ALTERNATIVE SOLAR WATER HEATER FOR DOMESTIC PURPOSE

A Thesis

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Of

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DECLARATION

We hereby declare that this thesis is based on the results established by us. Materials of work found by other researchers are mentioned in the reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

Signature of	**Signature of**
Supervisor	**Authors**

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ABSTRACT

In this report we aimed to incorporate solar energy in the domestic household. We designed a system that would allow the user to attain hot water in an efficient and cheap manner. Every household has domestic electric water heaters which consume a lot of electricity. Nowadays, there is a severe electricity crisis and therefore alternative resources must be looked into. This automated system would allow the user to get hot water from the solar water heater as long as the solar water heater can supply hot water above a set temperature. If the solar water heater is unable to supply water above the set temperature, then only will the electric water heater come into action. It is efficient because our controller ensures that the solar water heater is used to supply hot water 80% of the time, and the rest 20% will be supplied by the electric water heater. It is cheap because, our system runs on solar energy which is abundant and free. It uses very small amount of electricity and therefore, reduces the expenses for the user

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CHAPTER I

Introduction

1.1 Background

There is an immense potential for the use of solar PV technology in Bangladesh. Photovoltaic is a proven viable option in remote areas. [4]Bangladesh is a developing country with a population of 135 million in an area of only 147,570 sq. km. About 85% of the population lives in rural areas. Per capita energy consumption in Bangladesh is one of the lowest in the world.

Bangladesh is continuing its efforts for harnessing its solar power for reaching electricity in its hilly areas and islands where supply of traditional electricity will not be possible in foreseeable future. Although there are good prospects for solar PV system in Bangladesh, potential market development has rather been limited. The Govt., Private sectors and NGOs are taking increasing initiative towards development of the solar energy utilization.

1.2 Working Principle Of The Solar Water Heater

In any collection device, [7] the principle usually followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid like air or water. When no optical concentration is done, the device in which the collection is achieved is called a flat-plate collector.

The flat-plate collector is the most important type of solar collector because it is simple in design, has no moving parts and requires little maintenance. It can be used for a variety of applications in which temperatures ranging from 400 C to about 1000 C are required.

The principle of a thermosyphone is just like boiling the water. [8]In a flat bed collector in cold water flows to the collector, it gets warm by sunshine and flows upward as it becomes lighter than cold water and stored in the tank which can be used directly.

1.3 Components Of Solar Collector.

- A coated flat plate which absorbs solar radiation and transforms it into thermal energy
- an insulated storage tank used to reduce thermal losses of heated water glass or plastic
- cover to reduce upward thermal losses of the collector
- Bottom insulation to reduce downward thermal losses
- Tubes and channels for circulating water to collect thermal energy
- Wooden or metallic frame to house the collector assembly

Solar water heater is basically a flat-plate collector in which heat transfer fluid is water.

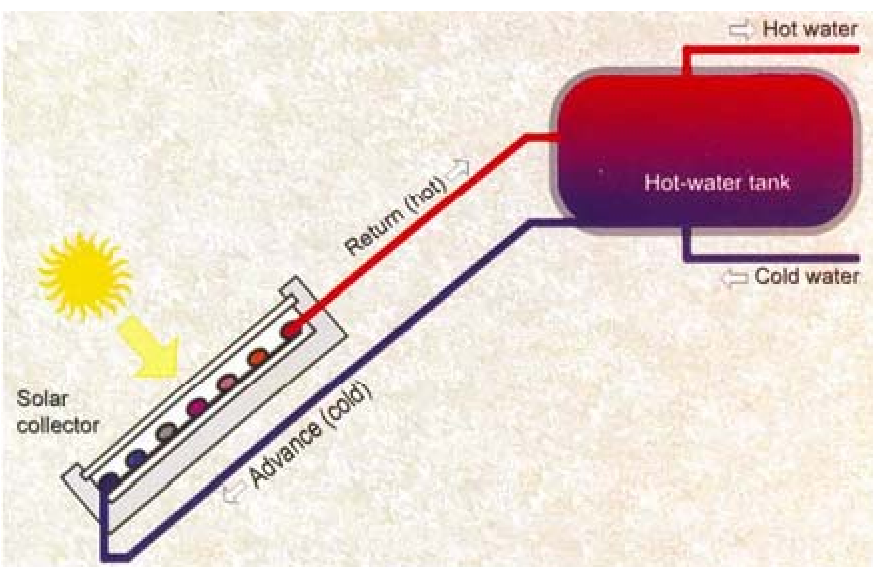


Fig.1.1 The working principle of solar water heater. [9]

The coated plate absorbs solar radiation, converts it into heat and transfers the resulting heat to circulating water. Hot water is then supplied to the storage tank for domestic or space heating use. These collectors are useful for supplying low-grade thermal energy at temperatures below 90^0C.

