Design, Fabrication and Control of a Solar Thermal Room Heating System

Senior Design Project Report

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Room Heating System WEC

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Senior Design Project Report

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In the Name of Allah, the Most Beneficent the Most Merciful

Final Year Design Project Thesis Report

Project ID	02	**Number Of Members**	02

Title	Design, Fabrication and Control of a Solar Thermal Room Heating System

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ABSTRACT

The growing demand for sustainable and energy-efficient heating solutions has led to the development of various solar thermal systems. The purpose of this project is to design, fabrication, and control of a PV-T (photovoltaic-thermal) solar thermal room heating system, aiming to provide an innovative and environmentally friendly approach to space heating. The system combines the benefits of photovoltaic electricity generation and thermal energy production to provide efficient and sustainable heating solutions.

The proposed PV-T solar thermal room heating system integrates photovoltaic (PV) modules and thermal collectors to simultaneously generate electricity and heat from solar energy. The PV modules convert sunlight into electrical energy, while the thermal collectors absorb and transfer solar heat to a heat transfer fluid (water). This dual-functionality design optimizes energy utilization and enhances overall system efficiency.

The fabrication process involves designing and constructing the PV-T system components, including the thermal collectors, heat transfer fluid piping, heat exchangers, storage tank and model of a room. The selection of appropriate materials, sizing of components, and assembly techniques are crucial to ensure optimal system performance and longevity.

To achieve effective control over the PV-T solar thermal room heating system, advanced control algorithms and strategies are implemented. These control mechanisms monitor and regulate various system parameters, such as fluid flow rate, temperature differentials, and electrical output, to ensure efficient energy production and delivery for space heating purposes.

The performance evaluation of the PV-T solar thermal room heating system involves conducting experiments and measurements to assess its thermal efficiency, electrical output, and overall system performance under different environmental conditions. The collected data is analyzed to validate the system's design and control strategies, providing insights into its effectiveness and potential for real-world applications.

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Chapter 1 - Introduction

The goal of this project is to reduce the temperature deratings of the photovoltaic (PV) cells so that they produce more electricity with the same amount of sunlight. This will be done by adding a simple heat exchanger to the PV panel, which will cool the panel and keep it at the right temperature. The heat that is made will be collected by the panel heat exchanger and used to heat a building or room by going back through a heater in the room[1]. A real-time data gathering system will be made with various temperature, light intensity, and mass flow rate monitors so that important system factors can be tracked and recorded. The data that was recorded will be used to estimate how well PV panels worked, how much thermal energy was received, and how much thermal energy was lost in the room or building[2].

1.1 Problem Statement

The growing need for energy around the world and the pressing need to cut greenhouse gas pollution has made it necessary to look for safe and efficient ways to heat homes. Solar thermal technologies, which use the power of the sun to make heat energy, have become a potential choice[3]. But traditional solar thermal systems often have problems with how they use room and how much power they can make at the same time.

This project focuses on the design, construction, and control of a PV-T (photovoltaic-thermal) solar thermal room heating system. Its goal is to make up for the problems with standard solar thermal systems. Here is a brief summary of the problem statement:

Most of the thermal energy produced by current solar thermal systems is used to heat spaces, which limits their total efficiency and energy use. Also, photovoltaic systems that work on their own mostly make power and aren't good at using the sun's heat. There needs to be a system that mixes the benefits of both making power and heat in a way that takes up little room[3].

The PV-T solar thermal room heating system has to deal with these problems:

1.1.1 Efficient Integration

In order for solar panels and heat collectors to work well together in a single system, they need to be carefully designed to gather the most energy, lose the least amount of energy, and work well with each other.

1.1.2 Optimal Energy Utilization

The system should effectively utilize solar energy to produce both electricity and heat, ensuring a high overall energy conversion efficiency. Maximizing the utilization of solar irradiance and thermal energy capture is critical to enhancing system performance[4].

1.1.3 Control and Optimization

Developing advanced control algorithms and strategies is necessary to regulate the system's operation, manage energy production and distribution, and ensure optimal thermal comfort and electricity generation.

1.1.4 Scalability and Adaptability

The PV-T solar thermal room heating system must be able to grow or shrink depending on the size of the building and the amount of energy it needs. For wide use in a variety of uses, you need to be able to change how a system is set up and choose which parts to use[5].

If these problems are solved, it will be possible to make a heating system that is efficient, cheap, and good for the environment. This will make it possible to use less energy from traditional sources. The goal of this study is to come up with new ways to improve the performance and integration of PV-T solar thermal systems used to heat rooms[4].

1.2 Aims and Objectives

The major goal of the project is to analyses and test the effectiveness of a PV-T Solar Thermal Room Heating System. These are the main goals of the project:

1.2.1 Mathematical modeling of the system

A PV-T solar thermal room heating system is modelled mathematically by explaining the physical processes and connections that make it work.

1.2.2 Design of a heat exchanger for collecting heat from a panel

A heat exchanger will be made and put on the back of the panel to collect solar thermal energy as the panel is exposed to sunlight.

1.2.3 Design of room heat exchanger (radiator)

A heat exchanger with a comfortable design will be used to heat a room or building with thermal energy. The heat energy from the panel will be recirculated in a controlled way through this panel. The heat exchanger will have a fan built in so that air can move through it and move heat around[6].

1.2.4 Data logging and control system for room and panel

A real-time data logging and control system will be made and put in place at the panel and in the room heat exchange so that important system factors can be measured. The system will measure the temperature of the panels and heat exchangers, as well as the temperature of the room's heat exchangers, the mass flow rate, and the amount of light coming in[7].

1.2.5 Data analysis for evaluating system efficiency and effectiveness

The real-time data collected by the data gathering system will be looked at to figure out how well the system works and what the solar panel's temperature degradation is like. It will also show how well the cooling system works and if it can be used for air ventilation.

1.3 Overview

The PVT Solar Thermal Room Heating System is a first-of-its-kind way to use solar energy to heat a room in an efficient and environmentally friendly way. This new system combines photovoltaic (PV) and solar thermal technologies to make the best use of energy and have the least impact on the environment. The goal of this project is to show how green energy can be used to meet heating needs while lowering carbon emissions[8].

The main parts of the system are photovoltaic (PV) cells, solar thermal collectors, and a heat exchange machine. The PV panels take in light from the sun and turn it into electricity. This energy can be used to run the system and meet other electrical needs. At the same time, the solar thermal collectors take in heat from the sun. This heat is then used to heat rooms, which makes the system more efficient overall[9].

Putting PV and solar heating systems together has a number of benefits. First, it lets power and heat be made at the same time, which makes the whole system more efficient.

The extra electricity that the PV panels make can be sent back into the grid. This helps integrate green energy and reduces the need for traditional power sources[9].

The PVT Solar Thermal Room Heating System also keeps the room warm both during the day and at night. The extra heat energy that is collected during the day can be kept in a heat storage device, like a thermal tank or materials that change state. This saved energy is then used at night or on dark days to make sure there is always heat available[10].

The system's control unit is a key part of making it work as well as possible. It checks and controls the flow of energy between the PV panels, solar thermal collectors, and heat exchange unit. This makes sure that the energy is used efficiently and keeps the system from being overloaded or underused[7].

The PVT Solar Thermal Room Heating System is a new and environmentally friendly way to heat a room. By using the power of the sun, this method helps people become less dependent on fossil fuels, cuts down on greenhouse gas pollution, and makes the future healthier and more sustainable. Figure 1.1 shows the main idea behind the suggested design of the PVT solar heating system's layout[11].

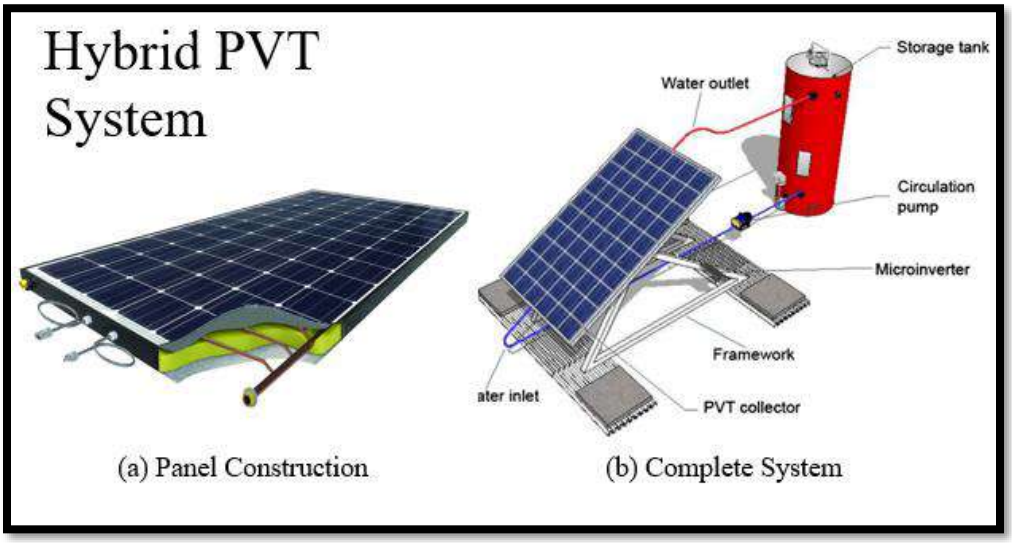

Figure 1.1 Proposed Architecture of Hybrid PVT System

1.4 Scope of Study

- Renewable energy source.
- Increased efficiency.
- Lower maintenance costs.
- Potential for government incentives

1.5 Significance of Project

The system can make both electricity and heat at the same time, which makes it more efficient than different systems that make electricity and heat separately. The system uses solar energy to make both electrical and heat energy. Solar energy is a free and renewable source of energy that can be used over and over again. This makes the system less reliant on grid power and fossil fuels, which lowers the cost of energy. By lowering the use of nonrenewable energy sources, the method cuts down on carbon pollution and helps slow down climate change. This method is more stable because it can get energy from both the sun and heat. The heating device that controls the temperature of the panels also makes the panels work better and last longer. The Hybrid system can be made to fit the needs of the building and can be changed to work in different conditions and areas. [12].

1.6 Technological Significance

The technological importance of this project is that it aims to make a prototype of a PV-T solar thermal room heating system that can measure the temperature of the top and bottom surfaces of a PV panel, the temperature of the water going into and coming out of a panel heat exchanger, the temperature of the room, the temperature of the water in the storage tank, and the amount of light in the room. Also, the flow rate of water and the STM32F401 microprocessor are being watched, which could be used or improved by other writers in the future[12].

