

# **Design and Implementation of Solar Heater System**

A thesis submitted to the Department of Electrical and Electronic Engineering

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## **Declaration of Authentication**

We certify that the research/project based thesis titled, “Design and implementation of solar heater system” is completely our group work. All sources and knowledge for this paper which were found by other researchers are acknowledged by reference. Materials of work such as images, figures, tables and citations in this paper are accepted by our Supervisor. We hereby declare that this thesis has not been previously submitted either in whole or in part, for any other degree or publication.

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## **Acknowledgement**

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## **Dedication**

This thesis is dedicated to our faculties and parents  
For always believing in us, encouraging us and inspiring us  
To achieve our goals and bringing out the best in us.

## **Abstract**

Overly populated and developing countries, such as our country Bangladesh is facing energy resources scarcity over the last few decades. Specially, the rural areas in Bangladesh which covers at least 50 % of our land suffers without electricity and the attempt to expand the grid system is incapable for the shortage of capacity. With the innovation of technology and high popularity of usage of renewable energy, the accessibility of electricity is present for all. Our aim is to design a project, which is the development of solar powered electric heater replacing the electric, or gas powered equipment. This allows the heater to be charged during the day by storing solar energy and be used during normal time. The future prospective is to bring along this success project to the commercial area and encourage investors to invest in this project and make it more popular among common people for household purposes.

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## SYMBOLS AND UNITS

Power  $P = \text{W} / \text{kW}$

Current  $I = \text{A}$

Voltage =  $\text{V}$

Resistance  $R = \Omega$

Irradiance  $G = \text{W}/\text{m}^2$

Insulation =  $\text{H}$

$\text{H} = \text{J}/\text{m}^2$

Energy  $E = \text{kWh}$

Battery Capacity =  $\text{Ah}$

$1 \text{ kWh} = 3.6 \times 10^6 \text{ Joule}$

# CHAPTER 1

## Introduction

### 1.1 Synopsis

This paper has been ordered in six chapters. The following chapters describe the approach of our experiments step by step and furthermore, the study of the results.

Firstly, the second chapter discusses about the hybridization of technology. The method of hybridizing is basically about the different sources of power that have been used. In the third chapter, the system design of the project is described in details. Size of the panels, amount of batteries required, role of the charge controllers and the current controllers are illustrated. Next, current controller, a significant part of this system has been explained. Chapter four deals with the field and data analysis, demonstrated with tables and graphs. After that, chapter five is about the comparative studies where this solar heater is evaluated with the conventional equipment; it also includes the case study analysis. Finally, the last section ends with the conclusion.

### 1.2 Motivation and Background

Energy is a non-renewable resource and crisis of electrical energy is the biggest problem in this period of time. For a third world country, such as Bangladesh whose population is densely populated, it is difficult to allocate these limited resources among the people. The only solution to this is to make adequate use of renewable sources such as wind, solar, water, etc to generate electricity. The climate of Bangladesh also favors the use of solar energy of throughout the year it is semi tropical. Considering these facts, we have come up with a project of a new technique of cooking which could fully utilize the concept of solar energy.

The design of the solar electric heater will be cost effective and very much similar to the typical conventional electric equipment.

Electricity is the most fundamental concept of life to let any appliance work. Over the years, the demand for electricity has increased with increase in population and also the industrial development. As the population escalated it couldn't meet the production of electricity, which gradually started to be a scarce resource. The alternate was thought to be natural gas, which is a vital source of energy in the rural areas. Initially it was planned, the 10% growth rate of gas consumption should only be sufficient for the rest 9 years. At present, from 17 gas fields only 730 BCF (Billion Cubic Feet) gas is supplied. Yet there is shortage of 182 BCF of gas annually. Now, Gas Sector Master plan is clear to reduce the scarcity, but if the reserve capacity doesn't increase according to the estimation then the reserve may decrease to a huge drop by 2015.

Nowadays, the popularity of solar-based electricity has reached a high note in Power Division. With the initiative of private sectors getting involved into bringing in more commercial projects, like solar irrigation, Solar Mini grid, solar rooftop applications, the government is more encouraging housing and offices to install solar panels. Lately, DESCO has additional clause of new construction buildings that unless solar panels are installed, mains electricity may not be supplied. The capacity has risen above 150 MW of solar power development. It is not only aiding in urban planning, but in rural areas, solar power plants are being used to run irrigation pumps. As per the demand and supply, using solar power in household may reduce the difference between reserve capacity and demand of the population.

### **1.3 Introduction to Photovoltaic Energy:**

Photovoltaic actually means “electricity from light” for which solid-state, semi-conductor type devices are used. The fastest growing renewable energy technology, which could change the future of global electricity, is the use of photovoltaic energy. Solar energy is directly converted into electricity by electronic devices such as photovoltaic cells. Presently known to be solar cells, were first invented by Bell Telephone in 1954. In 1960s, this technology was first used by the space industry to provide power for spacecraft out of the range. As space programs began to rise in numbers, the technology was more advanced and reliability had to be improved more. To keep up with the market, the cost had to be declined. In the era of energy crisis in 1970s, this photovoltaic technology gained popularity as a source to give power to other applications.

A PV system is made up of PV cells that are grouped together to form a module, and the inverter, controller and etc are the auxiliary components. Already, there is mass number of production of PV cell technologies, using different types of materials and in future the number may rise.

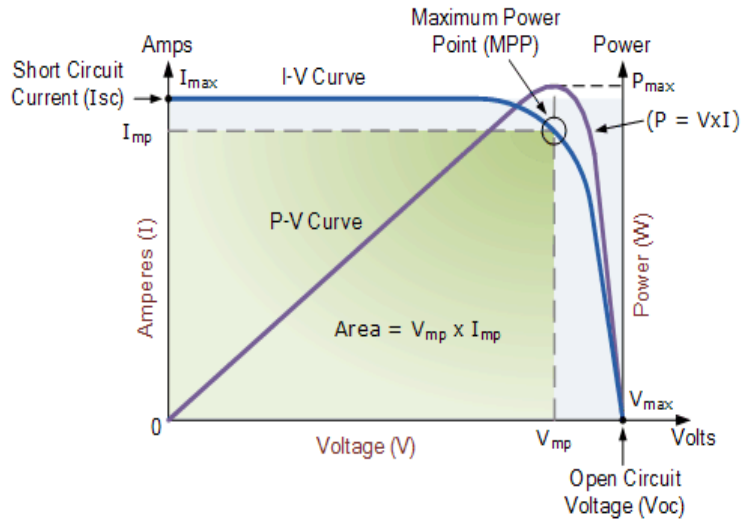
Photovoltaic (PV) cells absorb photons from sunlight with the help of pure crystalline form of silicon and then releases them as electrons. This causes an electric current to flow when the photoconductive cell is connected to the main load. The main electrical characteristics of a PV cell or module are in the relationship between the current and voltage. The current (I) is controlled by the intensity of the solar radiation that hits the photoconductive cell. Meanwhile, these increase the temperature of the cell and in return reduce the voltage (V).

The popularity of solar PV systems reached a height not only for their modular size, but for numerous significant benefits. Firstly, solar energy is a renewable resource that is available anywhere in the world. The photovoltaic technologies are relatively smaller and more efficient than any other electricity generation technologies. They may also be tested virtually to detect any problem. Secondly, solar PV requires no fuel costs and less maintenance and operation costing. Lastly, in countries where it is mostly summer gives photovoltaic driven systems a high coincidence with peak electricity demand for the use of cooling appliances.

With the advancement of technology, Pulse Width Modulation (PWM) charging has become popular in the arena of solar photovoltaic battery charge controllers. It assists in achieving constant voltage battery charging by switching the solar system controller's power device. When a battery voltage reaches the regulation threshold, the PWM algorithm slowly reduces the charging current to avoid heating of the battery. Yet, the maximum amount of energy is transferred to the battery. These features of PWM provides various benefits like the ability to recover the discharged capacity of the battery, reduce release of heat, increases the ability of the battery to recharge the lost charge and importantly, self-regulate the voltage drops and effect of temperature in the solar system. Thus, consumers receive more power for less cost of maintenance and operation.

### **1.3.1 Temperature Dependence of solar cell**

The amount of energy produced by the solar panel is affected by the temperature. The more heated the solar panel becomes, the less efficient it becomes. When we measure the current produced at different voltages, the amount of power the solar cell produces is determined. This is usually done depending on the intensity of light hitting on it. When the solar panel is heated, the current passing through will increase, which decreases the voltage. This reduces the overall efficiency. The function of the solar panel doesn't get affected during the summer, when the panel is getting overly heated. This shows temperature does not cause any effect on the functionality, but yet with the temperature the performance may rise or fall. However, the output power decreases with the increasing panel temperature. This graphical representation demonstrates the operation of a solar cell and also indicates the relationship between the current and voltage at a certain radiance and temperature.



**Fig1.1: Current vs Voltage Characteristics of solar panel [8]**

We know  $P = JV$ ,

Where P is the power produced

J is the current and V is the voltage.

The power is plotted in blue in the figure (1.1) above. At one point it is shown the power, P is at maximum value. This point is called the maximum power point and it is from here we calculate efficiency.

