred to in industry as Solar Domestic Hot Water (SDHW) systems and it is a technology that is not entirely new. In the 19th century, people used a stove to heat water by burning pieces of wood or coal. In cities, the wealthier heated their water with gas manufactured from coal.

In many areas, wood, coal or gas could not be easily obtained and hence such fuels were often expensive. problems, a much easier and safer way to heat water was created. This was achieved by placing outside a black painted metal tank full of waterto absorb solar energy. The disadvantage was that even on clear hot days it usually took from morning to early afternoon for the water to get hot. As the sun went down, the tank rapidly lost its heat because it had no insulation. In 1891, Clarence Kemp patented the old design of metal tanks exposed to the sun by adding a metal panel to the tank, shown below in Figure 2.1a, in order to increase the efficiency of the solar tank . In the beginning of the 20th century, inventors designed improved systems, but still the heating and the storage unit were one, and both were exposed to the weather and the cold nights.



Figure 1.4 : Solar Water Heating

1.5 Flate Plate Collectors

Flat-plate collectors are the most common for residential water-heating and spaceheating installations. A typical flat-plate collector consists of an absorber, transparent cover sheets and an insulated box. The absorber is usually a sheet of high-thermalconductivity metal with tubes or ducts either integral or attached. Its surface is painted.



Figure 1.5 : Flate Plate Solar Collector

The heat pipe as shown in Figure 2.4c3 is similar to the direct flow tube type. In this case there is a change of the state of the liquid. Inside the heat pipe there is a small quantity of purified water and some special additives. Due to the vacuum of the tube, the water boils at a lower temperature, typically 30 ºC, so when the heat pipe is heated above 30ºC the water vaporises. This vapour rapidly rises to the top of the heat pipe transferring heat into the condenser. As the heat is lost at the condenser, the vapour condenses to form a liquid and returns to the bottom of the heat pipe and the process starts again.

1.6 Solar Air Collectors

Solar air collectors operate similarly to liquid collectors at the difference that air is circulated through the collector to cause of heat transfer. Air collectors are simple flatplate collectors used primarily for space heating

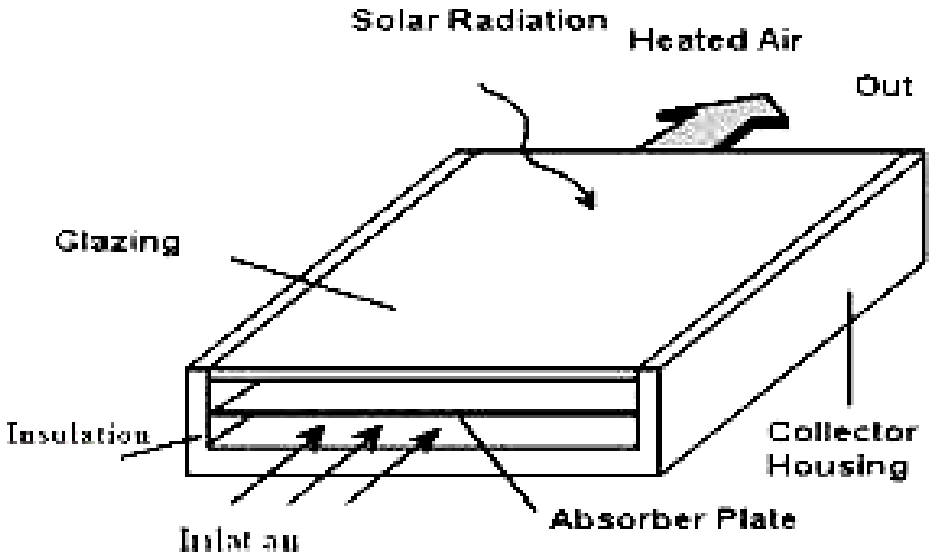


Figure 1.6 : Solar Air Collector

The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. Air collector absorber plates can be unfilled or wavy to create air turbulence that helps the heat to pass from the plate. The air flows through the absorber by natural convection or it is forced by a fan. As air conducts heat slower than liquid does, less heat is transferred between the air and the absorber than in a liquid collector. The disadvantage of this design is that it can also increase the amount of power needed for fans and hence increase the costs of operating the system .

1.7 Evacuated Tube –Heat Pipe Collectors

The Evacuated Tube Collector as shown in Figure consists of rows of parallel transparent glass tubes, each of which contains an absorber tube covered with a selective coating. When evacuated tubes are manufactured, air is evacuated from the space between the two tubes so forming a vacuum. Conductive and convective heat losses are eliminated because there is no air to conduct heat or to cause convective losses. There can still be some radiant heat loss (heat energy will move through a space from a warmer to a cooler surface, even across a vacuum); but this loss is small and of little consequence compared with thevamount of heat transferred to the liquid in the absorber tube.

Evacuated tube collectors can be classified in two main groups:

1. Direct flow tubes: the heat transfer fluid flows through the absorber,
2. Heat pipe tubes: tubes with heat transfer between the absorber and heat transfer fluid of the collector.

The direct flow collectors as shown in Figure 2.3 consist of a group of glass tubes. Inside each tube there is a flat or curved aluminium plate which is attached to a metal (usually copper) or glass pipe depending on the configuration.

The aluminium plate is generally coated with a selective coating. The heat transfer fluid is water and circulates through the pipes, one for the inlet fluid and one for the outlet fluid. In an evacuated-tube collector, sunlight enters through the outer glass tube, strikes the absorber tube and is transformed into heat. The heat is transferred to the liquid flowing through the absorber tube.

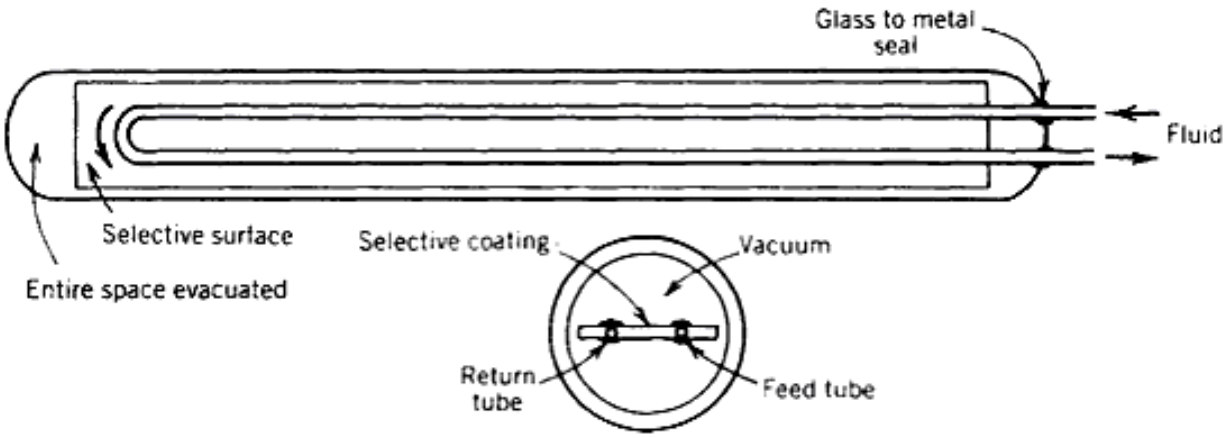


Figure 1.7:Direct evacuated tube Flow collector.

The heat pipe as shown in Figure 2.3 is similar to the direct flow tube type. In this case there is a change of the state of the liquid. Inside the heat pipe there is a small quantity of purified water and some special additives. Due to the vacuum of the tube, the water boils at a lower temperature, typically 30 ºC, so when the heat pipe is heated above 30ºC the water vaporises. This vapour rapidly rises to the top of the heat pipe transferring heat into the condenser. As the heat is lost at the condenser, the vapour condenses to form a liquid and returns to the bottom of the heat pipe and the process starts again.