1.7 Methodology

The methodology for the accomplishment of our project is as follows:

- Literature Review
- Design of Data logging system for measurement of solar flux, panel temperature, ambient temperatures, panel power
- Solar Panel deployment
- Data logging
- Analysis of Panel Characteristics based on logged data
- Design of heat exchanger
- Integration of heat exchanger and solar panel
- Data logging and analysis
- Complete system deployment and analysis

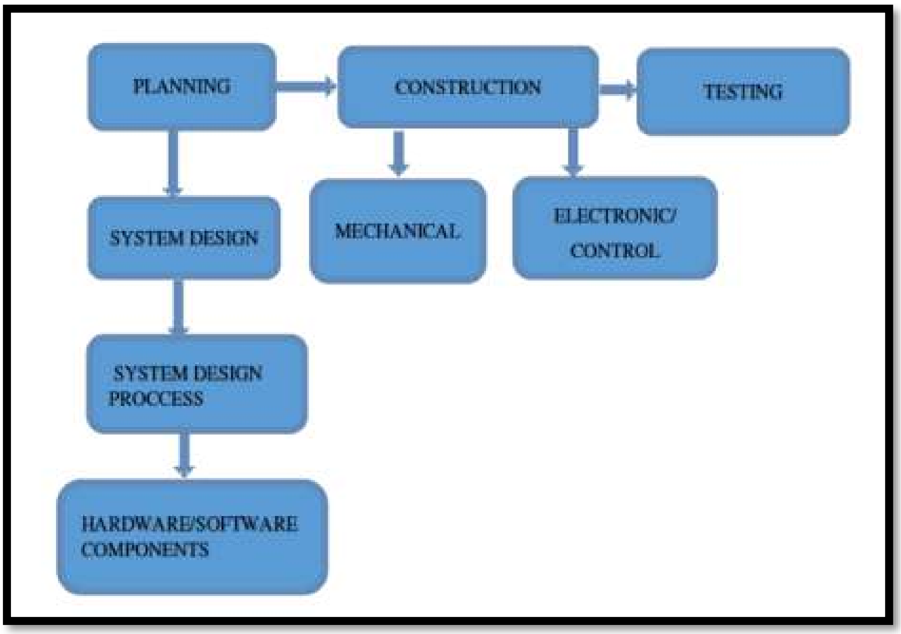

Figure 1.2 Project Execution Methodology

1.8 Background and Related work

In recent years, there has been a lot of interest in developing solar thermal devices to heat rooms. This is because we need to find more safe and green energy sources. Several research projects have looked into combine photovoltaic (PV) and solar thermal technologies to use energy more efficiently and make the system as a whole more effective[12]. The following study studies tell us a lot about the PVT Solar Thermal Room Heating System's history and linked work:

This study gives a techno-economic review of a PVT water heating system for homes. It talks about how to combine photovoltaic (PV) cells and solar thermal collectors, showing how it might be possible to make both power and heat at the same time. The study gives us important information about how well PVT systems work and whether or not they are cost-effective **(C. Sabedotti et al. (2019))**[11]**.**

In this study, the writers look into how well a combined PVT air catcher for heating a room works. They put PV panels and solar thermal collectors into a single unit and use both experimental and computer studies to figure out how well it works. The study gives information about how PVT systems for room heating are designed and how well they work **(K. Arasu et al. (2020))**[8].

This study shows the results of an experiment that looked at how well PVT solar collectors worked when they were used to heat things. The writers look at how well the system uses heat and electricity and how different factors affect how well it works. The results help us understand how PVT systems could be used to heat rooms **(M. Mahmoud et al. (2021))**[5].

This study looks at how well a PVT system for heating and generating electricity for homes works. The writers look at the system's thermal and electrical efficiency under different working situations and rate its ability to save energy and cut greenhouse gas emissions **(M. Monne et al. (2018))**[13].

This study paper looks at how a PVT water heating system works in the Indian climate and how it is designed. The writers look at the system's thermal efficiency, heat gain, and electricity-making ability. They take things like tilt angle, direction, and sun radiation into account **(A. Sharma et al. (2019))**[14].

In this study, the writers look at the energy and exergy of a combined PVT system that heats hot water for homes and heats rooms. They look at how well the system uses energy and exergy and how well it can make money. The study gives ideas on how to improve the system's performance and make it last longer **(A. A. Aly et al. (2020))**[14].

This study looks at how to improve the design of a PVT air catcher for heating homes. The writers look at how the performance of the system can be improved by changing the design factors and setups. Results include the best style, the best heating efficiency, and the possibility of saving energy **(A. Elaziz et al. (2021))**[15].

In this study, the writers look at how much energy and exergy a combined solar PVT system for heating a room uses. They look at how well the system uses energy and exergy under different working situations and how key factors affect its performance. Results include numbers for energy and exergy performance and suggestions for improving the system **(M. Gholamalizadeh et al. (2022))**[9].

This study looks at how well a PVT system works in cold areas to heat rooms and make power. The writers look at how well the system heats and uses electricity when the temperature is low. They also look at how well it can meet energy needs. Among the results are the system's success measures and suggestions for operation in cold climates **(S. Liu et al. (2022))**[16].

Chapter 2 – Basic Description and System Design

2.1 Conceptual Approach and Design Objectives

The main idea behind this project is to combine photovoltaic (PV) and sun thermal technologies to make a combined system for heating rooms. The PV panels will turn solar energy into power, and the solar thermal collection will turn it into heat. A PV–thermal (PVT) collector is a cell where the PV not only makes power but also soaks up heat. In this way, heat and power are both made at the same time. Since people often need both solar heat and solar energy, it seems like it would make sense to make a device that can meet both needs. Photovoltaic (PV) cells only use a small amount of the sun's energy to make power. The rest is mostly turned into waste heat in the cells and base, which raises the temperature of PV cells. Because of this, the programmed worked less well. Part of this heat is captured by the photovoltaic/thermal (PV/T) technology and used in useful ways. The cooling of the PV module at the same time keeps the electricity efficiency at a good level, so the PV/T collection is a better way to use solar energy that is more efficient overall[17].

- **Energy Efficiency:** In order to cut down on energy waste, this means that the most efficient solar thermal collectors and PV panels need to be chosen.
- **System Integration:** The mixed system design should work better to connect the two sections well and make it easier to switch between electricity and heat energy.
- **Control and automation:** This includes making control methods for the output of the PV system and the heat movement of the heating system.
- **Reliability and Durability:** When designing the system, it should be given top importance to be reliable and last a long time. This requires carefully choosing the parts, taking into account things like speed, durability, and protection of the environment.
- **Environmental influence:** The impact of the system on the environment should be taken into account by supporting the use of clean and green energy sources.
- **It is dual-purpose:** Both power and heat can be made with the same method.
- **It is efficient and flexible:** The efficiency of the combined system is always better than that of two separate systems. This is especially true in building integrated PV (BIPV), where there isn't much room between the panels on the roof.

- **It has a wide application:** The heat output can be used for both heating and cooling (desiccant cooling), based on the time of year, and is almost always good for home use.
- **It is cheap and practical:** It can be easily added to an existing building without making major changes, and changing the roof with a PV/T system can shorten the time it takes to pay for itself.

2.2 Description of Prototype

2.2.1 Solar Panel and Heat Exchanger

- Solar panel with solar and heating parts.
- The intake and exit both have DS18B20 temperature monitors.
- Extra sensors on the top and bottom sides to measure the surface temperature.

2.2.2 Room Model and Radiator Heat Exchanger

The temperature inside the room is measured by the sixth DS18B20 sensor. The heat exchanger in a radiator makes it easier for energy to move around the room.

2.2.3 Water Storage Tank and Flow Rate Sensors

- The DS18B20 temperature gauge keeps an eye on the temperature of the water that is being kept.
- Flow rate monitors at the outlet of the water holding tank and the outlet of the solar heat exchanger.

2.2.4 Microcontrollers and Communication

- Data and communication are handled by two STM32F401CCU6 microcontrollers.
- The first processor stores data from the solar panel sensors and the amount of light.
- A second microprocessor outside the room model is used to send and receive data.

2.2.5 Bluetooth Communication and Data Display

- HC-05 devices allow microcontrollers to send and receive data in real time.
- Seeing temps, flow rates, and light levels through a Bluetooth device.

2.3 CAD Design

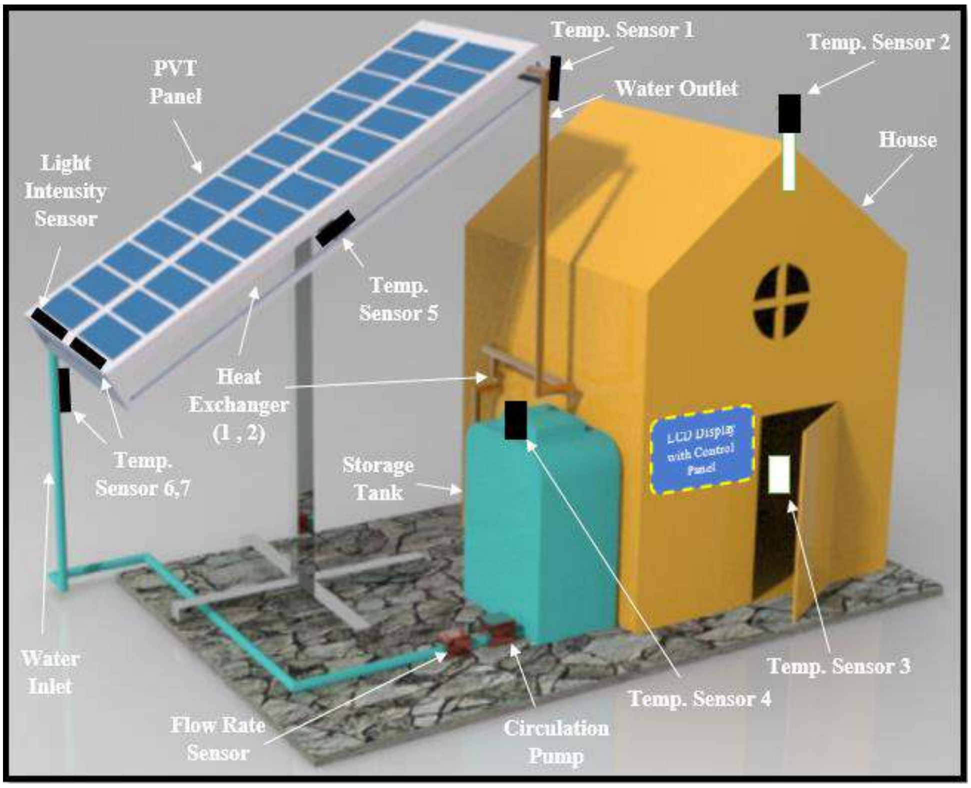

Figure 2.1 CAD Design of Complete System (Front Side)

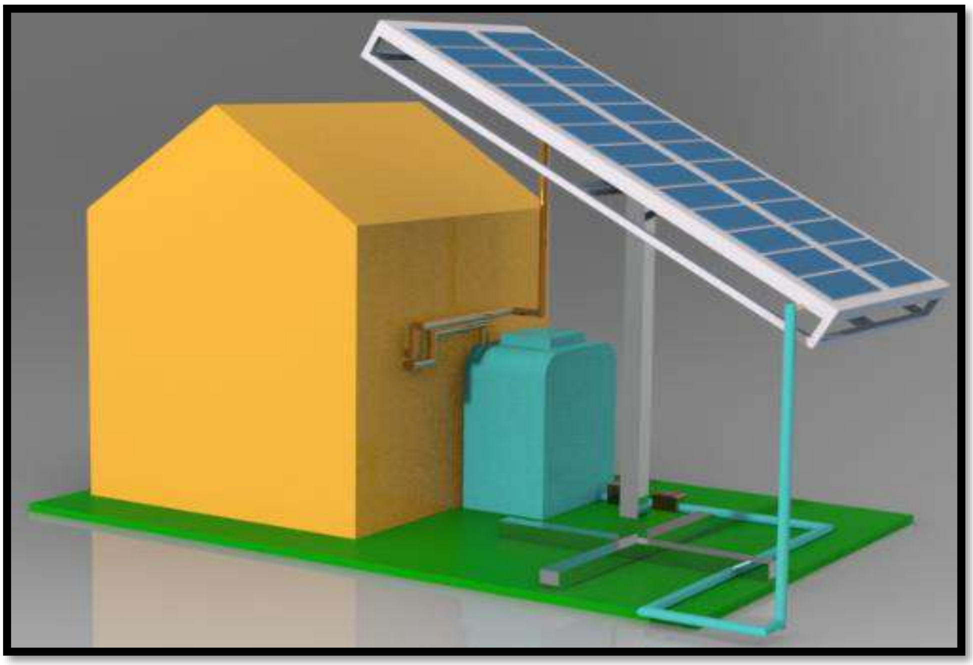

Figure 2.2 CAD Design of Complete System (Rear Side)

