Development of Smart Electric Double Burner Stove Powered By

Photovoltaic Energy.

A Thesis

Submitted to the Department of Electrical and Electronic Engineering

Of

BRAC University

By

Sanjida Firuz 11210010

Samira Siddiqua 11210015

Bareed Mohammad Nur 11221006

Raonaq Jawwad 11221060

Supervised by

Dr. A. K. M. Abdul Malek Azad

Professor

Department of Electrical and Electronic Engineering

BRAC University, Dhaka.

In partial fulfillment of the requirements for the degree of

Bachelor of Science in Electrical and Electronic Engineering

Spring 2016

BRAC University, Dhaka

DECLARATION

We declare here that, the research work named, “Development of smart double burner electric stove powered by solar energy” is completely our work. We have not presented it elsewhere for assessment. Materials used from external sources are properly acknowledged.

Signature of Supervisor

....

Dr. A. K. M. Abdul Malek Azad

Signature of Authors

....

Sanjida Firuz

....

Samira Siddiqua

....

Bareed Mohammad Nur

....

Raonaq Jawwad

ACKNOWLEDGEMENTS

Firstly, we want to express gratitude toward Dr. A K M Abdul Malek Azad, Professor, Dept. of Electrical and Electronic Engineering (EEE), BRAC University for his steady direction and inputs for finishing of this thesis. Furthermore, we would like to thank BRAC University for subsidizing and encouraging this task embraced by Control and Applications Research Center (CARC), BRAC University. We also want to thank the Project Engineer of CARC, Ms. Sheri Jahan Chowdhury who helped us in every single conceivable way. Our gratitude to each other individual without whose commitment this task would not be a success.

ABSTRACT

Bangladesh is facing overwhelming energy challenges that are merely likely to decline over the next few decades. Moreover, approximately fifty percent of Bangladesh's inhabitants live without electricity, and the grid expansion rate to connect rural areas is threatened by the alarming capacity shortage. By acknowledging the potential of renewable energy technologies and associated energy storage, Bangladesh could possibly meet its unprecedented energy demand, thus increasing electricity accessibility for all. Our goal is to design a project which involves the development of a solar-powered electric stove which would use sunlight as a source of power. The electricity and gas shortage in Bangladesh are strong motivators for a solar cook stove to replace the normal stoves. A successful design must be able to store solar energy, allowing the cooker to charge during the day and be used during normal cooking periods. We hope that this design could grab the attention of the investors to invest in this project and be a great initiative for effective cooking in the households of common people.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AM= Air Mass

UV= Ultra Violet

PV= Photo Voltaic

IR= Infra Red

TWY= Terra Watt Year (terra=10^12)

GWY= Giga Watt Year (giga=10^9)

MWY= Mega Watt Year (mega=10^6)

kWh= kilo Watt hour

TWh= terawatt-hours

AC= Alternating Current

DC= Direct current

SYMBOLS AND UNITS

Power P= W/ kW

Current I= A

Voltage= V

Resistance R= Ω

Irradiance G= W/m2

Insulation= H

H= J/m2

Energy E= kWh

Battery Capacity= Ah

1 kWh=3.6e+6 Joule

CHAPTER 1

Introduction

1.1 Synopsis

This project is advancement for the cooking environment in Bangladesh. It is dependent on renewable energy and also, aids in eradicating the scarcity of natural gas shortage. Electricity production in this country is always insufficient and it is not a good solution either. Use of renewable energy can help the cause and also contribute for the energy generation. To solve this problem we developed an electric stove, experimented with it and finally analyzed to check its compatibility in real market. For this stove, solar photovoltaic (PV) energy will provide the electrical energy essential for cooking. This of course needs stove development, testing and analysis and payback calculation. This paper discusses in details about each set of steps. On-field tests are also verified here. We are planning to design a cooking environment which is environment friendly at the same time compatible against cylinder gas stove and electrical stove. This stove is designed to have less wattage rating compared to the others in the market which also makes it cost effective.

1.2 Motivation and Background

Notably, Bangladesh is one of the worst victims of the large-scale energy crisis, but it is also in one of the most beneficial situations to make an evolution to a renewable energy path. Sunlight is abundant throughout the year in this semi-tropical region. Bangladesh is truly an incomparable, naturally capable and integrated, renewable 'energy mine.' Considering these facts, we have come up with a plan of a new technique of cooking which could take the full advantage of renewable energy, that is, solar photovoltaic energy. Our goal is to create a solar electric stove which is cost effective as well as similar in temperament with the typical cylinder and gas stoves.

Electricity, the most functional form of power, is one of the most significant issues for the financial expansion of a country. The average maximum demand for electricity was 3970 MW in 2007 which has increased to 4833 MW in 2011 (May, 2011) with an average increasing rate of 216 MW per annum. Under the business as usual scenario, the average demand might stand at 5696 MW by 2015. Although the government has taken several initiatives for reducing the crisis of electricity, yet the crisis perseveres. There has been an increase in the demand for electricity in the recent years as a result of industrial development and population growth. More population means more consumption of electricity. Population is escalating but the production of electricity is not increasing as required. [5]

Furthermore, Natural Gas is the most vital source of energy in our country as it accounts for about 75% of the total commercial energy of the country. At present, about 37% of production of natural gas is used as fuel for electricity generation of the country. At the present consumption rate and taking into account of 10% growth rate of gas consumption, remaining recoverable gas would be sufficient for the rest 9 years (from 2011 to 2019). At present, from 79 wells of the existing 17 gas fields, only 730 BCF (Billion Cubic Feet) gas is being supplied against the average annual demand of 912 BCF. As a result, there exists a shortage of 182 BCF of gas annually. If the reserve capacity does not enhance according to the estimation of the Gas Sector Master Plan, then after 2011 there would be huge difference between demand and supply and the present reserve may decrease to a greater extent by 2015. [5]

Encouraged by the availability of solar radiation, Power Division has initiated a program to generate 500 MW of solar-based electricity. Private sector is expected to implement commercial projects like Solar Irrigation, Solar Mini Grid, Solar Park and Solar Rooftop applications. The government is gradually meeting part of the lighting and cooling load of public offices by installing solar panels. The national capacity of solar power development currently exceeds 150 MW. According to their policy, the buildings which are newly constructed must have solar power plants on their rooftops. The output power must be at least 3% of the total peak load of the entire building. In rural areas, solar power plants are being used to run irrigation pumps.

Therefore, this system could make the most of the panels that are already placed on the rooftops of the buildings in the urban areas. Also, solar plants used in the irrigation pumps at the rural areas can also be functional for this project.

1.3 Introduction to Photovoltaic Energy

Photovoltaic cells are electronic devices that convert sunlight directly into electricity. The contemporary form of the solar cell was invented in 1954 at Bell Telephone Laboratories[11].At present, photovoltaic is one of the highest growing renewable energy technologies and it is expected that it will play a chief role in the future global electricity generation. Solar PV systems are also one of the most autonomous renewable technologies, in that their modular size means that they are within the reach of individuals, co-operatives and small-businesses who want to access their own generation and lock-in electricity prices.

At any rate, photovoltaic technology offers numerous significant benefits. First, solar power is a renewable resource that is available all over the world. Solar photovoltaic technologies are small and highly modular and can be used virtually anywhere, unlike many other electricity generation technologies. Second, unlike conventional power plants using coal, nuclear, oil and gas; solar PV has no fuel costs and relatively low operation and maintenance costs. Third, photovoltaic, although variable, has a high coincidence with peak electricity demand driven by cooling in summer and year round in hot countries.

A PV system consists of PV cells that are grouped together to form a PV module, and the auxiliary components, including the inverter, controls, etc. There are a wide range of PV cell technologies on the market today, using different types of materials, and an even larger number will be available in the future.

Solar Spectrum and its range:

In the electromagnetic wave spectrum, 99% sun rays have wavelengths within 2 µm to 4 µm. This range is from ultraviolet (UV) to infrared (IR) range. 8% of the radiation is in UV (< 0.39 µm), 46% is in visible light (0.39-0.78 µm) and 46% is in (>0.78 µm). [6]

Solar energy received at the earth's top:

Sun has a diameter of 1.39×10^6 km, whereas earth's diameter is 1.27×10^4 km. The average distance between them is 1.50×10^8 km. Those in length separation permits us will see the sunrays arriving at us as parallel beam, and the brilliance will be accepted equivalent all around those circle. The rate in which sun powered vitality lands at the highest priority on the climate may be the measure about vitality gained on unit period around a unit territory peroxide blonde of the sun's heading during the mean separation of the earth from the sun. It's worth will be 1353 Watt/m^2. This is a normal for ± 3% variety. [6]

The global solar resource is massive. Around 885 million TWh worth of solar radiation reaches the Earth's surface each year (IEA, 2011). The solar resource varies significantly over the day, week and month depending on local meteorological conditions. However, most of the annual variation is related to the Earth's geography.