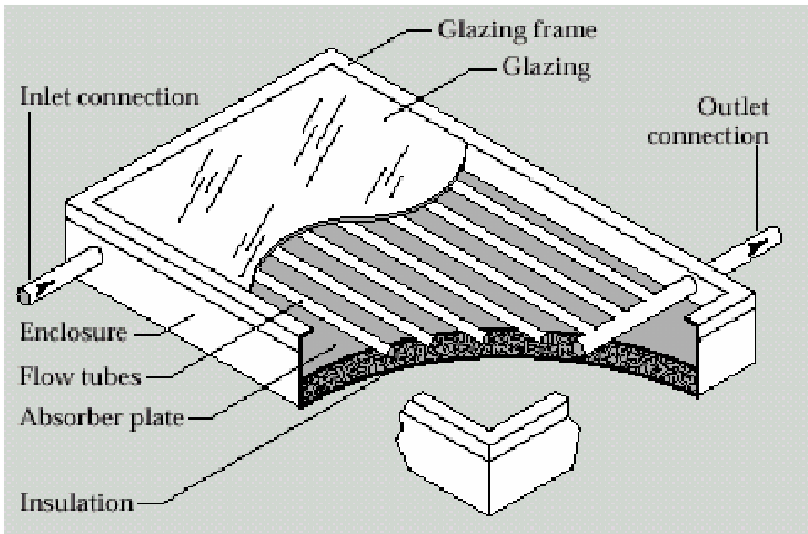


Fig.1.2 Important parts of a typical liquid heating flat-plate solar collector [4,9]

[1]Important parts of a typical liquid heating flat-plate solar collector are the" black" solar energy-absorbing surface, which means for transferring the absorbed energy to a fluid; envelopes transparent to solar radiation over the solar absorber surface that reduce convection and radiation losses to the atmosphere; and back insulation to reduce conduction losses as the geometry of the system permits.

Solar Water Heaters are recently being imported to Bangladesh. This thesis topic was suggested to us by ENERGYPAC, who wanted to sell this product to households who already had electric water heaters. Electric water heaters as their name suggests, runs on electricity. We are at a severe electricity crisis right now and thus, alternative resources must be looked into. If a domestic household who already had electric water heater installs the solar water heater and this control system, it would be saving money, and the payback for the initial cost of the solar water heater would be returned in 2.5 years. Our aim was to design a control system that would efficiently use solar water heater and electric water heater at a 4:1 ratio in order to supply hot water to the user .In chapter II we discuss the overview of alternative solar water heater for domestic purpose, we describe the components in more details. The components include capillary thermostat, 24V power supply, Solenoid valve and relays. In chapter III we get in depth about the experiments that have performed in the laboratory. We discuss the results. In chapter IV we talk about the cost analysis, we focus on how our design reduces costs for the user and calculate the pay back time. In chapter VI, we render upon the topic of practical implications of our system, where we suggest some practical steps that we have taken in order to improve our system.

CHAPTER II

Overview of Alternative Solar Water Heater for Domestic Purpose.

2.1 Project Overview

For this experiment we aimed at using Solar Water Heaters In the Domestic Households which already have Electric Water Heaters installed in them. The electric water heaters consume a lot of electricity and thus are very expensive.

In this Alternative system, both the solar water heater and the electric water heater will be installed in the household. During the day there is abundant sunlight, and the solar water heater can be used to heat the water saving electricity costs by a large amount. At night, the electric water heater can be used.

2.2Components

The components that we used in this control system include, a capillary thermostat, a pair of valves, a 24V power supply and a relay.

2.2.1 Capillary thermostat:

[2]The Capillary thermostat can control on-off according to the principle of liquid which expands with heat and contracts with cold.

The capillary thermostat operates on the principle of fluid expansion. A temperature change in a fluid filled sensing system consisting of probe (bulb), capillary and diaphragm capsule produces a volume change. Following an increase in temperature at the probe, the liquid expands in the capillary tube, causing the diaphragm to move. This movement activates a snap-action switch, causing opening or closing of switch contacts, i.e. the resulting movement of the diaphragm acts through a mechanism to operate the micro switch, a single pole, and single throw normally closed circuit breaks (opens) on rise of temperature.