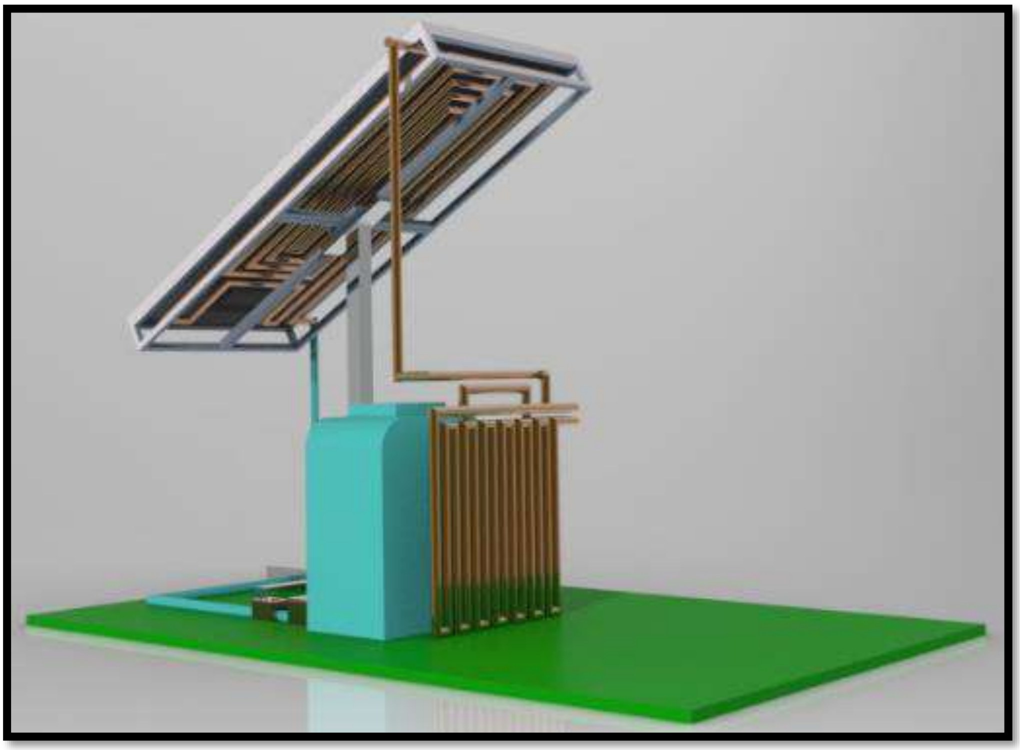

Figure 2.3 CAD Design for the Internal Structure of the System

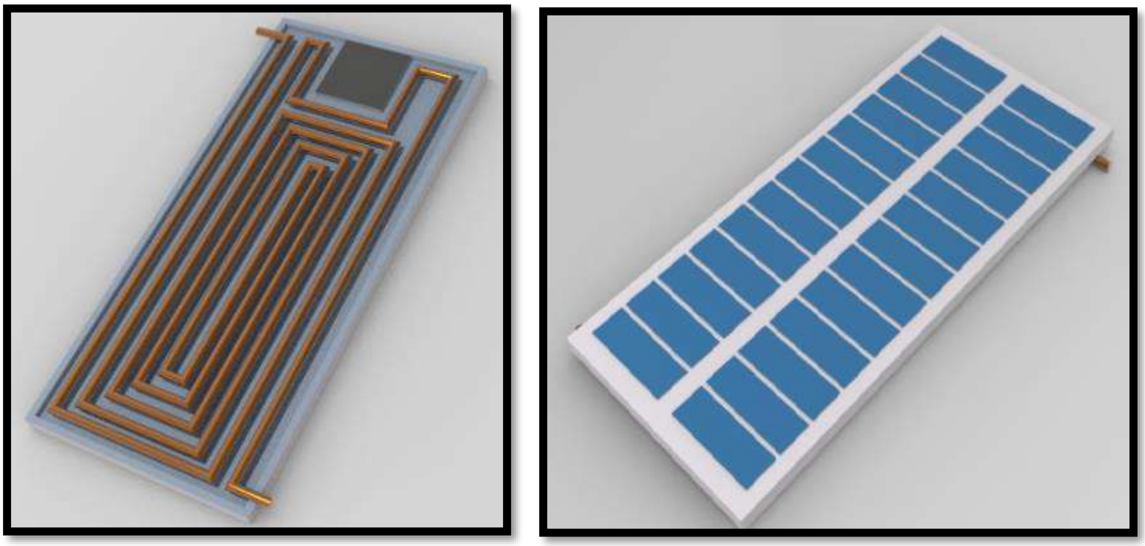

Figure 2.4 CAD design of PV Panel (Rear and Front Side)

2.4 Power Consumption of System

Sr. No.	Components	Voltage and Current Ratings of components
1	STM32 Microcontroller	**Voltage:** 3.6V **Current:** 200mA
2	Bluetooth Module	**Voltage:** 5V **Current:** 280mA
3	SD Card Module	**Voltage:** 5.5V **Current:** 100-200mA
4	Temperature Sensor (DS18b20)	**Voltage:** 5V **Current:** 1mA
5	Flow Rate Sensor (YF-S201)	**Voltage:** 5V **Current:** 15mA
6	Light Intensity Sensor	**Voltage:** 3.6V **Current:** 0.12mA
7	Water Pump-1	**Voltage:** 12V **Current:** 3.1A
8	Water Pump-2	**Voltage:** 12V **Current:** 1.1A

Table 2.1 Voltage and Current Ratings of Components

Sr. No.	Components	Power Consumption of components
1	STM32 Microcontroller	Power: 3.6V x 0.2A = 0.72W
2	Bluetooth Module	Power: 5V x 0.28 = 1.4W
3	SD Card Module	Power: 5V x 0.2A = 1W
4	Temperature Sensor (DS18B20)	Power: 5V x 0.001A = 0.005W
5	Flow Rate Sensor (YF-S201)	Power: 5V x 0.015 = 0.075W
6	Light Intensity Sensor	Power: 3.6V x 0.00043 = 0.00155W
7	Water Pump-1	Power: 12V x 3.1A = 37.2W
8	Water Pump-2	Power: 12V x 1.1A = 13.2W

Table 2.2 Power Ratings of Components

Now by adding the power of all the components, we can calculate the total power consumption of the system:

Total Power Consumption = (0.72W * 2) + (1.4W * 2) + 1W + (0.005W *7) + (0.075W * 2) + 0.00155W + 37.2 + 13.2 = **57.17655W**

Therefore, the combined power is **57.17655 watts.**

2.4.1 10h Energy consumption by the system

Assuming that intensity of light varies from 7:30am to 05:30pm

Energy consumed by a system in 24 hours, by using the formula:

Energy (W h) = Power (W) x Time (h)

Time = 10 hours

Power = 57.17655W

Energy = 57.17655W * 10h = **571.7655Wh**

Therefore, system will consume **571.7655Wh** of energy in **10h**.

2.5 The Solar Thermal Room Heating System

A solar thermal room heating system is a green energy-based system that blends photovoltaic (PV) power production with solar thermal energy collection for space heating.

In this method, solar cells not only make power, but they also collect the sun's heat to heat the room. Multiple temperature sensors and flow rate sensors are used in the setup you mentioned to track and handle different parts of the system[17]. Here's a list of the parts and monitors that make up the system:

2.5.1 Solar Panel

This is the photovoltaic panel that generates electricity from sunlight.

2.5.2 Heat Exchanger

In the setup, there are two heat exchanges. One is put behind the solar panel to receive heat from the sun, and the other is put in the room to move the heat from the solar panel to the model of the room.

2.5.3 Temperature Sensors (DS18B20)

- **1st Sensor:** Measures the temperature at the inlet of the solar panel heat exchanger.
- **2nd Sensor:** Measures the temperature at the outlet of the solar panel heat exchanger.
- **3rd Sensor:** Measures the temperature on the top surface of the solar panel.
- **4th Sensor:** Measures the temperature on the bottom surface of the solar panel.
- **5th Sensor:** Measures the ambient temperature.
- **6th Sensor:** Measures the inner temperature of the room model.
- **7th Sensor:** Measures the temperature in the water storage tank.[17]

2.5.4 Flow Rate Sensors

- **1st Sensor:** Measures the flow rate at the outlet of the water storage tank.
- **2nd Sensor:** Measures the flow rate at the outlet of the heat exchanger behind the solar panel[17].

2.5.5 Microcontrollers (STM32F401CCU6)

- The first microcontroller is placed behind the solar panel and is in charge of reading the temperatures of the four sensors (inlet and exit of the solar panel heat exchanger, top and bottom surface temperatures, flow rate sensor, and light intensity sensor, BH-1750).

- The second microprocessor is outside of the room model and is in charge of reading the temperature of the room, the temperature of the water holding tank, the temperature outside the room, and the first flow rate sensor.[16]

2.5.6 Bluetooth Module (HC-05)

- One HC-05 module is connected to the first microcontroller for communication.
- Another HC-05 module is connected to the second microcontroller for communication.

The sensors and flow rate monitors send information to the microcontrollers, which then use Bluetooth units to talk to each other. The data is then shown on a Bluetooth device, and LabVIEW software can be used to look at settings in real time[18].

