HARVESTING SOLAR ENERGY BY USING COIL TYPE THERMAL HEAT COLLECTOR

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A report submitted to the Department of Mechanical, Sonargaon University, Bangladesh in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Mechanical Engineering.

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Declaration

We hereby declare that this Project is our own works and has not been submitted elsewhere for the award of any degree or diploma.

Signed: ________________

Date: ________________

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Abstract

Thermal energy from solar thermal systems can be used for various processes i.e. low-grade. Thermal applications, high-temperature heating applications and also for preheating which Save a significant amount of fuel. This paper focuses to analyses the three types of solar thermal collectors (flat plate, line focusing and point focusing), their developments and Contributions in the field of solar thermal collectors with an emphasis on the material heat Transfer characteristics and solar materials manufacturing challenges. Moreover, it gives Detailed information about the types of materials that are used in the coating of solar thermal Collectors and their selection as per application requirements. The material proper selection leads to improve the efficiency and effectiveness of thermal solar collectors, users Satisfaction and life period of solar collectors.

Table of Contents

Abstract ... ii

Acknowledgment ... iii

List of Tables ... ix

List of Figures ... x

List of Abbreviations ... xiv

List of symbols ... xvi

Chapter 1 ... 15

Introduction & **Literature review** ... 15

Introduction ... 15

1.1 Basic Information ... 15

1.2 Solar water heating system components ... 18

1.3 Objective of the project ... 18

1.4 Literature preview ... 19

Chapter 2 ... 20

Methodology and description of the project ... 20

2.1 Introduction… ... 20

2.2 Methodology ... 22

2.3 Solar water heating system components ... 22

2.3.1 Solar controller … 23
2.3.2 Flat plate collector 23
2.3.3 Evacuated tube collector 24
2.3.4 Batch or integral collector 24
2.4 Storage Tank 25
2.5 Heat Exchange … 26
2.6 Pump …………………………………………………………………………26
2.7 Pipe …………………………………………………………..……………...27
2.8 Heat Transfer Fluid …………………………………………………………27
2.9 Thermocouple………………………………………………………………..28
2.10 Glass sheet ……………………………………………………………….28
2.11 Types of a solar heating system………………………………………………28
2.11.1Active solar hot water system……………………………………………….29

Chapter 3 31

Installation 31

3.1 Introduction.. 31
3.2 Site selection 31
3.3 Solar heater for Bangladeshi House… 32

Chapter 4 34

Performance of Project.. 34

4.1 Introduction 34
4.2 Test with Plastic Pipe … 35

4.3 Test in Open Loop….. 36

4.4 Test in Closed Loop……………………………………………………………38

4.5 Discussion …………………………………………………………………..40

4.6 Collector Performance…………………………………………………….41

4.7 Collector Efficiency …………………………………………………………42

4.8 Project Overview……………………………………………………….....42

Chapter 5 44

Conclusion 44

5.1 Summary 44

5.2 Future scopes…..45

References….. 46

List of Tables

Table 2.1: Hardware List of the project………………………………………………….....23

Table 4.1: Data for Open loop test 36

Table 4.2: Data for Closed loop test 38

List of Figures

Figure 1.1: Solar Heater in 1770.. 18

Figure 2.1: Solar water heating system... 22

Figure 2.2: Flat PLATE collector 24

Figure 2.3: Evacuated tube collector 24

Figure 2.4: Batch collector..25

Figure 2.5: Water Tank 25

Figure 2.6: Pump For collector 26

Figure 2.7: Copper pipe 27

Figure 2.8: Thermocouple 28

Figure 2.9: Glass sheet 28

Figure 2.10: Active solar heating system.. 29

Figure 2.11: Passive solar heat system 30

Figure 3.1: Physical View of the Bangladeshi village house..32

Figure 3.2: Physical View of the Bangladeshi city rooftop house...33

Figure 4.1: Heat Chamber without Glass cover …………………………………………….. 36

Figure 4.2: Project test with open loop 37

Figure 4.3: Project test with closed loop……………………………………………………39

Figure 4.4: Chamber Testing unit ……………………………………………………………..42

Figure 4.5: Project with storage…………………………………………………………………42

List of abbreviation

SHWS	Solar water heating system
HTF	Heat transfer fluid
ICS	Integral- collector storage
TES	Thermal energy storage
CEO	Chief executive officer
SHES	Sensible heat energy storage
LHES	Latent heat energy storage
PCM	Phase change material
TCES	Thermochemical energy storage

UTES	Underground thermal energy storage
CSP	Concentrating solar power plants
COP	Coefficient of performance
KSV	Kerava solar village
ECN	Energy Research Centre of the Netherlands
NL	Bangladesh
HVAC	Heating, ventilation and air conditioning
BEopt	Building energy optimization tool
OSB	Oriented strand board
ACH	Air change per hour
HRV	Heat recovery ventilator
PEX	Cross-linked polyethylene
CFL	Compact fluorescent
EF	Energy factor
GHG	Greenhouse gas
STES	Seasonal thermal energy storage
DTES	Diurnal thermal energy storage
ASHRAE	American Society of Heating and Air-conditioning Engineers
SSTES	Seasonal solar thermal energy storage
CSHPSS	Central solar heating plants with seasonal storage
SSHS	Solar space heating system
SH	Space heating
DHW	Domestic hot water
NRC	Natural resource.
IEA	International energy agency
BedZED	Bedding ton zero energy development

SHW	Thermal solar system
MVHR	Mechanical ventilation heat recovery

Chapter 1
Introduction and Literature Review

Introduction

1.1 Basic Information

Solar energy which is the primary source of all kind of energy on the earth originates on the sun as a result of the thermonuclear fusion reaction. Sun liberates a large Amount of heat energy. This energy is radiated by the sun in the form of electromagnetic radiation, of which 99% having their wavelengths in the range of 0.2–0.4 μm. In India, where the sun keeps on shining in most of the parts for almost entire year solar energy can be of very much importance. India government recognized this source of energy and developed a solar energy center under the ministry of non-conventional energy sources. Its activities include R&D on solar heating, solar nuclear power Generation, solar passive architecture and Green house technology.

A solar thermal system utilizes solar energy to convert it into heat (thermal) energy by means of a circulating fluid. A solar thermal system essentially consists of a solar collector. The solar collector absorbs solar energy as heat and then transfers it to a heat transporting fluid, which delivers this heat either to a thermal storage tank or heat exchanger to be utilized in the subsequent stages of the system. Since solar power has a low density per unit area (1 to 0.1 kW/m^2), therefore a large number of collectors are used in series to obtain a useful amount of Heat energy

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar Collector. Solar energy collectors are widely used recent in space and water heating systems and technological processes. There are the various types of flat plate solar collector produced at present time. Therefore it is complicate on one hand to make the comparison analysis of the collector performance without experimental tests and on other hand to determine the field of their expedient utilization. The possibility of comparison analysis are limited by absence of the simple and universal method of solar collector output estimation. Below such method of determination of the solar flat plate collector output for fixed inlet and outlet temperatures of working fluid is given.

Bangladesh is a south Asian country and the selected house is in area Rampur situated in the northern part with latitude (25.7° N) and longitude (89.3° E) . In Bangladesh, the bright sunshine hours varies around 3 to 11 hours daily in coastal regions. So the annual average solar irradiation in Bangladesh varies from 3.8 kWh/m2/day to 6.4 kWh/m2/day at an average of 5 kWh/m2/day. These indicate that there are good prospects for solar thermal and photovoltaic application in the Bangladesh .connection . An experimental study was conducted to show the performance of a flat plate based solar water heater and the result demonstrated that when the storage water volume reduced from 60 liters to 20 liters, the temperature of output water from storage tank was increased by 60% . Another experimental study was carried out to expend the area of aperture of cylindrical parabolic reflector in order to get the more absorbed heat from the sun and concluded that highest output temperature of solar water heating system can be achievable with the higher solar radiation and the instantaneous efficiency is directly proportional to the radiation . In addition, a transient model was built and validated experimentally, based on daily transient conditions. This analysis notified that due to increase the total volumetric flow, overall efficiency of the system also climbed with an in overall area of the system and helped to evaluate the total amount of water need to be heated . Another study has been made to figure out the performance of a centralized solar domestic hot water system, used field data from experiment and the simulation model. This research work concluded that output of a solar water heating systems varies and depending on separate climate conditions, a solar water heater can satisfy almost 80% of the overall hot water demand. A research suggested that the reflector should be inclined at with respect to the horizontal axis in order to achieve the highest amount of solar intensity and optimal performance .