FIG 2.1 CAPILLARY THERMOSTATS

We set the temperature using the knob. If the temperature is high, the diaphragm has to extend further in order to trip the switch. When the switch is tripped, a closed connection forms with the relay. This allows valve 1 to be on, and therefore hot water from the solar water heater is supplied to the end user. [5]If the thermostat switch is open, then the relay causes hot water from the electric water heater to be supplied to the end user using valve 1. The 240v power supply is stepped down to 24v to run the relay.

2.2.2 SOLENOID VALVE

FIG 2.2 Solenoid Valve

Solenoid valves were needed in order to direct the water to the end user.

[3]A solenoid valve is an electromechanical device used for controlling liquid or gas flow. The solenoid valve is controlled by electrical current, which is run through a coil. When the coil is energized, a magnetic field is created, causing a plunger inside the coil to move. Depending on the design of the valve, the plunger will either open or close the valve. When electrical current is removed from the coil, the valve will return to its de-energized state.

The illustration below depicts the basic components of a solenoid valve. The valve shown in the picture is a normally-closed, direct-acting valve.

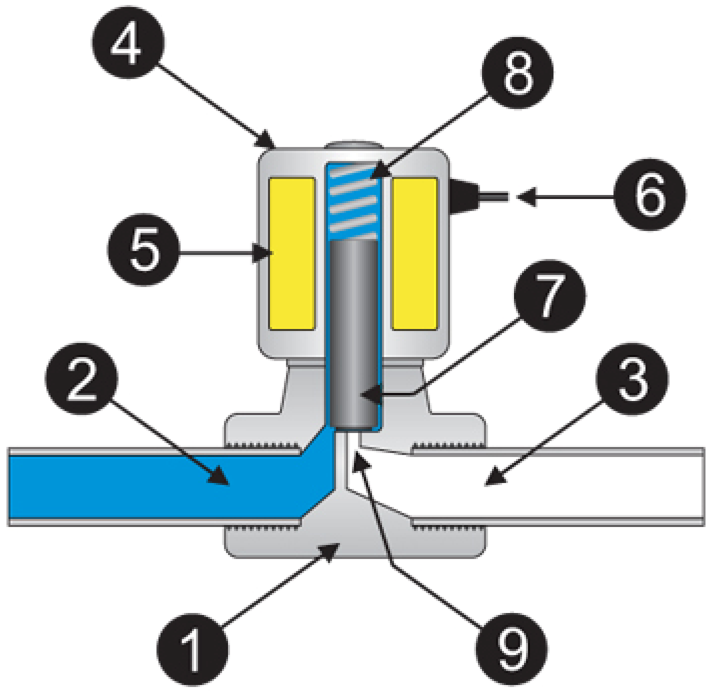


FIG 2.3 Internal Diagram Of Solenoid Valve

1. Valve Body	**4. Coil / Solenoid**	**7. Plunger**
2. Inlet Port	**5. Coil Windings**	**8. Spring**
3. Outlet Port	**6. Lead Wires**	**9. Orifice**

2.2.2.1 Working Principle Of Solenoid Valve

The media controlled by the solenoid valve enters the valve through the inlet port (Part 2 in the illustration above). The media must flow through the orifice (9) before continuing into the outlet port (3). The orifice is closed and opened by the plunger (7).

The valve pictured above is a normally-closed solenoid valve. Normally-closed valves use a spring (8) which presses the plunger tip against the opening of the orifice. The sealing material at the tip of the plunger keeps the media from entering the orifice, until the plunger is lifted up by an electromagnetic field created by the coil.

2.2.3 Power Supply

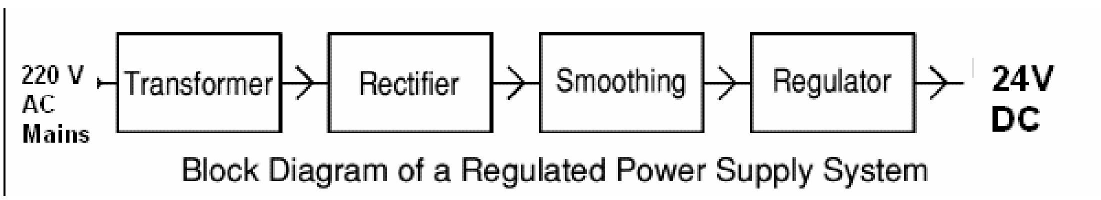


FIG 2.4 Block Diagram Of A Regulated Power Supply System

- Transformer - steps down high voltage AC mains to low voltage AC.
- Rectifier - converts AC to DC, but the DC output is varying.
- Smoothing - smoothes the DC from varying greatly to a small ripple.
- Regulator - eliminates ripple by setting DC output to a fixed voltage.