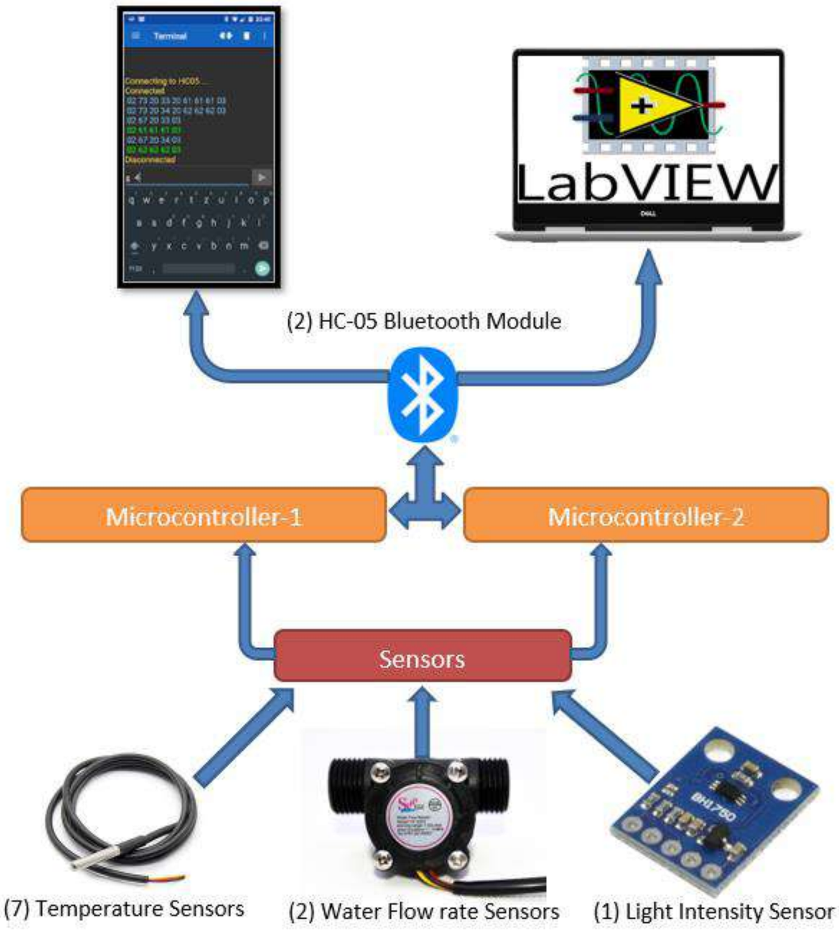

Figure 2.5 System Architecture

2.6 PSEUDOCODE: STM32F401CCU6 PSEUDOCOD

2.6.1 Microcontroller 1 (Installed behind the solar panel)

```
Initialize temperature sensors (DS18B20)

Initialize flow rate sensor (Flow Rate Sensor 1)

Initialize light intensity sensor (BH-1750)

Initialize Bluetooth module (HC-05)

Loop Forever:

    Read and store temperature values from:

        - Inlet temperature sensor (Sensor 1)

        - Outlet temperature sensor (Sensor 2)

        - Top surface temperature sensor (Sensor 3)

        - Bottom surface temperature sensor (Sensor 4)

    Read and store flow rate value from Flow Rate Sensor 1

    Read and store light intensity value from BH-1750

    Package the data into a Bluetooth message format

    Send the data via Bluetooth module (HC-05)

    Delay for a short period (e.g., 1 second)

End Loop
```

2.6.2 Microcontroller 2 (Placed outside of the room model)

```
Initialize temperature sensors (DS18B20)

Initialize flow rate sensor (Flow Rate Sensor 2)

Initialize Bluetooth module (HC-05)

Loop Forever:
```

Read and store temperature values from:

- Room temperature sensor (Sensor 6)

- Water storage tank temperature sensor (Sensor 7)

- Ambient temperature sensor (Sensor 5)

Read and store flow rate value from Flow Rate Sensor 2

Receive data from Microcontroller 1 via Bluetooth module (HC-05)

Display received data on the Bluetooth terminal and/or LabVIEW software

Delay for a short period (e.g., 1 second)

End Loop

The code for the microcontroller was written in the computer language C/C++, and the STM32cube IDE was used to build the code. STM32CubeIDE is a powerful C/C++ programming tool for writing STM32 devices. It has functions like analysis, code creation, and assembly. Then, the code file made by the software was uploaded to the hardware so that it could be tested to see if it worked.

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Chapter 3 - Operational Principle

3.1 How does Solar Thermal Room Heating System Work?

A passive solar thermal room heating system uses the sun's energy to heat rooms in a natural way. It means putting windows, thermal mass materials (like concrete or stone), and insulation in a way that makes the most of the sun's heat by capturing, storing, and distributing it. Sunlight comes in through windows that face south and are made to let a certain amount of solar energy through. The thermal mass elements soak up this heat and store it, slowly letting it out as the temperature inside drops. As the room cools, the heat that has been stored is released. This raises the temperature and makes the room more comfortable to live in. This system takes advantage of the sun's energy in an efficient way by using building design principles instead of a lot of mechanical parts[23].

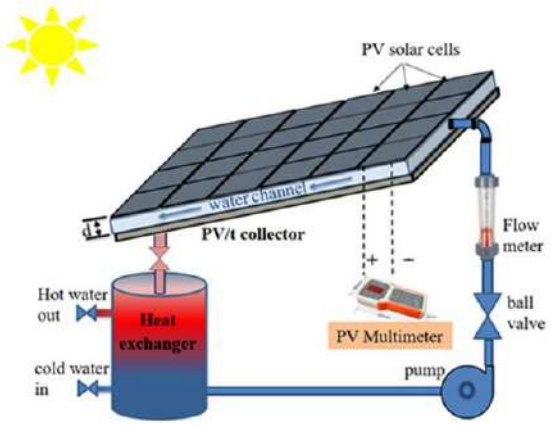

Figure 3.1 Working Flow Diagram

3.2 Block Diagram

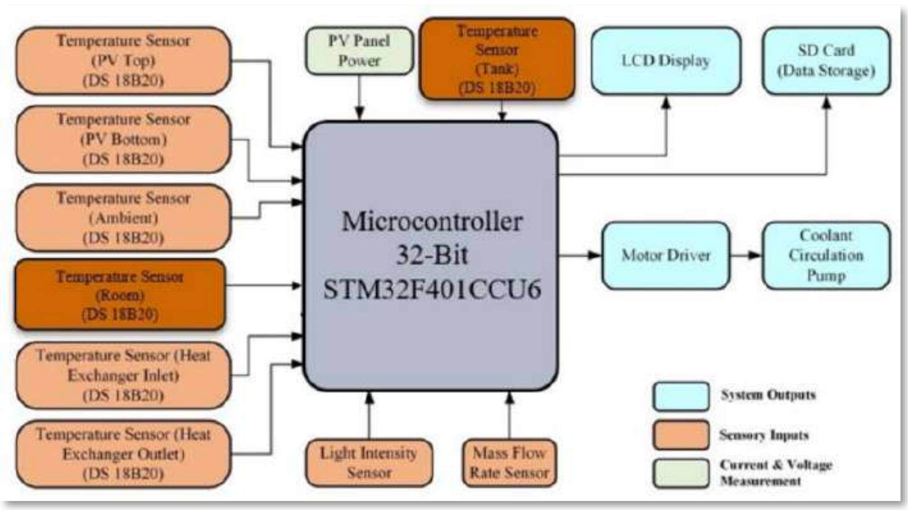

Figure 3.2 Block Diagram of the System

3.3 Solar Panel and Heat Exchanger

Your unique thermal room heating system is built around the solar panel. This panel is made up of a group of solar cells that are meant to soak up sunshine and turn it into heat. Then, this energy is sent to a heat transfer medium, which is usually a mixture of water and antifreeze that moves through a complex network of lines inside the panel. The goal of this process is to take advantage of the power of sun energy and turn it into a heat source that can be used.

The heat exchanger is right next to the solar panel. It is an important piece of equipment that moves the thermal energy from the solar panel to the heating system. It is usually made up of a set of twisted or finned tubes that the hot transfer fluid flows through. As the fluid moves through these tubes, it heats the water in the heating system. This smart exchange of energy improves how well heat moves and, as a result, how well the room heating system works as a whole[24].

Figure 3.3 Heat Exchanger and Solar Panel

3.4 Temperature Sensors (DS18B20)

The DS18B20 temperature sensors are your system's sense organs. They let you carefully monitor and control the temperature of your system. These sensors, which are known for their digital accuracy and ability to be addressed in a unique way, are placed at key places in the system[20].

3.4.1 Inlet and Outlet Sensors

Placed at the heat exchanger's entrance and exit, these gauges measure the difference in temperature between the hot fluid going in and the cold fluid going out. This comparison shows how well heat movement works and helps improve the performance of a system[22].

3.4.2 Solar Panel Surface Sensors

Surface temperature monitors on both the top and bottom of the solar screen make it possible to track its working temperature in real time. This information is crucial for preventing the panel from burning and figuring out how well it works[23].

3.4.3 Ambient Temperature Sensor

Monitoring the outdoor temperature helps us learn more about how the system's behavior is affected by the outside world. This information is very helpful for figuring out how the system and its surroundings work together.

3.4.4 Water Storage Tank Sensor

This monitor is placed inside the water storage tank. It measures the temperature of the water in the tank, making sure that a supply of properly hot water is available for distribution.

3.4.5 Room Temperature Sensor

This sensor, which is part of the room model, is in charge of measuring the temperature inside. With this kind of knowledge, the system can be adjusted to keep the temperature and humidity inside at a comfortable level.

3.5 Flow Rate Sensors

The flow rate gauges, which are needed to control the flow of the heat transfer fluid, are a great example of how your system's thermal mechanics are controlled in a dynamic way.

3.5.1 Tank Outlet Flow Rate Sensor

This sensor checks how fast fluid is leaving the water storage tank. This gives a direct measure of the flow dynamics, which affects when and how much hot water is sent to the heating system.

3.5.2 Heat Exchanger Outlet Flow Rate Sensor

The rate at which the fluid flows out of the heat exchanger is a key sign of how well the heat is transferred. This knowledge is used to help optimize systems.

3.6 Microcontrollers (STM32F401CCU6)

These microcontrollers act as the brains, coordinating data processing, communication, and making good decisions based on the information they have.

3.6.1 Solar Panel Microcontroller

This microprocessor is placed behind the solar panel and is in charge of getting data from the temperature sensors (inlet, exit, and panel sides), flow rate sensor, and light intensity sensor (BH-1750). The data is then processed and sent via Bluetooth (HC-05) to the external microprocessor.[25]

3.6.2 External Microcontroller

This microcontroller is outside of the room model and collects data from the room temperature sensor, the water holding tank sensor, the outdoor temperature sensor, and the flow rate sensor. Bluetooth is the way for the two microcontrollers to send and receive data.

3.7 Radiator and Room Heating

The radiator is the temperature contact between the system and the room. It is the very definition of how heat moves from one place to another[25].

3.8 Data Display and Visualization

Data that has been collected is shown in two ways. The Bluetooth device gives real-time information about how the system is running, and the LabVIEW software provides a visually engaging platform for dynamic data visualization, making it easier to optimize the system and make decisions[25].

Our solar thermal room heating system is made up of many different parts, each of which is important for doing its job. The solar panel, heat exchanger, temperature and flow rate monitors, microcontrollers, radiator, and data visualization tools all work together to make a way to heat a room that is green and efficient. When cutting-edge technology and careful building are combined, the result is a complete answer that can reduce energy use and improve comfort inside.