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. [6]

1.4 Literature review

Cooking with solar energy is not a new notion. It had in fact started in the early period, in 1767. Nonetheless, the last twenty years have seen great developments in this field. In 1767, Horace de Saussure, a French-Swiss scientist built a miniature greenhouse with five glass boxes with one inside the other, set on a black tabletop. Fruit placed in the innermost box was nicely cooked. That was the starting of a new technology. For this, he was called the father of solar cooking. [7] The contemporary solar cooking system movement began in earnest mid-century. In 1980s Barbara Kerr, with her other colleagues, continued to develop solar cooker models. In July 1987, Solar Cooker International was founded. Now, this organization is one of the biggest one working in this field. [8]

1.5 Project Overview

This project emphasizes on reducing the gas and electricity shortage of our country and at the same time making the best use of solar power. In this system, the coils of the burners are redesigned to produce maximum heat and the controller is used to control the heat. Batteries are used as a backup of the solar power and national grid is also connected in case batteries get out of charge. Several field tests are done to check the time required for cooking different kind of foods. The overall design of this system focuses on cost-cutting measures compared to the gas and electric stoves. Our aim is to provide people with a good product which is simple to use and also to make proper application of renewable energy.

1.6 Thesis Layout

This paper has been ordered in seven 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 heat controllers are illustrated. Next, heat controller, a significant part of this system has been explained in the fourth chapter. Chapter five deals with the field and data analysis, demonstrated with tables and graphs. After that, chapter six is about the comparative studies where this solar stove is evaluated with the gas stoves; it also includes the case study analysis. Finally, the last section ends with the conclusion.

CHAPTER 2

Hybridization of Technology

2.1 Outline of Hybridizing Technology

Corresponding to budding technologies, demand for more energy makes us look for innovative energy sources. The most significant ground of this exploration is renewable energy resources. Solar energy has been a conventional source owing to ease of use and convertibility to the electric energy. This project employs hybrid renewable energy system for a domestic application to utilize the solar power. Batteries in the system are charged by solar power. A hybrid solar system combines the best of both worlds: the convenience of a battery bank with the backup of a grid connected system. This means that even during a power blackout, we still have electricity. Power resources and batteries in the system are monitored and controlled by the charge controllers. [9]

2.1.1 Design and Implementation of the Hybrid Energy System

Hybrid Solar power systems enable us to either use or store solar energy in battery bank as well as using the main electricity grid at off peak times. The hybrid solar power system that is used in our project comprises of solar panels, charge controllers, battery bank and AC grid connection. Solar energy is converted to electricity and supplied to the batteries. This system employs the AC grid connection as a backup. This allows us to make use of the stove during sunlight hours and also, at night. On the whole, the stove is quite affordable for the reason that electricity (from national grid) is used in the least amount.

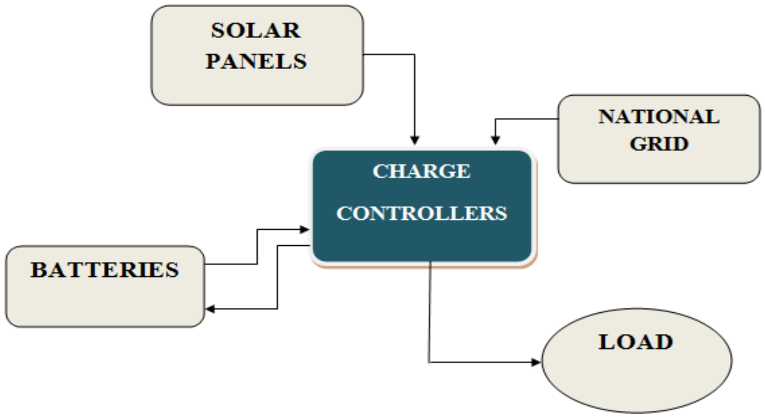


Fig 2.1: Hybrid System of our experimentation

2.1.2 System Configuration

In this setting, the batteries, charged by the solar panels, supply power to the load during the morning and mid-day and also, for some periods during the night. The national grid is brought into exercise during the darker hours and may also require charging the batteries at that moment in time. The scheme is planned in such a way that it can cook when it is a gloomy day as well. Throughout sunlight hours, most power comes from the solar panels. Additionally, the charge controllers charge the batteries in daylight hours when the stove is out of action. The system is planned to get the utmost energy and highest cooking hours.

2.2 Benefits

An advantage of hybrid systems is that they are able to control and balance the available sources of energy. If the power generated by a solar array is insufficient to supply daytime loads as well as charge the batteries, the system can recharge the batteries from the grid when a lower off-peak electricity rate is available.

CHAPTER 3
System Design

The double burner solar stove has mainly 5 components.

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

3.1 Heater Coil

For two stoves we bought two heater nicrome coils from the market. This coil is actually used for AC stove but here we used them for DC as our stove runs on DC power from solar. The coil rating was 1000W but for our system the power needed to be decreased to 500W. While decreasing the wattage we needed to find the correct voltage & current for the coil to run efficiently. There was a limitation for not to increase the voltage very high as because it will increase the cost of the battery. So the solution was to have higher current. For that the résistance of the coil needed to be decreased. As a result we made some modification of the coil.

3.1.1 Redesigning the Coil

The resistance of the existing coil was 51 ohms. To decrease the resistance we cut 3 parts from the coil. Each had 13.5 ohms. Then we connected them in parallel as we know the resistance decreases by parallel connection. The final resistance of the coil was $(13.5 \| 13.5 \| 13.5 \|)\ \Omega = 4.5\Omega$.

The parallel connection is shown in Fig 3.1

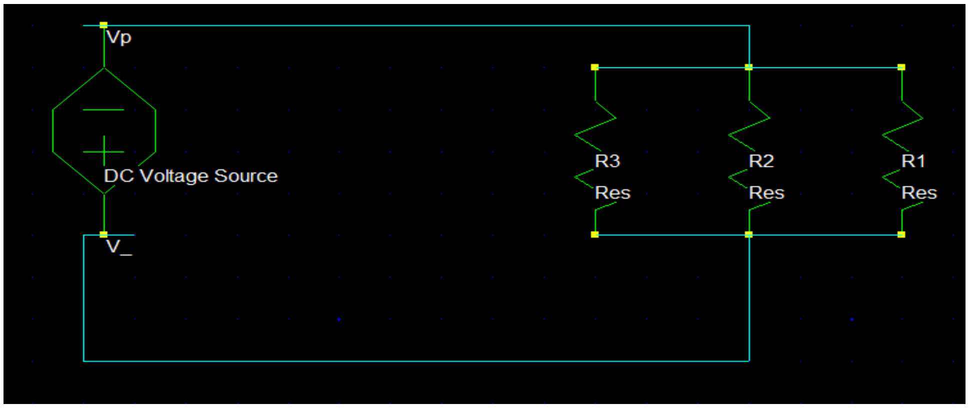


Fig 3.1: Re-designed coil simulation

Current through each of 3 pieces of the coil was 3.5A.So the total current through the stove was (3x3.5) A=10.5A

So, power P = (10.5^2×4.5) W

= 496.125W.

V= (496.125/10.5)V

= 47.25V.

So it was decided that the voltage for the stove will be 48v.[4]

For placing the modified coil in the mud casing we made two extra holes in the two corners of the casing. Fig 3.2 below will clarify the coil modification.

Fig 3.2: Re-designed coil for 2 stoves

3.2 Heat Controller

This is one of the most interesting addition in our system. We added a circuit to the system, by which the heat of the stove can be controlled by the user. We used one heat controller for each of the stove. There is a knob for each of the controller by which the user can increase or decrease the heat according to their preference.

All the details of the heat controller are given in the chapter 4. The analysis of its mechanism will be discussed there.