2.2.3.1 Transformer

[4]Transformers convert AC electricity from one voltage to another with little loss of power. Transformers work only with AC and this is one of the reasons why mains electricity is AC.

FIG 2.5: Transformer

Step-up transformers increase voltage, step-down transformers reduce voltage. Most power supplies use a step-down transformer to reduce the dangerously high mains voltage (230V in UK) to a safer low voltage.

The input coil is called the **primary** and the output coil is called the **secondary**. There is no electrical connection between the two coils, instead they are linked by an alternating magnetic field created in the soft-iron core of the transformer. The two lines in the middle of the circuit symbol represent the core.

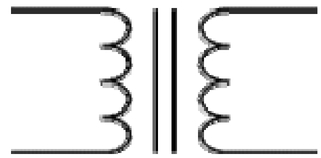


FIG 2.6: Circuit Diagram Transformer

Transformers waste very little power so the power out is (almost) equal to the power in. Note that as voltage is stepped down current is stepped up.

The ratio of the number of turns on each coil, called the **turns ratio**, determines the ratio of the voltages. A step-down transformer has a large number of turns on its primary (input) coil which is connected to the high voltage mains supply, and a small number of turns on its secondary (output) coil to give a low output voltage.

$$\text{turns ratio} = \frac{Vp}{Vs} = \frac{Np}{Ns} \quad \text{and} \quad \begin{array}{c}\text{power out = power in} \\ Vs \times Is = Vp \times Ip\end{array}$$

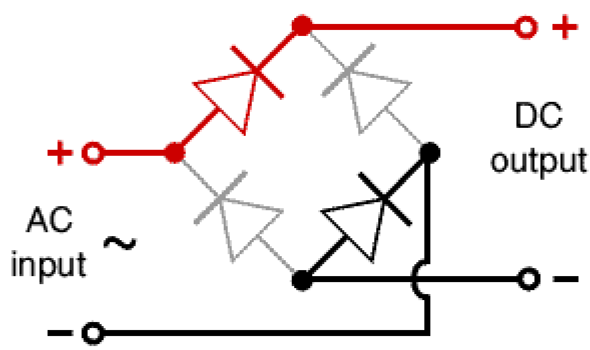
Vp = primary (input) voltage   Vs = secondary (output) voltage
Np = number of turns on primary coil   Ns = number of turns on secondary coil
Ip = primary (input) current   Is = secondary (output) current

2.2.3.2 Rectifier

Rectifiers convert AC to DC. The bridge rectifier is the most important and it produces **full-wave** varying DC.

Bridge rectifier

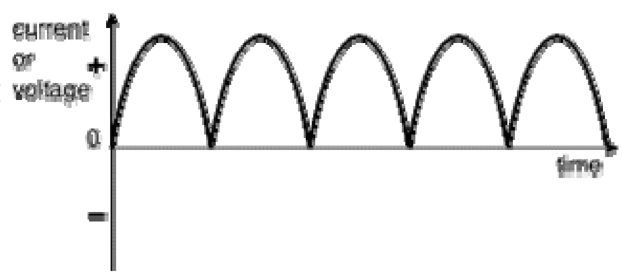
A bridge rectifier can be made using four individual diodes.It is called a full-wave rectifier because it uses all the AC wave (both positive and negative sections). 1.4V is used up in the bridge rectifier because each diode uses 0.7V when conducting and there are always two diodes conducting, as shown in the diagram below. Bridge rectifiers are rated by the maximum current they can pass and the maximum reverse voltage they can withstand (this must be at least three times the supply RMS voltage so the rectifier can withstand the peak voltages).



Bridgerectifier

Alternate pairs of diodes conduct, changing over the connections so the alternating directions of AC are converted to the one direction of DC.

FIG 2.7



Output: full-wave varying DC

(using all the AC wave)

FIG 2.8

2.2.3.3 Smoothing

Smoothing is performed by a large value electrolytic capacitor connected across the DC supply to act ash a reservoir, supplying current to the output when the varying DC voltage from the rectifier is falling. The diagram shows the unsmoothed varying DC (dotted line) and the smoothed DC (solid line). The capacitor charges quickly near the peak of the varying DC, and then discharges as it supplies current to the output.