3.9 Flow Chart

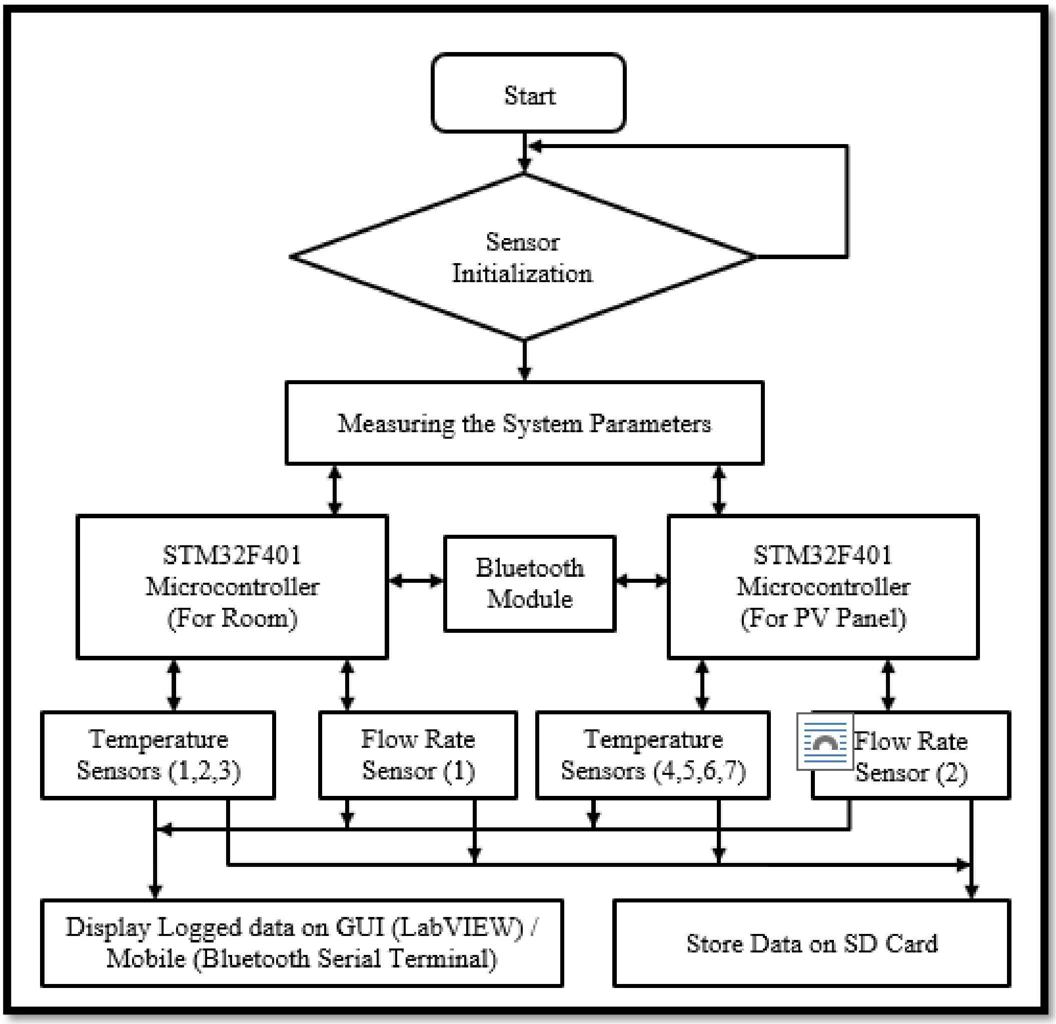

Figure 3.4 Flow Chart of the System

Chapter 4 – Mathematical Modeling

To model the system, we can use the following equations:

4.1 PV Panel: The electricity generated by the PV panel is given by

$$E_{pv} = A_{pv} \times I_{pv} \times \eta_{pv} \tag{1}$$

Where,

E_{pv} is the electricity generated by the PV panel,

A_{pv} is the area of the PV panel,

I_{pv} is the solar radiation falling on the panel, and

η_{pv} is the efficiency of the PV panel.

4.2 Solar Thermal Panel: The heat generated by the solar thermal panel is given by

$$Q_{st} = A_{st} \times I_{st} \times \eta_{st} \tag{2}$$

Where,

Q_{st} is the heat generated by the solar thermal panel,

A_{st} is the area of the solar thermal panel,

I_{st} is the solar radiation falling on the panel, and

η_{st} is the efficiency of the solar thermal panel.

4.3 Storage Tank: The temperature of the water in the storage tank is given by:

$$T_{tank} = \frac{Q_{st} - Q_{out}}{\rho \times V \times c} \tag{3}$$

Where,

Q_{out} is the heat lost from the storage tank,

ρ is the density of water,

V is the volume of water in the tank, and

c is the specific heat of water.

4.4 Heat Exchanger: Rate of heat transfer from storage tank to the room

$$Q_{heat} = U \times A_{heat} \times (T_{tank} - T_{room}) \quad (4)$$

Where,

Q_{heat} is the rate of heat transfer,

U is the heat transfer coefficient,

A_{heat} is the area of the heat exchanger,

T_{tank} is the temperature of the water in the storage tank, and

T_{room} is the temperature of the room or building.

4.5 Room or Building: The temperature of the room or building is given by

$$T_{room} = \frac{T_{out} + Q_{heat}}{\rho \times V_{room} \times c_{room}} \quad (5)$$

Where,

T_{out} is the outside temperature,

V_{room} is the volume of the room or building, and

c_{room} is the specific heat of air.

Let's calculate the solar radiation falling on the PV panel. We'll continue using the panel area of **1.48 meters** by **0.68 meters**.

4.6 Location (Wah Engineering College)

Average daily solar insolation is **5 kWh/m²/day**.

4.7 Panel Tilt and Orientation

The PV panel is mounted at a fixed tilt angle of **30 degrees** and faces **south**.

4.8 Day Length

The day length is now **10 hours**.

4.9 Panel Area

The area of the PV panel is (1.48 m x 0.68 m) = **1.0064 m²**.

4.10 Time interval for calculations

Daily

4.11 Calculate Daily Solar Radiation

Daily Solar Radiation = Solar Insolation

Daily Solar Radiation = **5 kWh/m²/day (Average Value)**

4.12 Values for the constants and parameters

- ✓ Area of the PV panel (A_{pv}) is **1.48m x 0.68m = 1.0064m^2** (Predefined Value)
- ✓ Solar radiation falling on the PV panel (I_{pv}) is **5 kWh/m²/day** (Avg. Value)
- ✓ Efficiency of the PV panel (η_{pv}) is **14.99%** (Predefined Value)
- ✓ Area of the solar thermal panel (A_{st}) **1.41m^2** (Practical Value)
- ✓ Solar radiation falling on the solar thermal panel (I_{st}) **5 kWh/m²/day** (Avg. Value)
- ✓ Efficiency of the solar thermal panel (η_{st}) is **60%** to **70%** approximately according to previous research.
- ✓ Heat transfer coefficient for water flowing in tubes (U) is **500 W/m^2/K** (Standard)
- ✓ Area of the heat exchanger (A_{heat}) **0.35m^2** (Practical Value)
- ✓ Density of water (ρ) is **1000kg/m^3** (Standard)
- ✓ Volume of water in the storage tank (V) is **0.036m^3** (Practical Value)
- ✓ Specific heat of water (c) is **4182J/kg^{0}C** (Standard)
- ✓ Specific heat of air (c_{room}) **1.005kJ/kg-K** (Standard)
- ✓ Volume of the room or building (V_{room}) is **2.769m^3** (Practical Value)
- ✓ Outside temperature (T_{out}) is **31^{0}C** (Practical Value)
- ✓ Initial temperature of the water in the storage tank ($T_{initial}$) is **30.5^{0}C** (Practical Value)
- ✓ Room temperature (T_{room}) is **27^{0}C** (Practical Value)

4.13 Calculations

- **Step 1:** Calculate the daily energy generation by the PV panel:

$$E_{pv} = A_{pv} \times I_{pv} \times \eta_{pv}$$

From eq (1): By substituting the values:

$$E_{pv} = (1.48 \text{ m} \times 0.68 \text{ m}) \times (5 \text{ kWh/m}^2\text{/day}) \times 0.1499$$

$$\boldsymbol{E_{pv}} = \mathbf{0.75\ kWh}$$

- **Step 2:** Calculate the daily heat generation by the solar thermal panel:

$$Q_{st} = A_{st} \times I_{st} \times \eta_{st}$$

From eq (2): By substituting the values:

$$Q_{st} = 1.41\text{m}^2 \times 5 \text{ kWh/m}^2\text{/day} \times 0.60$$

$$\boldsymbol{Q_{st} = 4.23}\ \mathbf{kWh}$$

- **Step 3:** Calculate the heat lost from the storage tank:

$$Q_{out} = (T_{initial} - T_{out}) \times \rho \times V \times c$$

$$Q_{out} = (30.5°\text{C} - 31°\text{C}) \times 1000 \text{ kg/m}^3 \times 0.036 \text{ m}^3 \times 4182 \text{ J/kg°C}$$

$\boldsymbol{Q_{out}}$**= -75276 J *(negative because heat is lost)***

- **Step 4:** Calculate the temperature of the water in the storage tank:

$$T_{tank} = \frac{Q_{st} - Q_{out}}{\rho \times V \times c}$$

From eq (3): By substituting the values:

$$T_{tank} = \frac{4.23 \text{ kWh} \times 3600 \text{ kJ/kWh} - (-75276\ J)}{1000 \text{ kg/m}^3 \times 0.036 \text{ m}^3 \times 4182 \text{ J/kg°C}}$$

$$\boldsymbol{T_{tank} \approx 31.222°C}$$

- **Step 5:** Calculate the rate of heat transfer from the storage tank to the room:

$$Q_{heat} = U \times A_{heat} \times (T_{tank} - T_{room})$$

From eq (4): By substituting the values:

$$Q_{heat} = 500\ W/m^2/K \times 0.35m^2 \times (31.222°C - 27°C)$$

$$\boldsymbol{Q_{heat} = 738.85\ J/s}$$

- **Step 6:** Calculate the temperature of the room or building:

$$T_{room} = \frac{31°C + 738.85\ \frac{J}{s}}{1000\,\frac{\mathrm{kg}}{\mathrm{m}^3} \times 2.769\ \mathrm{m}^3 \times 1.005\ \frac{kJ}{kg} - \mathrm{K}}$$

From eq (5): By substituting the values:

$$\boldsymbol{T_{room} = 27.45°C\ (Theoratical\ Value)}$$

Chapter 5 – Selection of Components

Electrical/ Electronic Components

5.1 PV Panel

5.1.1 Introduction

PV (Photovoltaic) solar panels, which are often just called "solar panels," are machines that use a semiconductor material to turn sunlight into energy. This green energy technology has become very famous over the years because it can make power that is clean, sustainable, and good for the earth.

5.1.2 Specifications

- Maximum Power (Pmax) = 165W
- Maximum Power Voltage (Vmax) = 18.60V
- Maximum Power Current (Imp) = 8.87A
- Open Circuit Voltage (Voc) = 23.30V
- Short Circuit Voltage (Isc) = 9.87A
- Module Efficiency = 14.99%
- Maximum System Voltage = 1000V
- Maximum Series Fuse = 15A
- Fire Resistance Rating = A
- Weight = 11.5KG
- Dimension = 1480*680*40mm

5.1.3 Component Diagram:

Figure 5.1 PV Panel

5.2 STM32F401CCU6 Microcontroller

5.2.1 Introduction

The STM32F401CCU6 is a microcontroller unit (MCU) made by the top semiconductor company STMicroelectronics. This MCU is part of the STM32F4 series and is made with an ARM Cortex-M4 core. It has a wide range of features and powers that make it useful in many different situations. The STM32F401CCU6 is made to be a good choice for developing embedded systems because it strikes a good mix between processing power, energy efficiency, and peripheral integration. [19].

In comparison to discrete logic-based systems, the STM32F401CCU6 excels in the following ways [11]:

- The STM32F401CCU6 can replace discrete logic for faster and more precise motor or actuator control in industrial automation applications.
- The STM32F401CCU6 is a microcontroller that can be programmed to manage a wide variety of sensors and actuators, making it ideal for use in home appliance applications.
- The STM32F401CCU6 can collect and process sensor data in a medical device in real time.
- The STM32F401CCU6 is well-suited for usage in consumer electronics where advanced functions like gesture recognition and image processing must be implemented.

