Development of Electric Stove for Smart use of Solar Photovoltaic Energy with National Grid.

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By

Md. Shariful Islam- 10121068
Md. Sabbir Bin Azad- 10121085
Humayra Fakir Rongon- 10121039

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
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DECLARATION

We hereby declare that research work titled "*Development of electric stove for smart use of photovoltaic energy with national grid*" is our own work. The work has not been presented elsewhere for assessment. Where materials were used from other sources, it has been properly acknowledged/ referred.

Signature of Supervisor

……………………………
Dr. A. K. M. Abdul Malek Azad

Signature of Authors

....
Md. Shariful Islam

……………………………...
Md. Sabbir Bin Azad

……………………………...
Humayra Fakir

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Abstract

Saving energy is now one of the major concerns for the researchers. Still a lot of fossil fuels are being consumed directly or indirectly just for cooking and hence affecting the global environment. With the rapid increase in demand of energy for cooking with proportion to population increase, it will not take much time to finish all the resources that are available now. According to the thesis, energy for cooking is mostly supplied from solar photovoltaic panels in alliance with national grid line. The major contribution of this project will be the invention of re-designing existing stove coil. The national grid will be in action only when, panel and battery are not giving sufficient power to the load. An Electric Charge Controller will ensure safety of the system and store charge in the Battery. The research given in this thesis aims at analyzing the time requirement for cooking same foods in comparison with the gas or normal electric stove. To show the effectiveness as compared to natural gas or electric stove, the thesis contains a huge statistical data, taken for a number of times. Modification of the stove for providing variable energy to cook different food is the future work of the thesis.

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ABBREVIATIONS

AM= Air Mass

UV= Ultra Violet

IR= Infra Red

BTOE= Billion Ton Oil Equivalent

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

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

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

AC= Alternating Current

DC= Direct current

kWh= kilo Watt hour

PV= Photo Voltaic

toe = tones oil equivalent

SYMBOLS and UNITS

Power P= W/ kW

Current I= A

Voltage= V

Resistance R= Ω

Energy E= kWh

Battery Capacity= Ah

Irradiance G= W/m^2

Insulation= H

H= J/m^2

1 barrel = 0.1364 toe

1 tcf = 25.4851650054429 mtoe

1.5 tones of hard coal = 1 toe

3 tones of lignite = 1 toe

CHAPTER 1

Introduction

1.1 Introduction to Photovoltaic Energy

Solar Spectrum

Considering the spectrum of the electromagnetic waves, 99% of the Solar radiation has a wave length within the range 0.2 to 4 μm, which is from ultraviolet (UV) to infrared (IR) range. 8% of the radiation falls within UV (< 0.39 μm) 46% within visible light (0.39-0.78 μm) and 46% within (> 0.78 μm). [**1**]

From the earth's perspective sun can be regarded as a disc with a diameter 1.39×10^6 km, whereas earth's own diameter is 1.27×10^4 km. The mean distance between the two is 1.50×10^8 km (distance varying throughout the year). The long distance allows us to regard the sunrays reaching us as parallel beam, and the brightness is assumed equal throughout the disc.

Solar constant (G_{SC}): energy received at the top

The rate at which solar energy arrives at the top of the atmosphere is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun.

Its value is 1353 Watt/m^2. This is an average with ± 3% variation. [**1**]

Some definitions useful for the calculation of radiation

- Air Mass(AM) = $\frac{\text{Optical thickness of atmosphere through which the beam comes}}{\text{Optical thickness of atmosphere if the sun is at zenith}}$
- Beam Radiation (or Direct Radiation) = The solar radiation received without being scattered by the atmosphere.

- Diffuse Radiation= The solar radiation received after its direction is changed by scattering by the atmosphere.
- Total Solar Radiation= Beam Radiation+ Diffuse Radiation
- Irradiance (G)= The rate at which energy is incident on a surface per unit area of the surface, in W/m^2

Irradiation or Insolation (H, I) = The incident energy per unit area on a surface found by integration of G over a time in J/m^2.

Symbol H is used insolation over a day. Symbol I is used over an hour.

Attenuation of beam radiation

This takes place by two processes – absorption and scattering.

i. Absorption: UV is absorbed by ozone layers. IR is absorbed by CO_2 and moisture. These narrow the band width that is transmitted mostly within 0.29 μm to 2.5 μm.

ii. Scattering: Water vapor, dust particles etc. scatter the light to various directions. Under favorable atmospheric conditions, the maximum intensity observed at noon on a properly oriented surface at sea level is 1 kw/m^2. Here Air Mass is AM1. As we go up Air Mass is reduced and at the top it is Solar constant G_{SC} which is Air Mass zero AM O.

1.2 Advantages of PV Energy to the Economy and Environment

Fossil fuel	Unit	2011 production	Reserves	Reserves-to-production ratio (years)	Recoverable resources
Crude oil	million barrels	31,875	1,642,354	52	3,356,964
Wet natural gas	trillion cubic feet	124	6,839	55	22,882
Coal	million tonnes	7,710	1,037,552	135	22,308,986
Hard coal		6,640	754,595	114	17,873,677
Lignite		1,070	282,957	264	4,435,309
Sources: Andruleit et al. (2012); U.S. EIA (2013)					
Fossil fuel	Unit	2011 production	Reserves	R/P (years)	Resources
Crude oil	million toe	4,348	224,017	52	457,890
Wet natural gas	million toe	3,160	174,293	55	583,152
Coal	million toe	4,784	597,382	125	13,394,221
Hard coal		4,427	503,063	114	11,915,785
Lignite		357	94,319	264	1,478,436
Total	million toe	**12,291**	995,692	**81**	14,435,262

Table1.1: Latest Estimates of Global Fossil Fuel Resources and Reserves, as of June 2013. Source [2]

Renewable Energy Sources:

- Solar: 2080 TWY
- Wind: 127 TWY
- hydro: 28 TWY
- biomass: 4.7 GWY

- geothermal: 2.2 GWY
- tide : 2.2 MWY

Extracting energy from conventional energy also pollutes environment as it pollutes from its use. Again these sources are limited. So it is high time to look for renewable energy sources.**[3]** There are a few renewable energy resources but solar energy has the major contribution. Although solar energy is the combination of solar thermal and solar photovoltaic energy, here solar PV will be mostly discussed.