A research group divided the solar collectors into water type (Hydroid) where working fluid was water and air-type that used air as a working fluid and mentioned that air-type collectors are having low thermal efficiency as well as low heat transfer coefficient compared to water-type solar water heater . However, a study regarding control strategies

was conducted to find out the controller that can be user friendly, risk free and readily available and the suggested controller is Atmega32, can be very responsive to the operating conditions and there is no need of technical knowledge while operating in a solar hot water control system From the literature search, it can be said that[10] Discussed the design parameters of net-zero energy building in terms of sizing the HVAC system, renewable energy technologies, and energy storage systems. From their studies, it can be said that building system size and the overall initial investment cost are responsible to control the indoor temperature set points. They also added that the system's efficiency and Co-efficient of Performance (COP) are noticeable and significant with medium impacts of wall thickness and window to wall ratios. Moreover, the infiltration rate and losses have very fewer impacts, while the PV efficiency has different effects, relies on the system sizes and the cost. Kalogirou et al. studied and simulated four-zone featured buildings, adding dense concrete wall as the thermal mass in the south façade. They compared the result having thermal mass and without the thermal mass and finally recommended that the optimal thickness of 25 cm thermal mass can be suitable to diminish the heating loads around 47 % and increase the cooling loads by approximately 4.5 %. Fay et al. evaluated the Australian residential building and its insulation materials with all properties. They concluded that after adding the better insulation material in building the total embodied and operational energy can be saved about 6
% over a 100-year lifespan. For cold climate zones, they also mentioned that not only the additional insulation but also some efficient strategies could be beneficial for saving more

energy. Pikas et al studied the energy efficient building and the optimal design for the building components. They figured out a few factors that are mainly contributed to select the possible optimal solution. These factors are a small window to wall ratio based transparent triple glazed argon filled windows and 20 cm thick insulation of the house wall. The findings mentioned above become further verified by Thalfeldt et al. From their outcome, it is recommended that window to wall ratio can be increased to (40-60) % if the heat transfer coefficient or U-value of the window would become the range of (0.21 -0.32)

Goia et al. [15] deliberated about the optimal window to wall ratio for various low energy office building in Frankfurt, having different HVAC system efficiency. They demonstrated that the optimal window to wall ratio is between 35 % and 45 % with different orientations of the building. Vanhoutteghem at al studied the net zero energy house, taking some features like the effect of size, orientation, and the glazing properties of the window. The result exposed that high g value and large window to wall ratio for south oriented house is less useful to reduce the space heating demand of the house. On the other hand, for the north-facing houses, high g value, low U value, and large window to wall ratio are suggested to uphold the space heating demand within the end-user's range. Besides, Li et al. figured out the design of zero energy building, measuring energy efficiency, and the various renewable energy technologies. They included that thermal insulation, thermal mass, glazing, and day lighting are the significant factors that have a high impact on building energy use with measuring energy efficiency. Ihara et al. [18] mentioned the façade properties of the office building in Tokyo. The result determined that the lessening of solar heat gain coefficient, U value of the windows, and increasing the solar reflectance is the best way to reduce the annual energy demand, but in case of opaque parts of the high rise buildings, the annual energy demand increased with reducing the U value. After analyzing the literature, it is obvious to say that before taking any decision or implementing the solar thermal systems with energy storage, thermal modeling of the house becomes inevitable to know the annual electrical demand of the individual loads. It also helps to select the best house materials and appliances in order to make the balance between energy demand and supply. As the low energy building and energy-saving matters rely on the house properties and the ventilation system, so the thermal modeling and simulation are effective ways to get the idea of these parameters. The simulation results and necessary graphs are discussed below in the latter section.

Bangladesh is a developing country and the per capita energy consumption in this country is one of the lowest amongst the sub-continent but has ample amount of renewable energy resource and the best option to utilize this solar energy is domestic and industrial use through the proper design, sizing, control and dynamic modeling. In this research work, section 2 will present the thermal modeling and analysis, section 3 will show water heater sizing, modeling and analysis, system dynamic modeling and system control design and analysis will be discussed Respectively.

1.2 History of innovation

In 1891, Kemp patented a way to combine the old practice of exposing metal tanks to the sun with the scientific principle of the hot box, thereby increasing the tanks' capability to collect and retain solar heat. He called his new solar water heater the Climax – the world's first commercial solar water heater

1767, Construction of the First Solar Collector

The first solar collector was created in 1767 by the Swiss scientist Horace-Benedict de Saussure. It was an insulated box covered with three layers of glass to absorb heat energy.

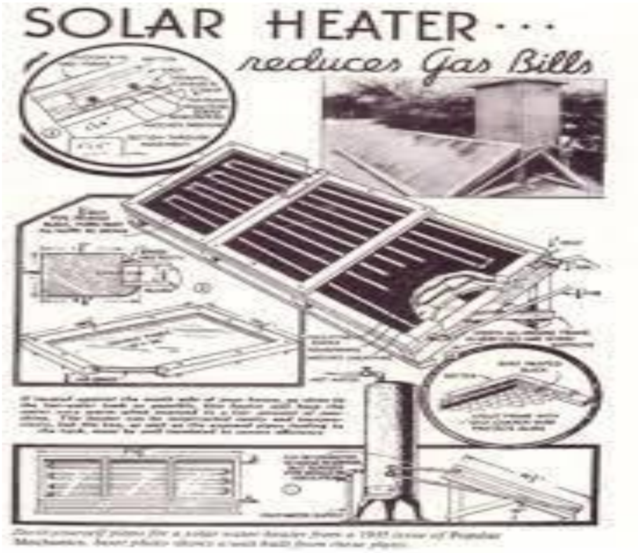


Figure 1.1: Solar heat collector in 1770

1.3 Objective of Project:

The following objectives will be explored to develop a simple and cost effective high efficiency solar thermal heat collector.

(a) It’s easy to install any type of building.

(b) Optimized high cost maintenance.

(c) To produce high efficiency collector.

(d) To do extensive literature review on solar water heating system with thermal energy storage for collecting proper data and get to know their various types and methods.

Solar collectors are essential components of most solar energy devices. Indeed, quite a substantial fraction of the cost of solar devices is covered by the cost of the collectors. Collectors should have high performance and economics. Flat-plate solar collectors have been developed in several countries over the last several years. Design parameters of flat-plate collectors are fairly well established. However, research and development to improve the efficiency and reduce the costs of the collectors will have to be pursued. The guidelines for the design of solar collectors are available in standard texts.

Solar water heaters are an extension of solar collectors and are the simplest of the solar energy devices. Several commercial concerns both in developed and developing countries are manufacturing solar water heaters. These are extensively available in many countries. The technology for the fabrication of solar water heaters is well established and can be translated into commercial production both in developing and developed countries.

Solar space heating technology has not yet reached the stage where it lends itself generally to be introduced to developing countries.

1.4 Literature preview

In 1912, the parabolic solar collector was invented, mainly that time it’s used in for boiling or make heating. But that time is efficiency is low. In 90 centuries, it's made a revelation. People are thinking and searching the eco-friendly renewable energy sources that is also low-cost. That they discovered the solar thermal collector and it's made better efficiency device. Now a days we can see that many of solar farm with fully automatic. Many of them produce electricity to national grid, like name project: Noor / ouarzazate Solar Power Station which is in Morocco its capacity is Electrical capacity 510 MW. There is many of big and small project in USA, Spain, UAE, South Africa, India, China Many of project are. The main limitation on the maximum temperature is imposed by the thermal oil currently used as the working fluid so, our goals are making more efficiently and low-cost device and update the technology. Our target is 60 % efficiency and it heating temperature near to 35 to 65 degrees Celsius.