The efficiency is given by

$$\eta = (J_{max} \times V_{max}) / P_{in}$$

Where

$\eta$  is the efficiency

$J_{max}$  is the current at the maximum power point

$V_{max}$  is the voltage at the maximum power point and

$P_{in}$  is the power incident on the solar cell (the power from the light shining on it).

This can also be written as

$$\eta = (I_{sc} \times V_{oc} \times FF) / P_{in}$$

where

$I_{sc}$  is the current at short circuit (when  $V = 0$ )

$V_{oc}$  is the voltage at open circuit (when  $J = 0$ )

When the solar cell is heated, the current,  $J_{sc}$  will increase, but the voltage,  $V_{oc}$ , will decrease. Since the voltage decreases faster than the current increases, the result is that the overall efficiency goes down.

$$\eta \downarrow = (I_{sc} \uparrow * V_{oc} \downarrow \downarrow * FF) / P_{in}$$

The following equation shows the relation between output power of solar PV panel and temperature.

$$P_{pv} = Y_{pv} \times f_{pv} \times (GT/GT_{STC}) \times [1 + \alpha_P \times (T_c - T_{c, stc})]$$

Where

$Y_{pv}$  = the rated capacity of the PV panel, which is its power output under standard test conditions [kW]

$f_{pv}$  = the PV de-rating factor [%]

$GT$  = the solar radiation incident on the PV panel in the current time step [kW/m<sup>2</sup>]

$GT_{STC}$  = the incident radiation at standard test conditions [1 kW/ m<sup>2</sup>]

$\alpha_P$  = the temperature coefficient of power [%/°C]

$T_c$  = the PV cell temperature in the current time step [°C]

$T_{c, stc}$  = the PV cell temperature under standard test conditions [25 °C]

The temperature coefficient of power indicates how much the PV panel power out depends on the temperature of the cell. It is shown that the output power decreases with the increase in temperature.



## 1.4 Ranges of Solar Spectrum:

Table (1): The average incident solar radiation of one year at Dhaka (NASA)[9]

Month	Average incident solar radiation (kWh/m <sup>2</sup> /day)	Average incident solar radiation (kW/m <sup>2</sup> )
January	4.182	0.174
February	4.677	0.195
March	5.546	0.231
April	5.654	0.236
May	5.578	0.232
June	4.475	0.186
July	3.895	0.162
August	4.117	0.172
September	3.964	0.196
October	4.704	0.165
November	4.250	0.177
December	4.058	0.169
Annual average	4.591	0.191

### Calculation of module efficiency

The formula written below is used to calculate the module efficiency.

$$\eta = (I_{sc} \times V_{oc} \times FF) / P_{in}$$

Where

$\eta$  = Module Efficiency

$I_{sc}$  = short Circuit current

$V_{oc}$  = Open Circuit Voltage

$FF$  = Fill Factor =  $V_{mp} \times I_{mp}$

Where,

$V_{mp}$  = Optimum operating voltage

$I_{mp}$  = Optimum operating current

$P_{IN}$  = Input Solar Power

For this design purpose 200W Mono-crystalline solar module is used manufactured by **Electro Solar Ltd.** from the technical specifications given it is shown that at STC(at 25°C and AM1.5),

$I_{sc}$  = short Circuit current =6.5 A

$V_{oc}$  = Open Circuit Voltage =43.2 V

$V_{mp}$  = Optimum operating voltage =34.4 V

$I_{mp}$  = Optimum operating current = 5.81 A

$FF$  = Fill Factor =  $(V_{mp} * I_{mp}) / (I_{sc} * V_{oc}) = (34.4V * 5.81 A) / (6.5 A * 43.2V) = 0.71$

Dimensions of the module = 1.58m \* 0.808m \* 0.035m

$P_{in}$  = Input Solar Power =  $1000W/m^2 = 1000 * 1.58 * 0.808 W$   
 $= 1276.64 W = 1277 W$

$\eta$  =  $((6.5 * 43.2 * 0.71) / 1277) * 100 = 15.61 \%$

#### 1.4.1 Average Output Power Calculation

The solar power output per month is calculated using the equation:

$P_{pv} = Y_{pv} * f_{pv} * (GT/GT, STC)$

Where

$Y_{pv}$  = the rated capacity of the PV array, meaning its power output under standard test conditions [kW]

$f_{pv}$  = the PV derating factor [%]

$G_T$  = the Solar radiation incident on the PV array in the current time step [ $\text{kW}/\text{m}^2$ ]

$G_{T,STC}$  = the incident radiation at standard test conditions =  $1 \text{ kW}/\text{m}^2$

It is seen that the temperature coefficient is very small, thus when calculating the power the negligible temperature is ignored.

From the technical specifications of the used **200W Monocrystalline solar module** it is known that,

At STC (at  $25^\circ\text{C}$  and AM1.5),

Rated capacity of the PV module = 200 W.

So Peak output Power of the designed system =  $200 \times 230 \text{ W} = 46 \text{ kW}$

$Y_{pv}$  = the rated capacity of the PV array = 46 kW

$f_{pv} = 0.8$

$G_{T,STC} = \text{the incident radiation at standard test conditions} = 1 \text{ kW}/\text{m}^2$

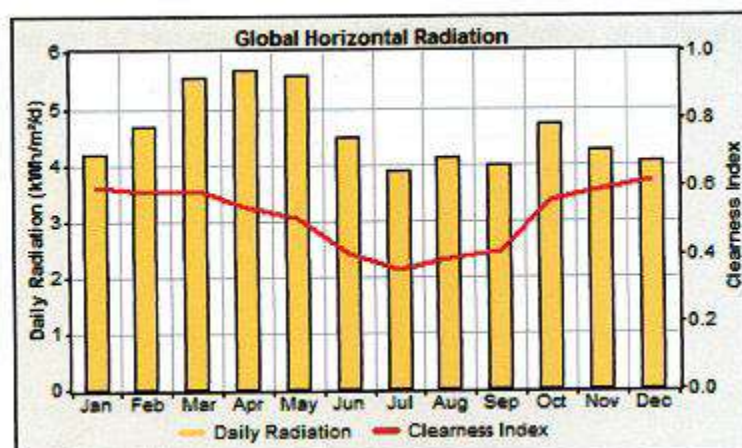
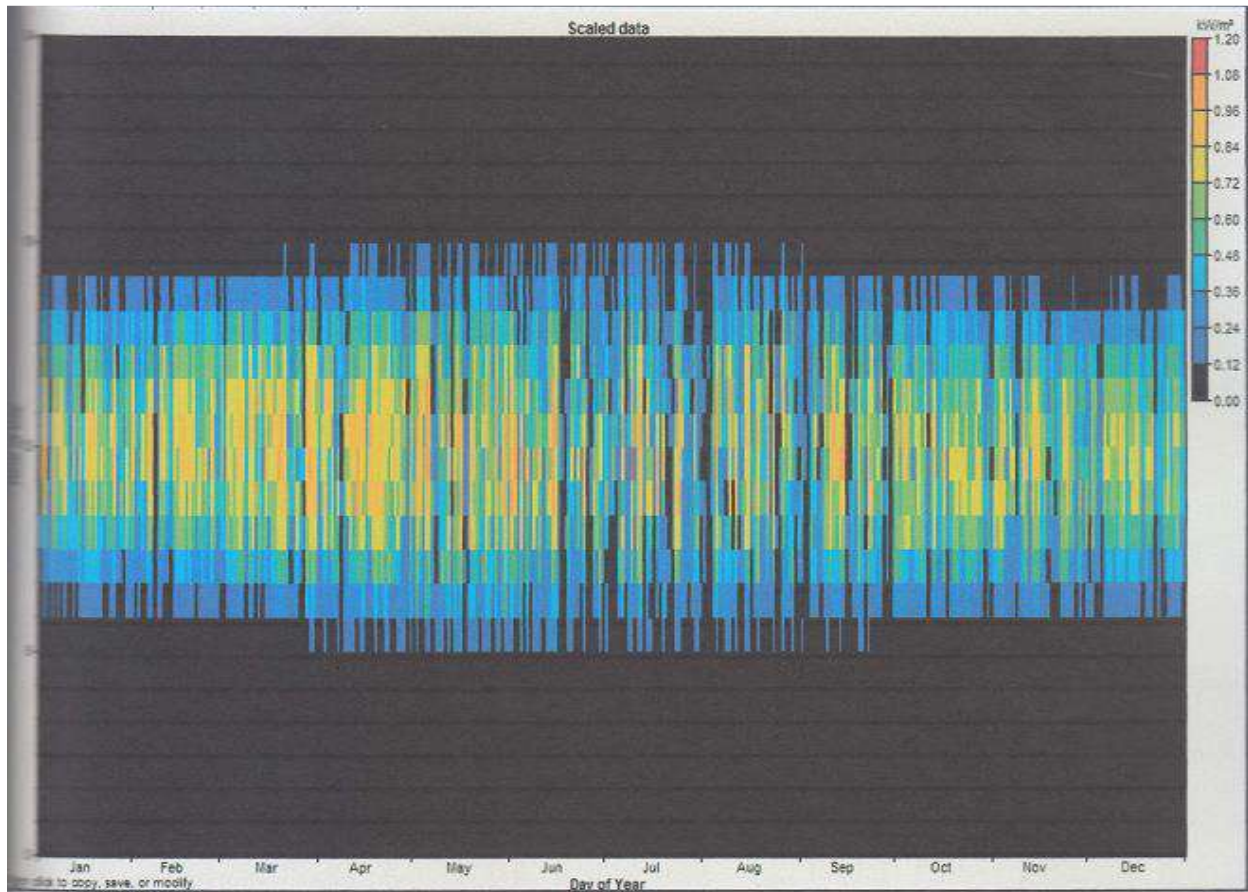


Fig 1.2: solar radiation map of a single year [9]

For the month of January,

$G_T =$  the solar radiation incident on the PV array in January =  $0.174 \text{ kW/m}^2$

$P_{pv} = 46 \times 0.8 \times (0.174/1) \text{ kW} = 6.40$



**Fig 1.3: Hourly variation of solar radiation of a single year [9]**

Month	Average incident solar radiation (kWh/m <sup>2</sup> /day)	Output power from the designed system (kw)
January	0.174	6.40
February	0.195	7.18
March	0.231	8.50
April	0.236	8.68
May	0.232	8.53
June	0.186	6.84
July	0.162	5.96
August	0.172	6.33
September	0.196	7.21
October	0.165	6.07
November	0.177	6.51
December	0.169	6.22
Average Output Power	0.191	7.03

**Table (2) : The Monthly average output power for monocrystalline solar module[9]**

Average hours of operation in a day = 12 hrs.