1.3 Motivation and Background

Everyone knows renewable energy is the energy for tomorrow. Still it is not affordable to use renewable energy to full fill all our needs. All have to be smart with using renewable energy for different requirements. Cooking is one of the biggest sources where renewable energy can have a significant role. The electric stoves that people use consume a lot of energy and hence cost inefficient. Also the gas stove will no longer be there in future. In this case hybrid stove can be an excellent replacement. In this stove majority of energy will be supplied by PV panels. Weather condition in Bangladesh is also suitable for this project. The average sun shine data of Bangladesh clarifies the opportunity of the product in real life. [**4**]

Hours/ Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5:30			1	5	17	19	11	7	3			
6:30	3	8	29	66	106	93	86	66	58	46	31	11
7:30	57	93	148	198	252	200	198	180	165	169	157	97
8:30	175	254	318	354	406	321	355	288	303	324	331	237
9:30	300	424	489	521	561	416	438	433	435	473	490	382
10:30	411	573	629	666	681	494	503	514	485	487	580	479
11:30	494	672	712	751	727	532	548	537	485	520	614	498
12:30	518	701	722	764	711	543	570	535	486	488	573	489
13:30	483	646	657	693	641	500	503	482	441	406	510	426
14:30	379	528	541	553	577	451	463	453	385	323	377	309
15:30	236	353	377	402	419	329	372	356	281	208	204	183
16:30	94	175	204	237	257	215	244	231	164	76	57	54
17:30	10	37	55	72	93	93	107	89	45	6	1	2
18:30			2	4	11	17	18	8	1			
Daily average (kwh/m^2 –day)	3.16	4.46	4.88	5.28	5.46	4.22	4.42	4.18	3.74	3.53	3.92	3.17

Note: 5:30 represents period between 5 am and 6 am

Table1.2: Monthly average hourly GHI (wh/m^2)

The above table shows that, from {10:30-13:30} irradiance (G) is significant number. Fortunately these 3 hours are mostly cooking time. So, if one can finish his cooking in this time, he may not need any help from any other source rather than sun light which is free. National grid will contribute when there is not enough solar energy also battery supply is not sufficient. Designing the charge controller for this regard is the first challenge. Complexity comes when the amount of energy needed is huge for cooking as lot of space wanted for PV panels. To decrease the power we have to consider the time required for cooking. An effective solution to the problem could be reduction of heat loss.

1.4 Problems and Expenditures of Existing Electric Stove

The regular electric stoves are high in wattage ratings. Normally they differ between 1500W-3000W. The lowest, one can find is 1000W. From that wattage rating it can be approximated, how much the cooking cost could be with those stoves.

For example with a 2000W stove, if total cooking time for a given family is 3 hours for a day, then cost for that days cooking will be

2 X 3=6 kwh which means 6 electrical units for the consumers. If each unit costs 6.81 taka**[5]** then total cooking cost is (6.81 X 6) taka= 40.86 taka. Then monthly cooking cost would be (40.86 X 30) taka=1225.8 taka.

That can be an example of a small family. For a moderate or big family the cost can be more. Also in many urban areas, especially in the apartments people do not have gas connection. Those people are consuming cylinder gas. Each cylinder costs almost 2500 Tk. For a big family often one cylinder is not enough. Understandingly that is very expensive.

On the other hand Bangladesh does not have sufficient production of electricity according to the demand. She has 800MW of electricity shortage every day. [**6**] Also electricity is not available for all. 50% of its population has access to electricity. [**7**] Rural areas are still to be connected to the electricity. Some hilly regions and tribes are yet to see the power of electricity.

So electricity is very important. There is no meaning to consume precious electricity for cooking. Rather it should be used more, in industrial, research and service work. Even if electricity shortage is zero none should waste electricity in that reason. Gas storage is limited and in production of electricity most of gas reserved is utilized. That means, it is not possible to use gas for cooking in long period of time either.

That is why one should concentrate in using conventional fossil fuels as less as possible. Thinking in that way, this thesis found out this new way of cooking with solar energy.

1.5 Project Overview

The reason behind investing time and money into this project was to build a stove which is environmental friendly, cost efficient and effective. Most of the people of Bangladesh cook with the stove that is run by gas or other natural resources. Those techniques are less expensive but harmful to the environment. On the other hand modern cooking techniques by electricity are environment friendly but more expensive and not possible for users especially who are not connected to the electricity network. Therefore situation demanded such kind of cooking technology. To test the feasibility it was necessary to buy a stove from nearby market avoiding hassles of assembling the parts and saving time. It was first checked by running it with DC source. Then it was designed for 500W DC solar power with sufficient battery backup and also manual AC line as standby for emergency case. In the procedure of testing, came out the demand of re-designing the stove. Firstly modified the stove and then started experimenting. The research could not end, without real cooking experiments. So, sufficient cooking experiments were taken on the roof top with panels, controller, batteries and all other necessary equipments. The block diagram below may help to understand the system.