Chapter 2

Methodology and Description of the Project

2.1 Introduction

Parabolic collector is useful and simple technology. But there are other ways to make heat and production. Non-renewable energy sources: - the main Non-renewable energy sources are fossil fuels. Like gas, petroleum, coal, new clear energy etc. Form those we get energy by burning them, but they produce carbon dioxide, carbon monoxide, sculpture dioxide etc. toxic chemicals. Which is distorting our environment and making up temperature high. But now days storage of fossil fuels is become shot. We need to think other way for energy. Renewable energy sources: -World most common renewable energy resources are water and wind power plant. It's efficiency near to 80 to 95% and those are ecofriendly. But for it first need right place. But those are not available in our country but sun light or radiation is able in here. We can collect the sun radiation using, photo voltaic or solar panel. A solar panel convert sunlight to direct electricity. It’s a renewable energy source. So, in this way it's better. Is maximum efficiency being 47%

Generally in our country we see that is 18 to 25 percent efficiency. Moreover, its technology and solar sell import for others. To make a silicon base solar sell is difficult. Moreover, its pollution the environment too much. To install a solar panel, we need battery for backup electricity. It's also costly. On the other side parabolic solar collector can easily make and using our country goods like wood, mirror, metal etc. Those are eco-friendly and low-cost price .and also renewable energy sources Too. Collection the sun radiation its efficiency is 50 to 85 percent. But heat to electricity conversation now day is 30% it's near to photo voltaic. But heat to electricity conversation technology is importing day by day. Thermocouple is good for heat to electricity conversation but its efficiency is low 5 to 15%.some of update its efficiency can be increase. Now a days to store the sun Thermal modeling assists to know the yearly electrical consumption of the house that makes the consumer to focus on using more energy-efficient appliances in the house. This type of thermal analysis not only studies the human behavior impact on the house's annual load profile but also uses to design renewable energy system, especially solar water heating system. In this chapter, a house is modeled and simulated using thermal simulation software. Here the hourly value was considered to analyze output results. The output result from the thermal model is compared with the monthly electricity bill that showed a good agreement to know the annual load consumption of all the appliances of the house.

Thermal modeling and optimization of the house using different techniques and software is essential. These options can work both for existing and new houses. The annual house loads depend on many factors like house size, house materials for insulation, and the number of occupants living in the house. The thermal analysis of a house shows the yearly energy demand of various loads on a monthly basis. Several software and techniques have been available in the literature to make the thermal analysis of the house. Mentioned that building construction plays a vital role in the environment, and it indirectly emits greenhouse gases as waste. They concluded that to make the house more efficient, it is necessary to reduce the energy demand during operations. Christopher et al studied the Thermal analysis to find out the annual energy demand of an old house in Thessaloniki, Greece, using HOT2000 software. After comparing the electricity bills with actual utility bills, they concluded that climate conditions and the existing house materials have a significant effect on the energy efficiency of the single-family house. Johannes et AL discussed the electricity consumption profile in dwellings in Northern Ireland. The author founds some factors that are responsible for increasing electricity consumption. These factors are dwelling type, floor area, number of occupants and bedrooms, tenure, occupant age, and household income. Among these, the electricity consumption profile is mostly influenced by the floor size in the house.

Studied and modeled the hourly residential electricity consumption based on various house characteristics in Osaka city, Japan. The result revealed that occupant's time use, indoor temperature, efficiencies of the household appliances, and dwelling thermal features are contributed greatly to change the daily electricity consumption. Papadopoulos et al. modeled and analyzed two multifamily domestic building energy use using simulation software Energy Plus to find out the optimal economic and environmental performance of house space heating. They mainly discussed and compared three types of systems. Among them, the electrically driven heat pump and gas-fired space heating system showed the rival characteristics in some instances and found heat pump system is a best and suitable option for domestic space heating. Pesters et al. worked with the overall heating efficiency of the house, employing building insulation quality and the emitter's control strategy. Though the result showed that building heating efficiency and insulation quality improvement are inversely proportional to each other, but they recommended to use a modulating boiler, an outdoor air temperature compensation, and a thermostatic radiator valve. Fluorides et al. demonstrated the house space heating and cooling load variation in Cyprus using simulation software TRNSYS. They emphasized to put the better roof insulation in the house as this property of the house can minimize the heating load up to 75 % and cooling load up to 45.5 %. El Fouih et al. studied the low energy building and the ventilation system to analyze the energy performance of the house. The result concluded that humidity-controlled ventilation is suitable for the moderate and warm climate, and for cold climates. A heat recovery ventilation system can be more efficient if it has low power consumption and high heat exchanger efficiency. have introduced a methodology and calculation approach for making the cost-effective design for net-zero energy building in a residential application. Their study ended that the net zero energy building becomes so expensive in terms of initial cost than life cycle cost. Also, they found that the optimal design solution can be lower in mild-winter climates than cold-winter climates as the local climate and economic conditions influence it. Sun et al. radiation or heat used water, salt (sodium carbonate), etc. But latest officially a smart technology invented that is liquid sun light storage it ‘scan store here for 18 years. It's a revelation technology. It's a chemical component which use to store the radiation. In this we are working on the parabolic solar thermal collector

2.2 Methodology:

The aim of the project is to design a cost effective and high efficiency device when use technical support from various source for achieving our goal we need thermocouple and small LED display for to see temperature and we are use 6 volt battery for power supply. We trying to scribe the offline how all of those item work together. We need to enough sunlight and good weather to run our project. We are read the temperature after 5 minute all over we are reading 30- 50 min for a day

2.3 Solar water heating system components

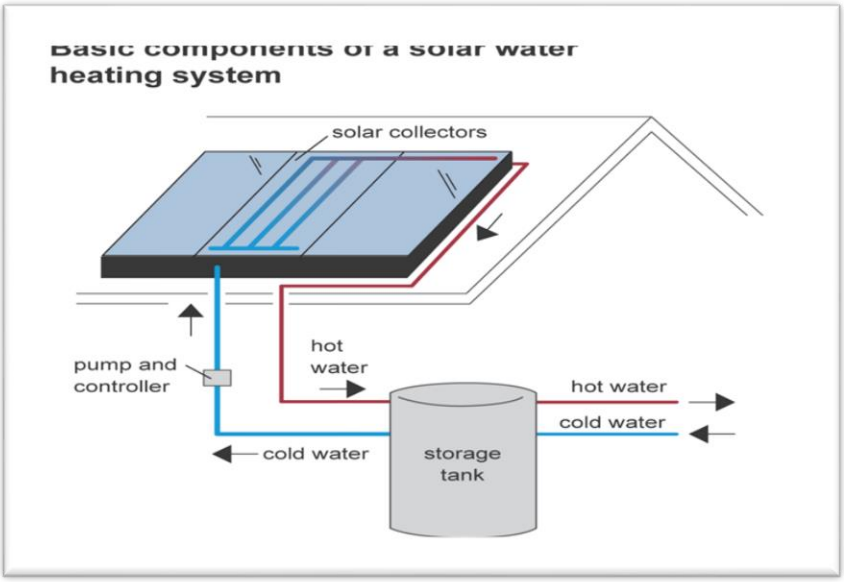


Figure 2.1: Solar water heating system [2]