1.8 Problem Statement

The increasing reliance on conventional energy sources for water heating contributes to environmental degradation, high energy costs, and greenhouse gas emissions. Despite the abundance of solar energy, its potential remains underutilized in many regions, particularly for water heating applications. The lack of efficient, affordable, and user-friendly systems hampers widespread adoption of solar technologies. This project addresses these challenges by developing a flat plate solar collector (FPSC)-based water heating system, designed to harness solar energy efficiently and sustainably. By reducing dependency on non-renewable resources, the project aims to offer an eco-friendly, cost-effective, and reliable solution to meet hot water demands across various sectors.

1.9 Objectives

We have some specific objectives for this project and they are pointed below:

- Design And Construct of a Flat Plate Solar Collector Using Water Heating System.
- To implement and study of Flat Plate Solar Collector Using Water Heating System.
- To design & construct water Heating system.
- To take necessary notes from the project for future improvements.

1.10 Structure of the Project

This Project is organized as follows:

Chapter 1 Introduction: The first chapter contains the statement of the introduction, problem statement, objectives of the study and the project outline.

Chapter 2 Literature Review: The chapter two contains our introduction, literature review part.

Chapter 3 Hardware and Software Analysis: Chapter three describes the theoretical model. Here we mainly discuss about proposed system Hardware and software development of our project etc.

Chapter 4 Methodology: Chapter three describes the theoretical model. Here we mainly discuss about proposed system architecture in details with having block diagram, circuit diagram, structural diagram, project working principle, complete project image etc.

Chapter 5 Result and Discussion: Chapter four deals with the result and discussion and discuss about our project advantages and application.

Chapter 6 Conclusion: Chapter five all about our project conclusion and future scope.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is arranged on Literature Review. Here's a look at some of last year's literature, like our project. By reading them, we can overcome the mistakes of the previous project and make a more effective project.

2.2 Related Research/ Works

Mohamed Abu Waseem et. al. (2018) This plan seeks to enhance the effectiveness of the heat transfer rate from the absorber pipe wall to the working fluid by using different kinds of inserts and inner caps. Some of the techniques of enhancing the effectiveness of the heat transfer rate to the operating environment are: increasing the contact region of the fluid with the absorber pipe,using certain barriers, such as introduction, which raises the residual time of the fluid and thus reduces the stress across the pipe, decreasing the speed of the working fluid. The analysis was carried out to investigate the impact of heat transfer in absorber pipes with different kinds of fine profile and also to compare the outcomes with the absorber pipe without fine [18].

D Prakash et. al. (2018) This research concentrated on the efficient use of solar energy through a new solar water heating scheme and the flow of heat in the indoor construction is detained by adequate ceiling insulation material. The altered isolated ceiling with solar water heater is intended and numerically simulated with validation in the commercial computational fluid dynamics software. Through this research, the variables affecting the efficiency of the solar water heating scheme and thermal insulation capability are analysed and the optimal layout of the adapted ceiling structure is defined. The modified roof system produces 25 L of hot water per day with a temperatureincrease of 60 ° C in the summer season. The same roof system also maintains the ceiling temperature at about 27 ° C for a full day in the summer season [19].

S. Sadhishkumar et. al. (2018) The present work was initiated to study the possibility of using Phase Change Materials (PCMs) to store solar energy and to use this energy during the night to heat water for domestic purposes. In this research, the efficiency of an

enclosed water-in-glass pipe solar water heater was explored using three techniques (i.e.) with no reflector, reflector and reflector cum PCM (Paraffin wax). Factors influencing the efficiency of water-in-glass evacuated tube solar receiver pipes will be discussed and a numerical analysis of water circulation through the pipes will be provided. The findings of the simulation were then output with those of the test outcomes. It was found that the use of the suggested arrangement can result in 5 °C to 7 °C benefits over prolonged phases of moment in the stored warm water temperature [20].

Ankit S. Gujrathi et. al. (2017) In this research, an attempt is produced to use Ansys 15.0 Workbench software to model a Parabolic Trough Collector. The PTC has been intended for a concentration ratio of 25. The PTC has been simulated at distinct mass flow speeds of 0.25 kg / hr, 0.5 kg / hr, 0.75 kg / hr and 1 kg / hr respectively, and the outcomes are discussed. The heat transfer features such as heat transfer coefficient, Nusselt number and thermal flux are also researched for distinct mass flow speeds. The peak water temperature is discovered to be 3670 K for a mass stream speed of 0.25 kg / hr with a collector effectiveness of 51.2%. The mass flow speed of water through the receiver pipe is diverse and all the outcomes achieved have been observed. The peak water outlet temperature is 3660 K and is discovered to decline to 3180 K with a rise in the mass flow rate from the mass flow frequency of 0.25 kg / hr to kg / hr respectively. Although the temperature reduces, the heat transfer rate increases with the rise in the mass flow rate shown by the enhanced heat transfer ratio and the Nusselt number [21].

Arun K. Raj et. al. (2017) Experimental investigation on flat table solar water heater raiser pipe with and without fine. In addition, investigation on Raiser pipe with increasing fine contact region such as raiser tube with standard fine (90 ° contact area), reversed raiser tube with standard fine, raiser tube with altered fine (270 ° contact area) and inverted raiser tube with modified fine. As the surface area increase heat transfer from fins also get increases. Comparing the outcomes of these five distinct propellers, it is discovered that the region of touch between the raiser pipe and the fine heat transfer rises. The reversed raiser pipe also provides more water production temperature than the conventional raiser pipe. Thus, the application of the fine in panel flat panel collector (FPC) is also the most successful methods that boost the heat transfer rate and reduce the region of touch between the fine and the raiser pipe arising in a rise in water supply temperature through the raiser pipe [22].

K. Vasudeva Karanth et. al. (2017) This research analyses the heat efficiency consequences when distinct sizes and shapes are chosen for the absorber plate pipes. The CFD analysis shows that the circular cross-section tube of the collector having flattened the contact surface with that of the absorber plate provides significantly better thermal performance vis-à-vis other settings in terms of the Nusselt number. The numerical research demonstrates that the heat efficiency differences are important while for the solar panel pipes distinct shapes and sizes are regarded based on the criteria of steady cross section area and steady perimeter. The criterion with a steady cross-sectional region indicates that the pressure drops and absolute temperature increase across the pipe is comparatively big for triangular pipe construction [23].

Mohammed Abdul Junaid et.al. (2017) The main objective of this study is to present the design of the solar flat plate collector using CAD software to perform thermal analysis at 11 am, 12, 1 pm & 2 pm in the month of March and keep the mass stream frequency as steady. GAMBIT 2.4 is used for modelling purposes and ANSYS FLUENT 14.5 is used for evaluation. It is calculated from the time-related simulation of FPC at 11.00am to 2 pm. The input temperature is higher in the 12:00 collector i.e. 40.89 ° C when the water inlet temperature is 25 ° C so that the temperature rises to 15.890C and as the time increases the output temperature declines [24].

V. Y. Chaudhary et. al. (2017) The research demonstrates the use of solar energy with the assistance of CFD Analysis containing evacuated tube heat pipe which transforms radiation energy into helpful heat. The current use of nanofluids in solar thermal technology to improve heat transfer is of concern. Geometry is made up of two heat pipes. The working fluid used for heat pipes is water and Al2O3 respectively. Nanofluid thermal output includes closed tube heat pipe solar water heater is enhanced than standard evacuated tube heat pipe solar water heater (SWH). The impact of the mass flow rate over the condenser and the inclination angle on the results of the evacuated tube heat pipe is also researched [25].

Kumavat Mukesh Manilal et. al. (2016) This research tries to show numerical simulation of solar collector designed for drying meat products and how to boost their effectiveness. Technically and economically, solar drying is highly viable. Due to continuous research and development connected with the implementation of sophisticated techniques, there has

been a notable accomplishment in solar drying of meat products. The Computational Fluid Dynamics (CFD) tool was used to simulate the condition of different types of absorber plates with different shapes and configurations to achieve better efficiency than ordinary solar collectors. The solar flat panel collector's 3D model is modelled by UGS NX and then exported in STEP format, then exported into ANSYS Workbench and then the meshing was developed in ANSYS ICEM. Results were acquired using ANSYS fluent software [26].