So, total hours of operation in a year = 4380 hrs/yr.

Average solar energy production /yr = 7.03 kW \* 4380 hr/yr

= 30791.4 kWh/yr= 30792 kWh/yr.

In terms of the sun rays correspond to the electromagnetic radiation, wavelength classified under the range of values of electromagnetic spectrum. In extent to the criteria of wavelength, the range lies under 2(micro)m to 4(micro)m which represents the chain from Ultraviolet(UV) to Infrared(IR). The percentage of radiation calculated under the basis of wavelength is noted below:

- 8% of the radiation is in UV under the wavelength of (<0.39 micro m)
- 46% of the radiation is in visible light under the wavelength of (0.39-0.78(micro)m)
- And the rest 46% shares under the wavelength of (>0.78(micro)m) [6]

Earth's diameter is  $1.27 \times 10^4$  km while the diameter of the sun is  $1.39 \times 10^6$  km. The distance subtracted from earth and sun is measured  $1.50 \times 10^8$  km. The top of the earth received solar energy. And the differences on distance measured between sun and earth permit sunrays entering like a parallel beam of light. This parallel light accepted at all points in the circle. During the average value under separation from earth to the sun, the rate in accordance with sun powered lands at the highest priority on the climate. The value would be around  $1353 \text{Watt/m}^2$  within a variety of  $\pm 3\%$ . The solar resource globally is massive and correspondingly the solar resources varies over day, week or year in direction towards the condition of local meteorological phenomenon. Each year the earth surface receives solar radiation with values worth around 885 million TWh. (IEA, 2011). In topic to solar energy utilization Bangladesh is situated under the ideal location that depicts 20.30-26.38-degree north latitude and 88.04-92.44 degree east. The solar radiation measured varies from 4 to 6.5KWh per square meter on the basis of average values recorded. During March-April Radiation is maximum while in December- January the radiation recorded minimum.

## **1.5 Project Overview:**

This project emphasizes on the replacing the shortage of gas and electricity with the help of the most popular and available renewable resource, solar energy. In this system, the maximum heat is produced by the redesign of coils of the heater and the controller is used to control the current. The backup of the solar power is provided by the batteries and national grid is also connected in

case batteries get out of charge. Several tests are done to check the time required for heating different amount of water. The main objective of the project is to design a solar powered system which is more efficient and cost friendly than gas and electricity and also more easy to use.

# CHAPTER 2

## Hybridization of Technology

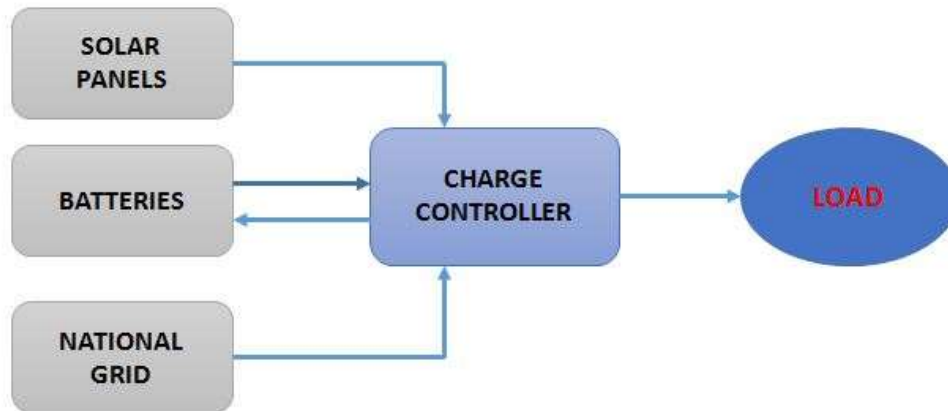
### 2.1 Outline of Hybridizing Technology

In parallel to the growing technologies and population, scarcity of resources increases our curiosity of innovation to ease up life. It is known solar energy is most convenient resource to convert to electricity and be provided into appliances. This project utilizes the solar power for a domestic application in a hybrid renewable energy system. Batteries in the system are charged by solar power. It is known to be hybrid as it gives the benefits of a battery bank with the backup of a grid connected system. This means that even during a power blackout, we still have electricity. The charge controller monitor and control the power resources and batteries in the system.

#### 2.1.1 Design and Implementation of the Hybrid Energy System

Hybrid Solar power systems enable us to use the electricity from the main grid at off peak times and also use the stored solar power in batteries. The hybrid solar power system that is used in our project consists of solar panels, charge controllers, battery bank and AC grid connection. The fundamental graft of a battery is to store the converted electrical charges from the solar power. The AC grid connection acts as a backup for this system. This allows us to make use of the stove during sunlight hours and also, at night. Our stove cuts down the cost in a way as being a hybrid system, electricity from the mains is least used.





**Fig 2.1: Hybrid System of our experimentation**

## **2.1.2 System Configuration**

Our system is planned in such a way that it obtains the maximum energy and highest cooking hours without much consumption of electricity from the mains. Usual scenario, during day time and mid-day the batteries which are charged by the solar panels provide power supply to the load and also some periods during the night. Hence, no stress is given to the main loads and throughout sunlight hours, most power comes from the solar panels. The national grid or the main load is into action during the darker hours and this power may also be needed to charge the batteries. The project is planned keeping in mind the times of gloomy weather, where mostly the main grid power is used.

## **2.2 Benefits**

The main objective of building a hybrid system is that create a perfect blend of control and balance on the availability of energy of resources. If solar power stored isn't sufficient enough to supply during day time, the system can recharge the batteries and provide the appliance with power from the grid.

# CHAPTER 3

## System Design

A standard solar heater needs mainly 5 components.

1. Heater coil
2. Current controller
3. Battery
4. Charge controller
5. Solar panel

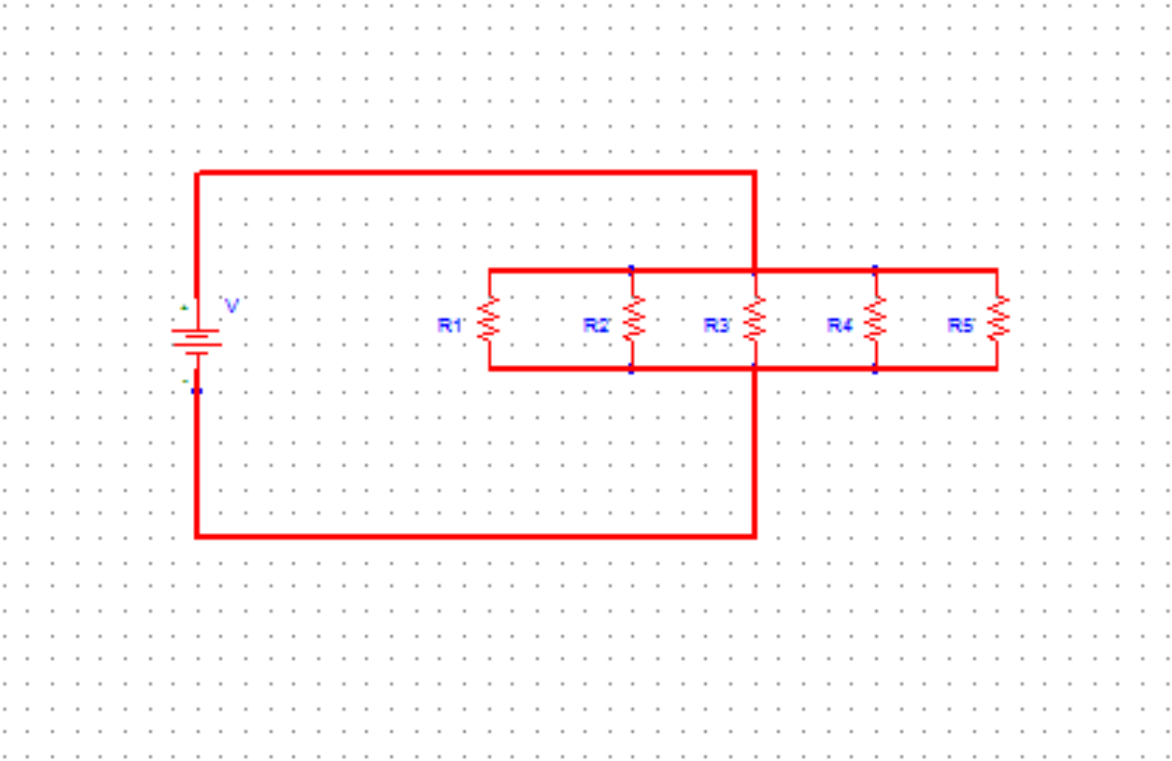
### 3.1 Heater Coil

For solar heater we bought one heater Nicrome coil from the market. Even though this coil is used for AC power, but our stove runs on DC power from solar and the AC connection is only for backup. For our system we had to go through some modification, like we used 500W coil, instead of a 1000W keeping in mind the correct voltage and current for the coil so that it runs efficiently. While doing so we had to keep an optimum voltage, as increasing voltage will rise the cost of the battery. The solution to this limitation was to increase the current by reducing the resistance of the coil.