Table 2.1: Hardware list of the project

SL No	Hardware	Specification	Quantity
1	Chorksheet	Height: 5 feet Width: 3feet Thickness : 1 inch	3 pc
2	Submersible water pump	Step Angle (degrees) : 1 Phase Rated Voltage : 6V-12V DC Rated Current : 1.2 amp Rate :10L / Min	1 pcs
3	Power Supply Battery	Model: VIS-MKB-001 Lead Acid Voltage: 4V Capacity : 700 mph	1 pcs
4	Pipe	Copper Pipe Diameter : ¾ Length : 20 Feet	20 feet
5	Glass Plate	Length : 2.5 Width : 2.5 Thickness:	1 pc
6	Bucket	25 Liter	1 Pc
7	Water tank	30 liter	1 pc
8	Thermocouple	Read Capacity : -50 C to 120 C With LED Display	1 pc

2.3.1 Solar collector

A solar collector is one of the crucial parts of a solar water heating system. It can be used as a heat exchanger. They collect the energy in the form of radiations from the sun, convert it into heat, and then transfer that heat to a colder fluid (usually water or air) [3]. This energy can be used for residential or commercial space heating and domestic hot water, solar pool heater, etc. [4]. The selection of suitable solar collectors depends on several factors. In, it is necessary to select a solar collector that can be protected from freezing [5]. There are three types of solar collector available in the market, and these are as follows,

1.1.1 Flat plate collector

Flat plate collector divided into glazed and unglazed. Glazed collectors are made with insulation, copper tubes, and weatherproofed boxes that contain a dark absorber plate and glass cover. On the other hand, an unglazed collector having a dark absorber made of metal or polymer, copper tubes, and without a cover [3]. The typical flat-plate collector is shown by the figure (1.2).

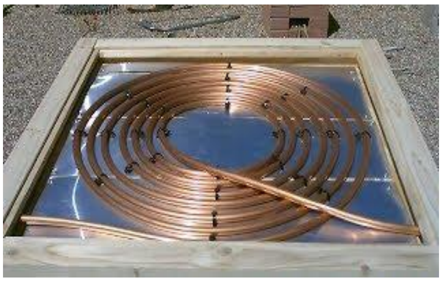


Figure 2.2: Flat plate collector [6]

2.3.2 Evacuated tube collector

This type of collector is more popular nowadays and efficient to collect energy from the sun. The cost of an evacuated tube collector is higher than the flat plate collector. They can work well in temperatures as low as -40°C (-40°F) and in overcast conditions [5]. They feature with parallel rows of transparent glass tubes. Each tube contains an outer glass tube and metal absorber tube that is attached to a fin. The fin’s coating absorbs solar energy but prevents radioactive heat loss [3]. An evacuated tube collector is shown by the figure (1.3

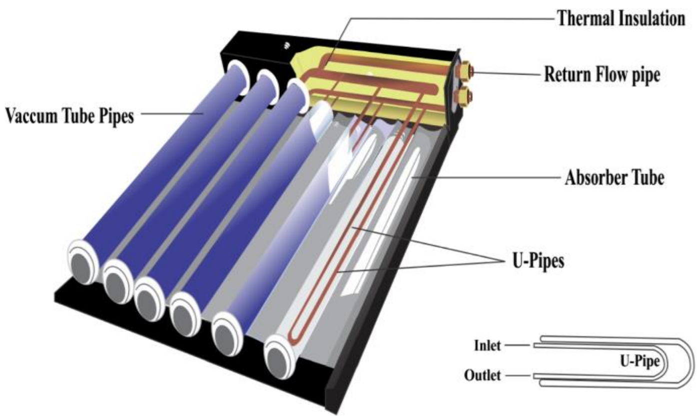


Figure 2.3: evacuated tube collector

2.3.3 Batch or Integral collector

This type of collector system featured with one or more black tanks or tubes in an insulated and glazed box. The associated system with this collector follows the conventional backup heater. They are not recommended for cold climates because the outside pipe could freeze in severe cold [3] [8]. A batch collector is shown by the figure (1.4),

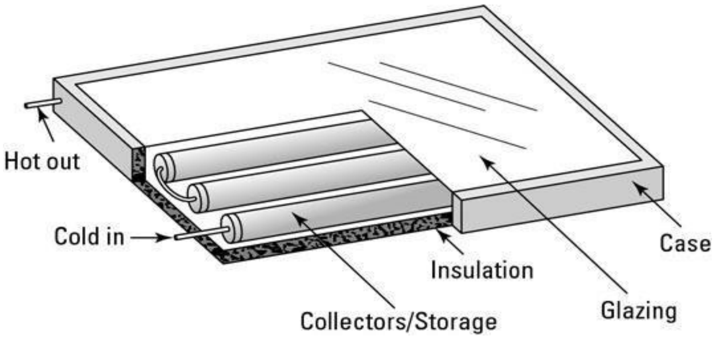


Figure 2.4: Batch or integrated collector [8]

2.4 Storage tank

Storage tanks mainly stored the hot water for later use and made of steel, concrete, plastic fiberglass, and other suitable materials. Among all the materials, steel tank is mostly accessible in the residential and commercial uses because of easiness to maintain and available in many sizes. To avoid corrosion and heat losses, a steel tank should be galvanized and appropriately insulated [3]. More details of a storage tank mentioned in chapter 3.

Figure 2.5: Water Tank (30 liter)

2.5 Heat exchanger

Solar water heating systems commonly use a heat exchanger to exchange useful heat from collectors to liquid or air for space heating and hot water. Heat exchangers can be made of steel, copper, bronze, stainless steel, aluminum, or cast iron, but the solar heating systems usually use copper because it is an excellent thermal conductor and has a higher resistance to corrosion. There are three types of heat exchangers with liquid to liquid, air to liquid, and liquid to air. They can be designed as a coil in the tank, shell and tube, and tube in tube. Some factors contributed to the proper and efficient design of the heat exchanger and featured with the working fluid, flow rate, inlet, and outlet temperature of all fluids [9] [10].

2.6 Pump

The pump is one of the crucial components of a solar water heating system to circulate the hot water or glycol solution from the collector to the storage tank. In any solar heating system, there are several loops available, and based on the loops, necessity pumps need to be selected. Proper controlling helps to maintain the pump speed as the speed and enough pressure head are prime factors for selecting an appropriate pump. Most of the solar system uses the centrifugal pump, and in our research, a centrifugal type constant speed pump was used. This pump was selected because it was able to meet some crucial features and design criteria like Flow rate of the system, the power consumption of the pump, system type, operating temperature, friction losses, and the type of heat transfer fluid [11] [12]. A solar water heating pump is shown by the figure (1.5),

Figure 2.5: Typical pump for a solar heating system [13]

2.7 Pipe

The piping network usually makes way for transporting the hot water and heat transfer fluid in the solar water heating system. The choice of a smart piping system is essential for long term feasibility and easy to install. Owners are looking for a cost-effective and trouble-free piping system in their heating system. Each pipe and fittings have some physical and thermal properties to meet the operating conditions and help to choose the most effective pipes. The selection of the right piping system depends on the pressure and temperature rating, joinability and ease of fabrication, availability, resistance to corrosion, type of application, the lifetime of the material and installation, etc. and it should follow the local codes [12] [14].

Figure 2.6: Copper Pipe for chamber

2.8 Heat Transfer Fluid (HTF)

Heat transfer fluid extracts typically heat energy from the collector and take this heat in the storage tank either directly or using the external or internal heat exchanger. HTF should have some properties like high specific heat capacity, high thermal conductivity, low viscosity, low

Thermal expansion coefficient, inexpensive, and anti-corrosive quality. Based on the properties mentioned above and readily available with popularity, the most common type of heat transfer fluid is water, air, ethylene glycol, a mixture of water and ethylene glycol, silicon oils, refrigerant, and hydrocarbon oils. It should be chosen carefully for the places where the temperature drops below zero in winter [15] [16].

Except for the description of the above-mentioned significant components, a solar water heating system featured with different kinds of values, control strategy, temperature and pressure sensor, etc. in order to make the system more efficient and reliable.

2.9 Thermocouple

A thermocouple is a sensor that measures temperature. It consists of two different types of metals, joined together at one end. When the junction of the two metals is heated or cooled, a voltage is created that can be correlated back to the temperature. So we are read the temperature by this.