The Fig 3.3 shows the heat controller circuit installed in the stove

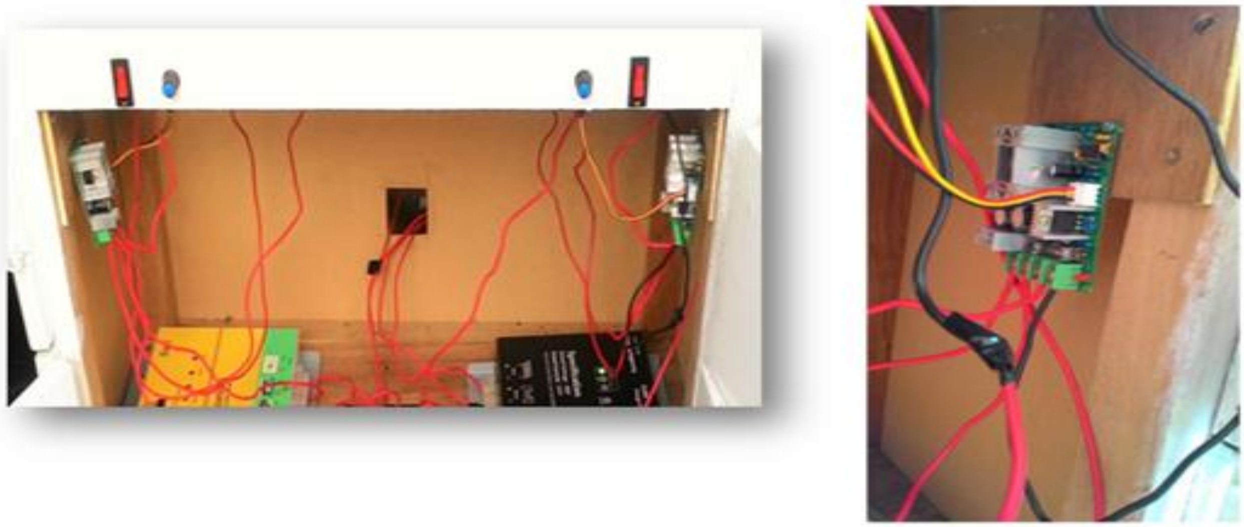


Fig 3.3: Heat controller installation

3.3 Battery

For each stove, 48v was required. So, two sets of 48v battery were used (one for each stove).In each set of 48v, four 12V sealed lead acid batteries of 20Ah were connected in series. The battery set is connected with the charge controller& it shares the load power with the solar panel. When the stove is on, one portion of the 10.5 load current comes from the battery& the rest of the current comes from the solar panel. When the load is off, the PV panel charges the battery. Fig 3.4 shows the batteries.

Fig 3.4: Batteries for 2 stoves

3.4 Charge Controller

Charge controllers were used for charging the battery and share the load power. Two charge controller were used for two stoves in our system. Each charge controller has 4 ports, PV+, PV-, Battery+, Battery -.the solar panel connection goes to the PV+ & PV- ports. Battery positive and negative terminal goes to the battery + and battery – ports. The two end of the stove goes to the battery + and battery – ports. When the stove is off, the solar panel charges the battery, through the charge controller. When the stove is on, the load current comes from the battery & the PV panel. The ratio of the current sharing depends on the sunlight. When the sun is scorching bright the PV current will provide more percentage of load current. In a gloomy day the battery can provide more percentage of the load current.

The Fig 3.5 shows the two charge controllers that we have used in the double burner Stove.

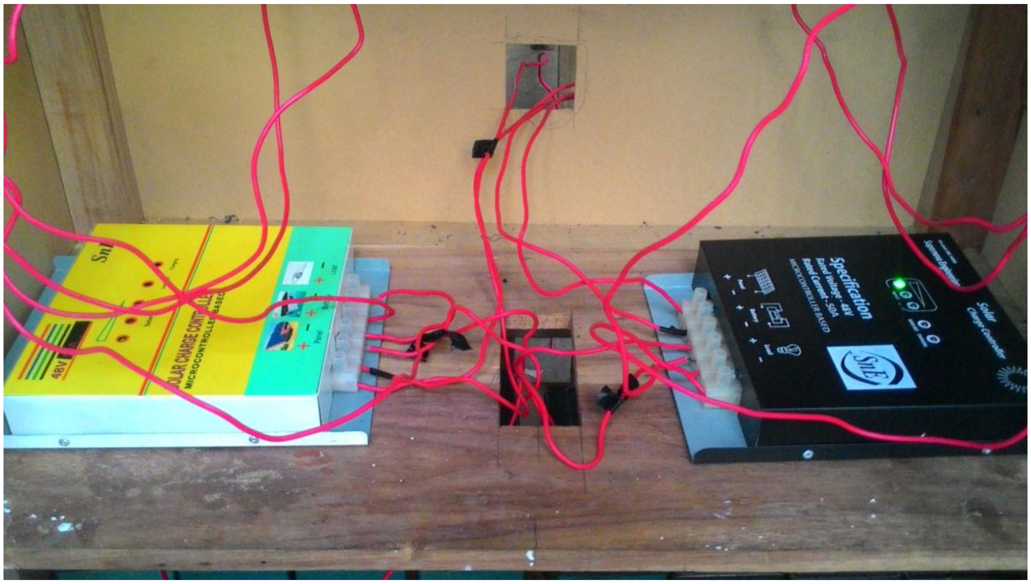


Fig 3.5: Charge controllers

3.5 Solar Panel

This is one of the most important component of the system. Each stove requires 48V, 10A.So the solar panel needs to provide that amount of current and voltage should be higher than 48v.First 2 200W panel was connected in series. Each 200W panel had the optimum operating voltage of 34.4v, so the series of two 200 W can provide at least 69v. It fulfilled the requirement of the voltage doesn’t meet requirement of current. The series of two 200W panel can provide highest 5.61A.So another series of two 180 W panels was made and connected parallel with the previous one. This set of 760W (200W+200W+180W+180W) fulfilled the requirement of voltage and current of one stove. So another set of 760 W panel was made for the second stove.

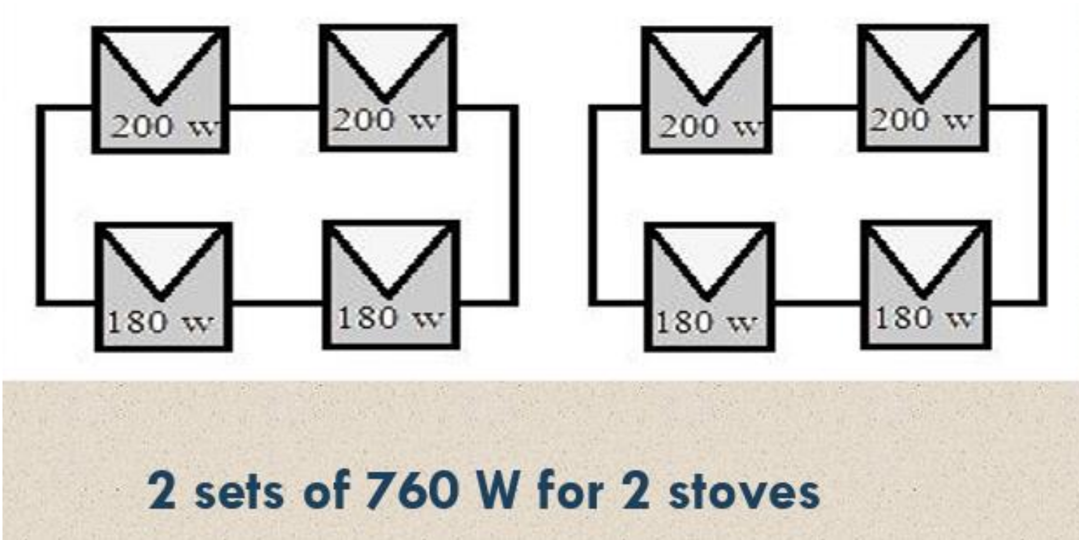


Fig 3.6: Solar panel connection

We used mono crystalline 200 W & 180W panel for the system. Here are the specification of a 200W panel &a 180W panel.

200Wp Mono Crystalline Solar Module

Electrical Characteristics	Rating
Maximum Power at STC (Pmax)	200W
Optimum Operating Voltage (Vmp)	34.4V
Optimum Operating Current (Imp)	5.61A
Open Circuit Voltage (Voc)	43.2
Short Circuit Current (Isc)	6.5A

Table 3.1:Panel specifications for 200w panels

180Wp Mono Crystalline Solar Module

Electrical Characteristics	Rating
Maximus Power At STC(Pmax)	180w
Optimum Operating voltage(Vmp)	36.00V
Optimum Operating Current(Imp)	5.00A
Open Circuit Voltage(Voc)	44.30V
Short Circuit Current(Isc)	5.48A