#### 3.1.1 Designing the Coil

Using a multi-meter, we measured the resistance of the whole coil used which is of 85 ohms. In order to reduce the resistance and increase the current, we cut the coil into 5 parts to get our recurred power. Each part having a resistance of 15 ohms. We know connecting resistors in parallel to each other reduces the amount of value of resistance. Hence, the final resistance of the coil was  $(15 \parallel 15 \parallel 15 \parallel 15 \parallel 15) \Omega = 3 \Omega$ .

The parallel connection is shown in Fig 3.1



**Fig 3.1: Re-designed coil simulation**

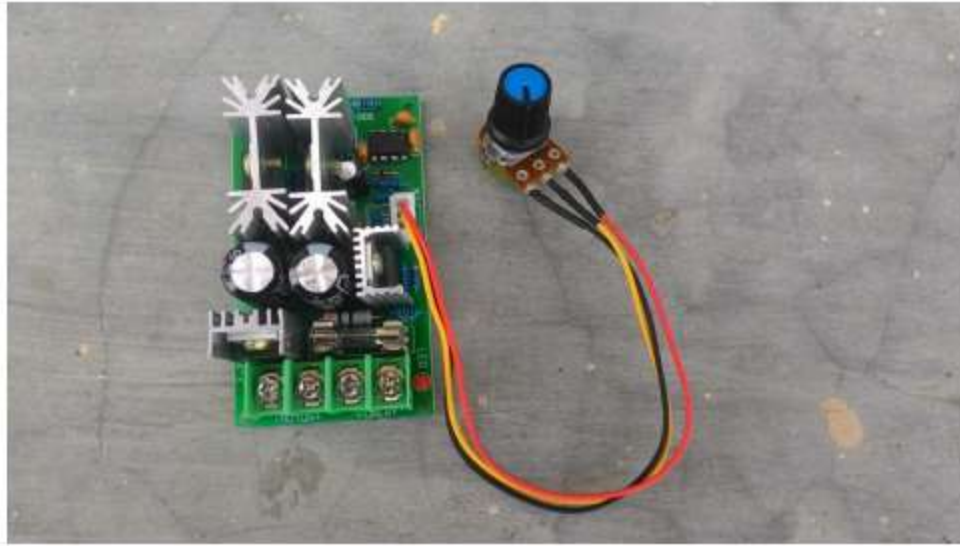
Our each part of the coil can deliver 100 W powers. So from the 5 parts of the coil we can get total  $(100 \times 5) = 500$  W power.



**Fig 3.2: Re-designed coil for solar heater.**

### **3.2 Current Controller**

This is one of the most interesting additions in our system. We added a circuit to the system, by which the current of the heater can be controlled by the user. We used one current controller for the heater. There is a knob at the controller by which the user can increase or decrease the current according to their preference. As the technologies and population are growing, the scarcity of resources increases our curiosity of innovation to ease up life. It is known solar energy is most convenient resource to convert to electricity and be provided into appliances. This project utilizes the solar power for a domestic application



**Fig 3.3: Current Controller.**

### **3.3 Battery**

For our project, the solar heater requires 36V of voltage. We connected a set of three 12V sealed lead acid batteries of 10Ah in series connection. The battery set from one end is connected to the load power which is connected to the solar panel and the other end with the charge controller. When the heater is on, one part of the current load is received from the battery and the rest of the current comes from the solar panel. Meanwhile, when the load is off, the PV panel charges the battery.

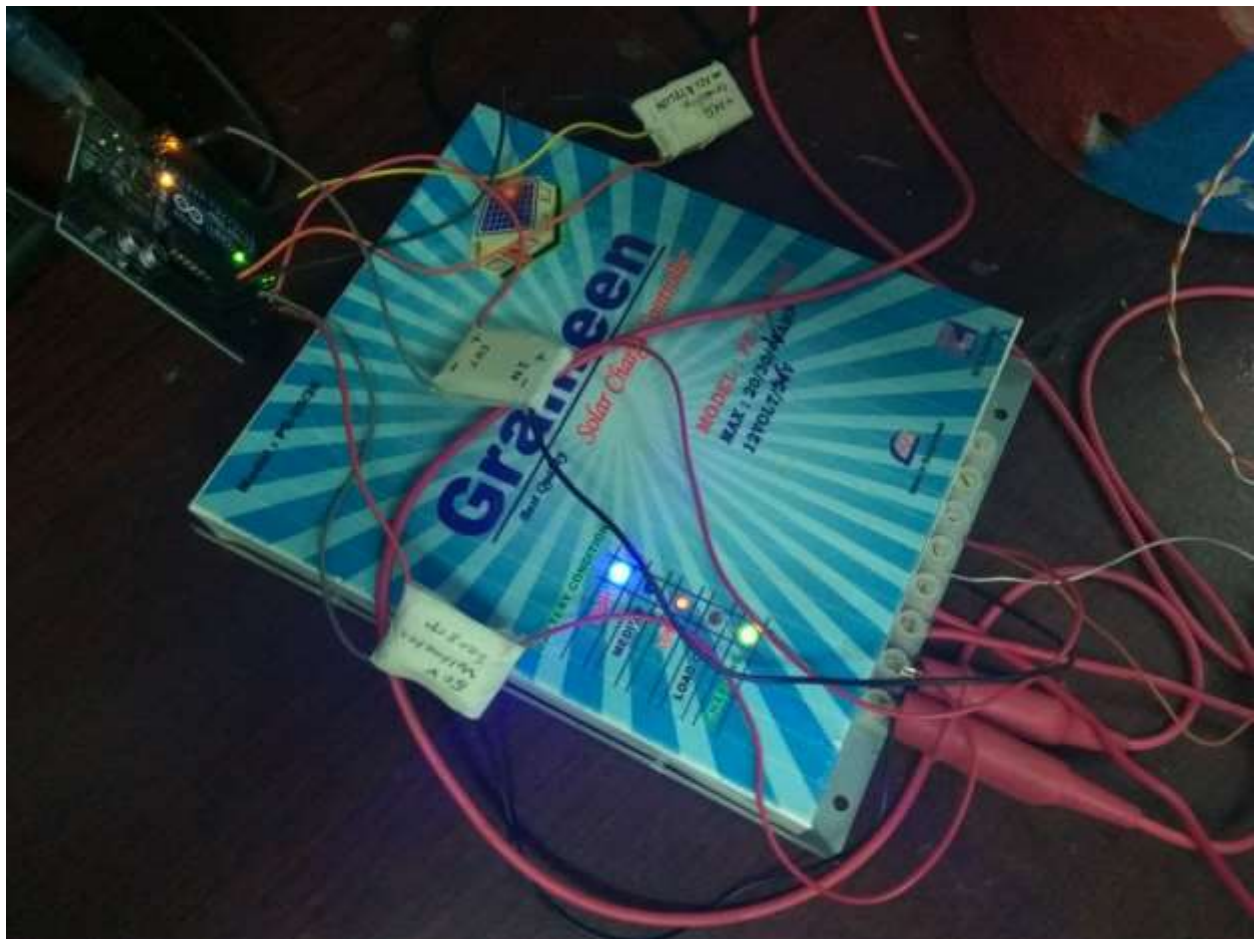


**Fig 3.4: Batteries for solar heater**

### **3.4 Charge Controller**

As our project is based on solar heater system, we only need one charge controller for charging the battery and sharing the load power whether from the solar panel or the national grid. The charge controller has 4 ports, PV (+), PV (-), Battery (+), Battery (-). The solar panel connection goes to the PV (+) and PV (-) ports. The positive and negative terminal of the battery goes to the battery (+) and battery (-) ports. The two ends of the heater goes to the battery (+) and battery (-) ports. When the heater is on, the load current comes from the battery and the PV panel and when heater is off, the solar panel is continuously charging the battery through the charge controller.

The amount of current we are getting from the solar panel depends on the intensity of the sunlight hitting the photoconductive cells. When it is bright, sunny day the PV current will provide more for the load current to run the heater and in a gloomy day, the already charged battery has to provide most of the load current. For the safety of the battery and also for the system we designed Low Voltage Cutoff (LVD) and High Voltage Cutoff (HVD) in our charge controller. When the weather is gloomy for long days the battery will be fully discharge and over discharging can damage the battery. In order to solve this problem we have used LVD which will disconnect the supply from the battery when its voltage is 10V. On the other hand over charging also damage the battery, so we have to limit the charging voltage. Here we used HVD 40V that's mean when the panel supplies over 40V the system will automatically stop charging.