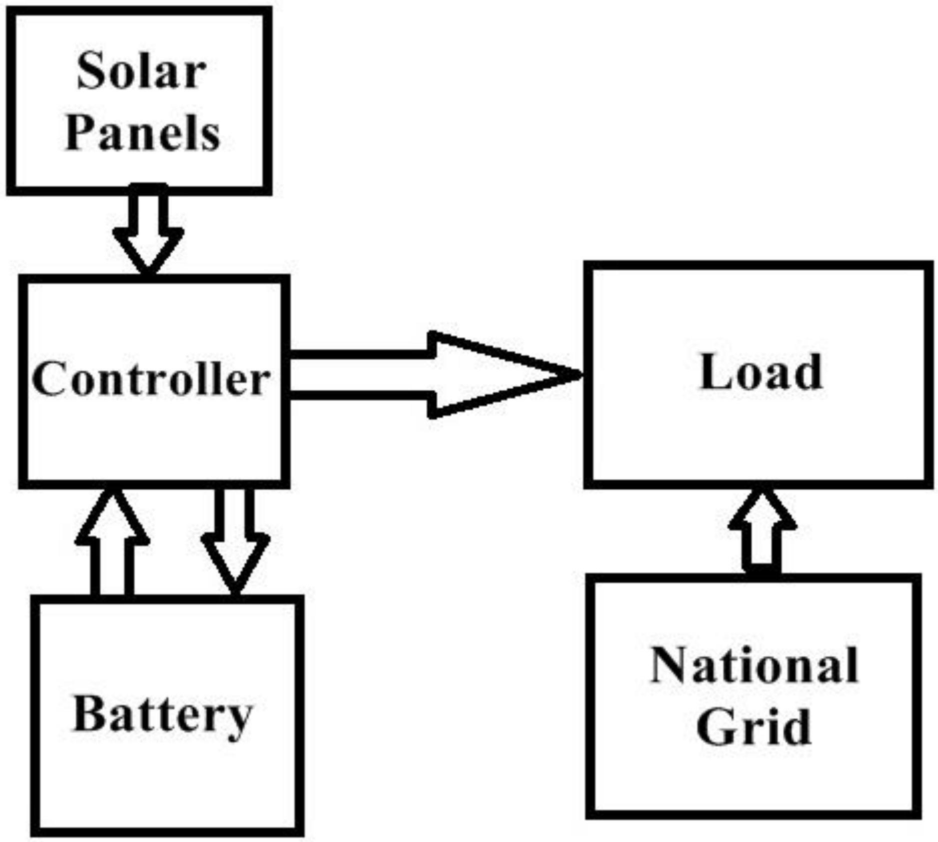


Fig 1.1 Block diagram of the system

Main objective was to reduce the cooking time to the comfortable and effective level with considering the average solar hour. The research gathered a good number of data to support its work. At the end, approximate cost was calculated to show its 'economy of scale'.

1.6 Summery of Following Chapters

In the second chapter the system design is described fully. The process of re-designing is explained clearly in this chapter. Determination of controller's specifications is mentioned with relative data and necessary pictures. Estimated panel size, required battery and technology of reducing heat are explained in details.

Chapter 3 deals with hybridizing technology and its necessity. The process of hybridizing and a smart algorithm, built for this process are also described in this chapter. Simulation data and on-field data are mentioned in the next chapter. In chapter five data analysis are illustrated with graphs to make it easy to understand. Load sharing analysis between panels and batteries is also an important part of this chapter.

Comparative study is the topic of chapter six. Case study analysis and governments renewable energy policy are two important subsections of the chapters. The last chapter draws the conclusion of the thesis. Before that future work and areas of improvement are also expressed in this chapter.

CHAPTER 2

System Design

2.1 Stove Coil

The stove, used in this project was bought from nearby market. It is actually an AC stove. These are mainly used in the hostels for cooking, using AC connection. First target was to run the stove with DC source. The stove is of 1000W. It was determined to reduce the wattage rating to 500W. So, to achieve that, it was tested with different voltage and currents. Measuring wattage the performance was verified. At the same time it was tested for AC source but reducing wattage to 500W by enforcing additional resistance. Hopefully it was found that the performance was better for DC source than AC. The performance was determined on the basis of time consumption of boiling the same amount of water with all other conditions remaining constant. **Fig 4.3** clarifies more about the experiment.

On the other hand, it was also experimented with the normal gas stove. Time consumption found similar there too. Having all this experiments it was decided that, 500W DC powered stove can cook effectively and efficiently than AC stove or other electric cooker available in the market. Finally it is **132.3V** and **3.79A** are the ratings of voltage and current respectively for the system. This gives the wattage ratings of **501.417W.**

Fig.2.1 Current Reading

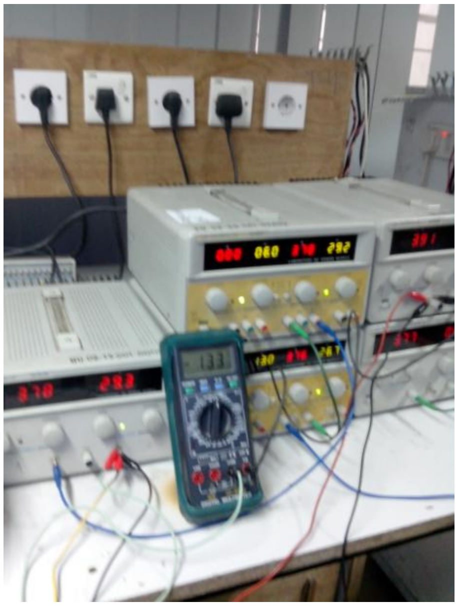


Fig 2.2 Voltage Reading

Then it seemed, providing **132.3V (Fig 2.2)** is a big problem for the system. Panel size would be very big for that and that's how it would not be efficient. A primary solution to this problem could be using a micro-inverter to increase the voltage level. But that increases the cost of the system by a significant value. In search of the solution to this problem, the plan is made to change the coil or modify it.

2.1.1 Coil Re-design

It was calculated that, **3** coils of smaller resistance in parallel can increase the total current to reduce the voltage from a constant 500W DC source. Calculated value of each resistance was **13.5Ω** and current through each coil is **3.5A**. Thus total current is (3x3.5) A=10.5A and the resultant resistance = (13.5││13.5││13.5││) Ω.

=4.5Ω

So power P = (10.5^2×4.5) W

= 496.125W.

V= (496.125/10.5)V

= 47.25V.

Fig 2.3: Original coil.