Figure 2.7: Thermocouple

2.10 Glass Sheet

We are using glass sheet for covering the chamber, because of we need to increases the heat to chamber, then increasing the temperature and heat change with copper pipe.

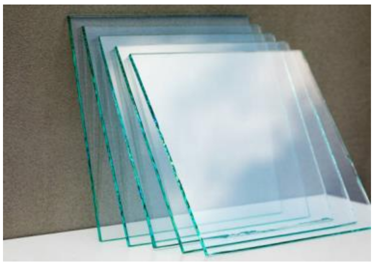


Figure 2.8: Glass Sheet

2.11 Types of a solar water heating system

Solar water heating systems are divided into “Active” and “Passive” solar water heating system or the combination of both. The active solar water heating system uses mechanical device or circulator that can be used to transfer heat energy into the system and on the other hand, passive system operates without reliance on external devices. Also, the active system needs more maintenance and expensive than the passive system. The main components of an active solar water heating system are solar collectors which can be concentrating or non-concentrating. This device absorbs heat energy from the sun, converting it into heat, and transfers the heat into working fluid (anti-freeze, air, water) following through the collector. This warmed fluid carries the heat directly to the useable hot water or space heating equipment or a storage medium from which can be drawn for use at night and on cloudy days [4].

2.11.1 Active Solar hot water system

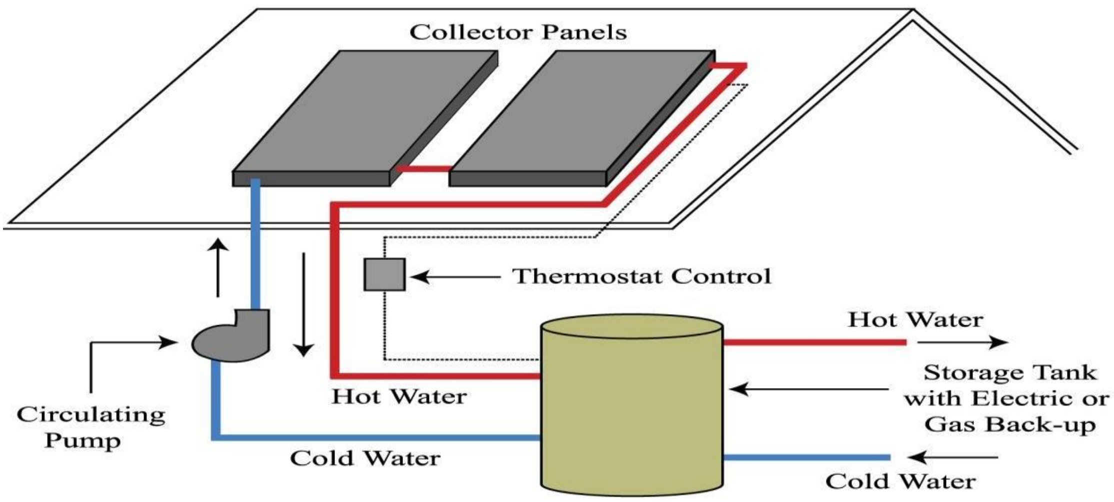


Figure 2.9: Active solar water heating system [2]

In an active solar water heating system, the mechanical device pump is used to circulating the liquid through the whole system as well as to control the system correctly; electrical control devices also needed. It can be categorized by two and shown by the figure (1.6),

2.11.1.1 Direct circulation system (Open-loop system)

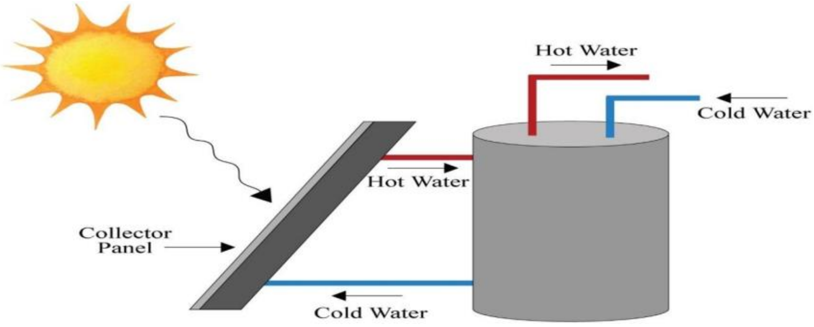
This system circulates water from the storage tank up to the solar collector and back it again with the help of a pump. In this method, heat energy from the sun is transferred to circulating potable water directly through the collector and the tank. That is why it is called a direct circulation system or an open-loop system. An anti-freeze can be used in this system. It also uses the various controller to sense the required temperature regarding turn on and turn off the pump when it is needed and has one or more collectors that mounted on the roof and a storage tank located suitably in the building [17].

2.11.1.2 Indirect circulation system (closed-loop system)

This system is suitable for colder countries, where the freezing condition can occur. Working fluid and heat exchangers have required the feature. In this way, heat from the sun is transferred to a working fluid solution and circulates this working fluid from the collector up to the storage tank, and a heat exchanger transfers heat from working fluid to storage tank water before back it again with the help of a pump. Usually, a double-walled heat exchanger is required when it used toxic working fluid. Heat transfer occurs within a closed-loop cycle; that is why it is called an indirect circulation system or closed-loop system. This loop includes the collector, connecting pipe, pump, expansion tank, heat exchanger, and controller. It is remembered that the heat exchanger coil should be placed in the lower half of the storage tank to alter the heat accurately [17].

2.11.2 Passive Solar hot water system

In a passive system, there is no need for an electrical device as it relies on gravity and has



the tendency to circulate the water naturally when it is heated. It also has a longer lifespan compared to an active solar water heater, more reliable and very easy to maintain. This type of heaters can be categorized below and shown by the figure (1.7),

Figure 2.10: Passive solar water heating system [2]

Chapter 3

Installation

3.1 Introduction

Thermal modeling, energy consumption analysis of modern houses is a vital aspect of making the houses more energy efficient. Our project designed for all kind of house.

We know that people in many villages of Bangladesh are deprived of electricity and live a hard life in cold winters. My project is mainly for them where we can give them projectors for only a small amount of money and we can install our solar thermal 'heat collector projectors in any kind of house. In that case we will not only need a lot of equipment but we also need some main items which can be found in the village so we hope to be able to install it in our village and also use it on the roof of big building Given that the main purpose of our project we are working on and hope and all will be done.

3.2 Site selection

To model and analyze any house in colder countries, it is necessary to select a proper site for the house. Many available data are required in order to get an accurate output, and the proper place where the house should be located ensures these accessible data efficiently for the designer. The selected house was. (47.56 ºN) and longitude (52.71 °W). The selected house is in climate zone.

3.1.1 Solar heater for Bangladeshi House

Its can set up or install all type of Bangladeshi house even also house in village are shown by the figure (2.1) and figure (2.2). We need to change the chamber depended on the house size The dimensions of the house length: 45 feet and width: 30 feet is perfect for our project model size.

Figure 3.1: Physical view of the Bangladeshi Village House

Figure 3.2: Physical view of the Bangladeshi city rooftop

After analyzing the result, it is obvious to say that thermal collector of the house is an indispensable way to know the thermal characteristics of the house as well as to get a clear idea of the annual electrical loads. These loads contribute to the design and modeling of an energy-efficient renewable energy system. This analysis also helps to attain the knowledge of house materials, insulation properties, estimates the yearly loads, and the Electricity consumption of the various home appliances, etc. These aspects assist in taking action to reduce the annual electricity loads, make more energy-efficient and energy-saving houses. Nowadays, energy-efficient houses are an attraction to the people. This tends to have less electricity bill. From the thermal analysis of the house, the total electrical energy demand is found around 19511.