**Fig 3.5: Charge controllers**



### 3.5 Solar Panel

The core of the system is the solar panel. Our heater requires maximum 48V and minimum 2.10A. So the solar panel needs to provide that amount of current and voltage should be higher than 48V. We have one 100W and two 50W monocrystalline solar panel. We connected all the panels in series. Each 50W panel had the optimum operating voltage of 18.5V, so the series of two 50W can provide at least 37V. And the optimum operation voltage of 100W panel is 18.9V. So the total set of these three panel is 200W (100W+50W+50W) which provide us the total optimum voltage around 56V (18.5V+18.5V+18.9V). It fulfilled the requirement of the voltage and the current for the heater.



**Fig 3.6: Solar Panel**

## **Chapter 4**

### **Testing and Analysis**

Basically, our field test was to check the amount of heat for different level of current and voltages at different weather like sunny day and gloomy time with the whole set up. We set up the whole system of our solar heater on the rooftop of BRAC University UB04, Dhaka, Bangladesh. This field test was very important to check the efficiency of the heater. It was very necessary to check how efficiently it can heat, how much time it takes to heat and what are the difficulties one can face while using the heater. This experiment was also important to check how long the batteries can supply power if there is no solar energy. So, we also experimented with load connected with batteries and PV disconnected. This was particularly for night times or for the rainy days. The main purpose was to see whether this product is effective and user friendly or not.

#### **4.1 The main objectives of test and analysis**

The main agenda was to check:

- If the whole system altogether works properly or not.
- How long it works without any kind of difficulties.
- The product is safe or not.
- How long batteries can serve without PV panel.
- The charge controller is compatible with the whole system or not.
- The current controller is behaving perfectly or not.

- How long it takes to heat different item at different weather.

## 4.2 Items

To analysis our data we used different amount of water to check the heating process. We have used half litter, 1 litter and 1.5 litter water to check the difference of heating time at different weather.

## 4.3 Data acquisition method

We have used programmable Arduino Board to measure the different input-output voltage, current and temperature in each minute. To get the temperature reading we have used DS18B20 sensor.

### Arduino Codes:

#### Temperature Code:

```
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 2

#define voltage_1 A0
#define voltage_2 A1

double v_1;
double v_2;

OneWire oneWire(ONE_WIRE_BUS);
```

```

DallasTemperature sensors(&onewire);

void setup(void)
{
  Serial.begin(9600);
  sensors.begin();
  pinMode(voltage_1, INPUT);
  pinMode(voltage_2, INPUT);
  Serial.println("Voltage 1 \t voltage 2 \t\t Temperature");
  delay(100);
}

void loop(void)
{
  for(int i = 1 ; i <= 150 ; i++)
  {
    v_1 += analogRead(voltage_1) / 19.0590999999;
    v_2 += analogRead(voltage_2) / 18.8409999999;
  }
  sensors.requestTemperatures(); // Send the command to get
temperatures
  Serial.print(" ");
  Serial.print(v_1/150);
  Serial.print("\t\t ");
  Serial.print(v_2/150);
  Serial.print("\t\t ");
  Serial.print(sensors.getTempCByIndex(0));
  Serial.println();
  v_1 = 0;
  v_2 = 0;
  delay(300);
}

```

### Voltage Code:

```
#define voltage_1 A0
#define voltage_2 A1

double v_1;
double v_2;

void setup() {
  // put your setup code here, to run once:
  pinMode(voltage_1, INPUT);
  pinMode(voltage_2, INPUT);
  Serial.begin(9600);
  Serial.println("voltage 1 \t voltage 2");
  delay(100);
}

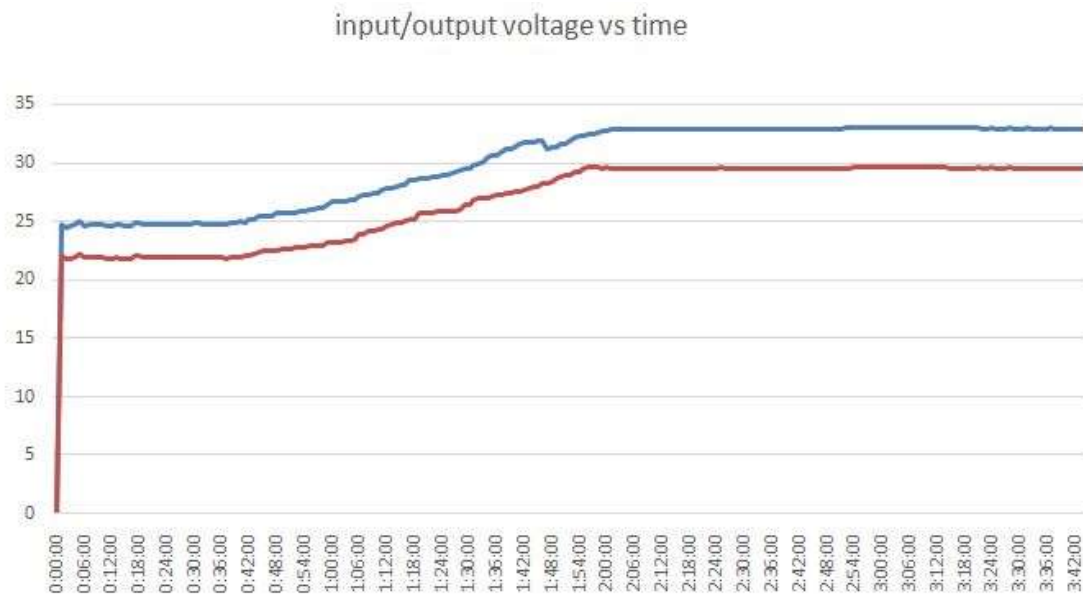
void loop() {
  // put your main code here, to run repeatedly:
  for(int i = 1 ; i <= 150 ; i++)
  {
    v_1 += analogRead(voltage_1) / 19.16376306620209;
    v_2 += analogRead(voltage_2) / 19.16376306620209;
  }
  Serial.print(" ");
  Serial.print(v_1/150);
  Serial.print("\t\t ");
  Serial.print(v_2/150);
  Serial.println();

  v_1 = 0;
  v_2 = 0;
  delay(300);
}
```

## 4.4 Data Analysis:

We have started our experiment for data collection at 11:30AM which was clear sunny day. At first we collected the data for 3 hour and 40 minutes using Arduino program. Here we have collected the data from solar panel and heater where the heater getting the voltage only from the panel. We have stopped the first part of our experiment at 02:40 PM and started the second part for low sunlight at evening time. It was 03:30 PM for the second part and we collected our data for one hour. We have compared the data of these two types experiment using graph which are shown below step by step.

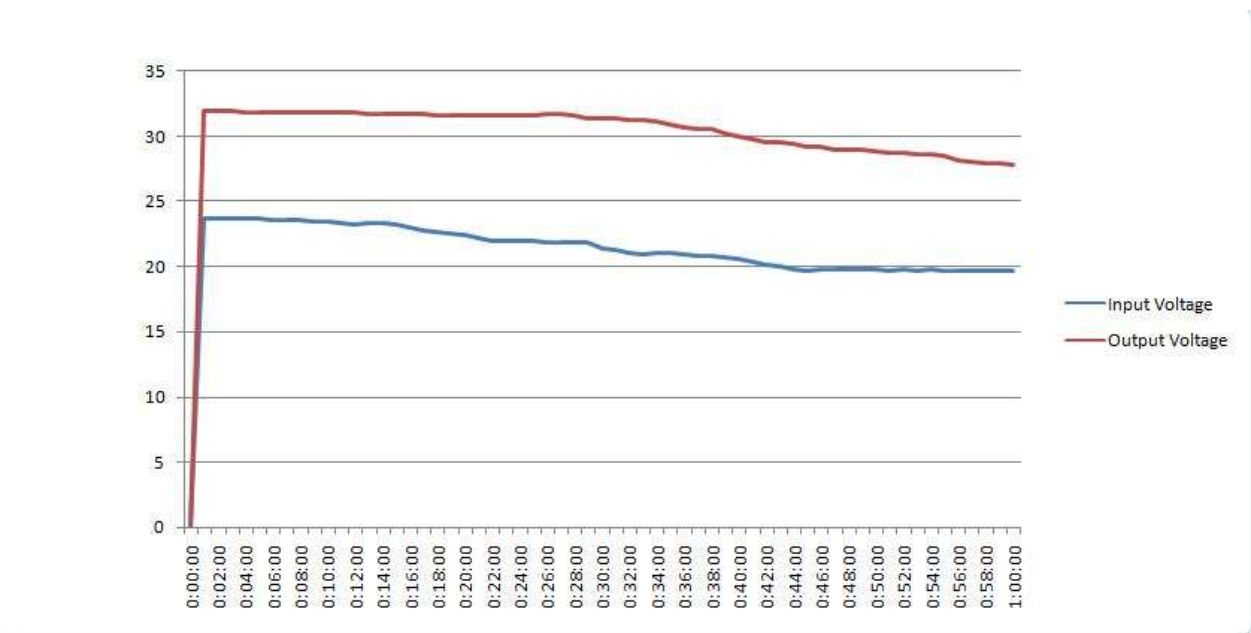
### Input / Output voltages of the charge controller at (11.30-2.30p.m.) :



**Fig 3.7: Input / Output voltage vs Time.**

The graph is showing the input and output voltage of the charge controller. Initially the input voltage coming from the panel is 24.5 V and the output voltage delivering the charge controller is 22.02V. Depending on the sunlight the voltage is changing. We have got maximum input voltage 33.04V and output voltage 29.61V.