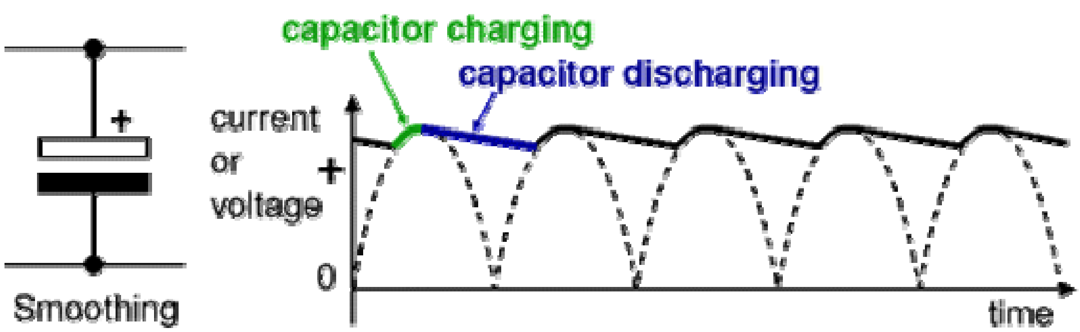
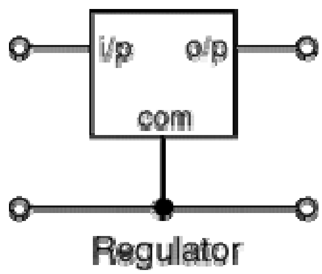


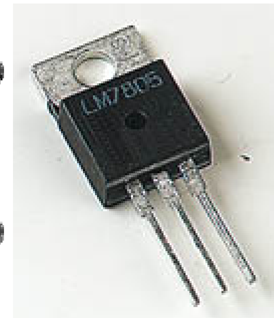
FIG2.9 Smoothing Capacitor

Smoothing is not perfect due to the capacitor voltage falling a little as it discharges, giving a small **ripple voltage**. For our case, capacitor values of 4700µF /25V were used

2.2.3.4 Regulator

Voltage regulator ICs are available with fixed (typically 5, 12 and 15V) or variable output voltages. They are also rated by the maximum current they can pass. Negative voltage regulators are available, mainly for use in dual supplies. Most regulators include some automatic protection from excessive current ('overload protection') and overheating ('thermal protection'). In our case, we needed output voltage +24V, so LM 7824 was used.





Voltage regulator FIG:2.10

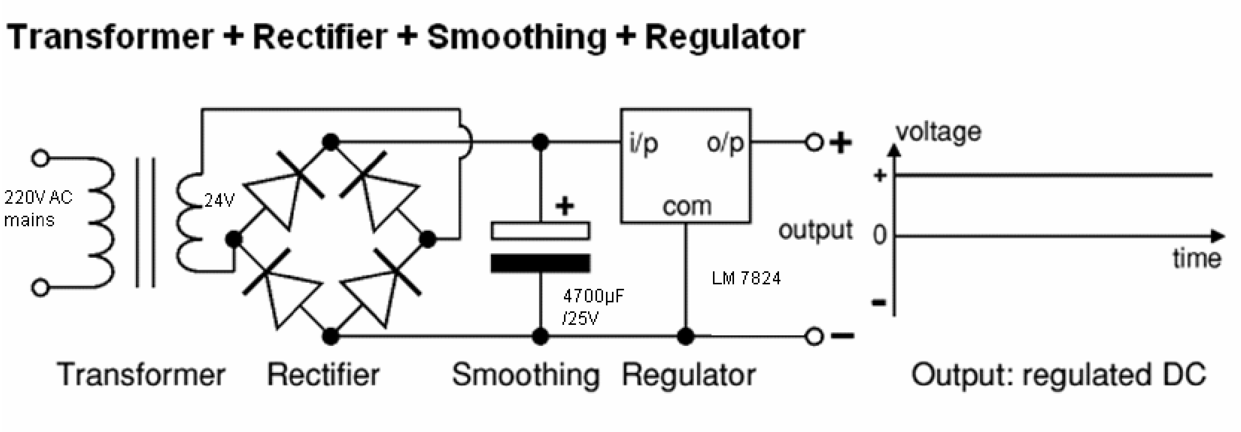


FIG2.11

2.3 Controller Overview

A thermocouple is used to measure the temperature of the solar water heater. A voltage is produced that is proportional to the temperature. This voltage is fed to the Thermostat.. A set temperature is assigned in the Thermostat. If the set temperature is less than the actual temperature, valve 1(V1), remains on while valve 2 (V2) remains off. Water from the solar water heater then passes to the outlet. If the set temperature is more than the actual temperature, hot water from the electric water heater is supplied at the outlet.