M. Dinesh Babu et.al. (2016) An effort was produced to explore the impacts of a solar water heater with fins externally connected to the riser pipe on the battery effectiveness. Then analyse the solar collector utilizing Computational Fluid Dynamics (CFD) either with or without inner fins to detect the solar collector for a better insight of the collector's heat exchange capabilities. The results for finned pipe obtained from the CFD are validated with the CFD and experimental values for plain tube and found a temperature increase of about 3-4 ° C for finned tube. Based on this, manufacturing is performed and experimental assessment is performed with fresh collection of collectors. The findings acquired from the experimental evaluation show that there is an improvement in effectiveness of about 3-5 percent when we go to the finned pipe rather than the simple tube [27].

Shrikant G. Pise et. al. (2016) The present work shows that loss of energy between collector and receiver is due to convection and radiation heat loss. Heat loss between the two is mainly because of the temperature of liquid paraffin produced which is heated due to solar irradiations. Due to that, as temperature of liquid paraffin increases, directly affecting the percentage loss, which also increases along with rise in temperature. Experimental findings indicate that about 70 percent of the energy loss in the form of heat occurs when the temperature inside the liquid paraffin pipes is 3000 C and higher. CFD models can indicate that the current set-up can generate about 1180C temperature at the plant, whereas practically only it exceeds 1080 C temperatures [28].

Jignesh A. Patel et. al. (2015) The present work includes conducting a comparative thermal performance study of the straight tube solar water heater with the proposed experimental set-up of the spiral tube solar heater; it consists of a spiral-shaped copper tube, flat plate collector, K type thermocouple, changing water temperature for 100 liters

per day water capacity. Thermal efficiency was widely assessed throughout the month of May; a peak temperature difference of 16 C between the inlet and outlet of the solar water heater, the effectiveness of the solar water heater spiral pipe was calculated. During the test era, the highest value was discovered to be 47.63%, which was more than the straight pipe solar air heater [29].

K A Muhammed Yarshi et. al. (2015) The aim of this study was to evaluate the effects of pipe shape variations on the effectiveness of flat panel solar receiver. The effect of important parameters such as mass flow rate, absorber material was also studied. The numerical analysis is conducted using ANSYS CFD Fluent software. Inlet and outlet temperature comparison for distinct heat fluxes. The outcome demonstrates excellent consensus on the impact of different parameters. 3-D numerical simulation was performed to explore the effectiveness of a plain plate solar collector. Different geometries and working circumstances were examined to evaluate the impact of pipe region form on stack performance and the impact of mass flow rate and absorber content on thermal efficiency [30].

2.3 Summary

The above has been discussed in detail in the past few literature's which has given us a lot of motivation to do this project.

CHAPTER 3

HARDWARE AND SOFTWARE ANALYSIS

3.1 Introduction

In this section, we will discuss elaborately about our hardware design of " Flat Plate Solar Collector Using Water Heating System." and the component description, features, working procedure and description of our all equipment.

Software

- Easy EDA

Hardware

- SMPS
- Pump Motor
- Switch
- Coper Pipe
- Flat Plate Solar

3.2 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.



Figure 3.1: SMPS

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and

instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

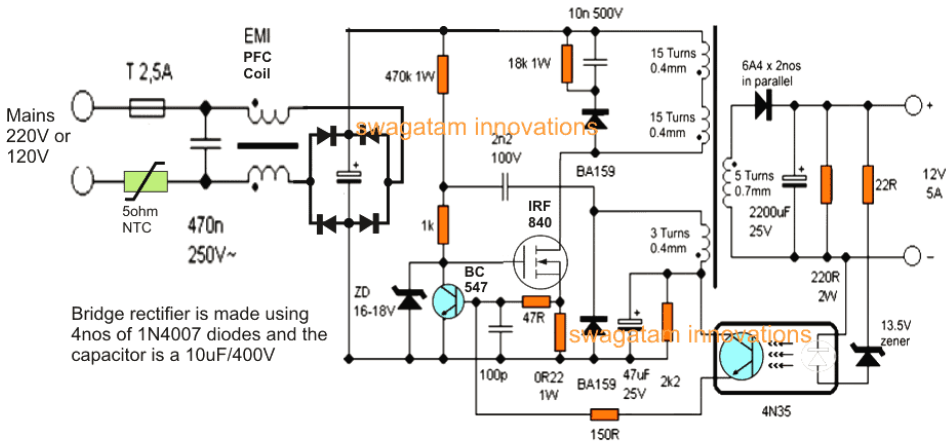


Figure 3.2: SMPS Circuit

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned. The continuous switching of the capacitor maintains the voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) pre-regulator followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pin outs, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer.

There are different circuit configurations known as topologies, each having unique characteristics, advantages and modes of operation, which determines how the input power is transferred to the output. Most of the commonly used topologies such as flyback, push-pull, half bridge and full bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer and the power conversion is provided by the inductive energy transfer.

Advantages of switched-mode power supplies:

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density
- Disadvantages:
- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency. Linear voltage IC regulators have been the basis of power supply designs for many years as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components such a zener diode and a resistor, or transistors and even op-amps.The most popular linear and fixed output voltage regulator types are by far the 78… positive output voltage series, and the 79… negative output voltage series.

These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits.There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well providing an output voltage which is continually variable from just above zero to a few volts below its maximum voltage output.

Switch Mode Power Supply

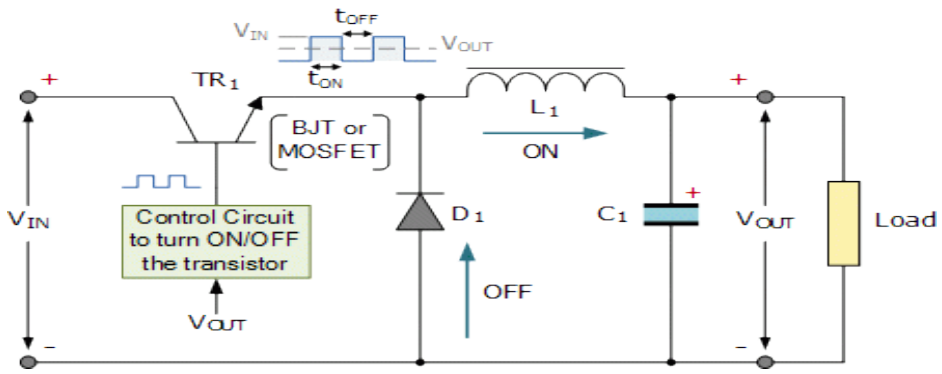


Figure 3.3: SMPS Circuit Connection

Most d.c. power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabiliser circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical d.c. power supply would look something like this:

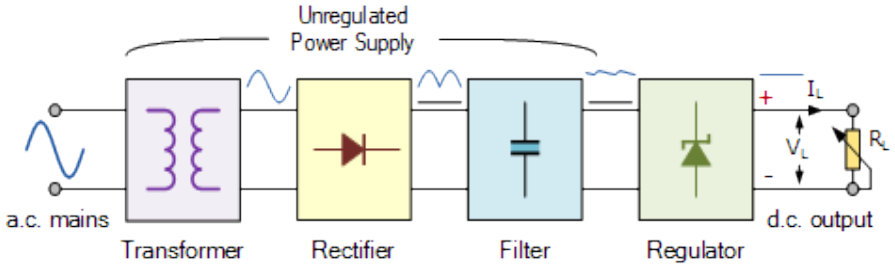


Figure 3.4: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

3.3 Pump Motor

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action, typically converted from electrical energy into hydraulic energy. Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration, in the car industry for water-cooling and fuel injection, in the energy industry for pumping oil and natural gas or for operating cooling towers and other components of heating, ventilation and air conditioning systems. In the medical industry, pumps are used for biochemical processes in developing and manufacturing medicine, and as artificial replacements for body parts, in particular the artificial heart and penile prosthesis.



Fig. 3.5: water Pump.