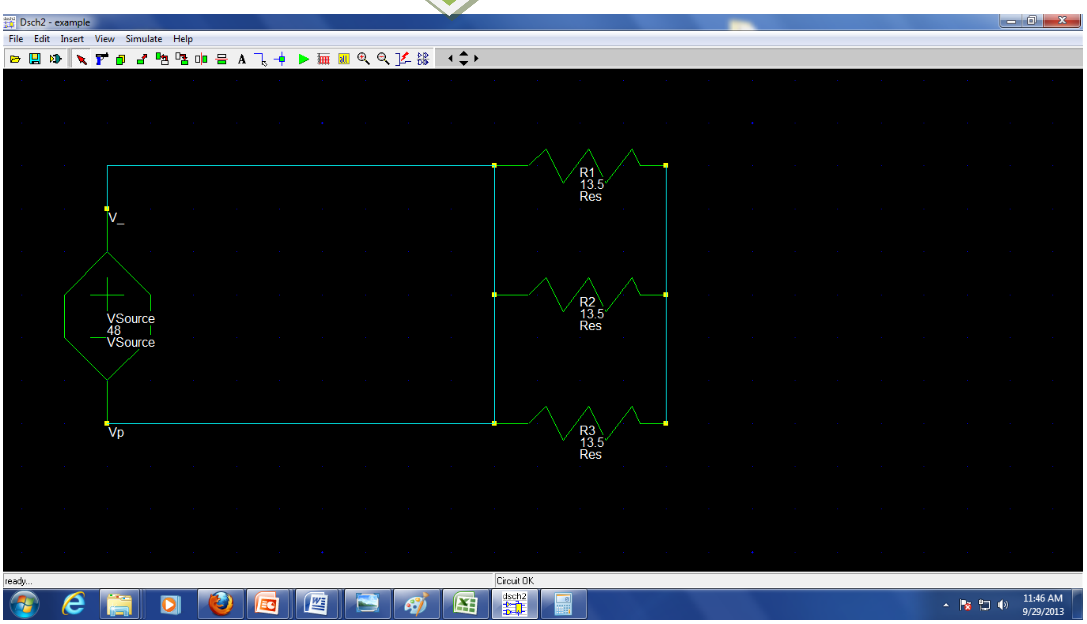


Fig 2.4: Re-designing simulation.

$R_1=R_2=R_3= 13.5\Omega$ $\quad I_1=I_2= I_3=3.5A$

$R_p=4.5\ \Omega$ $\quad I_t=(3 \times 3.5)A$

$P= (R_p \times I_t)$ $\quad =10.5A$

$=496.125W$

The re-designed coil was planted to the same mud structure that holds the coil and insulates the coil from being shorted. It was done to reduce the hassles of re-designing the mud insulator. Our modified coil was installed there with making two additional holes. Three small pieces of coils were joined underneath the mud insulator in parallel. Then with tightening the screws, the stove was ready to taste its performance.

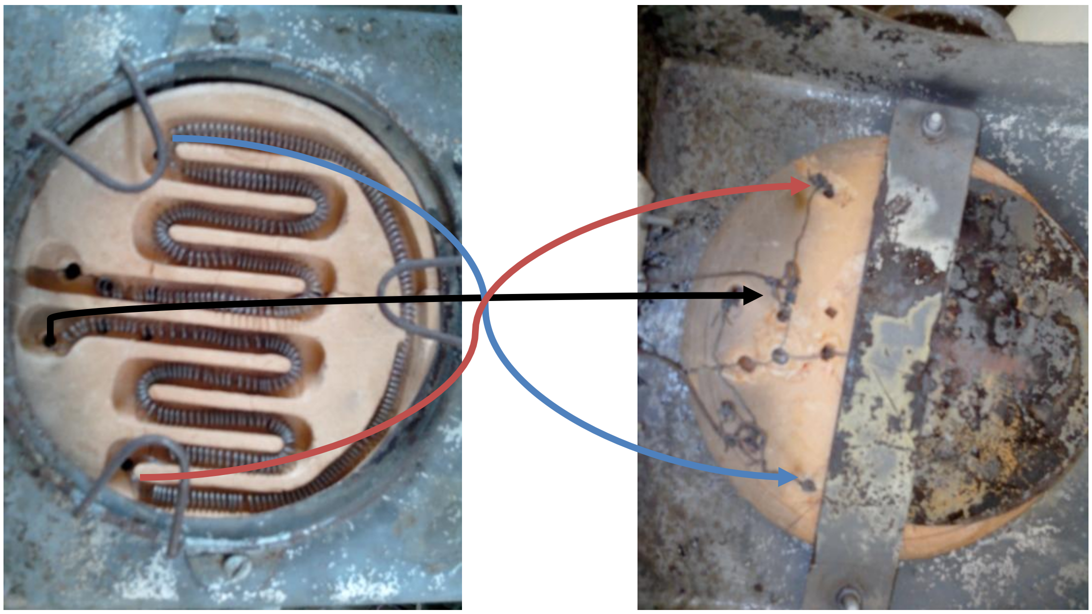


Fig 2.5 Re-designed coil **Fig 2.6 Coil installed**

Then there would be no need for micro-inverter. Load will directly draw that much of wattage through a **48V** and **10A** charge controller.

2.1.2 Performance Taste

Performance test was carefully executed to show the similarities between re-designed stove data and previous data. It was found similar. That permitted to go further with that stove and continue experimenting in the real field.

2.1.3 Limitation

Although the system is established to provide **10A** of current but in practical it does not reach to that mark. Internal loss of the system and line loss may have caused that problem. That caused the load power to be less than **500W**. It affects the timing to finish cooking in desired time by little. Improvement in reducing losses is needed to solve this problem.

2.2 Controller

The load is design to have **48v** and **10.5A** of current rating. Though the sunlight alone will not always be sufficient for cooking, it needs to have battery as back up. Now including batteries in the system brings additional attention to the safety of the system. The system was designed to have 4, **12V** batteries in series as a battery bank.