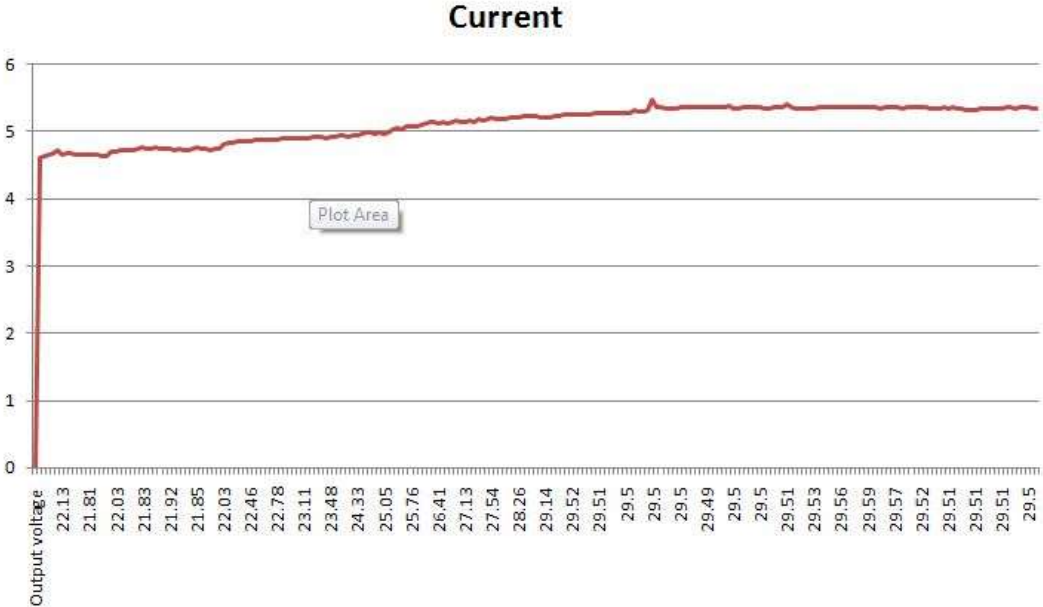
**Input / Output voltages of the charge controller at (3.20-4.20 p.m. ):**



**Fig3.8: Input / Output voltage vs Time**

At evening the power of the sunlight become low so the input voltage of charge controller become low but the output voltage is almost unchanged because the load is also getting voltage from the battery. When the charge of the battery getting low the output voltage is becoming low too.

**Output Current vs. Output Voltage at (11.30-2.30p.m.) :**

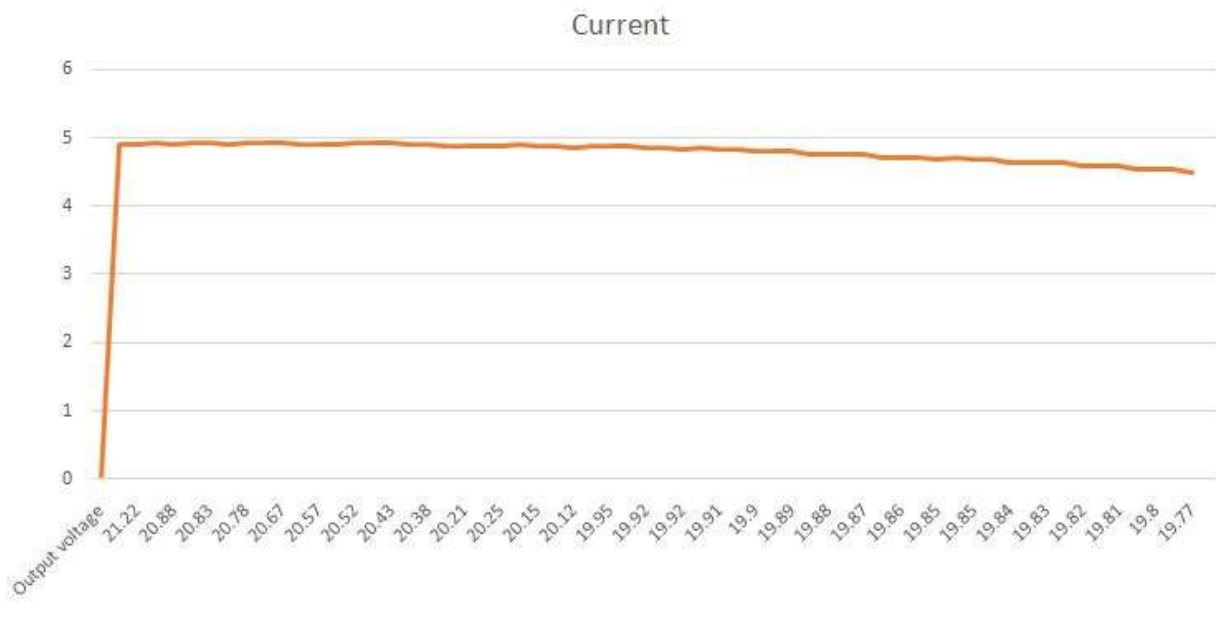


**Fig3.9: Current vs. Voltage**

The output current is getting high during the pick time of solar radiation. We have seen from the graph that initially it takes some time to increase the amount of value. After 2<sup>nd</sup> hour we get the highest amount of value. However, the current does not increase linearly all the time, at the end of the time it becomes saturated and it becomes flat.



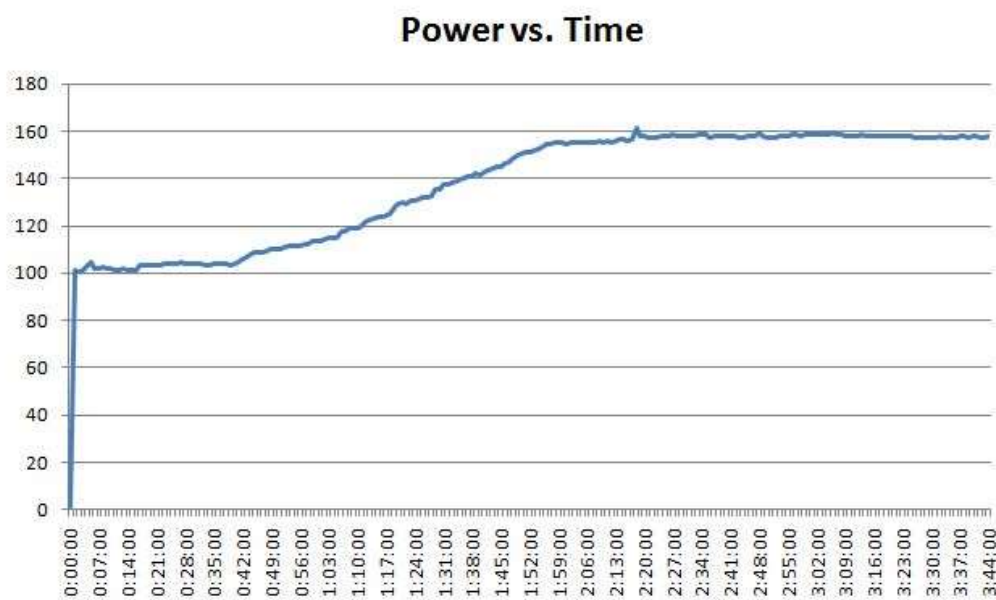
### Current vs. Voltage at (3.20-4.20 p.m.):



**Fig3.10: Current vs. voltage at off pick hour.**

Since we are getting backup from the battery there will be little bit difference between noon time and evening time output current and voltages.