Specification:

- Material: ABS (Acrylonitrile Butadiene Styrene) + Stainless Steel
- Overall Size: Approx. 80 x 48 x 63mm/3.15 x 1.89 x 2.48"
- Pump Inlet Diameter: 16mm(Outer), 12mm(Inner)
- Pump Outlet Diameter: 12mm(Outer), 6.9mm(Inner)
- Inlet/Outlet: 1/2" male thread
- Voltage: 6-12V DC
- Maximum Rated Current: 1.2A
- Power: 16.8W
- Max Flow Rate: 700 L/H
- Max Water Head: 5M
- Max Circulating Water Temperature: 60°C

3.4 Copper Pipe

Copper pipes are commonly used for exchange heat to the another medium in the construction industry for water supply lines and refrigerant lines in HVAC(heating, cooling and air-conditioning) systems. Copper pipes can be manufactured as soft or rigid copper and offer excellent corrosion-resistance and reliable connections.



Figure 3.6: Copper Pipe

Key Features of Copper Pipes in Solar Collectors

High Thermal Conductivity

Copper's superior ability to conduct heat ensures that the heat absorbed by the collector's absorber plate is efficiently transferred to the water flowing through the pipes. This high thermal efficiency is critical for maximizing the performance of the solar collector.

Durability and Longevity

Copper pipes are highly resistant to corrosion, especially when exposed to water and varying temperatures. This makes them reliable and long-lasting, ensuring that the system operates effectively over many years.

Resistance to High Temperatures:

Solar collectors often experience extreme temperature variations, and copper's ability to withstand high heat levels makes it a stable choice for the system. The copper pipes can

endure the heat generated by the sun without degrading, maintaining long-term system efficiency.

Flexibility for Design:

Copper pipes can be easily bent and shaped to fit the design of the flat plate solar collector, which is essential for optimal placement in the system. They are usually arranged in serpentine or spiral patterns on the absorber plate to maximize the exposure to sunlight and facilitate efficient heat transfer.

Connection to Water Flow System:

Copper pipes connect the absorber plate to the storage tank, enabling the circulation of water or fluid through the collector. This water is heated as it moves through the pipes and then stored for use.

Eco-Friendly:

Copper is a sustainable material, being recyclable and having a lower environmental impact compared to other metals. It also contributes to the overall eco-friendliness of the solar collector system, which is designed to reduce reliance on fossil fuels.

3.5 Switch

A switch that has a single input and two dissimilar outputs is known as SPDT. The term SPDT stands for Single Pole Double Throw Switch which is used to control two dissimilar circuits through a similar single input. The operating of this switch can be done manually or included through the electromagnetic coil.



Figure 3.7: Switch

Switch Applications:

- This switch is used in a three-way circuit for controlling a load from two locations like from the top and bottom of a staircase.
- This switch is used to control two different circuits through a similar single input.
- Control Circuit.
- ABB/Siemens VFDs.
- PLC system output switches.
- Selector switches through a single common arrangement.

3.6 Flat Plate Solar

This project focuses on the development, construction, and performance evaluation of a flat plate solar collector designed for water heating applications. The flat plate solar collector is a widely used renewable energy device that effectively converts solar radiation into thermal energy, providing an eco-friendly alternative to conventional water heating systems.The collector comprises essential components, including a black-coated absorber plate made of copper or aluminum to maximize solar energy absorption. Tubes or channels attached to the absorber plate allow water to flow and capture the generated heat. To minimize thermal losses, a layer of insulation like fiberglass or polyurethane foam is positioned beneath the absorber plate. A transparent cover, typically made of low-iron tempered glass, protects the system from environmental factors while allowing maximum sunlight penetration. The entire assembly is housed in a durable, weatherproof casing, ensuring longevity and performance stability.



Figure 3.8 Flat Plate Solar

Performance testing of the solar collector evaluates its efficiency based on parameters like solar radiation intensity, water flow rate, and temperature rise. Tools such as pyranometers and thermocouples measure these variables, enabling the calculation of thermal efficiency as the ratio of useful heat gained to solar energy incident on the collector. Testing under various weather conditions ensures reliability and effectiveness.This project highlights the potential of flat plate solar collectors to provide cost-effective, energy-efficient, and environmentally sustainable solutions for water heating. Their adaptability makes them suitable for residential, commercial, and industrial use, contributing to reduced energy consumption and fostering a greener future.

3.7 Easy EDA

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share - publicly and privately - and discuss schematics, simulations and printed circuit boards. Other features include the creation of a bill of materials, Gerber files and pick and place files and documentary outputs in PDF, PNG and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

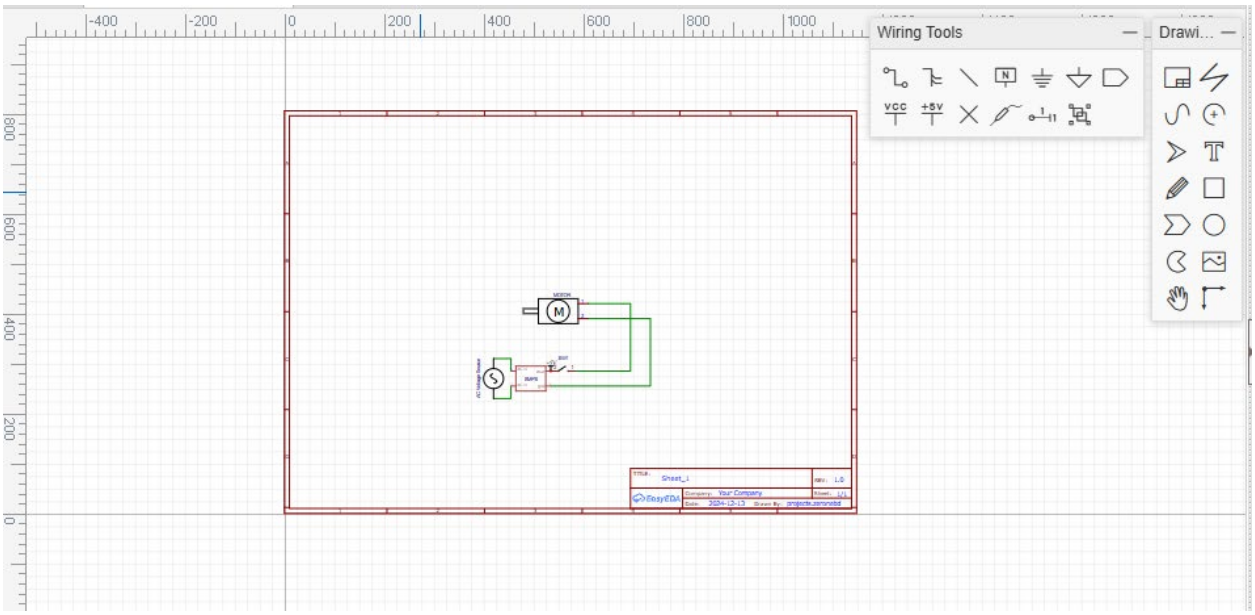


Figure 3.9: Easy EDA Software Interface

Subscription-free membership is offered for public plus a limited number of private projects. The number of private projects can be increased by contributing high quality public projects, schematic symbols, and PCB footprints and/or by paying a monthly subscription.Registered users can download Gerber files from the tool free of charge; but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third party tools.

CHAPTER 4
METHODOLOGY

4.1 Our methodologies for the project

Our methodologies for the project:

- Creating an idea for the design and construction of "Construction and Performance Test of Flat Plate Solar Collector Using Water Heating System". And designing a block diagram to know which components we need to construct it.
- Setting up all the components in a PCB board & soldering. Then assembling all the blocks in a board and finally running the system to check if it actually works or not.