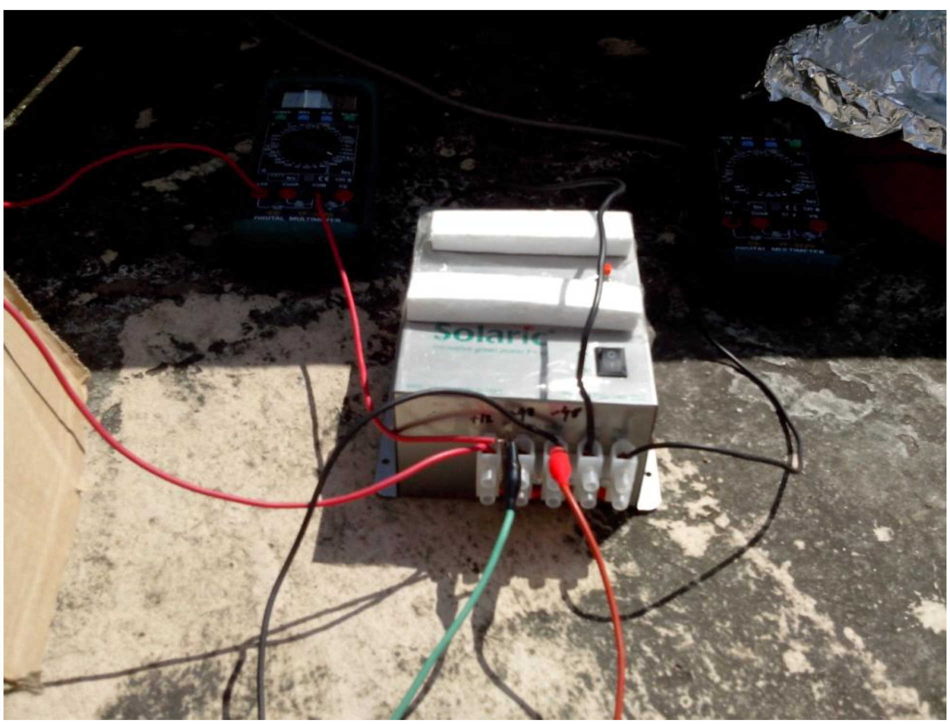


Fig 2.7 Controller installed with all components

2.2.1 Specifications Determination

To find the specifications, first the batteries were fully charged. Then the system was assembled again, but without the panels. After that, batteries were discharged through the load. Monitoring the multi-meters was required to check over discharging. The method, applied to determine over discharging is, calculating total Ah of the battery bank. Each battery was rated for **20Ah.** As it is restricted, not to discharge more than **80%** of its stored energy, to be on the safe side **75%** was considered as the cut off point for the system.

2.2.2 State of Charge 12V Battery

Battery state of charge is determined by reading either terminal voltage or the specific gravity of the electrolyte. The density or specific gravity of the sulphuric acid electrolyte of lead acid battery varies with the state of charge. 12 V lead acid battery state of charge (SOC) vs Voltage while under discharge is given below.[8]

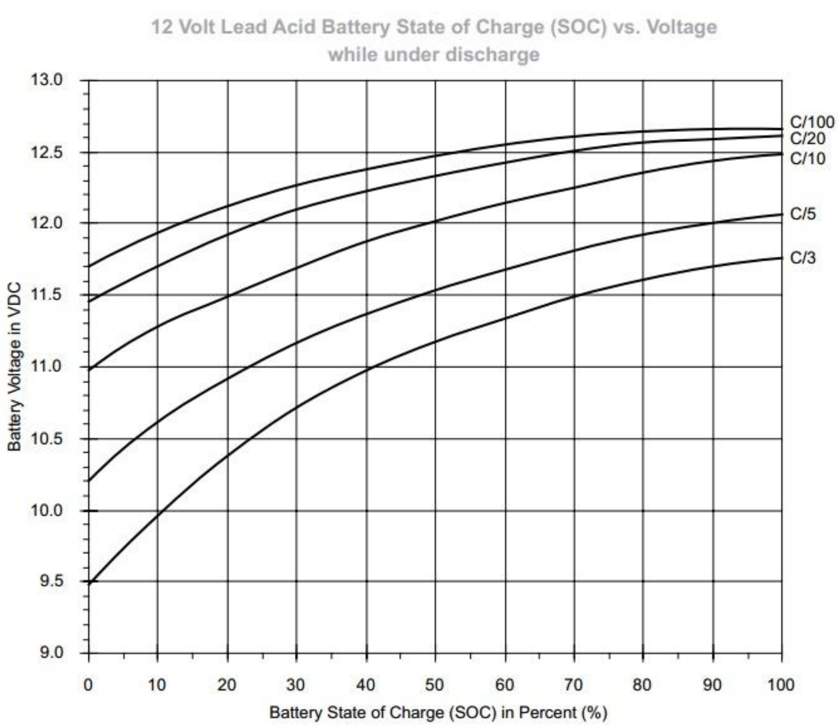


Fig2.8: State of Charge (SOC) vs. 12V battery voltage while discharging

Fig 2.9 Battery discharging by load through controller

We checked the volt meters and ammeters to determine cut off voltages and currents respectively. Graph below can verify that.

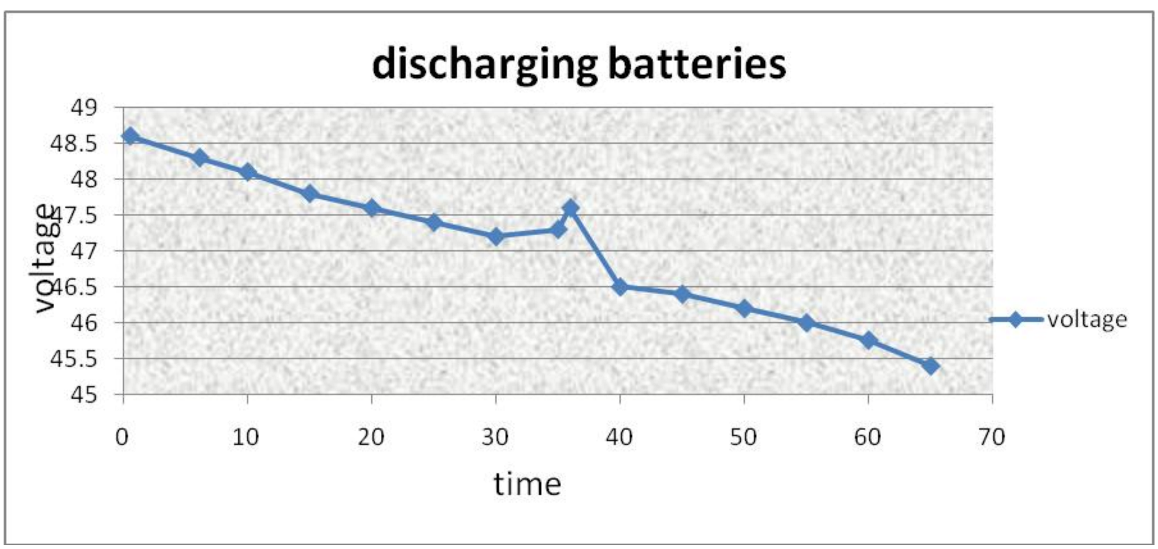


Fig 2.10 Graph of discharging batteries

Comment:

The graph has a pick near at 40 minutes because while testing the discharging process, the experiment had to be stopped due to raining. All the equipments had to be shifted to the stairs (**fig 2.10**). Rearranging them again killed some time. Due to that time delay, battery voltage jumped up.