Chapter 4
Performance of Project

4.1 Introduction

The global energy demand, as well as the use of conventional energy production, has been increasing rapidly and can affect the environment in the form of global warming, wildfires, etc. Reducing Greenhouse Gas (GHG) emissions and increasing the use of renewable energy are the major challenges nowadays that can lead to a better environment. According to Natural Resources. (2015), in the residential sector, space heating consumed around 62% of total energy, whereas consumption of space heating is about 55% in commercial use. It is noticeable that space heating consumed the highest energy in both cases. Also, in Bangladesh, the consumption of space heating energy is higher and uses approximately 70.9%. Greenhouse gases included space heating, produces 91.8% [1] [2]. Researchers and energy companies around the world have emphasized the need to find a solution that can be used to produce and store thermal energy from solar energy during the summer and be used during the winter as it is free energy, but it is not readily available. To overcome these flaws, seasonal solar thermal energy systems with more extended storage periods can be an effective way for colder countries throughout the world to utilize the abundant resource of solar energy feasibly. System performance is one of the crucial factors for end-users and relies on various system configurations like solar collectors, low-temperature storage water tanks, auxiliary heaters, and heat pumps [3].

Extensive research has been going on to obtain the best and most feasible options to store thermal energy seasonally that can mitigate the mismatch between supply and demand. Out of them, the sensible heat storage system is one of the suitable choices because of its cost- effectiveness, longer lifespan, and easiness to maintain. Antoniadis and Martinopoulos [4] designed a solar thermal system with seasonal thermal energy storage and simulated, the energy use of a single-family detached house in Thessaloniki, Greece, using TRNSYS software. They found that the STES system covered only 52.3 % of the space heating demand, but that was Able to fulfill the hot water load over the whole year. A seasonal solar thermal energy storage system using TRNSYS simulation software made for a student housing project at Virginia Commonwealth University followed the American Society of Heating and Air-conditioning Engineers (ASHRAE) specifications. Due to the availability and cost, sand was used as the storage medium. Simulations were done for five years to make the sand-based system reach a steady and concluded that an effective and efficient SSTES system could meet up to 91% of the heating energy demand of the building [5]. A solar-assisted heat pump system's performance was simulated by Lie et al. [6] with the help of TRNSYS software for covering the space heating and domestic hot water demand with seasonal storage. Water was used as a storage medium of their system, as well as an air-to-water heat pump unit, while a water-to- water heat pump unit with other necessary components was used for making the simulation model. After completing a one-year simulation period and comparing the findings to conventional space heating systems, it was noticeable that the domestic hot water solar fraction and the energy-saving ratio was around 68.1% and 52% respectively every month.

On the other hand, the annual seasonal storage tank's energy storage efficiency was about 64% for space heating. A loss-free thermal energy storage system was built by researchers in Germany using a small size Fraunhofer's zeolite, which can store heat up to four times more effective than water for indefinite periods [7]. A water tank based system was designed and simulated by Lund [8] for Central Solar Heating Plants with Seasonal Storage (CSHPSS) and concluded that about 35% to 60% of solar fractions for this type of system was increased using a stratified storage tank rather than the thoroughly mixed tank. Wills et al. [9] designed and simulated a solar thermal system with seasonal storage as a part of the C-RISE project. A domestic hot water tank and a buried concrete tank were used to provide hot water and space heating demand for the selected house. A co-simulation tool was used to do the different parametric and sensitivity analysis and found that the system at the C-RISE House met about 89.2 % of space heating and domestic hot water demand. A study showed that renewable energy has been contributing to meet around 17% of primary energy demand in., which will lead them to lessen GHG emissions by 30% of 2005 levels by 2030 [10].

From the literature search, it found that renewable energy-based systems and projects should be implemented in the residential sector to reduce greenhouse gas emissions and provide a better and more livable environment. The best option to utilize this solar energy in residential and industrial uses through proper design, sizing, and control to make the system economically viable and more practical. If this happens, then the proposed solar space heating system will be useful to supply thermal energy in the houses .

In this work, section 2 will present thermal modeling and analysis. Section 3 will show the proposed system and methodologies. Sizing of proposed system components and results with discussion will be discussed respectively, and the paper will end with a conclusion.

4.2 Test with plastic pipe

We first made a few plastic pipes in the chamber. We made the coil in the chamber and with that we started the first test. We wanted a much higher temperature but we cannot get with plastic pipes because plastic pipe conductivity is so low that we decided to replace the chamber made of plastic pipe with a new thermal pipe chamber. we took some data, these are given below

Figure 4.1: Chamber with Plastic Pipe

4.3 Test in open loop

This system circulates water from the storage tank up to the solar collector and back it again with the help of a pump. In this method, heat energy from the sun is transferred to circulating potable water directly through the collector and the tank. That is why it is called a direct circulation system or an open-loop system. An anti-freeze can be used in this system. It also uses the various controller to sense the required temperature regarding turn on and turn off the pump when it is needed and has one or more collectors that mounted on the roof and a storage tank located suitably in the building

Table 4.1: Data for open loop test

Time (Min)	Temperature (Room Water)	Temperature (Heated Water)	Temperature (Room Weather)	WFR (Water Flow Rate)
5	27.5	28.5	36.3	5.5
10	27.8	30.5	36.5	5.5
15	28.3	31.5	36.6	5.5
20	28.6	31.9	36.6	5.5
25	29.2	34.2	36.5	5.5
30	29.3	34.6	36.8	5.5

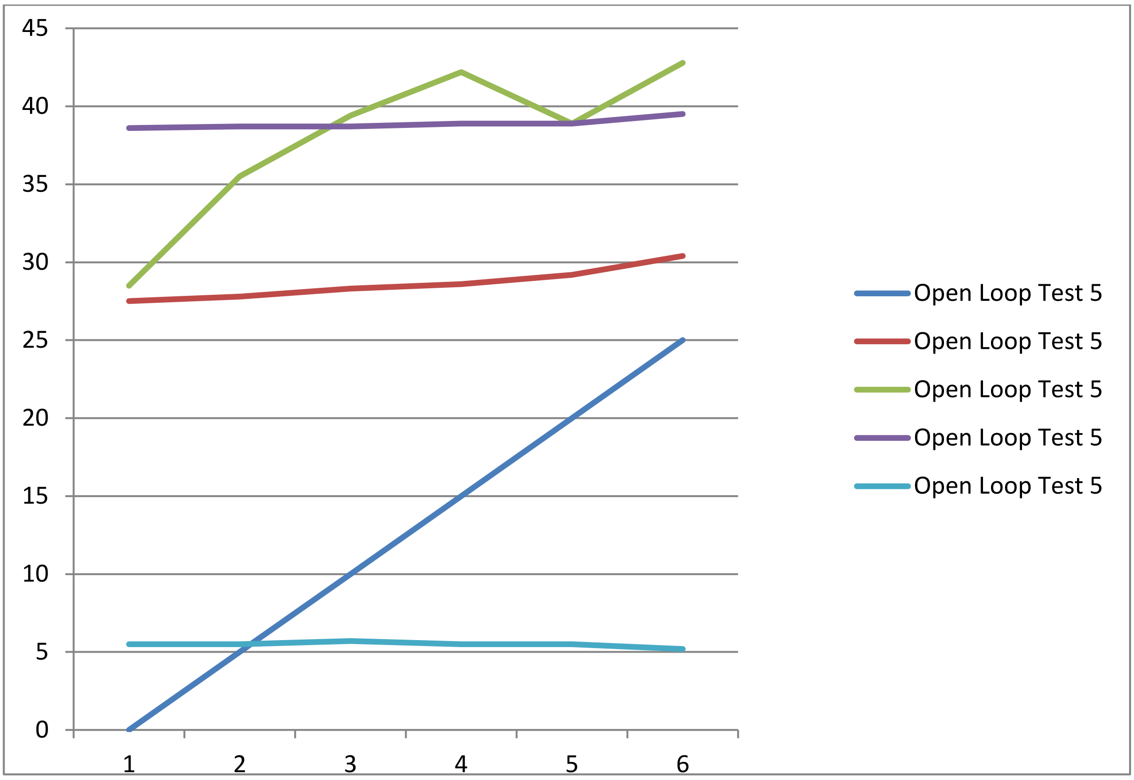


Figure 4.2: Test with open loop in Different weather

4.4 Indirect circulation system (closed-loop system)

This system is suitable for colder countries, where the freezing condition can occur. Working fluid and heat exchangers have required the feature. In this way, heat from the sun is transferred to a working fluid solution and circulates this working fluid from the collector up to the storage tank, and a heat exchanger transfers heat from working fluid to storage tank water before back it again with the help of a pump. Usually, a double-walled heat exchanger is required when it used toxic working fluid. Heat transfer occurs within a closed-loop cycle; that is why it is called an indirect circulation system or closed-loop system. This loop includes the collector, connecting pipe, pump, expansion tank, heat exchanger, and controller. It is remembered that the heat exchanger coil should be placed in the lower half of the storage tank to alter the heat accurately.