Table 3.2: Panel specifications for 180w panels

The Fig 3.7 shows the 760W solar panel installed on the BRAC University rooftop

Fig 3.7: Solar Panels on the rooftop of BRAC University UB02

3.6 System Block Diagram:

The following block diagram will show how the whole system works

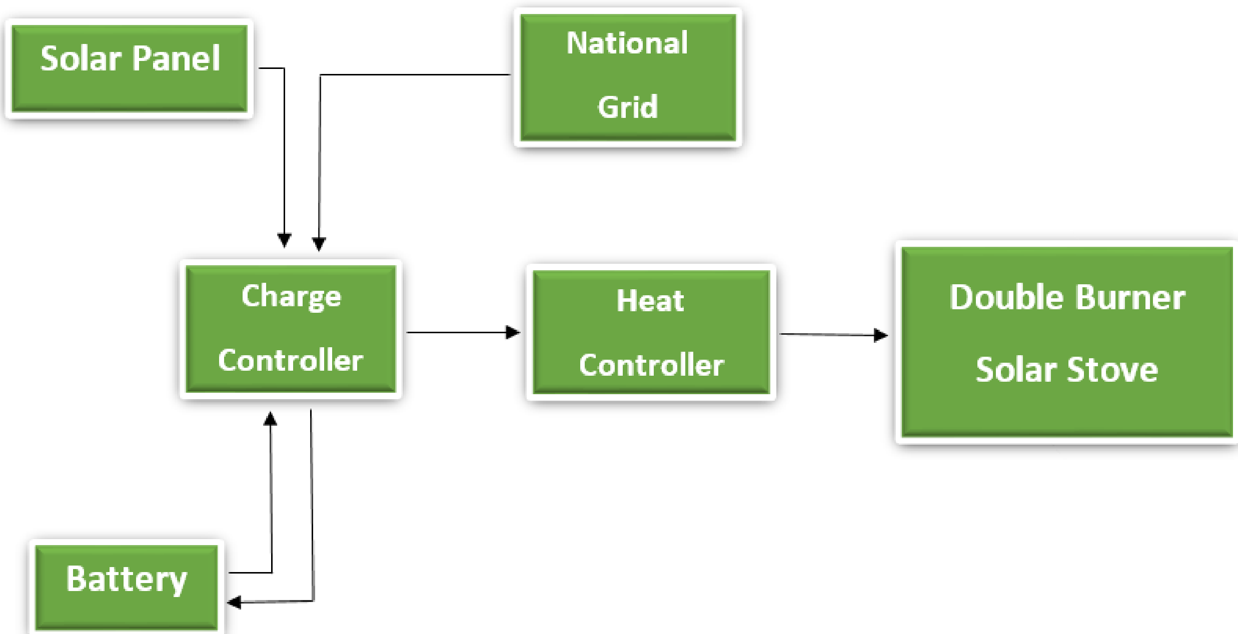


Fig 3.8: System block diagram

When the stoves are on the solar panel and the battery shares the power by sharing the supply current. When there is not enough sunlight national grid can supply the power but this is our future development plan. The power is supplied through the heat controller to control the current flow thus control the heat of the stove. When the stove is off the solar panel can charge the battery.

3.7 The Connection Diagram

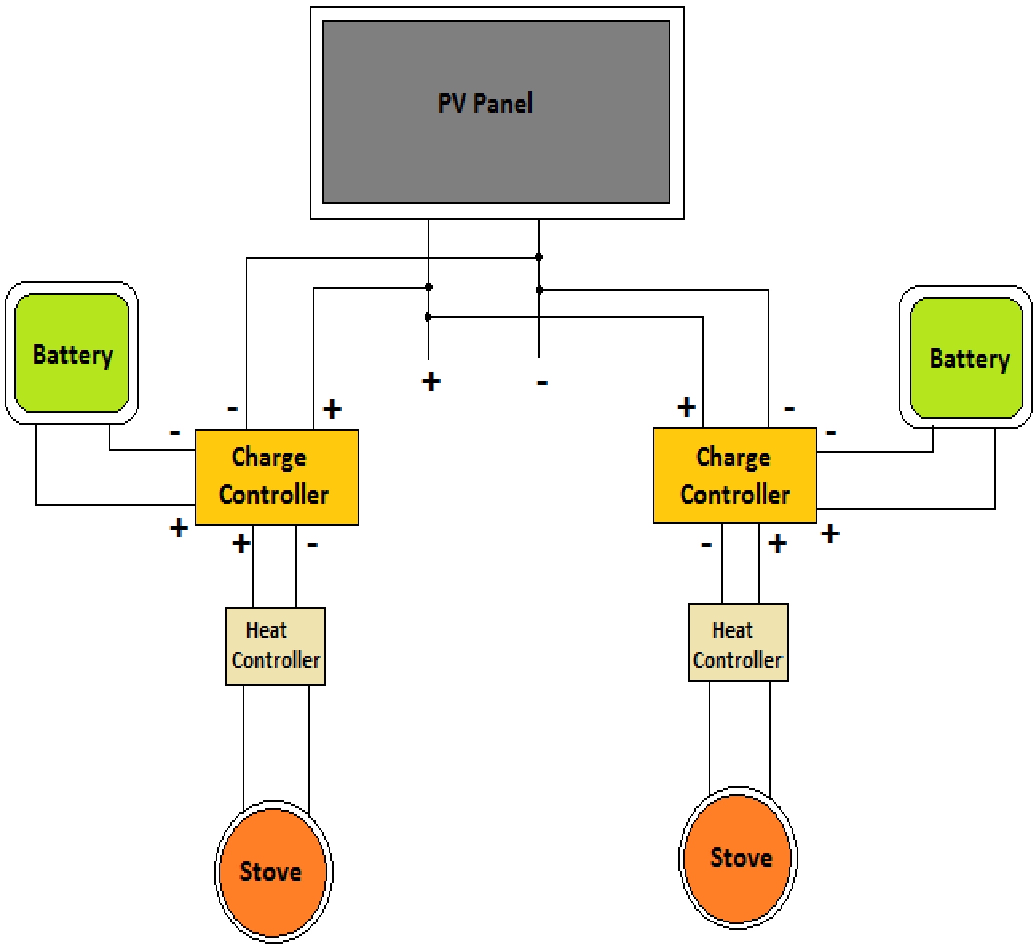


Fig 3.9: System connection diagram

3.8 Body Construction:

The whole system needs to a standard structure to operate smoothly and make it user friendly. So we have built a double burner stove body for the system. The material we used to build it is *koroy* wood & tin.

The structure of the whole body is shown in Fig 3.10

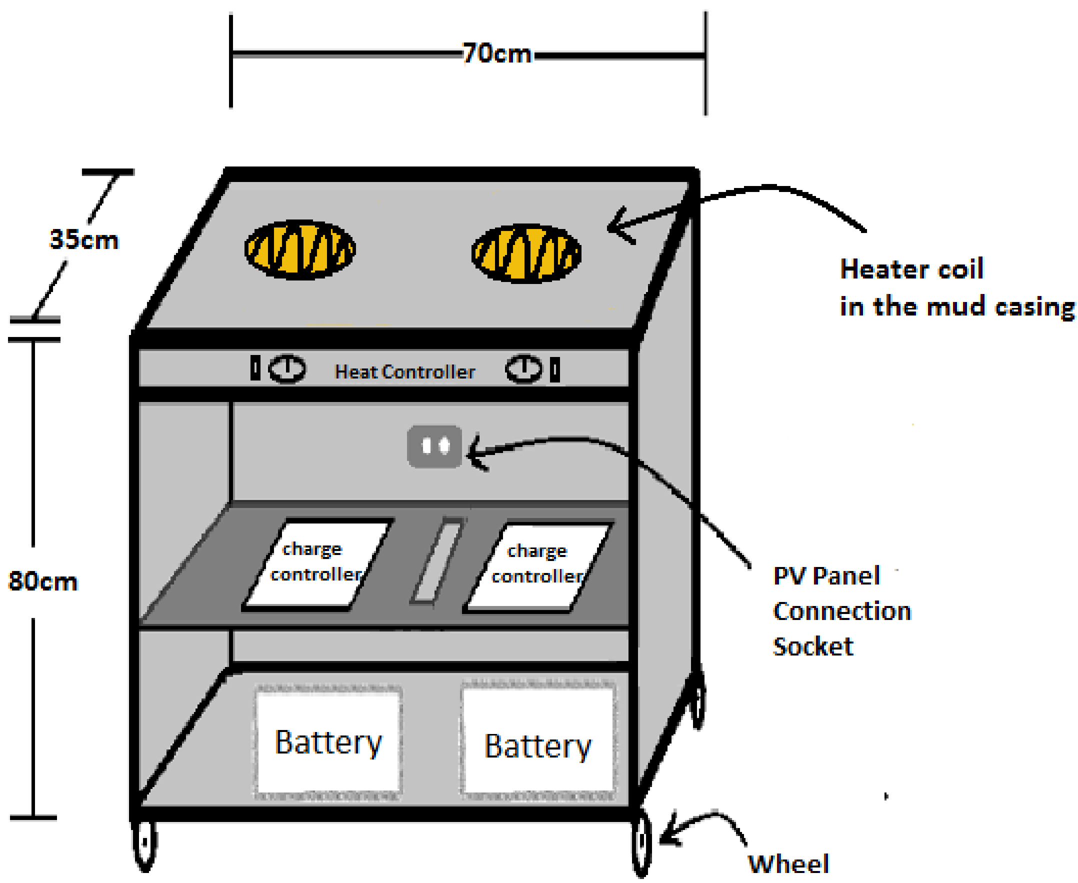


Fig 3.10: Stove body

The upper plate of the stove which hold the heater coil is made of tin. This is the same material that is used to make the gas stoves in our houses. For fixing the mud casing of the heater coil on the upper plate, we used steel bar screws. This is done under the upper plate, that is why it is not shown in Fig 3.10.