2.2.3 Controller Installation

The controller had five ports. **+12V, +48V, -48V, +P, -P.** A push button is used to switch the controller on or off. To switch on the controller **12V** needs to be supplied to its specified terminal. It will be supplying constant voltage which is **48V** and almost constant current **10A** to have constant load power. It will balance the load share of panel's contribution and battery's contribution. If the panels provide more energy, needed for cooking or when the load is off energy will be stored to the battery to the extent that it is not over charged. On the other hand when the load is on and panels are not providing sufficient energy, battery will be discharged to the extent that it is not over discharged. Only then national grid will provide necessary energy to the load. Though the connection of national grid will be manual it is not shown in the controller installation. The picture given below shows the arrangement of the process.

Fig 2.11 Water boiling test with full system including controller

2.3 Effective Heating Technology

One of the attractive features in this research is the introduction of effective heating technology. Though in the project, proper application of the technology was not included, in fact that can be another topic of research. Still the importance and usefulness of the technology can be found in this paper. This technology is very simple to understand, how much energy can be wasted during cooking, without the technology. In this project a box with two faces was used to minimize the heat loss as much as possible. Inside the box, a thin layer of aluminum foil is used to concentrate heat more to the pan or any other cooking tools. These were done to emphasize the opportunity of manufacturing such product depending on its experimental advantage. Several tests with different positioning of the foil indicate the efficiency, as long as the required time for cooking is concerned. Best case occurred with both the upper and lower sides were covered by the box and the whole stove, by foil. (**Fig 4.3**)

2.4 Estimated Panel Size

Panels are one of the main components of the system. The system was designed to have **48V** and **10A.** It is not possible to have that much of current, using a single panel. Therefore in the system 2 panels, having **5A** (5.6A to be exact) was connected in series to increase the current rating. Since those panels were providing less than **48V,** it needed another set of similar arrangement but connected in parallel. Thus the system reached desired ratings for voltage and current.

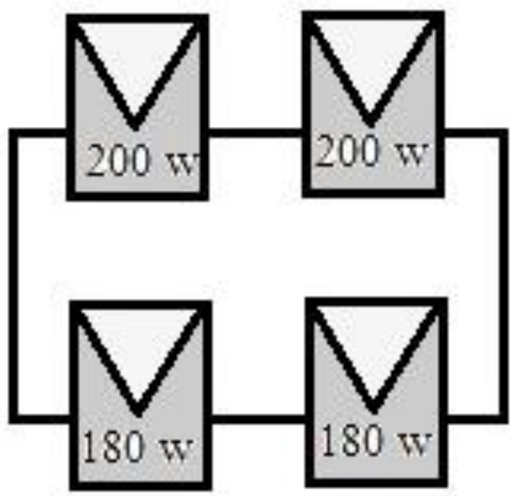


Fig 2.12: Solar Panel Connection Block Diagram

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 2.12 module description for 200W panel

Comment:

In the system 2 panel of 200W each and another 2 panels of 180W each were connected in series in between themselves according to the diagram. This makes the total system for 760W. This is more than required value. Using 4 panels of 150W each we can achieve the target. Then the wattage rating will be reduced to 600W.

2.5 Required Batteries for the System

To ensure **48V** from the battery backup, the system used 4, **12V** batteries of **20Ah**. 20Ah battery was chosen, as achieving higher Ah from the panel during the solar hour is not possible. Hence, battery will not be fully charged. During discharging that will hamper providing desired voltage level. The batteries were connected in series to make it a battery bank.

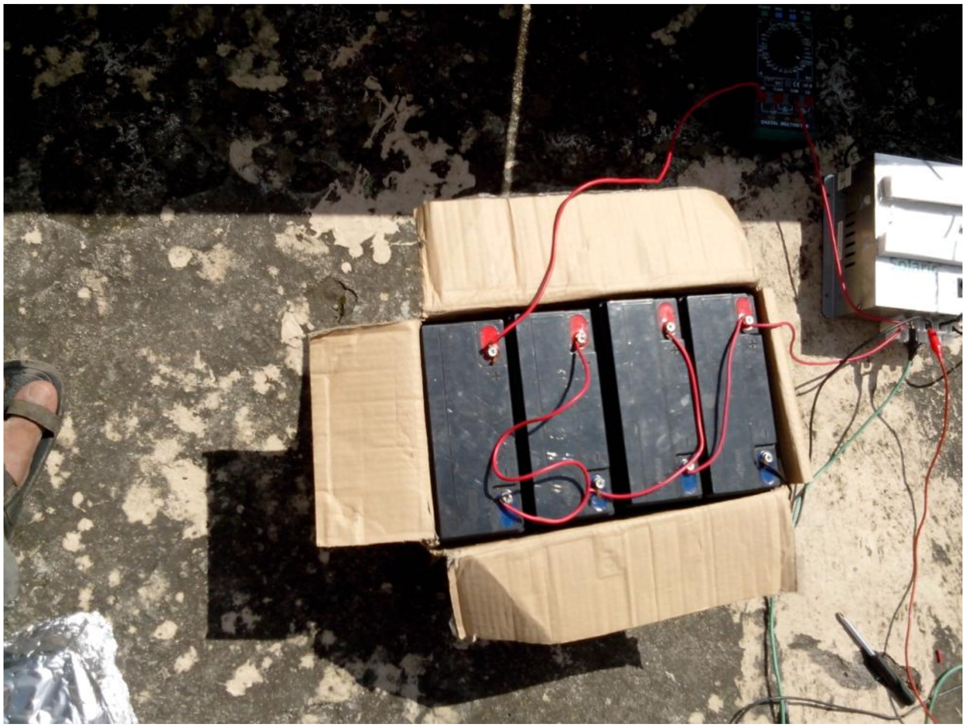


Fig 2.13 Battery bank

In determining the batteries for the system, the project had to consider timing of charging and discharging. SWERA data helped in this regard. Batteries were chosen to be charged between the non-cooking times. So that, or during cooking batteries can discharge and share load with the panel. More explanation can be found from “**case study analysis**”, which is provided in the later part of the paper.

CHAPTER 3

Hybridizing Technology

3. Overview of Hybridization System

Nowadays, the power system utility has started to consider the green power technology in order for the world to have a healthier environment. The system is designed to supply electricity to solar charge controller by a hybrid power system consisting of renewable energy, backup battery and surplus ac grid connection. It is a great process for saving electricity from national grid and cooking efficiently. It also is a smart process as the system can perform daytime and night time. Besides, it saves a lot of energy and a lot of money. Where natural gas is not available for cooking, people use electricity to cook that come from national grid. It is not only expensive but also a loss of electricity. To reduce this loss, the system is hybridized with solar panels and national grid.