Table 4.2: Data for closed loop test

Time (Min)	Temperature (Room Water)	WFR (Water Flow Rate)	Temperature increase per Min
5	27.6	5.3	5.7
10	33.3	5.3	6.1
15	39.4	5.3	4.7
20	44.1	5.3	5.2
25	49.3	5.3	6
30	55.3	5.3	4

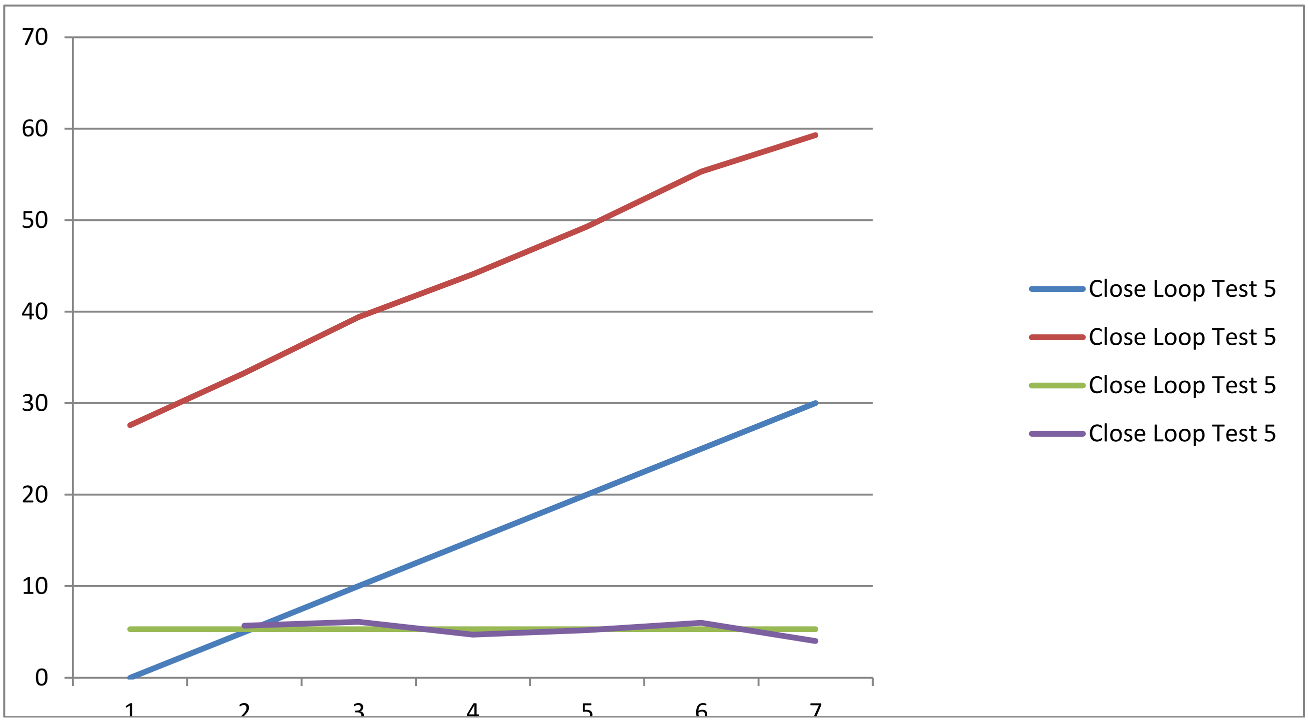


Figure 4.3: Daily pump solar loop temperature

Figure (3.15) determines the supplied heating energy and the room temperature of the building for the designed system. The room temperature was near or above 17 ºC during the heating periods as it was the set temperature for the building, but in summer months, it went higher and reached 22.5°C because of the comparatively lower space heating consumption mentioned in the earlier section. Moreover, the supplied heating energy was enough to meet the space heating demand.

Figure (3.16) shows the overall solar fraction and irradiation fraction of the proposed system. From the results, it can be said that the overall solar fraction was 61.4 %, but in the summer months, the percentage was 100. On the other hand, the overall solar irradiation on the

4.4.1 Solar collector

System performance and efficiency depend on the perfect sizing of the components of any system. In our system, the main components are mainly the solar collector and storage tank. To design the solar collector size correctly, different equations were used from the literature we reviewed that can meet the space heating demand of the house in the heating period. The calculation method for getting the solar collector area is as follows:

4.4.2 Working fluid

The working fluid is one of the vital features where freezing conditions can occur in colder countries. Therefore, the selection of a suitable working fluid depends on many factors. The working fluid will be more efficient when it extracts the maximum amount of thermal energy from the collector field. A propylene mixture was used as a working fluid, with a fluid concentration of around 33.3 %, in this proposed system.

4.5 Discussion

Figure (3.14) demonstrates the daily pump solar loop temperature. In the proposed system, three different pump loops were used, as mentioned earlier. After analyzing the daily loop temperatures, it was evident that the solar pump loop and the transfer circuit loop have similar temperature patterns. The temperature started to rise after 9 AM and reached its highest point at noon. Then the temperature started to decrease in value because the solar collector received the highest level of solar radiation at that time. On the other hand, the pump heating loop showed a slightly different profile with a low-temperature difference. However, in cases of yearly loop temperatures, pump solar loop and transfer circuit loop possessed the highest temperatures in summer while the pump heating loop achieved the highest temperature in winter. Collector was 93.8%, but during the summer months, the percentage was 100. Due to the various losses and inefficient collectors cause higher space heating demand in winter months.

Discussed in this research. These losses occur in tank, building, ventilation, and infiltration. Among these, the building was the primary source of loss. In our next phase of research, minimizing the overall losses of the system will be the prime target. this study, a solar space heating system was designed and simulated with professional Polysun software to fulfill the annual space heating demand with seasonal energy storage of a single-family house. The simulation results depend on the actual sizing of the system components and the other values given as inputs for the simulation environment. After demonstrating the output, it can be said that the proposed system was more practical, profitable, and efficient in colder countries with more considerable seasonal differences. It was concluded that the proposed system should consist of 16 m^2 flat plate collector area, 47 m^3 proper insulated storage tank with a height and diameter of 3.91 m and a 5-kW heat pump. Then, this system will meet the space heating demand in the heating periods of the selected house. A heat pump was used to boost up the backup heat to this system for the heating months, as discussed earlier. This system can be further modified by controlling the individual components and the cost analysis of the full system to make it more affordable and reliable.

4.6 COLLECTOR PERFORMANCE

The thermal performance of a collector can be calculated from a first-law energy balance. according to the first law of thermodynamics, for a simple flat-plate collector an instantaneous steady-state energy balance is

(Useful energy gain (Qu) = (energy absorbed by the collector) – (heat loss to surroundings)

The thermal performance of a collector can be calculated from a first-law energy balance. According to the first law of thermodynamics, for a simple flat-plate collector an instantaneous steady-state energy balance is

(Useful energy gain (Qu) = (energy absorbed by the collector) – (heat loss to surroundings)

And,

Absorbed energy = AC FR S

Lost energy = AC FR UL (Ti-Ta)

Where;

AC Collector area, m2

FR = Heat removal factor, unitless

S = Absorbed solar radiation, J/m2

UL = Heat transfer loss coefficient, J/m2 °C

Ti = The mean absorber plate temperature, °C

Ta = The ambient temperature, °C.