The Fig 3.11 shows the fixation of the coil casing inside the body.

Fig 3.11: Coil casing fixation

There are two shelves in the body. On is in the lower part of the body and the another one is in the middle part. These shelves are made of *koroy* wood. The lower shelf holds the 2 sets of 48v batteries and the upper shelf holds the 2 charge controllers. The shelf holding the charge controllers has a rectangular shape hole in it. The wires coming from the battery goes through the hole and connected to the battery ports of the charge controller.

The heat controller circuits are fixed in the two sides of the body. The control knob coming from the circuit are attached in a plywood board on the front side. Beside the knobs there are switches for off and on the burner. for As we have mentioned before heat controller circuit has 4 ports(2 for the power and 2 for the load).Wires   coming from power ports are connected to the charge controller on the upper shelf. The wires from the load ports are attached with the two ends of each coil. In this way the 2 burners are connected with the charge controller through the heat controller. The following image will show the heat controllers inside the body.

Fig 3.12: Heat controller inside the body

In the back side of the body there is a socket for the PV panel. It is connected to the PV ports of the charge controller. The positive and the negative wire from the PV are connected to the socket. The whole system gets the power from the PV panel.

As the whole structure is heavy, it's not possible to drag the whole thing for moving. So, we have attached 4 wheels under the body. This will give us easy portability as we can move it very easily.

The whole structure dimension is 70cm*35cm*80cm, 70 cm length, 35 cm breadth and 80cm height. The charge controller shelf is 30cm above the lower shelf.

Fig 3.13: Stove body outlook

CHAPTER 4

Heat Controller

One of the main component of the stove is heat controller. This component can decrease and increase the heat of the coil. The controller takes the power from the load side of the charge controller and the coil's two sides are connected to it. There is a volume knob in it which can control the current to the coil.

The fig 4.1 shows the connection of the heat controller.

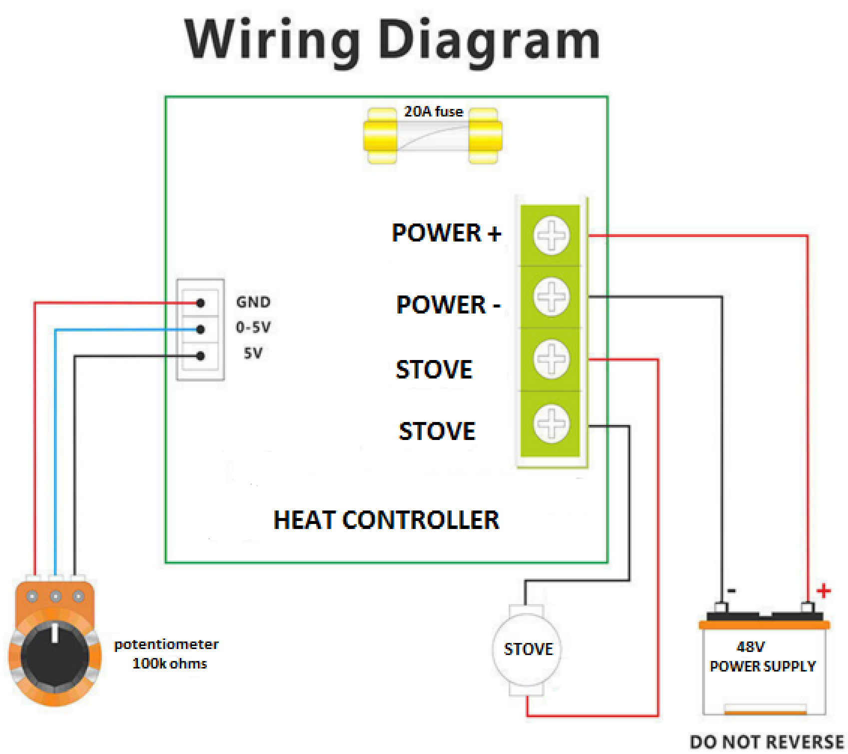


Fig 4.1: Heat controller connection diagram

The main job of the heat controller is to control the current supply to the coil as the heat of the coil is proportional to the current flowing through it. Connecting a variable resistor or a rheostat is series with the load can vary the current, but in this system the current is too high for the variable resistor. For handling with this big amount of current pulse with technology was needed.

4.1 Pulse Width Modulation

Pulse Width Modulation (PWM) is method of providing partial power to the load by changing the off & on period for providing the power. It is a powerful way of control a digital signal by means of altering it's on & off state and frequency of this. In this technique a square wave of the signal is modulated. Here is how a square wave looks like.

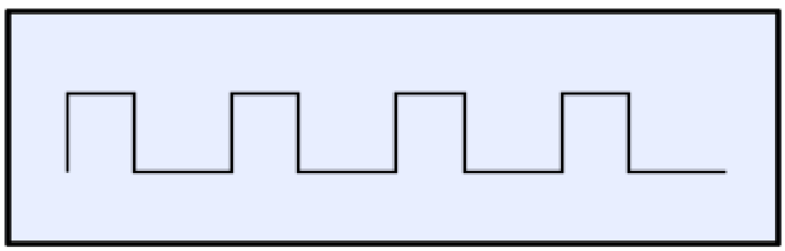


Fig 4.2: Square wave

This modulation changes the duty cycle of the signal. Duty cycle is a percentage measurement of how long the signal stays on. The image below will give a clear idea about the duty cycle

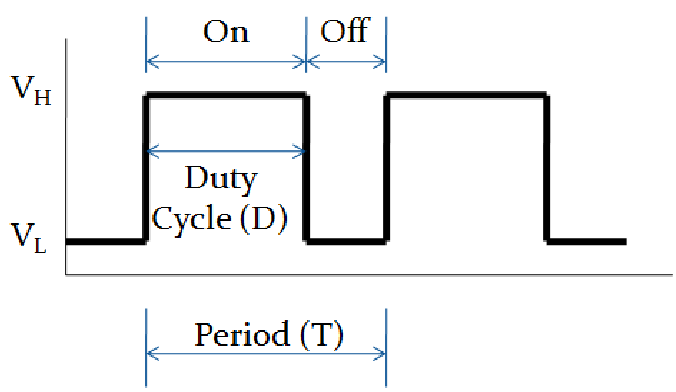


Fig 4.3: Duty cycle and period

The period of a signal consist of the on state & off state. The duty cycle of a signal is determined by

$$Duty\ cycle = \frac{On\ Time}{Period} \times 100\%$$

In the modulation of the duty cycle, when the on state lengthen, the off period is shorten. Again when the duty cycle is shorten the off time is lengthen. The duty cycle is changed but the period is always same. So the frequency is also always same as frequency is just the inverse of the period. Frequency of the signal measured in Hz.[10]

The image will show different modulation of a signal.