3.1 Hybrid Energy

A combination of different but complementary energy generation systems based on renewable energies or mixed with backup provision is known as a hybrid power system ("hybrid system"). Based on type of load demand electricity generation coupled at DC/AC bus line through different converter arrangement.[**9**]

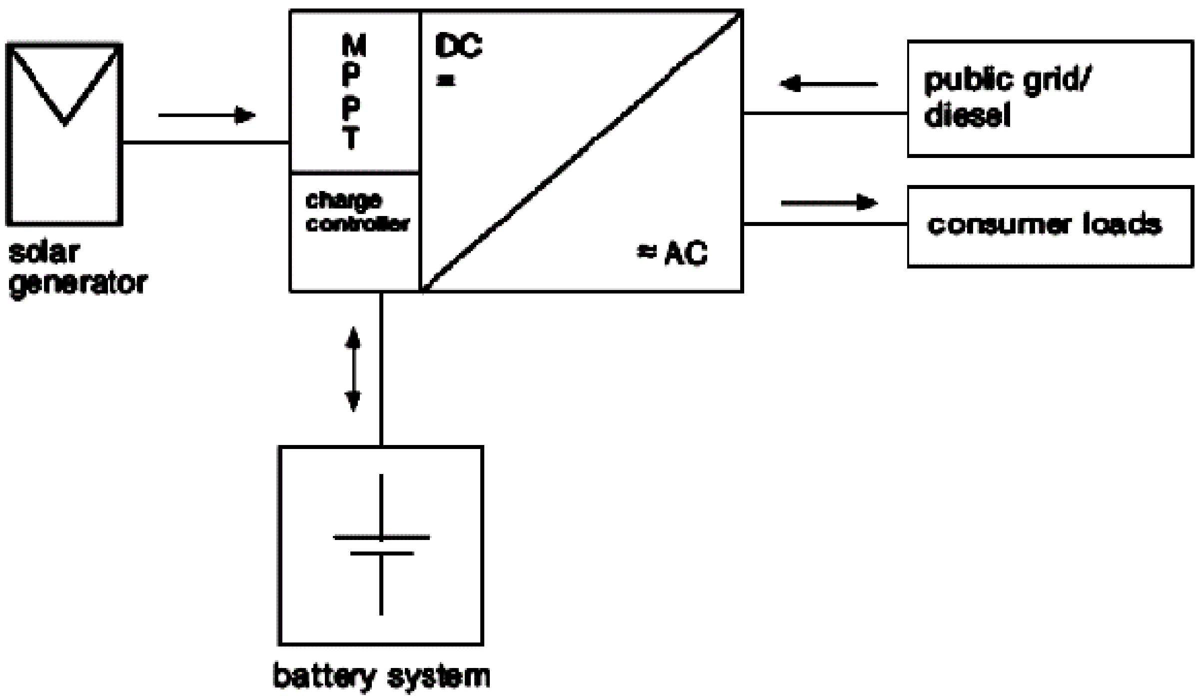


Fig 3.1: Sample Hybrid System

3.2 Necessity of Hybridization

Since the highest power demand occurs during sunshine hours, a significant share of the PV generated electricity can be used directly when generated. A storage system should preferably be large enough to supply the evening and the night loads in order to limit the use of national grid power and hence the running costs. If there is a peak in power demand during daytime, electricity from national grid can be used to cover that peak demand together with the PV panels. Using a hybrid solution to cover the demand peaks, instead of using only PV, will limit the required size of the PV production unit needed, which can lower the investment cost of the system.

Another option, particularly useful if explicit peaks in power demand do not occur, is to design the system so that the normal load can be supplied by the PV generation together with the batteries when favourable to normal weather conditions occur. For days or periods of higher power demand, or lower electricity production from the PV panels due to low solar irradiation, national grid can be used to charge the batteries and supply the loads. Hybridization would also, in this case, lower the investment costs since the system can be designed for quite favourable conditions, at the same time as increasing the reliability of the system.[**10**]

3.3 Hybridizing Technology

In this context, solar panels and batteries provide the opportunity to supply a low load for many hours overnight and, according to the installed PV capacity level, to cover partly or fully the morning and mid-day load. The national grid is used to cover the evening peak and complete the battery charge if required. The system is designed to get the maximum energy and maximum cooking hours. It is designed in such a way that the system can cook when the irradiation is not present or it is night time. Charge controller device is used to control the stove with the required voltage and current that come from the solar panel, batteries and the national grid. During day time when the sun is present, maximum power comes from the solar panels. If there is enough solar thermal to run the stove, the controller will take the energy only from the solar panels. On that time the stove does not need to use the power from battery and national grid. Moreover, the charge controller will charge the batteries in day time when the stove is not used

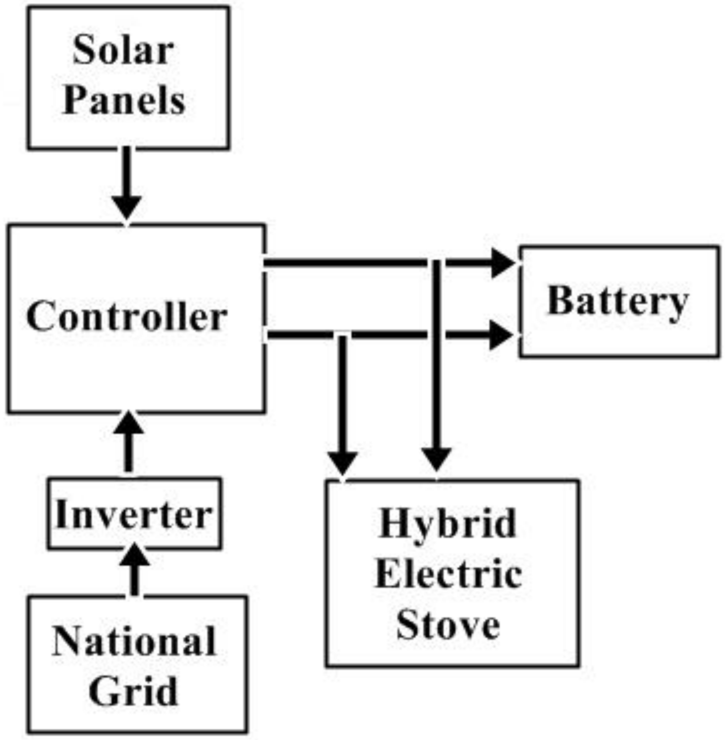


Fig3.2: Block diagram of hybrid system

3.3.1 Operational Scheme

The intended hybrid energy system is incorporated of Renewable source PV and AC grid supply. Battery is acting the part of storage device charged by PV current. A Power Converter has been used for changing the source bus from DC to AC. This integrated system is totally designed for supply electrification to the selected sample load.[**9**]