In this way, the user can get hot water throughout the day, in an efficient and cost effective way.

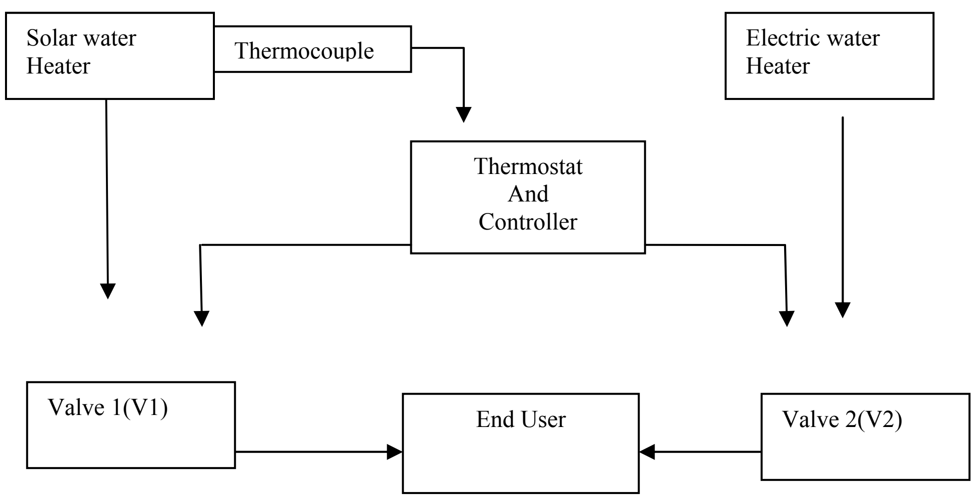


Fig 2.12 Block Diagram of the Control Process

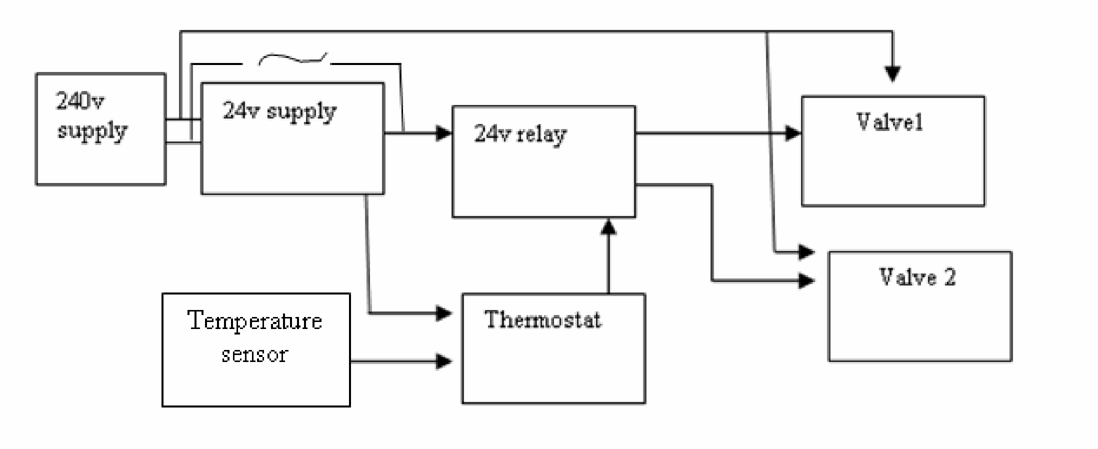


Fig 2.13 Block Diagram of the Controller

CHAPTER III

Experiments and Results:

3.1 Calibration of thermostat

Figure shows the comparison between the set temperature of the capillary thermostat and the thermometer temperature. Here we used two thermometers- thermometer 1 and thermometer-2.