4.2 Block Diagram

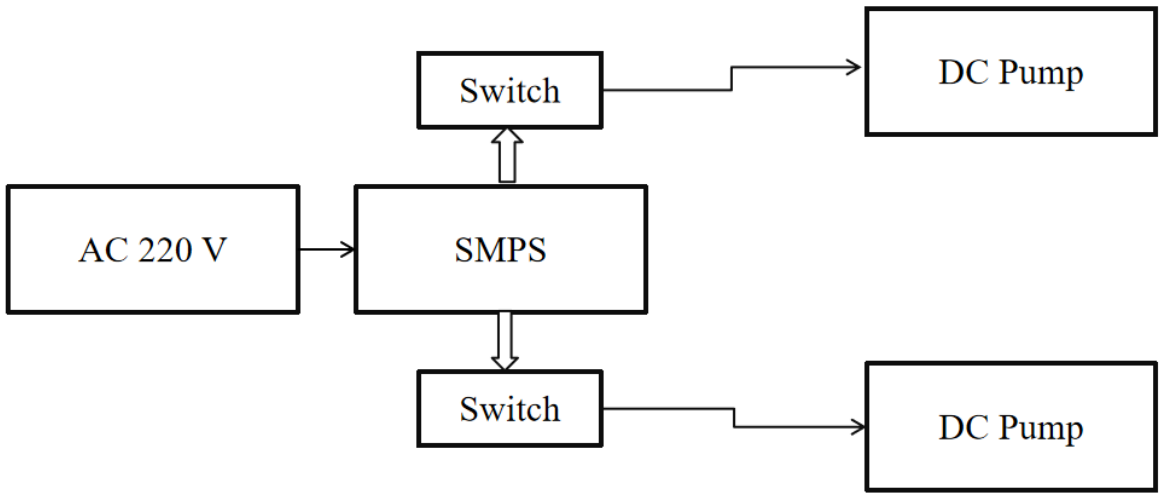


Figure 4.1: Block Diagram

4.3 Circuit Diagram of proposed Model:

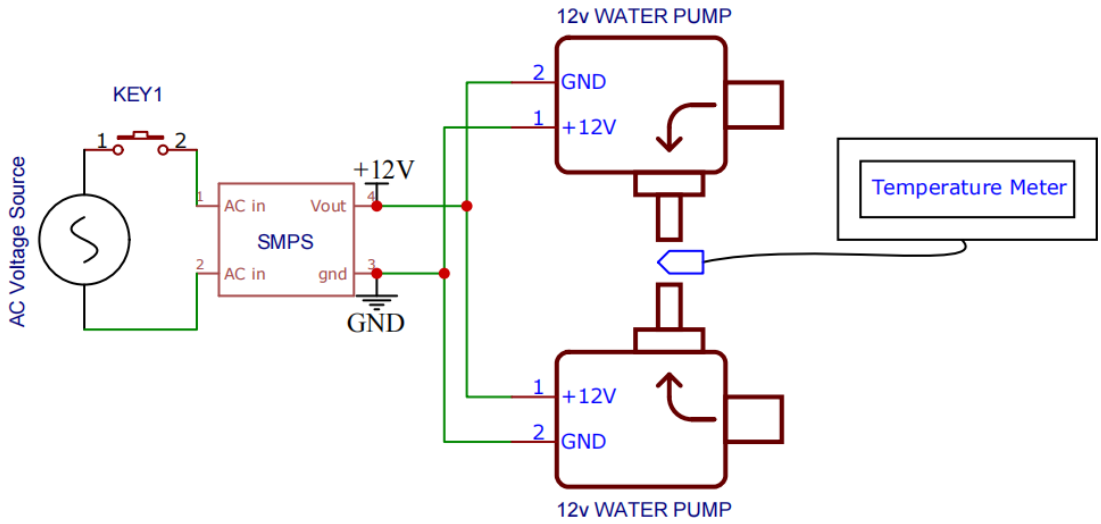


Figure 4.2: Circuit Design

4.4 Working Principle

The flat plate solar collector works by absorbing solar radiation to heat water using key components such as an SMPS, pump motor, and copper pipes. The copper pipes serve as conduits for water flow and are attached to the absorber plate, which captures solar energy. The pump motor circulates water through the pipes, ensuring consistent heat transfer. The SMPS provides stable power to the system's electrical components, ensuring efficient operation. Insulation minimizes heat loss, while a transparent cover enhances solar absorption. The heated water is stored or directly utilized, offering an efficient and sustainable method for water heating using renewable energy.

4.5 Our Proposed System

The proposed system is a Flat Plate Solar Collector for water heating, which utilizes solar energy to heat water efficiently. It consists of a flat plate absorber, typically made of copper or aluminum, coated with a selective material to maximize heat absorption. The absorber is connected to a series of pipes where water circulates and absorbs the heat. The system is equipped with insulation to minimize heat loss, and an advanced controller to regulate water temperature. The heated water can be used for residential or industrial purposes, reducing energy costs and promoting sustainable energy use.

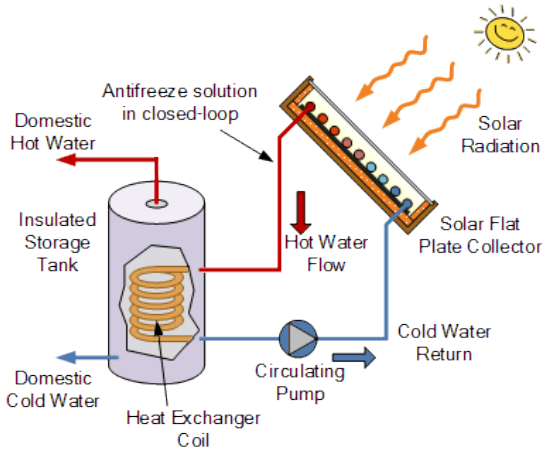


Figure 4.3: Our propsed system

4.6 Structural View

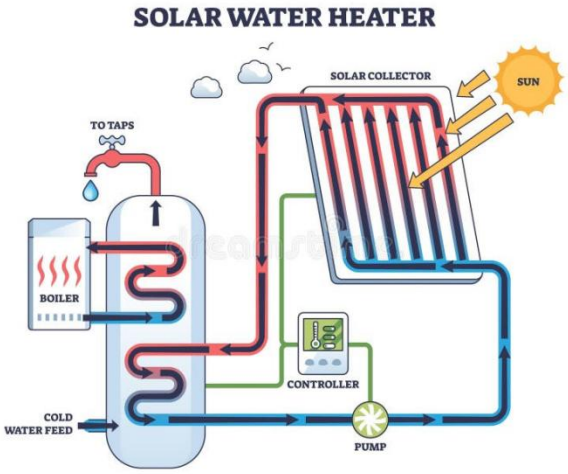


Figure 4.4: Our propsed Structural Image

4.7 Cost Analysis

Table 02: Component's Name and Price

Sl. No	Components Name	Specification	Quantity	Unit Price	Total Price
1	SMPS	5v 7a	1	800	800
2	Pump Motor	DC 12v	1	600	600
3	Coper Pipe			1600	1600
4	Solar Plate			1000	1000
5	Others			2500	2500
Total					6500/=