5.2.2 Specifications

- 3.6 V power supply
- Microcontroller Family: STM32F4
- Core: ARM Cortex-M4F
- Core Frequency: Up to 84 MHz
- Flash Memory: 256 KB
- SRAM: 64 KB
- Operating Voltage Range: 2.0V to 3.6V
- GPIO (General Purpose Input/Output) Pins: Up to 51
- Communication Interfaces:

- USART/UART (Universal Synchronous/Asynchronous Receiver/Transmitter)
- SPI (Serial Peripheral Interface)
- I2C (Inter-Integrated Circuit)
- USB (Universal Serial Bus) 2.0 Full-Speed

- Analog-to-Digital Converter (ADC): 12-bit, up to 16 channels
- Digital-to-Analog Converter (DAC): 12-bit, 2 channels
- PWM (Pulse-Width Modulation) Channels: Up to 14
- Operating Temperature Range: -40°C to +85°C

5.2.3 Component Diagram

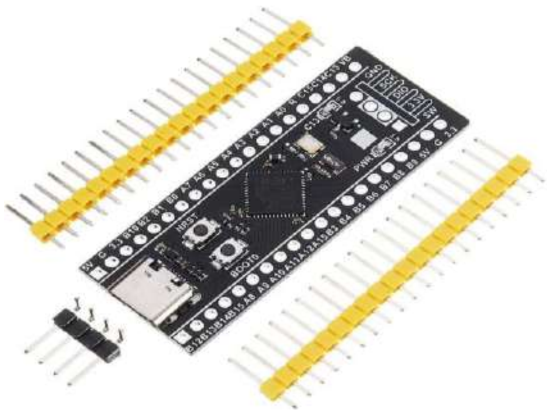

Figure 5.2 STM32F401CCU6

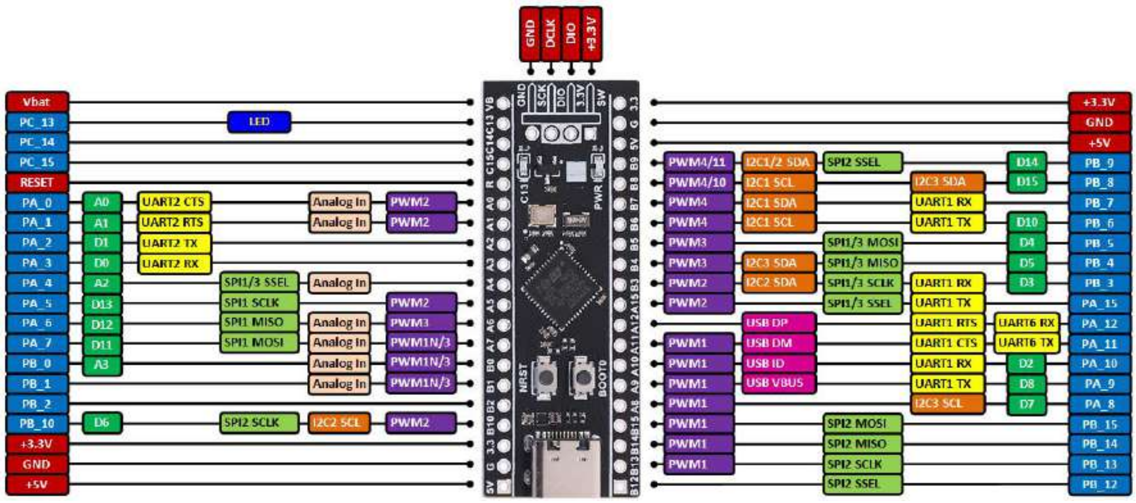

Figure 5.3 STM32F401CCU6 Pinout Description

5.2.4 Software for STM32F401CCU6

With peripheral setup, code generation, code compilation, and debug facilities for STM32 microcontrollers and microprocessors, STM32CubeIDE is a powerful C/C++ development platform. For development, it is built on the Eclipse / CDT framework, the GCC toolchain, and GDB for debugging. It enables the insertion of the many existing plugins, which number in the hundreds, to complete the functionality of the Eclipse IDE[18].

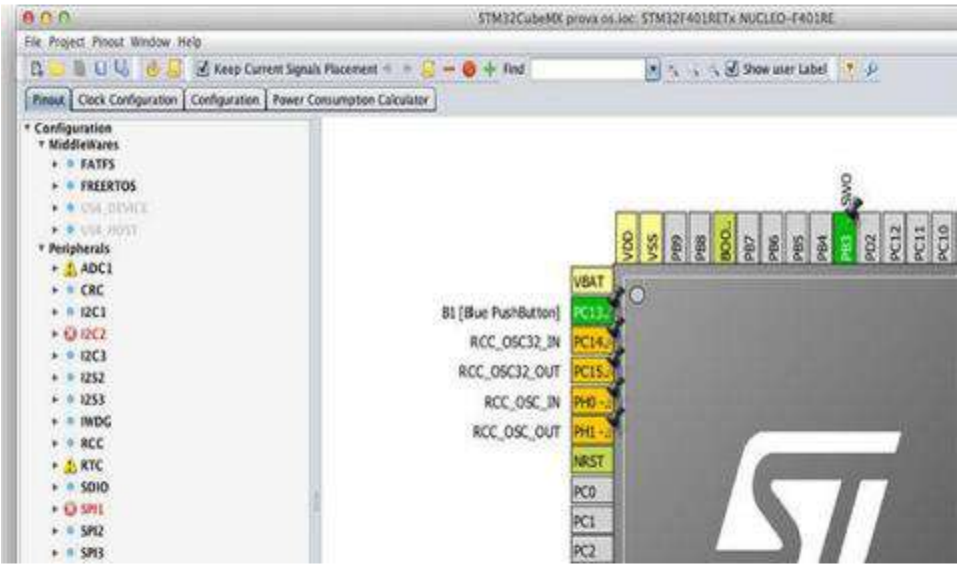

Figure 5.4 STM32 Cube IDE Software

5.3 Temperature Sensor (DS18b20)

One kind of temperature sensor is the DS18B20, which can output temperatures with values ranging from 9 bits to 12 bits. These figures represent the temperature of the particular apparatus under discussion. One-wire bus protocol, which uses only one data line for transmission, may be used by this sensor to communicate with an internal CPU[19].

5.3.1 Specifications

- 3V to 5V Operating voltage
- -55°C to +125°C Temperature Range
- Digital Temperature Sensor
- Communicates through one Wire

5.3.2 Component Diagram

Figure 5.5 DS18b20 Temperature Sensor

5.4 Flow Rate Sensor YF-S201

The YF-S201 is a water flow measuring monitor with a very high bar for how well it seals. The flow rate ranges from 1 to 30 liters per minute, and the Hall effect is how it works. The module has three pins, which are marked Power, Ground, and the Analogue output, respectively. The YF-S201 uses very little power and can work with up to 1.75 MPa of working pressure[20].

5.4.1 Specifications

- 4.5V-18V Operating Voltage
- 15mA at 5V Maximum current draw
- ±10% Accuracy
- 2.0 MPa Maximum water pressure
- 1 to 30 Liters/Minute Working Flow rate

5.4.2 Component Diagram

Figure 5.6 Flow rate Sensor YF-S201

5.5 SD Card Module

An SD Card Module is a breakout board that lets a microprocessor read and write to an SD card. This gadget is used to work with SD cards. The board can be used with devices that use microcontrollers. You can easily plug a regular SD card into the board, but if you want to use microSD cards, you will need an adapter[20].

5.5.1 Specifications:

- 3.3V-5V supply Voltage
- 0.2-200mA Current
- Supports Micro SD up to 2GB
- Pinouts GND, VCC, , SCK, CS ,MISO, MOSI for SPI interface

5.5.2 Component Diagram:

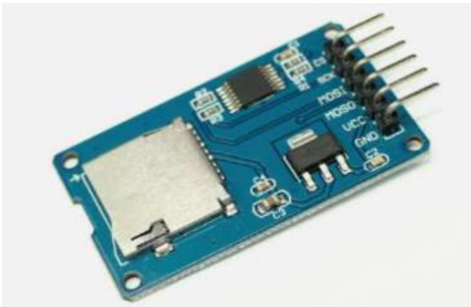

Figure 5.7 SD card Module

5.6 Bluetooth Module HC-05

The HC-05 can work in two ways: in Command mode or in Data mode. The HC-05 has a push button that lets you change how it works. When the push button is pressed, the HC-05 goes into Command mode. In Command mode, a user can change the system settings (pin code, baud rate, etc.) by using the host driver of a PC running desktop software and a serial to TTL converter. Any changes made to the system's settings will still be there when the power goes out. If you turn off and, on the HC-05, it will go back to Data Mode. Only when the UART is in Data Mode can data be sent transparently to a connected remote device[21].

5.6.1 Specifications

- Bluetooth v2.0+EDR
- 2.4GHz ISM band frequency
- Supported baud rate: 9600 (default), 19200,38400, 57600, 115200, 230400, 460800.
- Speed: Asynchronous: 2.1Mbps(Max) / 160 kbps, Synchronous: 1Mbps/1Mbps
- Power supply: 3.6V to 6V DC
- Passkey: 1234

5.6.2 Component Diagram

Figure 5.8 HC-05 Bluetooth Module

5.6.3 Fritzing Software

The Fritzing open-source project's main goal is to make CAD software for designing electrical gear that can be used by hobbyists. This programmed is made so that designers and artists can use samples to make circuits that will last longer. The University of Applied Sciences in Potsdam was the place that made it happen. Fritzing's source code is stored on GitHub. The GNU Public License (GPL) lets files be sold for a fee, but the programmed itself is free to use and is licensed by a newer version of the GPL[22].

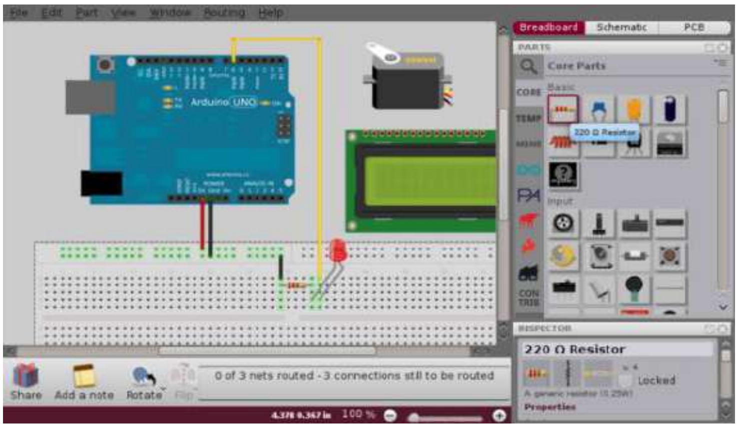

Figure 5.9 Fritzing Software Circuit Example

5.7 Water Pump

The motor of a 12 Volt water pump is dc electric and is powered by a 12V direct current power source. It uses the centrifugal force made by a fast-spinning propeller to boost, move, lift, or move around liquids like water, oil, and coolant in sprayers, cars, fountains, showers, gardens, etc.

5.7.1 Specification

- Discharge Size: 0.3750 inch.
- Maximum Discharge Flow: 3.2 GPM.
- Media Temperature: 185 F.
- Power Source: DC Powered.