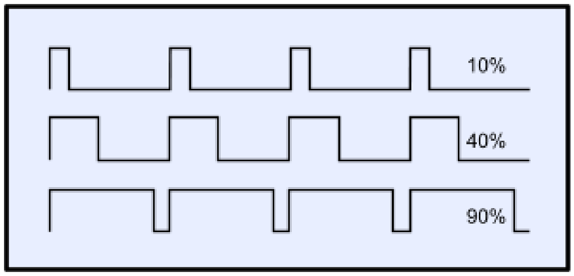


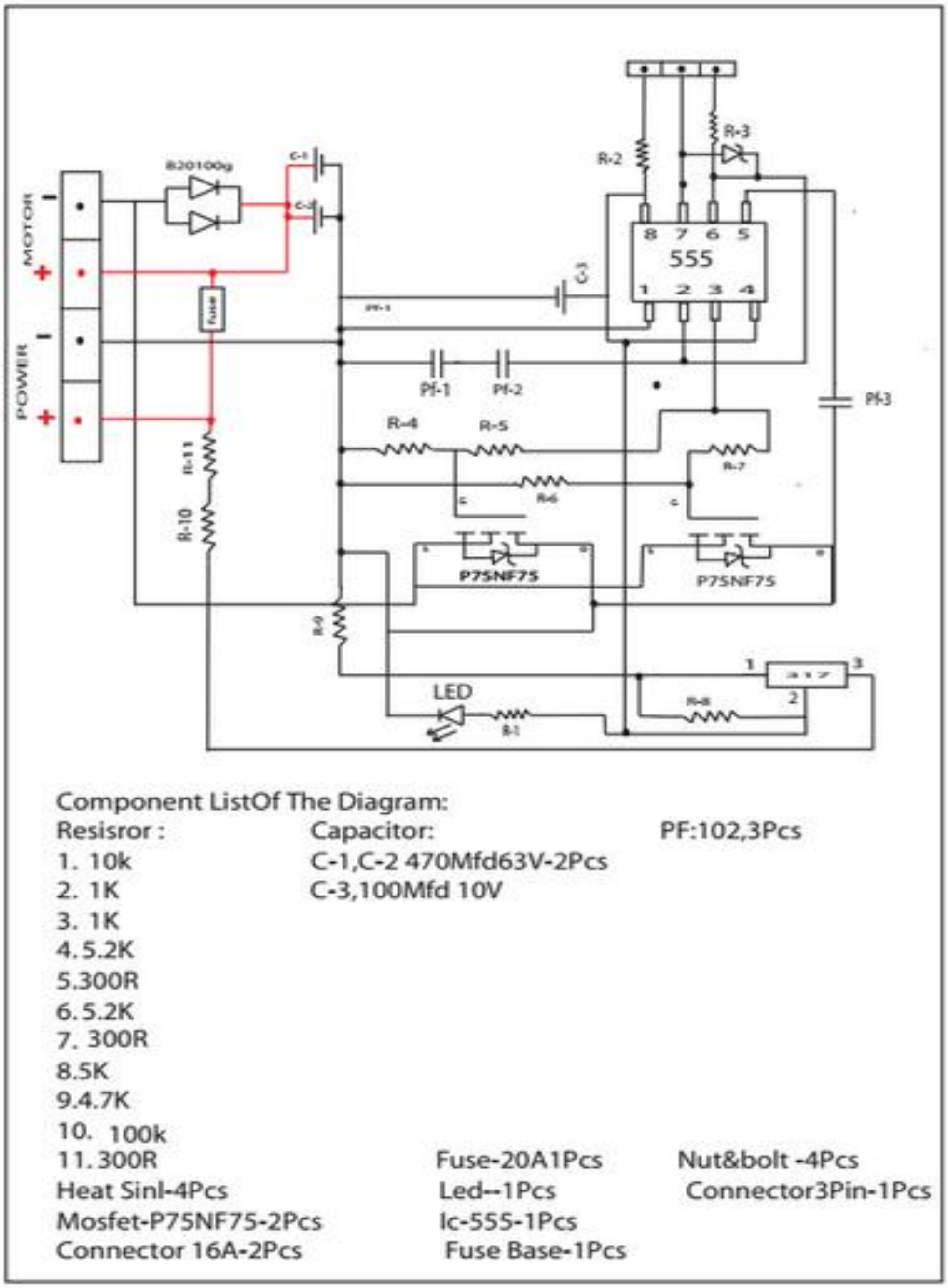
Fig 4.4: Different modulation

Here 10% duty cycle means that the positive stated remains positive for 10% of the period of the signal. This technique is applied in in the heat controller. There is a volume type potentiometer in the circuit which can change the duty cycle. When the duty cycle is 10%, only 10% of the full current is supplied to the coil thus the heat is reduced to 10% of the full heat.

4.2 Circuit components:

- ❑ Capacitor
  - P75NF75&
  - LM317T
  - B20100G
  - 555 timer
- ❑ Capacitor (100 µF, 470µF, 1000 pF)
- ❑ Resistor(10k, 300, 5.2k, 1k, 100k, 4.7k, 5k)
- ❑ 20A fuse
- ❑ Led
- ❑ Power connection & stove connection ports
- ❑ 100k Potentiometer
- ❑ Potentiometer connection port

4.3 Circuit diagram:



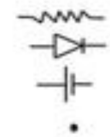


Fig 4.5: Circuit diagram

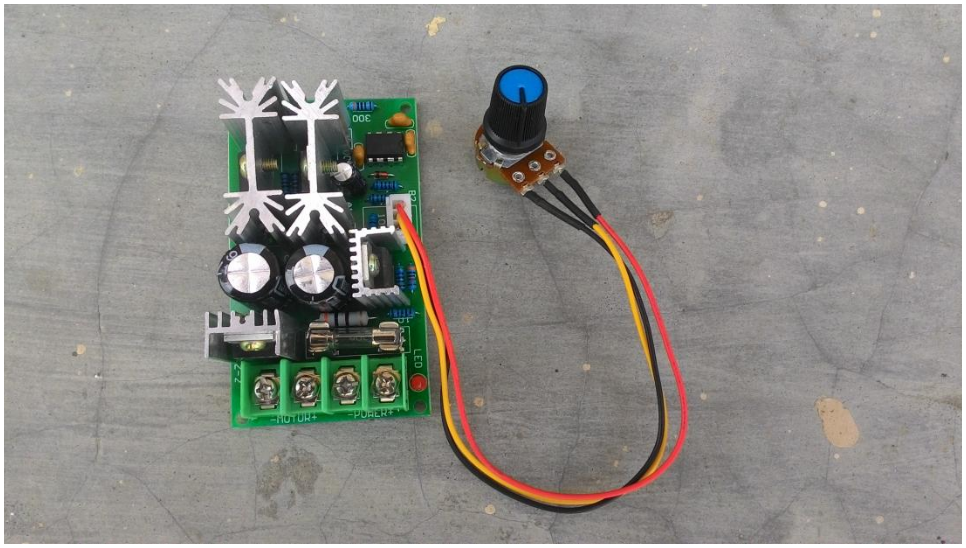


Fig 4.6: Heat controller outlook

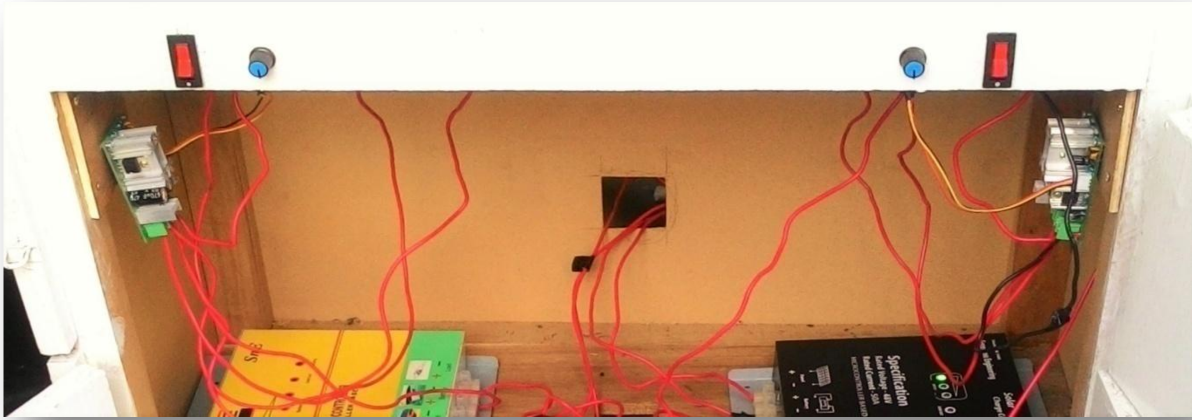


Fig 4.7: Heat controller fixation

CHAPTER 5

Field Test and Analysis

Basically, our field test was to cook different types of food items with the whole set up. We set up the whole system of our stove on the rooftop of 20^{th} floor of BRAC University UB02,Dhaka, Bangladesh. This field test was very important to check the efficiency of the stove. It was very necessary to check how efficiently it can cook, how much time it takes to cook different food items and what are the difficulties one can face while cooking. We cooked using two stoves simultaneously and also made proper use of the heat controller by maximizing and minimizing the heat according to necessity. 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 user friendly or not.

5.1 The Main Objectives of Field 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 controllers are compatible with the whole system or not.
- The heat controllers are behaving perfectly or not.
- How long it takes to cook different food items.
- How efficient the heat controllers are.

5.2 Choosing Food Items and Deciding Quantities for Each Item

Our target was to cook items which were common and necessary to a normal household. That was why we chose boiling water, cooking rice, noodles, frying fish fillet etc. We wanted the quantity of food to be same as a household including 4/5 people would need

5.3 Data Acquisition Method

We have used Clamp meter to measure high current, Multimeter to measure voltage and Thermometer to measure temperature while needed.