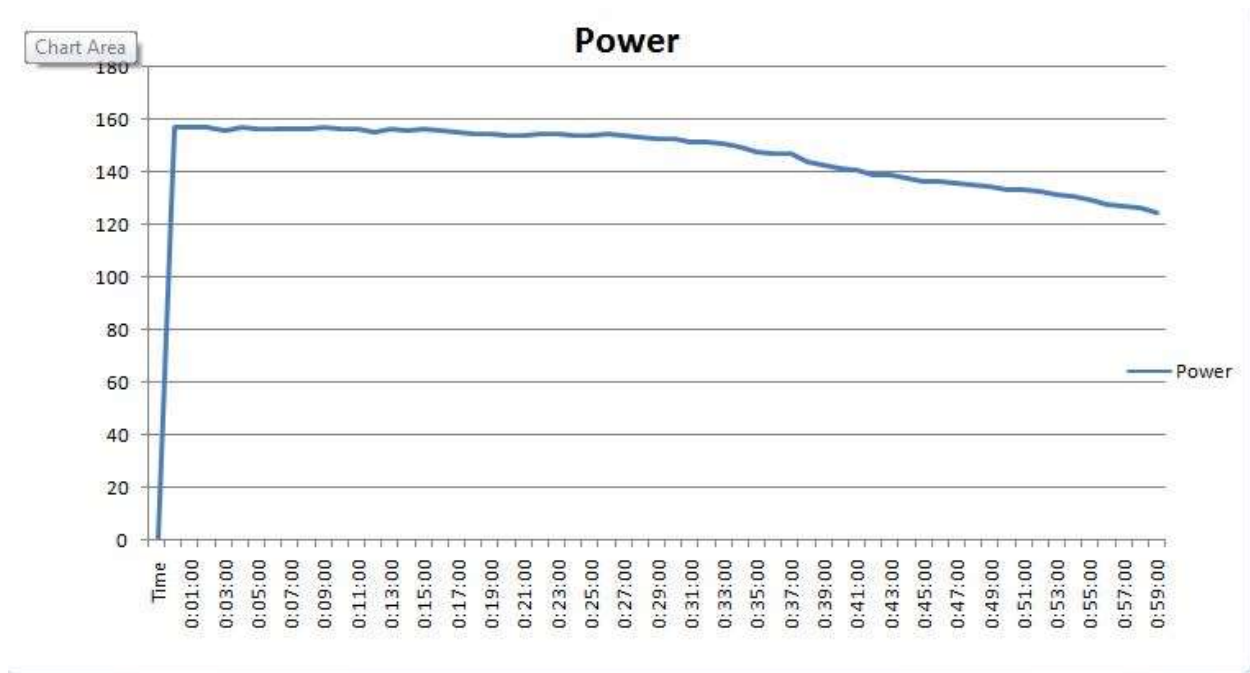
### Power of the heater at (11.30-2.30p.m.):



**Fig3.11: Power vs Time.**

The power of the load follows the output voltage and current. We measure the max load power at noon is 161W and the average power was 138W. We have seen some fluctuation here, this might be the reason of running cloud.

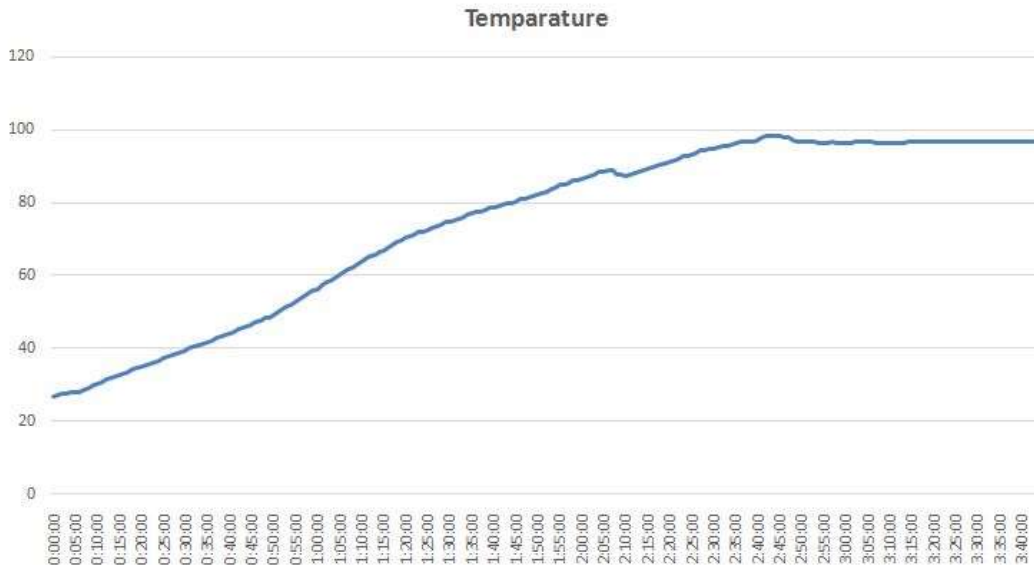
### Power of the heater at (3.20-4.20 p.m.):



**Fig3.12: Power vs Time**

At evening time, it is certain that we will get lower voltage from solar panel since the radiation from sun is low. And here in this case battery is backing up the demand of load. So initially the output power is good enough and our solar heater is producing good heat. However, as the battery has characteristics of discharging, battery voltage decreases as the time passes. So the battery backup time decreases and the amount of output power become lower as well.

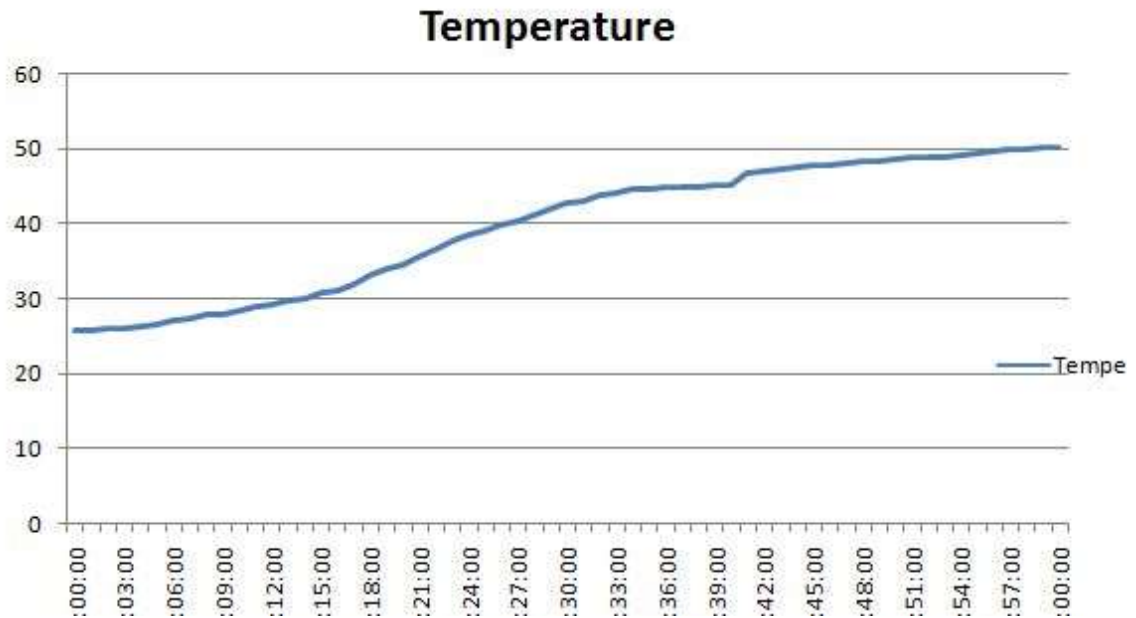
### Temperature at (11.30-2.30p.m.):



**Fig3.13 : Temperature vs Time**

During the highest sun light that is 11 a.m to 2 p.m is the perfect suitable time for solar power system as in this time maximum efficient of solar panel can be found. From input voltage reading we have seen that we are getting highest 33 voltage though voltage was not flat all the time, at first it was rising but for cloud and dust in the solar panel it gives ups and down value. However, there was some cloud throughout testing time that is why we have seen some fluctuation. We found that water temperature has risen up to 99.4 degree Celsius which is close to 100 degree Celsius and we are quite happy with reading. But what we have seen here that after certain temperature it is not getting higher anymore, that means the temperature is between 97-99 degree Celsius. So the temperature becomes saturated.

### Temperature at (3.20-4.20 p.m.):



**Fig3.14: Temperature vs Time**

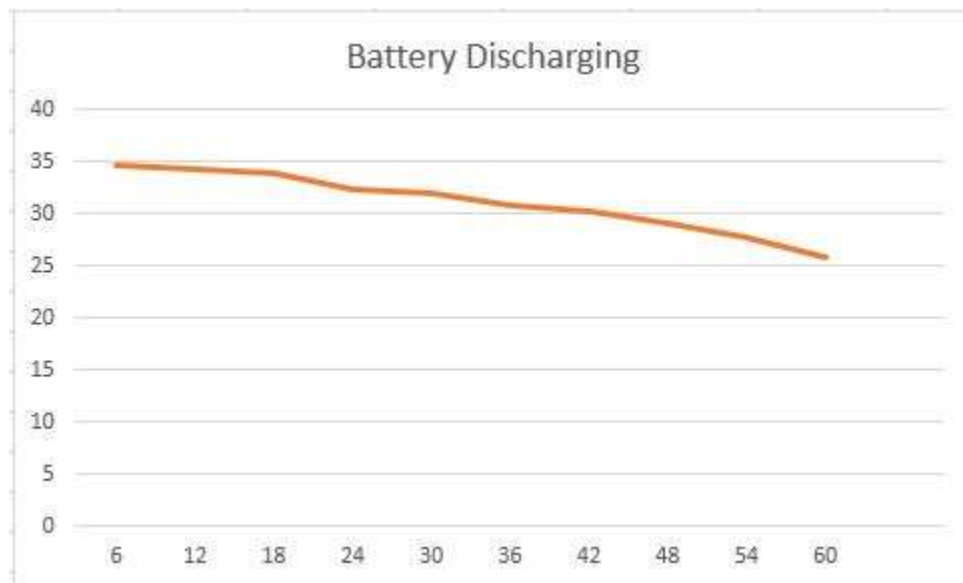
We have chosen the evening time because we want to see how the solar power system works in this project when power of sun light is lower. At the starting sun light was good enough, but as time passes the sun is setting to west gradually. So the sun radiation is decreasing as time goes. It affects the incoming voltage and voltage coming through the solar panel was lower than the noon time. However battery is backing up at this time and the output voltage is better than the incoming voltage from the solar panel. So the temperature of water is rising quickly at the starting time but as the sun light is decreasing and also battery voltage is draining, battery backup time is also decreasing, the temperature become saturated when it comes to 50 degree Celsius.