5.7.2 Component Diagram

Figure 5.10 Water Pump

5.8 Diaphragm Pump

DC 12V Diaphragm Pneumatic Water Pump the Motor R365 water pump is cheap and easy to move. It is perfect for non-submersible pumps that move liquids and air in many different ways. It can be used with needles to make spray systems because it has enough power. A diaphragm pump is a positive displacement pump that can be powered by hydraulics or mechanically. It moves liquids by using a rotating motion and either a flapper valve or a ball valve.

Diaphragm pumps don't need to be primed and work well with thick liquids. Almost every major industry uses diaphragm pumps. Most of the time, they are used to move gritty liquid, like concrete, as well as acids and chemicals. They are also often found in cars and planes.

5.8.1 Specification

- Chamber diaphragm pump.
- Continuous duty.
- Bypass: reduces cycling.
- Self-priming.
- Quiet operation.
- Ignition protected.
- Run dry capable for normal workloads.
- Automatic: controlled by pressure switch.

5.8.2 Component Diagram

Figure 5.11 Diaphragm Pump

5.9 Light Intensity Sensor BH-1750

The BH1750 is a light intensity sensor that can be used to change how bright the image on a cell phone or LCD screen is. It can also be used to turn on or off the headlights of a car based on how bright it is outside. The sensor is very easy to use with microcontrollers because it uses the I2C transmission protocol. I2C uses the SCL and SDA pins[21].

To measure the LUX value, you don't have to do any math because the monitor gives you the value right away. In fact, it measures how strong something is by how much light hits it. The voltage range for the BH1750 is between 2.4V and 3.6V, and it only uses 0.12mA of power. But this module has a voltage stabilizer that can take inputs from 3.3V to 5.0VDC. The sensor's data don't depend on the light source, and IR radiation doesn't have much of an effect. The difference between measurements is only +/-20%, so there isn't much chance of making a mistake[21].

5.9.1 Specification

- Power supply: 3V-5V
- I2C BI (f / s mode supporting)
- Spectral responsibility close to the human eye distinguish
- Luminance to digital converter
- Wide range and high resolution (1 - 65535 lx)
- Low current by power down function
- 50Hz / 60Hz Light noise reject-function
- 1.8V logic input interface
- It is possible to select 2 types of I2 C slave-address
- Small measurement variation (+/- 20%)
- Size (L x W): Approx. 3.2cm x 1.5cm

5.9.2 Component Diagram

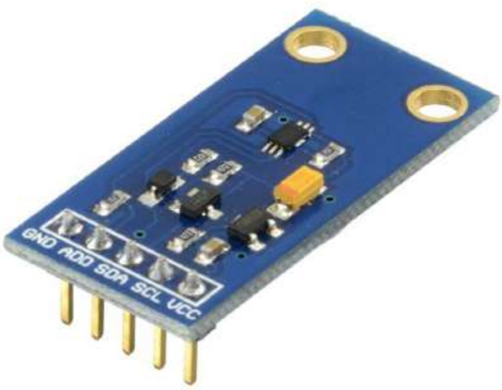

Figure 5.12 Light Intensity Sensor

Mechanical Components

5.10 Heat Exchanger One

A heat exchanger is a machine that moves heat (thermal energy) from one stream to another in an efficient way. Heat exchangers are used in many industrial processes, HVAC systems, power plants, and other places where heat needs to be transferred from one stream to another.

5.10.1 Specifications

- Aluminum Fins Diameter = 1” x 1”.
- Aluminum Fins Length = 55ft Approx.
- Water Storage Capacity in Aluminum Fins = 10.5 liters Approx.

5.10.2 Component Diagram

Figure 5.13 Heat Exchanger One (Rare Side of the PV Panel)

5.11 Heat Exchanger Two (Radiator)

In cooling systems, a heat exchanger is usually called a radiator. It is a device that moves heat from one fluid (liquid or gas) to another fluid without the two fluids coming into direct touch. Heat exchangers are important parts of many heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems because they make it easy to handle and control temperature in many different industries and uses.

5.11.1 Specifications

- Water Storage Capacity in Aluminum Fins = 5 liters Approx.

3.11.2 Component Diagram

Figure 5.14 Heat Exchanger Two (Inside the Room)

5.12 Storage Tank

In cooling systems, a heat exchanger is usually called a radiator. It is a device that moves heat from one fluid (liquid or gas) to another fluid without the two fluids coming into direct touch. Heat exchangers are important parts of many heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems because they make it easy to handle and control temperature in many different industries and uses.

5.12.1 Specifications

- Water Storage Capacity = 36 liters.

5.12.2 Component Diagram

Figure 5.15 Storage Tank

Chapter 6 - Implementation and Results

6.1 Design and Software Integration

Our PVT solar thermal room heating system is made to use the sun's energy to heat a room in an efficient way. When hardware parts and software pieces are put together, they make a system that can watch and improve heat transfer processes. The system has a number of DS18B20 temperature sensors for accurate readings of temperature, flow rate sensors for analyzing fluid dynamics, and STM32F401CCU6 microcontrollers for getting data and controlling things[26].

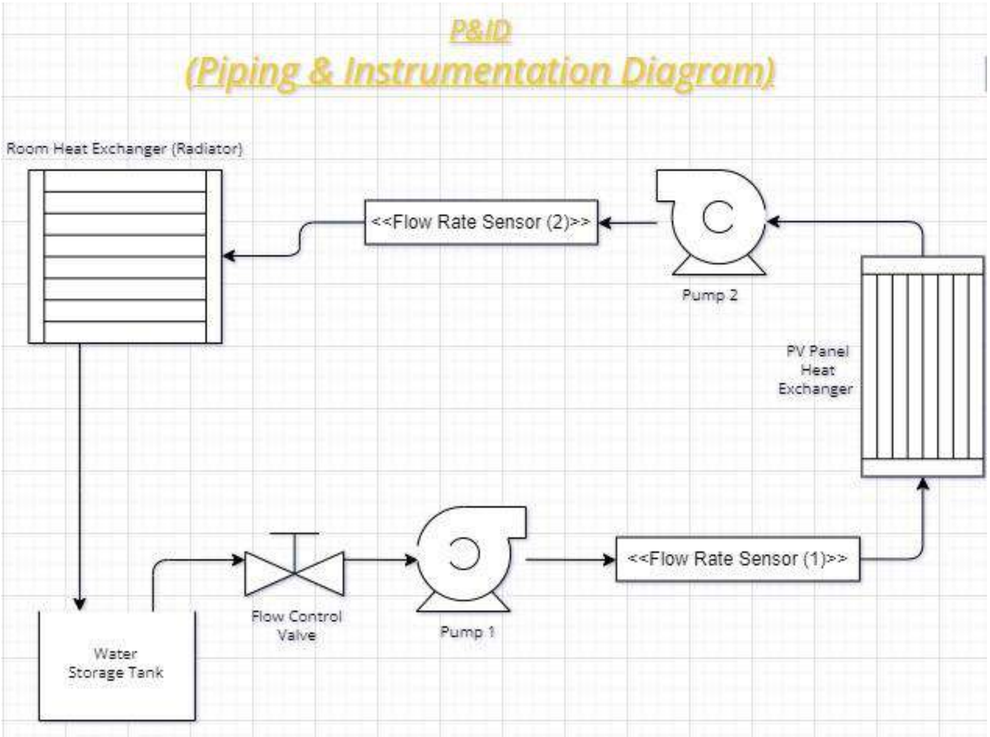

Figure 6.1 Piping & Instrumentation Diagram

6.2 Implementation

In order for the system to work, sensors and other parts need to be placed in a way that ensures accurate data collection and good heat transfer. Behind the solar panel is a heat exchanger with two DS18B20 temperature sensors at the entry and exit to keep track of how the temperature changes during heat exchange. Also, temperature sensors are put on the top and bottom of the solar screen to measure how the temperature changes. Another DS18B20 monitor is set up to measure the temperature of the surrounding air. A sixth sensor records the temperature inside the room model, and a seventh sensor is put in the water storage tank to measure the temperature of the water. There are two flow rate monitors. One is at the outlet of the water holding tank and the other is at the outlet of the heat exchanger. The STM32F401CCU6 microcontrollers are in charge of handling and collecting data, as well as sending and receiving messages over Bluetooth[27].

6.2.1 Programming the STM32F401CCU6 Microcontroller

The STM32F401CCU6 microcontroller has been set up to do important jobs. This includes using the One-Wire system to get data from temperature monitors and using ADCs to convert analogue data. The microprocessor takes the data from the sensors, uses the calibration factors, and figures out the temperature differences and heat transfer rates. It talks to the HC-05 Bluetooth module to send info to a faraway module in real time. Also, the code for the microcontroller includes methods for figuring out the flow rate based on the data sent out by the flow rate monitor[28].

The next step is to send the code to the STM32F401CCU6 microcontroller. This is done after the code has been fully written and tried with flow code and the design plan has been fully understood. The code in the STM32 cube IDE is changed to a. Hex format. This is done because the microcontroller can only read and run commands in a. Hex format. With the help of a monitor, the. Hex file is sent to the STM32.

6.2.2 Constructing the Circuit

The design of the circuit takes into account power distribution, signal filtering, and data transfer. Sensors and microcontrollers work steadily when they have a power supply that can be controlled. Level-shifting circuits are used to connect sensors to microcontrollers and keep the purity of the signals[29]. The HC-05 Bluetooth module is linked to the STM32F401CCU6 microprocessor so that data can be sent wirelessly. To keep noise disturbance to a minimum, proper grounding and blocking methods are used.

- The first step is to put the STM32F401CCU6 microcontroller on the circuit board for the project and carefully glue it to the board.
- When putting parts on the project circuit board, the circuit layout diagram is used as a help because it shows all the necessary information about the parts and how they are linked to each other.

- The STM32F401CCU6 microcontroller's temperature monitor is hooked to the right port. Last, the Flow rate gauge is linked to the right port on the STM32F401CCU6 microprocessor.
- The SPI interface is used to connect the wires to the right port on the STM32F401CCU6 microcontroller and connect the SD card slot to the board.
- Every other part of the project is placed correctly on the circuit board and linked to its connections correctly.