So,

QU= AC FR S-AC FR UL (Ti-Ta)

4.7 COLLECTOR EFFICIENCY

The basic method of measuring collector performance is to expose the operating collector to solar radiation and measure the fluid inlet and outlet temperatures and the fluid flow rate. The useful gain is;

$$Qu = m' Cp \ (To - Ti)$$

Equation: Energy gained by liquid.

Where;

m' = Fluid mass flow rate, kg/s

The above equation describes the thermal performance of a collector operating under steady conditions, can rewritten;

$$Qu= AcFr [G, (ta) -U_1 (Ti -Ta)] C$$

Equation: Useful gain energy equation.

When

(Ta) is a transmittance - absorptance product that is weighted according to the proportions of beam, diffuse, and ground reflected radiation on the collector

Figure 4.4: Chamber testing unit [17]

4.8 Project overview

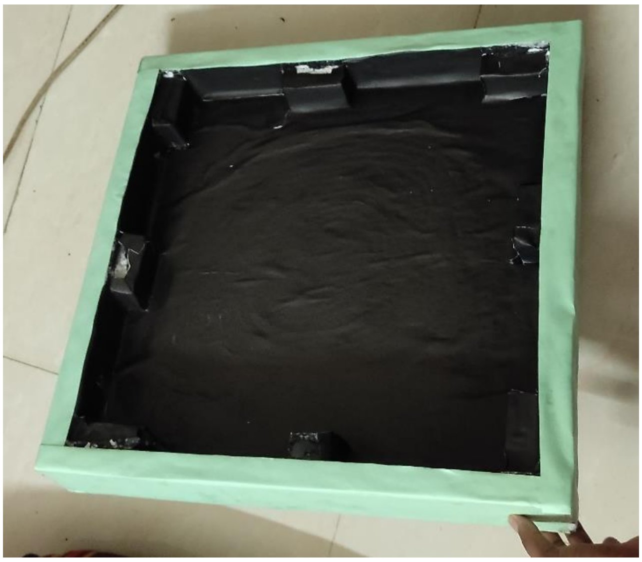


Figure 4.5: Heat Chamber without Glass cover

Figure 4.6: Project with Storage

Chapter 5
Conclusion

5.1 Summary

This chapter consists of the main contribution of this research work along with the proposed future works on the solar water heating system. The main objective of this research work was to design, model and analysis of a solar water heating system for meeting the annual space heating and domestic hot water demand for a single house in each chapter of this thesis worked with a specific task to meet the overall thesis goal. The individual chapter's summary is as follows,

In Chapter 1, the literature review of a solar water heating system, their classification, various methods were discussed. Also, different thermal energy storage system was considered in order to get the most feasible option for designing and modeling a solar water heating system. Though many parameters depend on each other but after evaluating the first chapter, it is obvious to say that the sensible heat energy storage system is suitable and more efficient for achieving the thesis aims.

In chapter 2, the thermal modeling of a house was done to find out the annual energy demand of individual loads as well as the thermal properties of the house materials with various characteristics. These aspects tend to design the most energy-efficient and energy-saving houses. This chapter concluded that the annual energy consumption of the house was about

After analyzing all chapters of this thesis, it is noteworthy to say that an active, closed-loop water heating system for supplying space heating and domestic hot water is suitable for St. Bangladesh,

After analyzing the result, it is obvious to say that thermal collector of the house is an indispensable way to know the thermal characteristics of the house as well as to get a clear idea of the annual electrical loads. These loads contribute to the design and modeling of an energy-efficient renewable energy system. This analysis also helps to attain the knowledge of house materials, insulation properties, estimates the yearly loads, and the

Electricity consumption of the various home appliances, etc. These aspects assist in taking action to reduce the annual electricity loads, make more energy-efficient and energy-saving houses. Nowadays, energy-efficient houses are an attraction to the people. This tends to have less electricity bill. From the thermal analysis of the house, the total electrical energy demand is found around 19511.

5.2 Future work

- ✓ In this thesis, a solar water heating system was designed with seasonal thermal storage, so a hybrid system can be considered to meet the space heating and domestic hot water demand entirely without using a boiler or heat pump.
- ✓ A study could be done about design of such system with a heat pump and check its effectiveness.
- ✓ Cost analysis is an essential factor in designing and analyze this kind of system. So, extensive cost analysis of the full system can be done to know the exact initial, running, and maintenance expenditure.
- ✓ In this thesis, a dynamic simulation of space heating system was done, so a full system including space heating and domestic hot water can be simulated for a few hours. A simulation method or software needs to be identified that can simulate performance of such a system for a year.
- ✓ An alternative technique with proper insulation can be used to reduce the energy losses of the standby storage tank and other system components.
- ✓ No control system was proposed in this study. Design of a proper control system is essential that should be considered for further work.

- ✓ Bangladesh gets a lot of snow. A study is required to determine impact of snow on solar collectors and a method needs to be determined for snow removal from the collector.
- ✓ Installation issue of the proposed system and proper drawings could be done in further work.

References

[1] C. N. Antoniadis and G. Martinopoulos, "Simulation of Solar Thermal Systems with Seasonal Storage Operation for Residential Scale Applications," Procedia Environ. Sci., vol. 38, pp. 405–412, Jan. 2017.

[2] L. T. Terziotti, M. L. Sweet, and J. T. McLeskey, "Modeling seasonal solar thermal energy storage in a large urban residential building using TRNSYS 16," *Energy Build.*, vol. 45, pp. 28–31, Feb. 2012.

[3] H. Li, L. Sun, and Y. Zhang, "Performance investigation of a combined solar thermal heat pump heating system," *Appl. Therm. Eng.*, vol. 71, no. 1, pp. 460–468, Oct. 2014.

[4] "Zeolite thermal storage retains heat indefinitely, absorbs four times more heat than water - ExtremeTech." [Online]. Available: https://www.extremetech.com/extreme/130523-zeolite-thermal-storage-retains-heat-indefinitely-absorbs-four-times-more-heat-than-water. [Accessed: 02-Jan-2019].

[5] P. D. Lund, "Effect of storage thermal behavior in seasonal storage solar heating systems," *Sol. Energy*, vol. 40, no. 3, pp. 249–258, Jan. 1988.

[6] A. D. Wills, "Design and co-simulation of a seasonal solar thermal system for a Canadian single-family detached house," 2014.

[7] N. R. ., "Renewable energy facts," 06-Oct-2017. [Online]. Available: https://www.nrcan.gc.ca/energy/facts/renewable-energy/20069. [Accessed: 02-Jan-2019].

[8] W. Weiss, *Solar Heating Systems for Houses: A Design Handbook for Solar Combisystems*. Routledge, 2003.

[9] "Heat pump," *Wikipedia*. 15-Dec-2018.

[10] "Radiator (heating)," *Wikipedia*. 15-Oct-2018.

[10] Z. Yao, Z. Wang, Z. Lu, and X. Wei, "Modeling and simulation of the pioneer 1MW solar thermal central receiver system in China," *Renew. Energy*, vol. 34, no. 11, pp. 2437–2446, Nov. 2009.

[11] G. Pernigotto and A. Gasparella, "Extensive comparative analysis of building energy simulation codes: Heating and cooling energy needs and peak loads calculation in TRNSYS and EnergyPlus for southern Europe climates," *HVACR Res.*, vol. 19, no. 5, pp. 481–492, 2013.

[12] Y. Tong, H. M. Kim, and H. H. Cho, "Theoretical investigation of the thermal performance of evacuated heat pipe solar collector with optimum tilt angle under various operating conditions," *J. Mech. Sci. Technol.*, vol. 30, no. 2, pp. 903–913, 2016.