5.4 Boling Water and Cooking Different Food Items

5.4.1 Data of Boiling Water in the Field Test:

We boiled 500ml water with our stove in the field test. Both solar panels and batteries were connected to the system for power supply. The stove was giving maximum heat as we did not minimize the heat with heat controller during the whole boiling process. We used an aluminum pot with a lid for this process. Initial time to start water boiling was 1.22 PM and initial temperature was 25 Degree Celsius.

Time	PV (I)	PV (V)	Batt. (I)	Batt. (V)	Load (I)	Load (V)	Temp.	PV Power	Batt. Power	Load Power
1:24 PM	2.5	55.5	7.6	53.3	10.8	53.7	34	138.75	405.08	579.96
1:26 PM	3.7	53.2	8.8	52.8	11.3	52.5	47	196.84	464.64	593.25
1:30 PM	4.4	51.5	7.5	51.8	10.9	52.3	72	226.6	388.5	570.07
1:34 PM	4.9	50.7	5.9	51.4	10.3	51.7	91	248.43	303.26	532.51
1:36 PM	4	50.4	5.6	50.2	9.7	50.1	100	201.6	281.12	485.97

Table 5.1:data of boiling water in field test.

5.4.2 Data of Cooking Rice in the Field Test:

We cooked half kg rice as it would be perfect for 4/5 people. Again we used an aluminum pot with a lid and did not the heat as rice is cooked best in full heat in gas stoves also.

time	pv I	pv V	batt. I	batt. V	load I	load V	pv power	batt. power	load power
12:04 PM	3.9	53.5	4.9	51.9	9.6	51.8	208.65	254.31	497.28
12:09 PM	4.4	48.2	5.6	48.4	9.7	48.7	212.08	271.04	472.39
12:14 PM	5.3	46.6	5.5	47.6	11	47.7	246.98	261.8	524.7
12:19 PM	4.7	49.4	6	48	10.5	47.8	232.18	288	501.9
12:24 PM	5.5	47.5	5.2	46.7	11.3	46.6	261.25	242.84	526.58
12:29 PM	4.8	46.5	5.7	47.7	10.7	46.6	223.2	271.89	498.62
12:34 PM	4.4	47.2	5.5	47.3	9.5	47.5	207.68	260.15	451.25
12:39 PM	3.7	48.5	3.9	47.8	9.3	47.5	179.45	186.42	441.75

Table 5.2: data of cooking rice in the field test.

5.4.3 Data of Cooking Noodles in the Field Test:

We took 1 packet of instant noodles to cook. An aluminum pot with a lid was used to boil the noodles and a nonstick frying pan was used to finish the cooking with oil and spices.

time	pv I	pv V	Batt I	Batt. V	Load I	Load V	pv power	batt. power	load power
1:49 PM	1.9	51.4	7.7	51.2	9.7	51.9	97.66	394.24	503.43
1:54 PM	3.6	50.2	6	49.4	9.5	49.4	180.72	296.4	469.3
1:59 PM	3.3	50.4	6.2	50	9.3	50	166.32	310	465

Table 5.3: data of cooking noodles in field test.

5.4.4 Data of Frying Fish Fillet in the Field Test:

A nonstick frying pan was used to fry the fish fillets.

time	pv I	pv V	Batt. I	Batt V	load I	load V	pv power	batt. power	load power
12:09 PM	4.3	52.7	5.4	51.7	9.8	51.8	226.61	279.18	507.64
12:14 PM	3.8	53.5	5.8	52.3	9.6	51.9	203.3	303.34	498.24
12:19 PM	5	52.2	4.7	51.7	9.6	51.7	261	242.99	496.32
12:24 PM	4.8	51.6	4.9	51.1	10	51.2	247.68	250.39	512

Table 5.4: Data of frying fish fillet in field test.

5.5 Time Duration for Cooking Different Items and Boiling Water

Here is an overview of time duration of cooking and boiling water in the field test.

No of items	Name of the items	Time duration in minutes
1	Boiling Water(1/2 litre)	14
2	Rice(1/2 kilogram)	35
3	Fried egg	4
4	Noodles	10
5	Chicken fry	22
5	Fish fillet	15
7	Lentils	45
8	Vegetable	40

Table 5.5: Time duration record for cooking on field test.

5.6 Comparative Studies

As our main competition is with gas stoves, we compared the timings with gas stove. Table 5.6 shows the comparison below.

No of items	Name of the items	Duration in gas stove in minutes	Duration in experimental stove in minutes
1	Boiling water(500ml)	8	14
2	Rice(.5kg)	25	35
3	Noodles	8	10
4	Fish fillet	12	15
5	Chicken fry	16	22
6	Egg	4	4
7	Lentils	34	45
8	Vegetables	30	40

Table 5.6: Comparison between the timing of gas stove and experimental stove.

As we can see from the above data sheet that even though the smart electric stove must have taken more time then gas stove for cooking, the difference is not huge. As our stove is much more beneficial than gas stove from environmental and economic perspective this time difference can be ignored. The foods were cooked within decent time duration and it can be used for a family. Also we cooked with two burners simultaneously so much time was saved here.

5.7 Power Sharing Between PV Panels and Batteries

When the stoves are off, the batteries are charged by the PV panels. At the time of cooking, the load power is shared by the batteries and the PV panel. We cooked different food items in the stoves and collected the data from the system. We analyzed the voltage and current of the batteries and the PV panel during the cooking time and found the power percentage sharing.

Power received from panel	Power received from batteries
212.08	271.04
246.98	261.80
232.18	288
261.25	242.84
223.2	271.89

Table 5.7: Power sharing between solar panels and batteries.

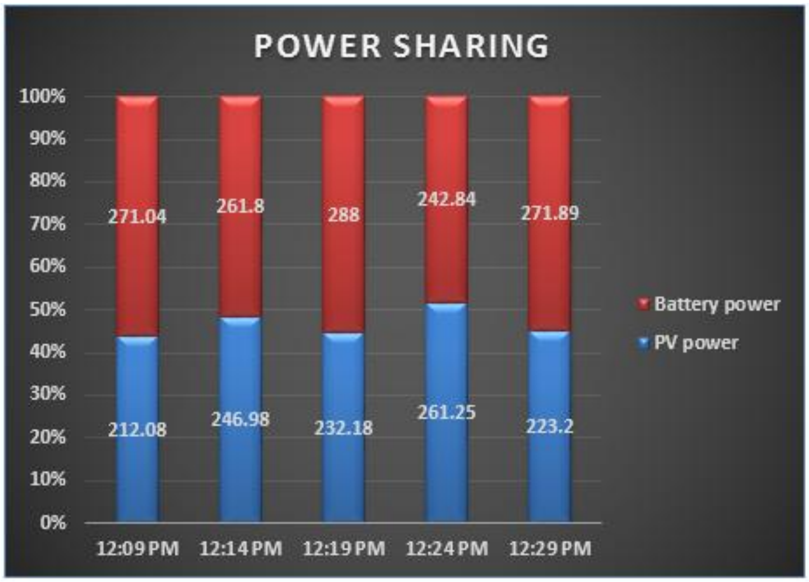


Fig 5.1: Bar chart percentage of power from panels and batteries.

This experiment was done with the load full on. That means the heat controller was on maximum.
No cooking was actually done at that time.

5.8Analyzing Battery Discharging Rate

Total 8 batteries were used in this system, for each stove 4 batteries. Each battery is 12v. So, total battery voltage (12*4)v+(12*4)v=48v+48v. 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 cook and we should know how long we can cook with only batteries. Though most of the cooking are generally done in daytime in households, we needed to know this because we are using batteries as our backup. So in this case, only batteries were connected to the load.

- Took 40 minutes to come down to 25% of the battery charge

INITIAL VOLTAGE	DISCHARGING TIME	TOTAL VOLTAGE(V)	CURRENT(Amp)
51.4 V	5 MIN	51	10.7
	10 MIN	50.6	10.4
	15 MIN	49.4	10.2
	20 MIN	48.5	10.2
	25 MIN	47.8	10.2
	30 MIN	47.5	10.1
	35 MIN	47.2	10.1
	40 MIN	46.6	10.1

Table 5.8: Record of batteries' discharging data.