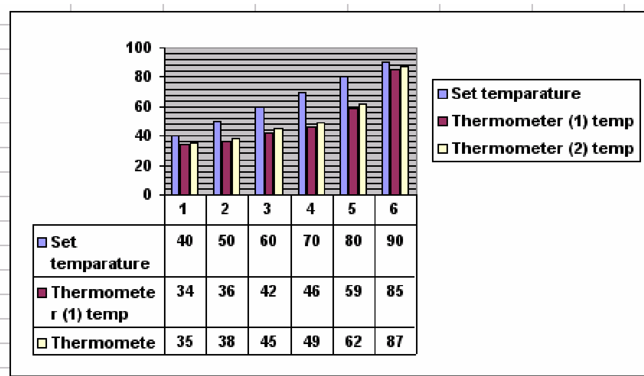
In our first experiment we saw, when the set temperature in the capillary thermostat was 40^0, thermometer 1 showed 34^0 and thermometer 2 showed 35^0. Here the temperature of the two thermometers is close to each other, but there is a big difference with the set temperature. The temperature difference with thermometer 1 and thermometer 2 is 6 and 5 respectively. Again when the set temperature in the capillary thermostat was 50^0, thermometer 1 showed 36^0 and thermometer 2 showed 38^0. This time the temperature difference with thermometer 1 and thermometer 2 is 14 and 12 respectively, so the temperature difference this time is much bigger. This big difference continues up to the set temperature 80^0.But when the set temperature was 90^0, thermometer 1 showed 85^0 and thermometer 2 showed 87^0, difference is very small this time. In this experiment the temperature of the two thermometers was close.

We performed the experiment twice. In the second experiment we found when the set temperature was 40^0, thermometer 1 showed 33^0 and thermometer 2 showed

34^0. This time temperature difference with thermometer 1 and thermometer 2 is 7 and 6 respectively. Here the temperature of the two thermometers is again close to each other but temperature difference with the set temperature is as big as first experiment. The smallest difference we got when the set temperature was 90^0. The temperature difference with thermometer 1 and thermometer 2 was 5 and 3 respectively.

The reason behind this temperature difference is still not fully understood In our experiment we totally merge the thermostat probe in to the water and there is nothing between the water and probe. A fluid inside the probe is responsible for the functionality of the thermostat. But in case of the thermometers, the movement of the mercury may be different from the fluid used inside the thermostats.

Set temparatur	Thermometer (1) tem	Thermometer (2) temp
40	34	35
50	36	38
60	42	45
70	46	49
80	59	62
90	85	87



Set temparatur	Thermometer (1) tem	Thermometer (2) temp
40	33	34
50	37	39
60	42	45
70	45	49
80	56	62
90	82	85

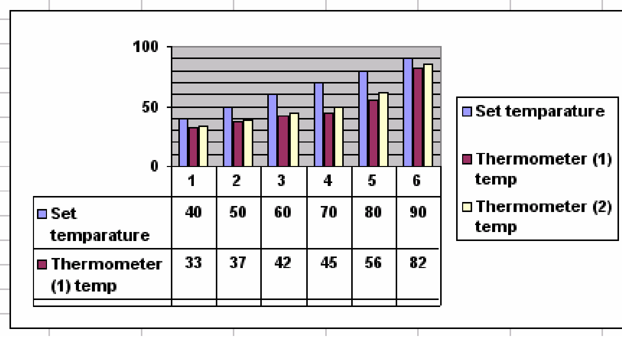


TABLE 3.1

3.2 Power Consumption and Temperature Measurement Of Valve

Using a wattmeter we measured the power consumption of the valve.

Current Consumption I= 0.13A

Voltage=225V

P=IVcosθ

P=17W

Power factor=0.95

Power Consumption & Temperature Of The Valve

Time	Temperature/°C	Power Consumption (Watt)
1:10	30	16
1:50	74	16
2:05	76	15
2:35	77	15
3:20	82	15
3:47	83.5	15
4:17	81.4	15
4:50	80	15
5:05	81	15

TABLE 3.2

This experiment was performed using a wattmeter and a thermometer. We used the wattmeter to measure the power consumption of the valve. The wattmeter supplied a 220V voltage for the valves. The thermometer war tied to the valve. The mouth of the thermometer was tightly attached to the outer surface of the valve. This was done for the purpose of achieving the temperature of the valve. The experiment was carried out for around 4 hours. We wanted to discover if we needed any heat sink for our design as one valve would be on at all times. We performed the experiment at our laboratory.

We started taking the reading at 1.10 pm at which the initial temperature of the thermometer was 30°C.This is the room temperature. Within 40 minutes the temperature of the valve rises to 74°C.From then onwards the temperature increments steadily. The power consumption becomes constant at 15W. After 3.47 pm the temperature of the valve starts decreasing in small orders .However, again at around 5.05 pm temperature starts increasing. From these values we can see that the temperature of the valve becomes very high. Since one valve is always ON. This can becomes a serious matter. For this case, we have to add a heat sink to our design.