## Analyzing Battery Discharging Rate

Total 3 batteries were used in this solar heater system, 12v each. So, total battery voltage  $(12 \times 3)v = 36v$ . It was very important to check how long the batteries run without PV panels connected. In rainy days or night times we may need to use it and we should know how long we can it goes with batteries.

Discharge Time in Minute	Battery Voltage (V)
6	34.6
12	34.38
18	33.96
24	32.33
30	31.91
36	30.83
42	30.29
48	29.02
54	27.78
60	25.81

**Table 3: Battery discharging data**



**Fig3.15: Battery Voltage vs Time**

## Chapter 5

### Comparative Studies

#### 5.1 Cost comparison

Bangladesh is going through shortage of gas and the expense of electricity is getting high day by day. As well as a lot of rural people are yet to get connection of the national electricity grid network. New apartments or houses which need new connections are not getting it easily. Also now-a-days there is an extreme crisis for electricity during cultivation time and summer seasons in all over Bangladesh. More over our solar heater can also be used as a cooker. At times, it becomes very difficult to cook during peak hours as the pressure of gas remains very low. So, people are using LP gas cylinders as backup which are not at all cheap. Though our solar heater can be use at different type of field, we can compare the cost individually for different uses:

#### Cost comparison as a room heater:

If a family uses a 2KW room heater for 6 hours in a day in winter season which is generally 4 months in Bangladesh, then as DESCO billing system it will cost 8.70tk kilo watt per hour. So at the end of the season the total electricity bill will be:

$$2\text{K W} \times 6 \text{ Hr} = 12 \text{ KW}$$

$$12 \text{ Kwh} \times 30 \text{ (days)} = 360 \text{ Kwh}$$

$$360 \text{ Kwh} \times 8.70 \text{ Tk} = 3132 \text{ Tk per month}$$

$$3132 \text{ Tk} \times 4 \text{ (Month)} = 12528 \text{ Tk}$$

$$12528 \text{ Tk} \times 10 \text{ yrs} = 125280 \text{ tk}$$

If we use this heater in the poultry firm instead 100W bulb, then cost will be as follows

Cost comparison as a room heater for a 600 sq. ft. farm

$$100 \text{ W}, 100 \text{ bulbs absorbed } (100 \times 100) = 10,000\text{W} = 10 \text{ Kw}$$

$$10 \text{ Kw} \times 10 \text{ Hr} = 100 \text{ Kwh}$$

$$100 \text{ Kwh} \times 30 \text{ (days)} = 3000 \text{ Kwh}$$

$3000 \text{ Kwh} \times 9.98 \text{ Tk} = 29,940 \text{ Tk per month}$

$29.940 \text{ Tk} \times 12 \text{ (Month)} = 3,59,280 \text{ Tk}$

$3,59,280 \text{ Tk} \times 5 \text{ Yrs} = 17,96,400 \text{ Tk}$

Then again, our product uses solar power which is free of expense. Indeed, it can possibly procure some cash by sparing extra power to the batteries. In spite of the fact that the underlying expense for set up is high, yet it can be met with government's endowments to this part

## **5.2 Payback Calculations**

We calculated the cost of each component of our solar heater for the payback calculation

Panel:  $200\text{W} \times 50 \text{ BDT/W} = 10000 \text{ BDT}$

Batteries:  $3\text{pcs} \times 2500 \text{ BDT/pcs} = 7500 \text{ BDT}$

Charge Controller:  $1\text{pcs} \times 400 \text{ BDT/pcs} = 400 \text{ BDT}$

Current Controller:  $1\text{pcs} \times 750 \text{ BDT/pcs} = 750 \text{ BDT}$

Heater Coil, wires & other costs: 500 BDT

Total cost for a heater with all accessories = 19150 BDT

## **5.3 Government policy regarding renewable energy**

In Bangladesh, lately the fall of regular gas in the nation became a reason to depend of renewable resources. Till the solution is made it is recommended by the government to hold onto the characteristics of gas. Now when solar panel or the PV technology gained its popularity, the government started to receiver undertaken for new structures for the approach. Up late, RAJUK made it compulsory for new construction building to install solar panels to get power association. This way DESCO keeps in count of the number of solar panels installed and the utilization saves a lot of cost. The energy from Sun is transferred into electricity. The government policy the increased the production of such panels so for now, boards are used directly. Solar energy is later transferred into electrical energy and this also helps to supply power from the charged batteries instead of the national grid. However, nowadays also the lamp posts in the road are powered by the charged battery to save the cost and increase efficiency.

## **5.4 Limitations:**

### **Charge controller and panel**

Firstly we designed our coil for 48V so that we can get the maximum power from the heater. According to the design we have managed a standard charge controller which had some special features for the system. This charge controller had designed automatic voltage control system. It had low cutoff voltage at 40V and high cutoff voltage 48V and reconnect voltage at 42V. Which mean when the system is using only the battery and the battery voltage become below 40V then the charge controller stop the system for the safety of the battery and the system will start again when the battery voltage is 42V. And in charging time if the battery is fully charged the charge controller will automatically stop the charging of the battery. But unfortunately we could not use this charge controller because of the limitation of proper solar panel. In order to use this charge controller we had to use 480W solar panel but we were able to manage only 200W solar panel. So we had to use a normal charge controller instead of the standard one. The new charge controller also reduced our output power. And though we have shortage of solar panel we have used 36V battery. In our new charge controller the low cutoff voltage was 10V and the high cutoff voltage was 40V.

### **Battery life was not good**

For our experiment we have bought normal batteries at low cost. When we connect the battery with our system it was taking too much time for charging and during discharging it was draining too fast and the battery and systems other component became hot. Firstly we thought it may be a fault of our system and we took time to find out the fault. At last we found that we are facing this problem for our normal battery. So we replace the battery with medium quality with higher cost. And then we get our expected feedback from the panel but the battery feedback was not good because the voltage of the battery was discharging fast. We could overcome this problem by using a standard battery.



### **Efficiency of the panel was not good**

We have used monocrystalline solar panel which commonly used in our country Bangladesh. We had total 200W panel where one 100W and two 50W panel. We have connected these panels in series. According to the panel we should get around 200W load power but we measure the maximum load power from our system is 161W. So the efficiency of the solar was not good.

## **Chapter 6**

### **Conclusion**

#### **6.1 Digest**

The main aim of the project is to introduce a heating technology in household cooking using the photovoltaic system. We used modified coil to meet the expectation of electric stove, but with high efficiency. Moreover, this project includes functionality which enables the stove to operate even in gloomy days. Our main objective of this project is introducing the heating technology effectively using the photovoltaic system. Using the mud insulator and modifying the coils for our required purposes, this product gives the expected outcomes. Moreover we introduce the current controller to control the heat which can be simply used. This project also includes battery backup which will help heating during gloomy days. As time consumption could be one of the most rising questions, that is why different experiments were done on different conditions which reflect the vast effectiveness regarding time issues. Implementation of several tests demonstrate this product nicely which we mentioned on field tests section. In addition, the total cost of this product easily proves the financial advantages rather than using other limited nonrenewable resources. As future availability of nonrenewable resources for heating is a burning task, this product is a great solution introducing by the non-polluting and renewable solar energy.

## References

- [1] S. M. Istiaque, F. Z. Khanam, M. F. Matin, Thesis on ‘Design and Integrate Dual Renewable Energy in A Residential Building of Urban Area: A Step towards the Self–Sustained Smart Energy System for Bangladesh’ MIST, 2013.
- [2] R. Mayfield, Photovoltaic Design and installation: Wiley Publication, Inc, 2010.
- [3] Prof. Dr. Arninul Hoque, ‘Smart energy system future of distribution grids, storage and hybrid systems in Bangladesh perspective’, 2012.
- [4] Islam, M. (2002, May 1). Assessment of renewable energy resources of Bangladesh. Retrieved from <http://www.geni.org/globalenergy/library/energytrends/currentusage/renewable/wind/global-wind-resources/bangladesh/bangladesh.pdf>
- [5] Carlson, D., Wronski, C. (1985). Topics in Applied Physics: Amorphous Semiconductors: Amorphous silicon solar cells. Springer Berlin / Heidelberg.
- [6] NASA Surface Meteorology and Solar Energy;://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi
- [7] S. Firuz, S. Siddiqua, B.M. Nur, R. Jawad Thesis on “Development of Smart Electric Double Burner Stove Powered By Photovoltaic Energy” BRAC University, 2015.
- [8] An evaluation of 3% roof top solar panel policy in Bangladesh.(2012, May 10). *Real Estate & Housing Association of Bangladesh Web site*. Retrieved from [http://www.rehab-bd.org/An\\_Evaluation\\_of\\_3percent\\_Roof\\_Top\\_Solar\\_Panel\\_Policy\\_in\\_Bangladesh.pdf](http://www.rehab-bd.org/An_Evaluation_of_3percent_Roof_Top_Solar_Panel_Policy_in_Bangladesh.pdf)