4.8 Real View of project



Figure 4.5: Our Project Hard ware Coper pipe image



Figure 4.6: Our Project Hard ware Coper pipe Setting Image

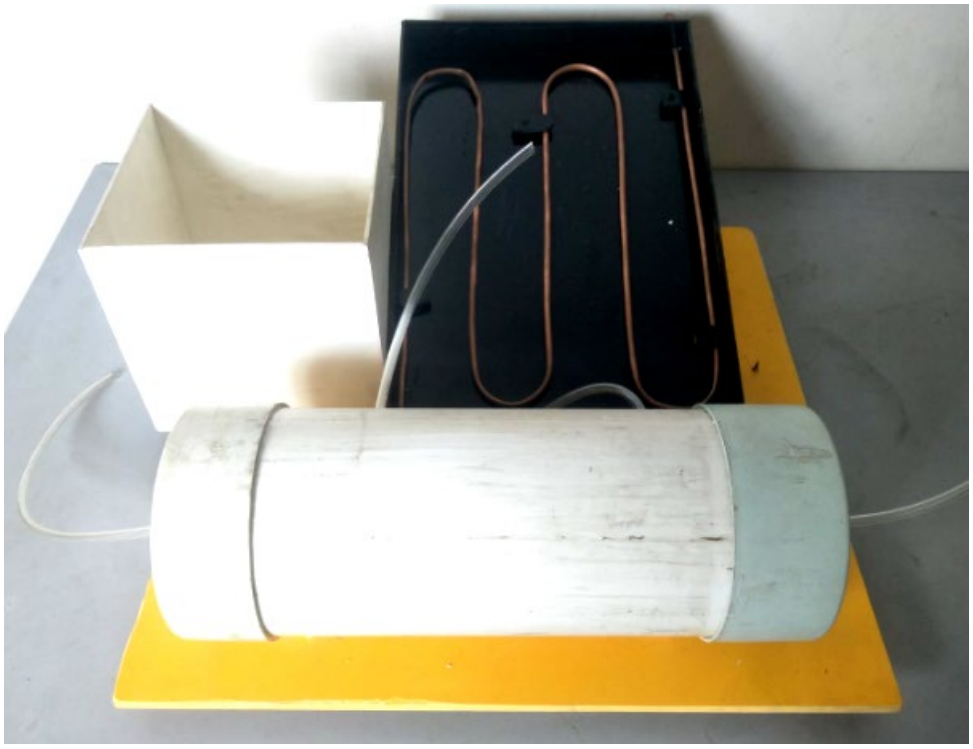


Figure 4.7: Our Project Progress Image

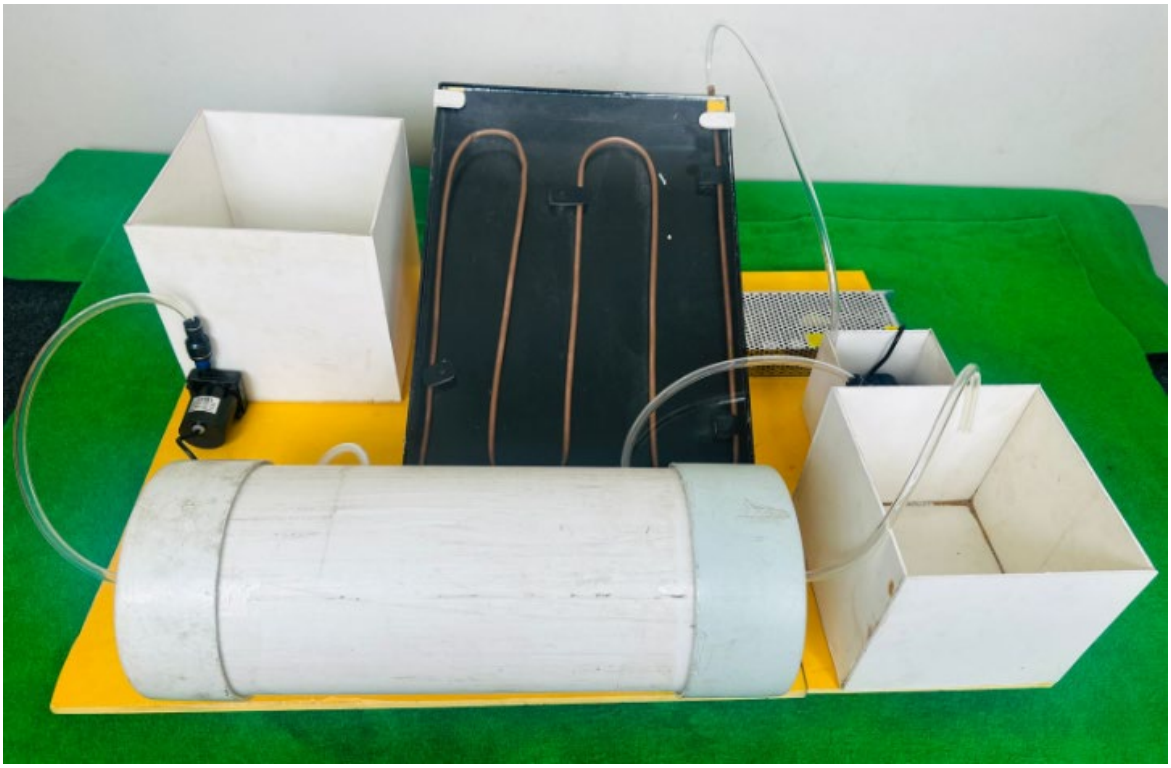


Figure 4.8: Complete Project prototype

CHAPTER 5
RESULT AND DISCUSSION

5.1 Result

After making our project we observe it very careful. It works as we desire. Our project give output perfectly and all equipment are work perfectly. We check how much it works and we get perfect output from this project.

- Finally, we have completed our project successfully & check our project its run accurately according to our objective.
- At first, we connect the AC 220 to system on.
- The absorber plate, made of copper, captures solar radiation and transfers heat to water flowing through embedded copper pipes.
- A pump motor circulates the water, ensuring consistent flow for efficient heat exchange.

5.2 Discussion

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and wiring, adding features for more efficient.

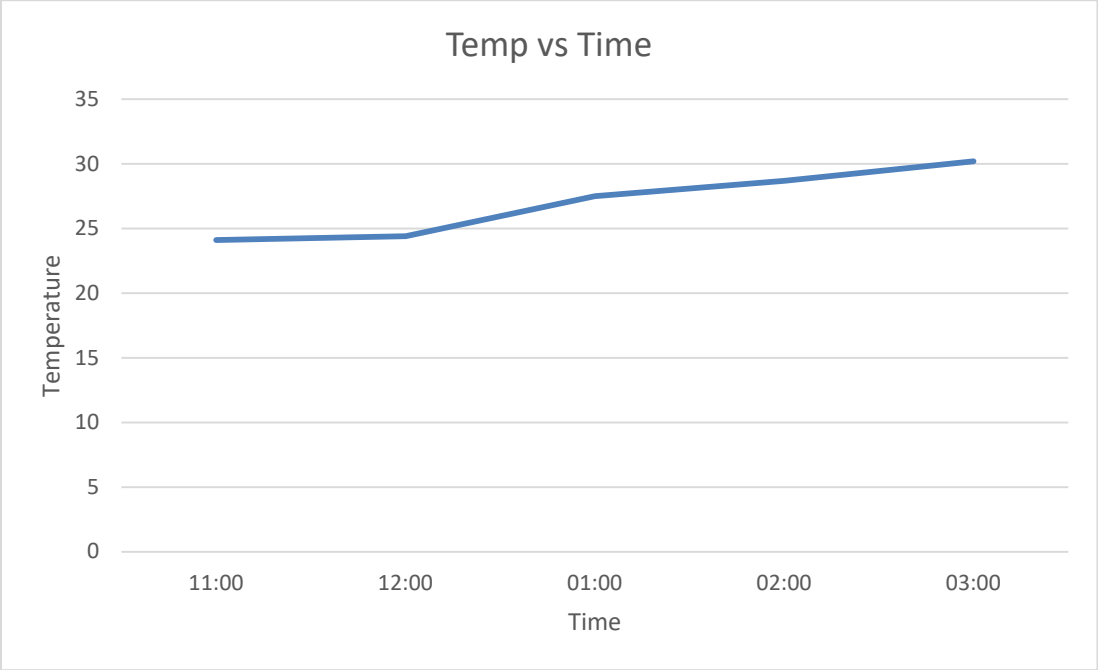
Experimental Table

12 January

Table :1

Time	Temp (◦C)
11:00	24.1◦
12:00	24.4◦
01:00	27.5◦
02:00	28.7◦
03:00	30.2◦

Graph 1:

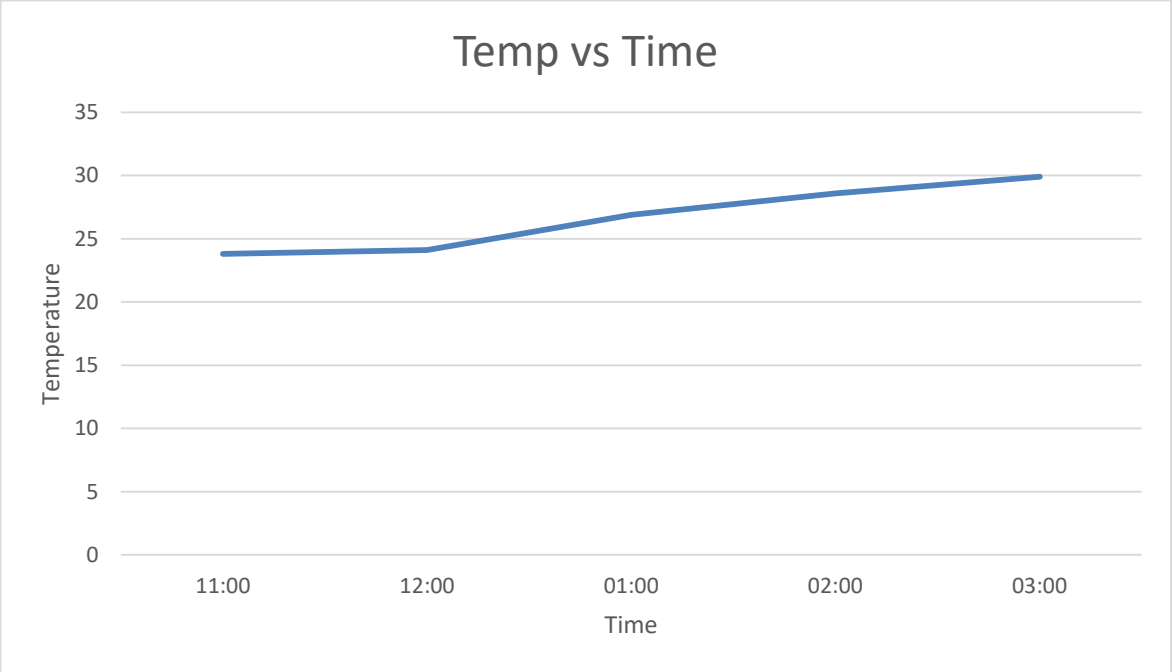


13 January

Table :2

Time	Temp (◦C)
11:00	23.8◦
12:00	24.1◦
01:00	26.9◦
02:00	28.6◦
03:00	29.9◦

Graph 2:

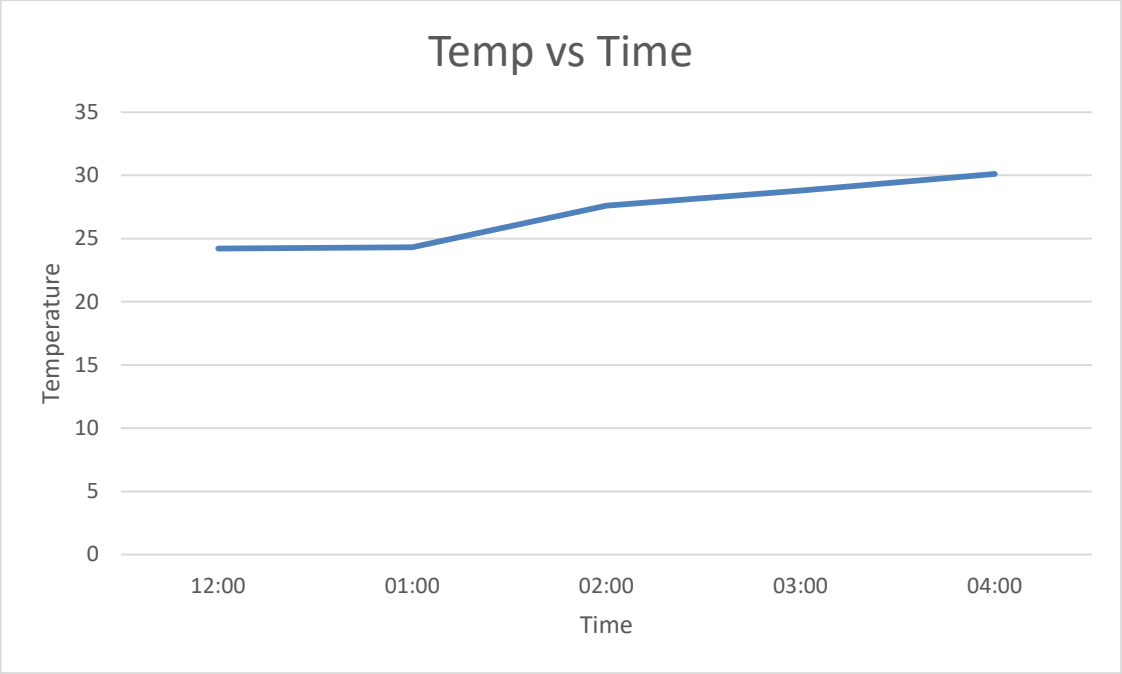


14 January

Table :3

Time	Temp (◦C)
12:00	24.2◦
01:00	24.3◦
02:00	27.6◦
03:00	28.8◦
04:00	30.1◦

Graph 3:

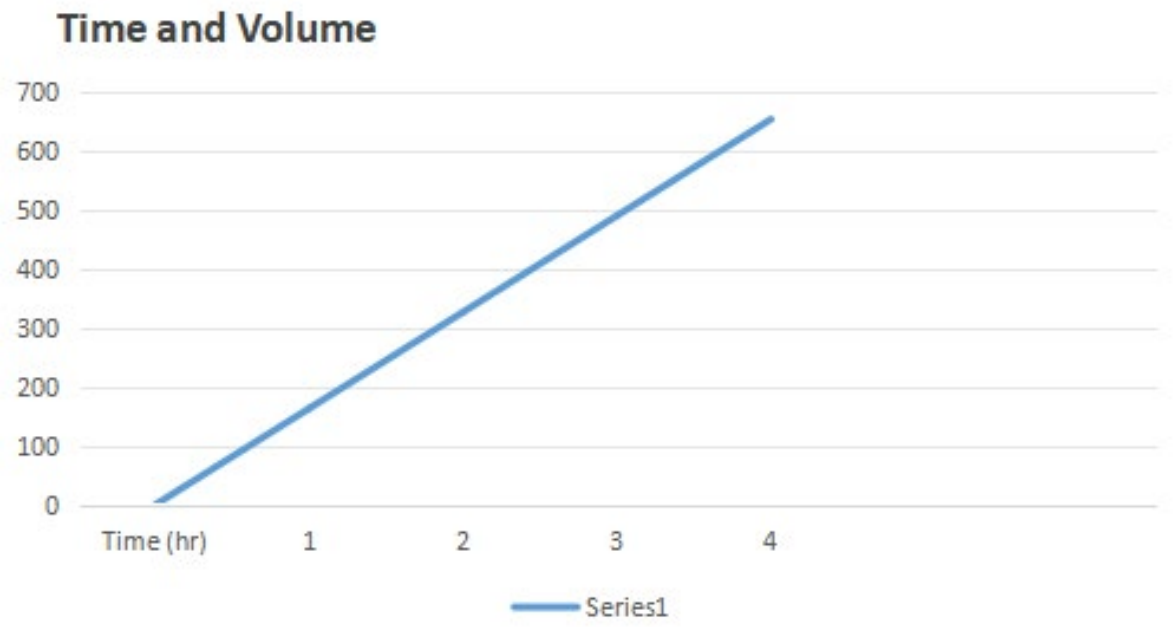


Water Flow:

Q = V/T

Time (hr)	Volume (L)
1	163.64
2	327.28
3	490.92
4	654.56

Graph



5.3 Advantages

There are many advantages of our project because of its accuracy. Some of the advantages are pointed out below:

- Do not waste time.
- Very Cost Effective.
- Very fast heat exchange can be done.
- Recycle the water in a manner.
- More accuracy.
- Can usable in any area of Water Recycling

5.4 Application

The application areas for this project in this modern and practical world are huge and some of these are given below:

- By some modification it can be used to control the water cooling.
- By increasing its pipe capacity, it can be used in industry's.
- It is also very useful in laboratories and workshops.
- It's can be widely used any productive industry.