3.3 Temperature Of Solar Water Heater at different times of day for different capacity

DATA FROM BUET

Time	Room Temperature/°C	200Ltr	100Ltr	Weather
11:45 am	24	41	51	Sunny
3:25 pm	21	44	51	Sunny
9:50 am	23	59	53	Sunny
3:15 pm	22	75	62	Sunny
10:15 am	21	55	48	Sunny
3:00 pm	21	68	53	Sunny
10:30 am	21	51	44	Sunny

TABLE 3.3

This is the data that we collected from BUET. Here, on different days, at different times the room temperature and the temperature of the water in the solar water heater was recorded. This takes into account two types of capacity of solar water heater. One is 200 litres and the other is 100litres.This reading was taken in winter. From the results we can see that room temperature remains quite steady at around 21°C for most of the days but the solar water heater very hot water. One of the more interesting derivations we get from this result is the fact when the room temperature is high, the solar water heater heats the water less when compared to the time when the room temperature is low. We can see that when the room temperature 24°C, the 200L and 100L tanks give 41°C and 51°C respectively. When the room temperature is 21°C, the solar water heater gives hot water with temperatures of up to 75°C.At ENERGYPAC, we have plans to take the same data and match our readings.

CHAPTER IV

4.1 Cost Analysis

This table shows the cost analysis of the electric water heater, solar water heater and the alternative water heater. Electricity consumption of the electric water heater is TK 85 per day where the electricity consumption of the alternative water heater is TK23.So, the user of the alternative water heater can save around TK61 per day. The solar water heater works for free only at day time, it’s not possible to get hot water from it at night or in a rainy day. The alternative water heater can save almost TK1850 per month and TK21845 per year which is a big advantage for the users. The maintenance cost of the alternative water heater is same as electric water heater.

For this calculation we had to make some assumption—

- 1) We assume electric water heater works for 4 hours daily.
- 2) Power consumption of the electric water heater is of 4kW
- 3) According to PDB per unit electricity charge is Tk5.25
- 4) In case of Alternative Water Heater we assume the electric water heater is being used for 1 hour.

Description	EWH (24 hours)	SWH (Day time only)	Alternative WH (24 hours)
Electricity charge per day	Tk84	0	Tk 23
Electricity charge per month	Tk2,520	0	Tk 690
Electricity charge per year	Tk30,240	0	Tk 8395
Electricity charge for 15 year	Tk4,53,600	0	Tk 1,25925
Maintenance cost	Tk1000-2000	0	Tk1000-2000

Table 4.1 Cost Analysis

EWH=Electric Water Heater

SWH=Solar Water Heater

The implementation cost of alternative water heater is Tk54, 000 (app.).We can say that alternative solar water heating system is the best solution for the hot water requirement for the user already have electric water heater installed in their home. The user will get the pay back within 2.5 years

CHAPTER V

5.1 PRACTICAL IMPLICATIONS ON SYSTEM

In order to improve this system, we came up with some practical implications. Firstly, let us discuss the things we already added to our controller. For the end user to identify which heater is supplying the hot water, we have added lights. If the solar water heater is ON, then the light indicating solar water heater will be illuminated. If the electric water heater is ON, then the light representing the electric water heater will be ON.

We have also added a fuse, in order to prevent high current from flowing into the circuit and damaging it.

We performed a number of experiments to make sure that there was no point in time where the controller rapidly shifted between ON and OFF of a particular valve.If this had happened it might have burnt the circuit. However, this is not a problem for our design. Our experiment results show that since water has a high specific heat capacity, it takes a long time for water to change temperatures. Therefore a rapid change in water temperature does not occur.

In future, we plan to add a digital display, which will display the exact water temperature at the solar water tank. This will make it easier for the end user to compare the input desired temperature and the output temperature.

For our current system, we see that we see that one valve is always working, no matter what. Therefore there is a high probability of the valve getting very hot, Thus, we have to add a heat sink, to remove heat from the valve.

Incase of two valves, we plan to use one T-shaped valve, which would by itself direct water from the solar water heater or the electric water heater. This would reduce the cost of our system by about 1400 Tk.

CHAPTER VI

6.1 CONCLUSION

This thesis topic was given to us by ENERGYPAC; this was aimed at solving their problem. We have already completed making the controller. We have given a demonstration at ENERGYPAC. They were impressed by our work. It has already been implemented there and we are hoping to perform more experiments to improve our product. We wish to find out the efficiency of the system at different times of the day. We plan to make a digital display using microcontroller which will be embedded in the control system.

At University we had a brain storming session for quality control and risk management of our product.

Before commercialization we plan to meet the BSTI requirements

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