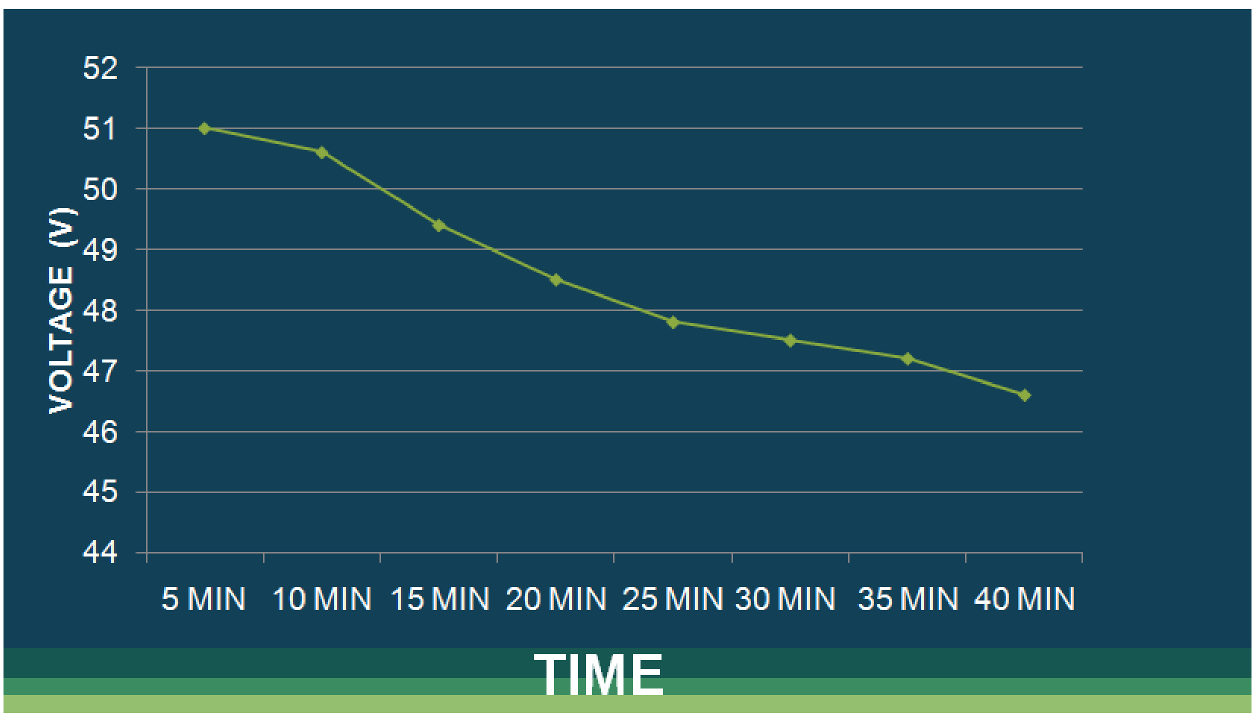


Figure 5.2: Graphical representation of rate of discharging battery.

5.9 Subjective Analysis

During the whole cooking process, no noticeable disturbance was occurred, nor did the product harm anyone. The heat controller was also behaving perfectly. So, we can say that product is safe and user friendly. One important thing one should care about while cooking is to save the system form getting wet. This can dysfunction in that case and also the coiled can damage being short circuited.

CHAPTER 6

Comparative Studies

6.1 Cost Comparison with Cylinder Gas Stove

Bangladesh is going through shortage of gas. That is why a lot of urban people are yet to get connection of the national gas network. New apartments or houses which need new connections are not getting it easily. Also now-a-days there is an extreme crisis of gas in all over Bangladesh. 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. For example, one gas cylinder of 12 kg is 2500. Table 6.1 gives the brief…overlook of how much cylinders can cost for small, moderate and large families.

Family Size	**Cylinder consumption**	**Per cylinder cost**	**Total cost per month**	**Total cost per year**
Big (8-10 people)	2	2500 BDT	5000 BDT	60,000 BDT
Moderate(5-7 people)	1.5	2500 BDT	3750 BDT	45,000 BDT
Small(2-4 people)	1	2500 BDT	2500 BDT	30,000 BDT

Table 6.1: Cost Calculation of Gas Cylinders

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.

6.2 Payback Calculations

For doing this calculation we first analyzed the present cost that the normal people has to bear for cooking. Almost every house in Bangladesh is depended on gas for cooking. Due to over use of the nation gas network, the new apartments will not get gas connection in recent times, that is why people are getting heavily involved with the gas cylinder now a days. Per cylinder cost is 2500 BDT.

Table 6.1 shows the yearly Expenditure for cooking with the cylinder gas :

We calculated the cost of each component of our double burner stove for the payback calculation

Panel: 1520W*63 BDT/W = 95760 ≈ 96000 BDT

Batteries: 8pcs*2500 BDT/pcs = 20000 BDT

Charge Controller: 2pcs*5000 BDT/pcs = 10000 BDT

Heat Controller: 2pcs*750 BDT/pcs = 1500 BDT

Stove body making cost: 4000 BDT

Heater Coil, wires & other costs: 500 BDT

We have done the payback calculation for two cases. For **case 1** we calculated our system cost including the panel cost. For **case 2** we have calculated it excluding the panel cost. The reason behind t case 2 is, the apartments which have already installed solar panel during the building construction don't need to spend for the panels as the consumer can get the power from the pre-installed PV panels.

Case 1 (including the PV panel): Total cost for the double burner solar stove: 96000 BDT + 36000 BDT=132000 BDT

If a family use the solar stove instead of the cylinder gas, the total money can be paid back in less than 3 years (for moderate family) and approximately 4 years for small family

Case 2 (excluding the PV panel): Total cost for the double burner solar stove: 36000 BDT

If a family use the solar stove instead of the cylinder gas, the total money can be paid back in less than 10 months (for moderate family) and approximately 15 months for small family.

6.3 Government’s Policy Regarding Renewable Energy

Bangladesh government is looking for option for energy source due to declination of held regular gas in the nation. The nation likewise could not meet the objective of store of regular gas in the year of 2010. Therefore a few procedures were attempted to relieve the dependence on characteristic gas. Solar energy venture came in such manner as a promising one. To set up the undertaking government forced a few approaches for the new structures. "This strategy requires that all recently built structures must incorporate a housetop solar power unit with a yield at least 3% of the structures complete top load."[1] So, this task will be a solid match to full fill the required interest of utilizing sun solar energy. One must purchase solar panels to get power association and the significant part of the expense of this venture is because of panels. In this way, this undertaking can without much of a stretch turn into a decent decision for using boards.

CHAPTER 7
Conclusion

7.1 Digest

This project is the solution of household cooking introducing solar energy which is sustainable for energy consumption. 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 which are nearly like electric stoves. Moreover we introduce the heat controller to control the heat which can be simply used. This project also includes battery backup which will help on cooking 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[3].As future availability of nonrenewable resources for cooking is a burning task, this product is a great solution introducing by the non-polluting and renewable solar energy.

7.2 Proposed Home System

The solar rooftop system in urban areas of Bangladesh has not been a success story; mainly because of the lacking of the understanding level of consumers realizing the proper usefulness of it. In this Dhaka city there are many apartments having solar rooftop system but it is not successful yet for not getting the desired result according to their expectations[2]. This “Double Burner Solar Stove” could be the first initiative by focusing their demand. This product can easily cook different items continuously using this solar rooftop system. This product could demonstrate the proper usefulness of the solar rooftop system. The solar industry in the world is growing so rapidly that it is now become necessary to update the units of measurement from megawatts (MW) to gigawatts (GW). And it is mentioned earlier that about 37% of production of natural gas is used as fuel for electricity generation of the country. Considering that limitation of natural gas and the scarcity of other resources, this solar power product can easily fill our cooking purposes maintaining the green economy.

REFERENCES

[1] 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

[2] Mahmud, F. (2016, January 3). Solar rooftop system. Retrieved from http://www.theindependentbd.com/printversion/details/28862

[3] Advantages of Rooftop Solar Systems. (2014, March 4). *Renewable Energy Corporation Website.* Retrieved from http://renewableenergysolar.net/advantages-rooftop-solar-systems/

[4] Islam, S., Azad, S.B., Fakir, H., Rahman, R., Azad, A. (2014, August 6-9). Development of electric stove for the smart use of solar photovoltaic energy. Retrieved from http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=7026328&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel7%2F7008054%2F7026305%2F07026328.pdf%3Farnumber%3D7026328

[5] 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

[6] Muhammad, I. (2013, May 27). Lecture 2 on “Solar Energy” by Dr. Ibrahim Muhammad,BRAC University

[7] Buti,Perlin, (1980). The Burning Mirror

[8] Knudson, B. (n.d.). State of the Art of Solar Cooking

[9] Fesli, U., Bayir, R., Özer, M. (n.d.). Design and implementation of a domestic solar-wind hybrid energy system. Retrieved from http://www.emo.org.tr/ekler/bda318ed422ebd9_ek.pdf

[10] Lazaridis, G. (2009, March 10). PWM modulation. Retrieved from http://pcbheaven.com/wikipages/PWM_Modulation/

[11] Nagy, A. (2014, April 25). 60 Years ago today, Bell Labs unveiled the solar Cell. Retrieved from http://gizmodo.com/60-years-ago-today-bell-labs-unveiled-the-solar-cell-1567543841