CHAPTER 6

CONCLUSION

6.1 Conclusion

In conclusion, the Flat Plate Solar Collector water heating system offers an innovative and sustainable solution for reducing energy consumption and promoting environmental conservation. By harnessing solar energy, the system effectively converts sunlight into heat, making it a reliable and eco-friendly alternative to traditional water heating methods that rely on fossil fuels or electricity. The flat plate solar collector's design, featuring a high-efficiency absorber and well-insulated pipes, ensures maximum heat retention and effective heat transfer to the water.

This system is particularly beneficial in regions with abundant sunlight, making it ideal for both residential and commercial applications. Its low maintenance requirements and long operational lifespan contribute to cost savings over time, while its reliance on renewable energy helps reduce greenhouse gas emissions and dependency on non-renewable energy sources. Moreover, the integration of advanced controllers for temperature regulation ensures optimal performance, even under fluctuating weather conditions.Despite some limitations, such as the initial installation cost and performance variations based on location, the benefits of the Flat Plate Solar Collector system outweigh these challenges. As global awareness of climate change increases, the demand for renewable energy solutions will continue to grow, positioning solar water heating systems as a crucial part of sustainable development.

In summary, this project demonstrates the potential of solar energy to provide a reliable, cost-effective, and environmentally friendly method for heating water, aligning with both economic and ecological goals.

6.2 Future Work

We are thinking about adding many features to our project in the future to get more desirable out comes. Some of the steps that we are thinking about taking are given below:

- In future we will add IoT System to operate in fully automatically.

- In future use of advanced materials and smart sensors for better performance.

REFERENCE

[1] A.H. Jaaz, H.A. Hasan, K. Sopian, A.A.H. Kadhum, T.S. Gaaz, A.A. Al-Amiery, Outdoor performance analysis of a photovoltaic thermal (PVT) collector with jet impingement and compound parabolic concentrator (CPC), Materials 10 (2017) 888.

[2] A.H. Jaaz, K. Sopian, T.S. Gaaz, Study of the electrical and thermal performances of photovoltaic thermal Collector-Compound parabolic concentrated, Results Phys. (2018).

[3] H. Bhowmik, R. Amin, Efficiency improvement of flat plate solar collector using reflector, Energy Rep. 3 (2017) 119–123.

[4] A.E. Kabeel, E.M.S. El-Said, M. Abdulaziz, Thermal solar water heater with H2O-Al2O3 nano-fluid in forced convection: experimental investigation, Int. J. Ambient Energy 38 (2017) 85–93.

[5] E.M.S. El-Said, M.M.A. Abou Al-Sood, Experimental investigation of air injection effect on the performance of horizontal shell and multi-tube heat exchanger with baffles, Appl. Therm. Eng. 134 (2018) 238–247.

[6] H. Liu, W. Wang, Y. Zhao, Y. Deng, Field study of the performance for a solar water heating system with MHPA-FPCs, Energy Procedia 70 (2015) 79–86.

[7] A.E. Kabeel, E.M.S. El-Said, "A hybrid solar desalination system of air humidification dehumidification and water flashing evaporation Part I. A numerical investigation," Sixteen International Water Technology Conference, IWTC16, 2012.

[8] V. Weitbrecht, D. Lehmann, A. Richter, Flow distribution in solar collectors with laminar flow conditions, Sol. Energy 73 (2002) 433–441.

[9] S. Jaisankar, J. Ananth, S. Thulasi, S. Jayasuthakar, K. Sheeba, A comprehensive review on solar water heaters, Renew. Sustain. Energy Rev. 15 (2011) 3045–3050.

[10] A.L.G. Vendramin, C.I. Yamamoto, C.E.C. Nogueira, A.M. Lenz, S.N.S. Melegari, Analysis of the performance of a solar water heating system with flat collector, World Acad. Sci. Eng. Technol. Int. J. Mech. Aerosp. Ind. Mechatron. Manuf. Eng. 9 (2015) 386–389.

[11] V.C. Sontake, V.R. Kalamkar, Solar photovoltaic water pumping system – a comprehensive review, Renew. Sustain. Energy Rev. 59 (2016) 1038–1067.

[12] G. Notton, V. Lazarov, L. Stoyanov, Optimal sizing of a grid-connected PV system for various PV module technologies and inclinations, inverter efficiency characteristics and locations, Renew. Energy 35 (2010) 541–554.

[13] A.E. Kabeel, E.M.S. El-Said, S.A. El-Agouz, A theoretical study of Cu-H2O nano-fluid effect on heat transfer enhancement of a solar water heater, Int. J. Ambient Energy 38 (2017) 286–294.

[14] P.R. Prasad, H. Byregowda, P. Gangavati, Experiment analysis of flat plate collector and comparison of performance with tracking collector, Eur. J. Sci. Res. 40 (2010) 144–155.

[15] P.K. Mongre, B. Gupta, Experiment study of solar water heater with circulating pump and using of Aluminum tube, Int. J. Eng. Trends Technol. 3 (2013).

[16] E. Hernández, R. Guzmán, Comparison of three systems of solar water heating by thermosiphon, J. Phys. Conf. Ser. (2016) 012007.

[17] Y.F. Maydanik, Loop heat pipes, Appl. Therm. Eng. 25 (2005) 635–657.

[18] Mohamed Abu Waseem, "Numerical analysis of absorber tube of solar parabolic trough collector with and without insertion by using Ansys Fluent", Journal of Engineering Research and Application, Vol. 8, Issue 12, Dec 2018, pp 01-04.

[19] D Prakash, "Thermal analysis of building roof assisted with water heater and insulation material", Indian Academy of Sciences, 2018.

[20] S. Sadhishkumar, "Thermal performance of water-in-glass evacuated tube solar Collector with and without phase change material", Indian Journal Sciences, 20(2), 193-201, 2018.

[21] Ankit S. Gujrathi, Sachin P. Ingale, Sudhir U. Patil, "Analysis of Parabolic Trough Collector using Ansys Fluent Software", Volume 5, Issue 4 December 2017.

[22] Arun K. Raj, K. Dileep, S. Jayaraj, "Solar ETC Type Water Heaters an Analysis Based on CFD Packages", Indian Journal of Science and Technology, Vol 10(15), April 2017.

[23] K. Vasudeva Karanth, "CFD Analysis of a Flat Plate Solar Collector for Improvement in Thermal Performance with Geometric Treatment of Absorber Tube", International Journal of Applied Engineering Research, Volume 12, Number 14, 2017, pp. 4415-4421.

[24] Mohammed Abdul Junaid, Mohammed Nazimuddin, Mohd Arifuddin, "Thermal Analysis of Solar Flat Plate Collector Using CFD", International Journal of Engineering Research & Technology, Vol. 6 Issue 04, April-2017.

[25] Y. Chaudhary, Bharat Kalamkar, Prashant Patel, "CFD Analysis of Evacuated Tube Heat Pipe Solar Water Heater", International Journal of Latest Technology in Engineering, Management & Applied Science, Volume VI, Issue VS, May 2017.

[26] Kumavat Mukesh Manilal, "Design, CFD Analysis and Fabrication of Solar Flat Plate Collector", International Research Journal of Engineering and Technology (IRJET), Volume: 03, Issue: 01, Jan-2016.

[27] M. Dinesh babu, m. Venkata ramanan, "Modelling and validation of solar flat plate water heating system subjected to varying absorber geometries", International Journal Chemistry and Science, 2016.

[28] Shrikant G. Pise, Milind Limaye, "CFD Analysis of Cubical Receiver Solar Water Heater with Concentrated Collector", International Journal of Current Engineering and Technology, 2016.

[29] Jignesh A. Patel, Tejendra B. Patel, Sadanand Namjoshi,"Comparative Study of Thermal Performance of Spiral Tube Solar Water Heater with Straight Tube Solar Water Heater", International Journal for ScientificResearch & Development, Vol. 3, Issue 03, 2015.

[30] K A Muhammed Yarshi, Benny Paul, "Analysis of Heat Transfer Performance of Flat Plate Solar Collector using CFD", International Journal of Science, Engineering and Technology Research, Volume 4, Issue 10, October 2015.