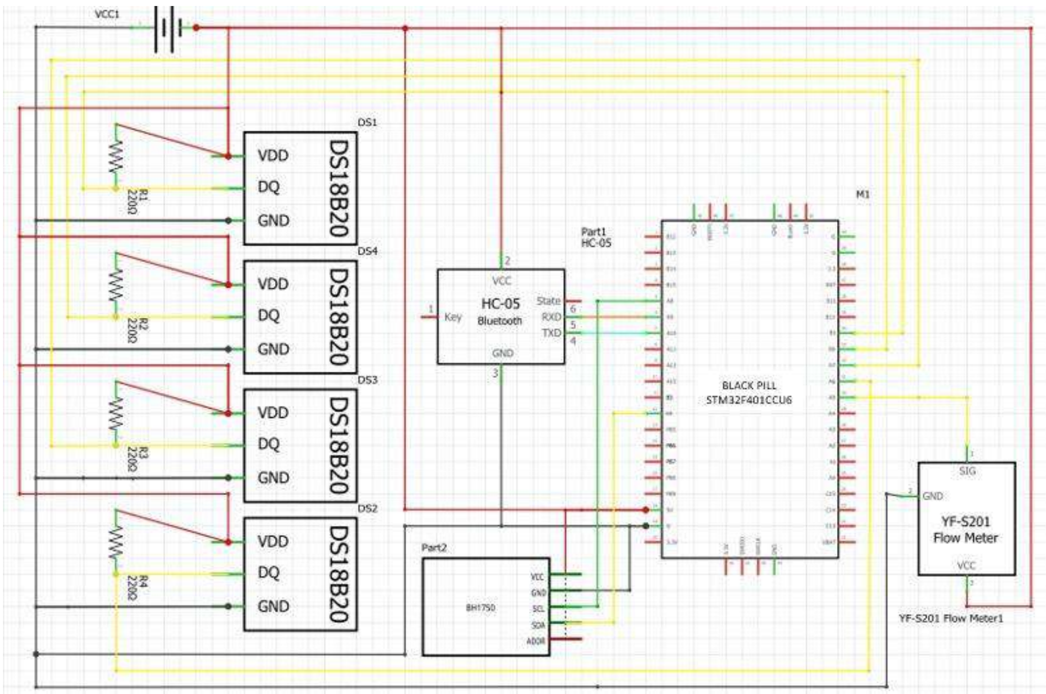

Figure 6.2 Circuit Diagram One

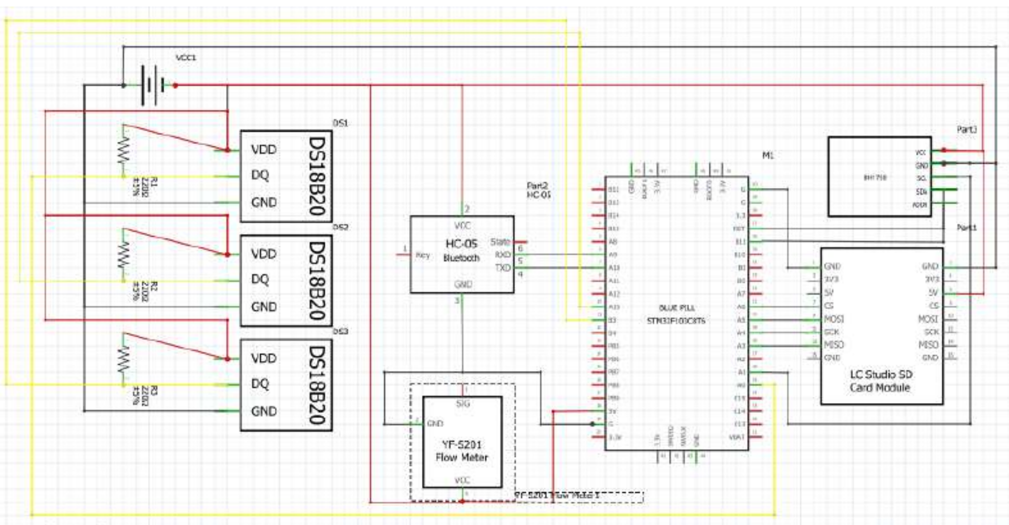

Figure 6.3 Circuit Diagram Two

6.2.3 Mechanical Design:

The goal of the mechanical design is on getting the best heat transfer and sensor placement. The fact that the heat exchanger is behind the solar cell makes it easier for heat to move. The angle and direction of the panel are carefully picked to get the most energy from the sun. The heater inside the room model is set up so that heat goes everywhere. The placement of sensors makes sure that readings are accurate and keeps heat interference from happening. The method is more useful because it is small and comfortable to use.

6.2.3.1 Component Placement

The smart placing of parts within the system is a big part of how well energy is changed and heat is transferred. When the solar panel is placed at the right tilt and azimuth angle, it gets the most sunshine and absorbs the most energy. The heat exchanger is placed behind the solar panel, where it gets full sunlight and heat. This choice of design makes sure that the heat exchanger works at high temperatures, which helps it send heat to the fluid that flows through it. The heater is placed inside the room model so that the heat it transfers is spread out evenly, keeping the room at a comfortable temperature.

6.2.3.2 Heat Exchanger Design for Solar Panel

The heat exchanger, which is made of aluminum fins and connections with high thermal conductivity, is a key part of moving the sun energy to the heat transfer fluid. Aluminum was chosen because it has good thermal qualities that allow heat to move quickly while keeping the structure strong. Also, the links improve the heat exchanger's structure strength by joining the fins together so they work as a single unit.

Figure 6.4 Heat Exchanger

6.2.3.3 Connector Design:

Placement of the system's parts is carefully planned to get the most out of energy absorption and heat transfer. Taking into account its direction, tilt, and azimuth angles, the solar panel is carefully placed to get the most sunlight. The heat exchanger is put behind the solar panel in a way that lets it directly get the energy from the sun. For the heat exchanger, L-shaped connections made of aluminum are cast to connect the fins next to each other. With a total of 12 fins, 24 joints are cast to make sure that the heat link is strong and works well.

Figure 6.5 Casted Connectors

Figure 6.6 Mold Design

6.2.3.4 Heat Exchanger Design for Room (Radiator)

A secondary heat exchanger, called a radiator, is put in the room model so that the moved heat can be spread around the room. This radiator is made with finned tubes, like the solar panel heat exchanger, to increase the amount of surface area that can move heat. The design makes sure that the room gets a steady, comfy flow of warm air, which helps heat the room as a whole.

Figure 6.7 Heat Exchanger (Radiator)

6.2.3.5 Aesthetic Integration

The mechanical design also thinks about how the system will look in its surroundings. The angle and direction of the solar panel are set so that it absorbs the most energy possible while still looking good. Sensors, microcontrollers, and transmission units are put together in a way that doesn't look cluttered.

6.3 Results

The results show that the Solar Thermal Room Heating System works well. Temperature maps from different monitors show that the system can use sun energy to heat a room. The heat transfer rates that were recorded show how well the heat exchanger and radiator work. Flow rate research gives information about how fluids move through the machine. The Bluetooth transmission technology sends data to the faraway gadget in real time. Overall, the method saves a lot of energy and helps make heating options that are good for the environment.

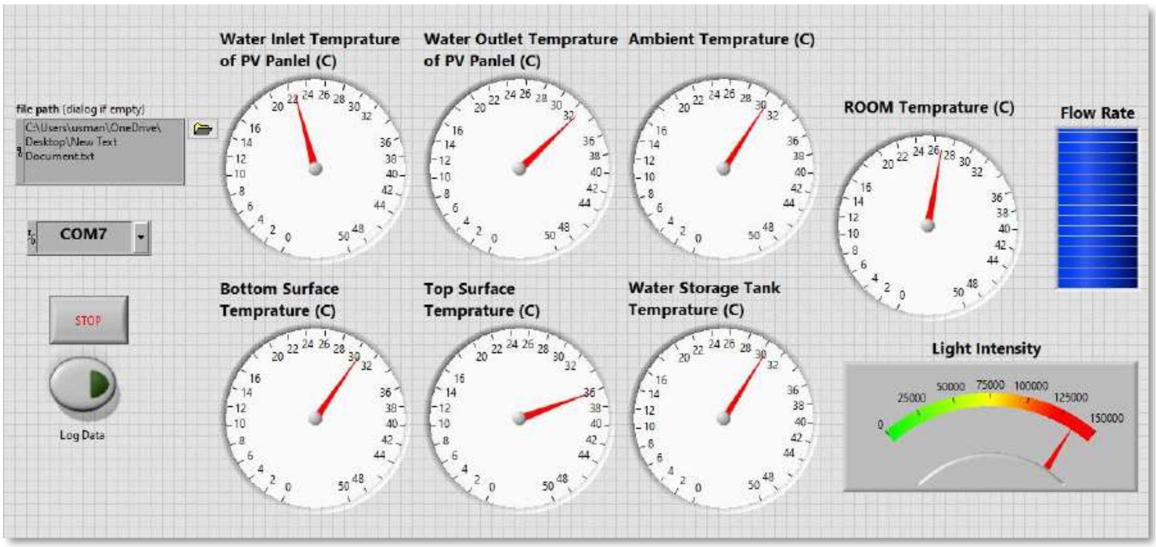

Figure 6.8 Real Time Monitoring Data in LABVIEW

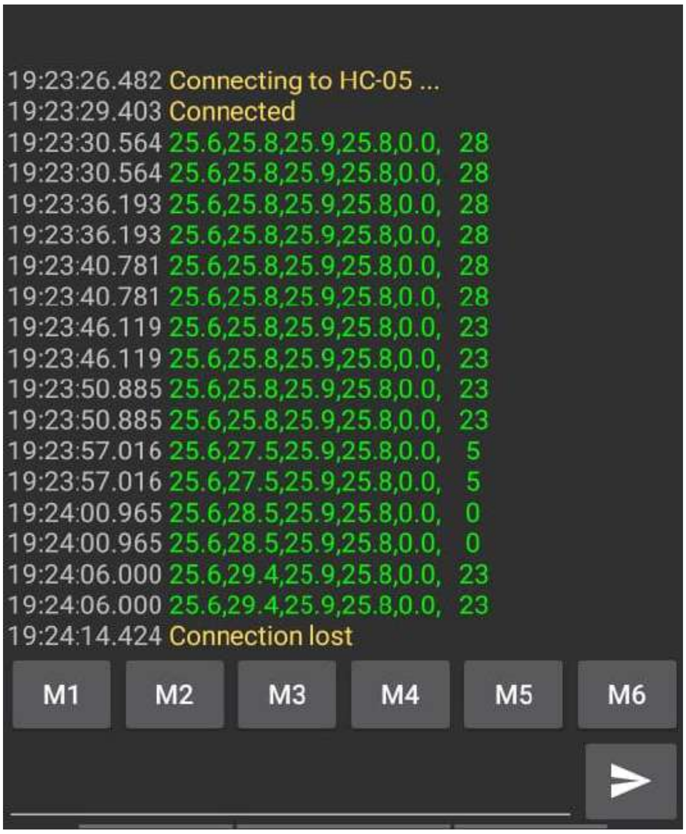

Figure 6.9 Real Time Monitoring Data in Serail Terminal

Figure 6.10 Complete Prototype

Chapter 7 - Conclusion and Future Recommendations

7.1 Conclusion

Multiple sensors and microcontrollers were used in the PVT solar thermal room heating system to track and control important factors. LabVIEW's real-time data visualization and analysis showed how well the system could use sun energy to heat a room. Future improvements, like improved settings, weather tracking integration, and the ability to grow, could help the system use energy more efficiently and have a bigger effect.

The Project gives us the following benefits:

- Uses sun energy to heat rooms, so less energy from non-renewable sources is needed.
- Improves the way heat moves, which saves money and uses less energy.
- Reduces the number of harmful gases that are released into the atmosphere.
- Gives you exact control over the room's temperature to make you feel more comfortable.
- Adapts to changing weather conditions and keeps working the same way.
- Can be controlled and monitored from a distance using Bluetooth.
- Makes it possible to study ways to save energy and control programmes.
- The same basic ideas can be used on a bigger scale.
- Brings together hardware, software, and apps in the real world.
- Helps reach goals for healthy growth by promoting the use of clean energy.

7.2 Future Recommendations

For this project to make more progress and get better, the following steps can be taken:

- By adding technologies like Machine Learning and Artificial Intelligence, the system will be able to analyses the performance and reliability of the well in more ways.
- Integration with tools for data analytics to make it easier to visualize, analyses, optimize, and handle data.

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