3.3.2 Manual Switching for National Grid

Manual switching is used in our system for national grid. It is used for saving electricity when sufficient power comes from the solar panels and batteries. Moreover, when there is no sunshine or battery backup, national grid can be used for stove.

CHAPTER 4

Data Record in Lab

Lab Data

Initially experiment was done in lab. Since the main goal of this experiment to cook food in electric stove with 500 watt, it was ensured at lab first that cooking can be done within limited amount of time with 500watt. Later than gathering all the test in lab and cooking in the lab quite a lot of time, the main experiment was taken place at the roof top with the solar panel.

4.1 Objective of simulation test

The major objectives of the simulation test were:

- How the whole system going to work.
- To see if the control system is working properly and safely.
- To analyze the protocol of the system.

4.2 Simulation test in lab

4.2.1 With DC Power Supply and Charge Controller

In order to implementation of the system, DC power supplies were connected with charge controller. It was done in lab without solar panel and electric stove. Instead of the electric stove, equivalent resistance of the electric stove, a copper coil with that equal amount of resistance was used. The measurement was taken with help of multi-meter.

Here, it was shown that:

$$P_L = P_P + P_S$$

P_L = Power of load

P_P =power from panel

P_S =power from DC source

This experiment was taken to ensure that the load power is equivalent of the sum of the power of panel and battery. The data which was taken is given below:

POWER(SOURCE)	POWER(PANNEL)	POWER(LOAD)
27.735	16.9	46.23
24.304	17.29	43.757
22.6625	17.822	42.108
21.538	17.955	41.0343
20.06	18.221	40.0635
17.433	20.904	39.772

Table 4.1 Load share lab test

The graphical representation of the data is also given below:

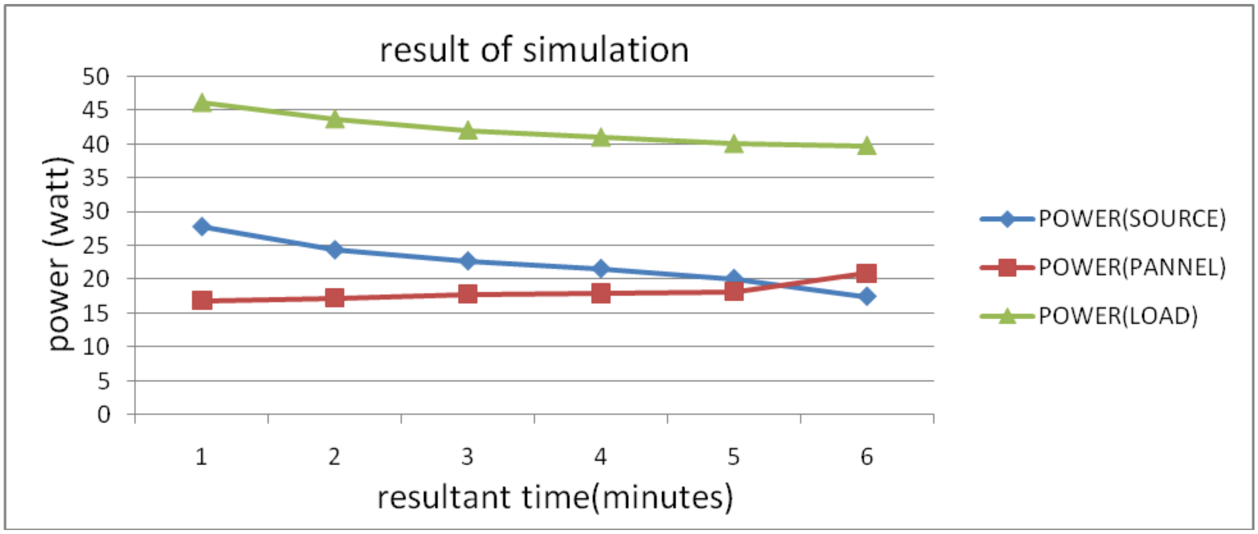


Fig 4.1: Graphical result of first simulation test

Experimental analyses

After doing this simulation, it was confirmed that power of the load can be taken in form of summation from two different sources. Since the result of the simulation was positive, the experiment can be done practically. Right after this simulation test an electric stove was bought from market which was redesigned later for experiment purpose.

4.3Data collected with an Existing Stove

4.3.1 Boiling 200 milliliters of Water

200 ml water was boiled as an experiment. Data was taken in every 30 second while water was in the stove till it was boiled up to 100 degree Celsius. The temperature of the water was being measured by thermometer.

Five time experiments were done with heat and without heat insulator with the DC and AC power supply.

With DC Power Supply

The condition for the first experiment was for boiling water, 4 DC (Power supply) were connected in series. Voltage and current were being supplied from these power supplies. Each DC power supply was giving (32.8 v, 32.2v, 33.6v and 33.2v; total voltage was 131.8) and current was 3.8 amps from each. The stove which was bought from market was covered with aluminum foil paper both the side and as well as it was surrounded by the foil paper. A box was used which was wrapped by aluminum foil paper and that box was used to cover the stove.

Fig 4.2: Electric stove covered with aluminum foil paper(heat insulator)

Resistance of the wire of the stove was 33 ohm. Total amount of power **(P=I*V**) which was being supplied was 500.84 watt. However multi meters were connected with the load to calculate the total amount of voltage and to calculate the amount of current was being supplied to the load from sources.

The condition for the second experiment was for boiling water, 4 DC (Power supply) were connected in series. Voltage and current were being supplied from these power supplies. Each DC power supply was giving (32.7 v, 32.37v, 33.6v and 33.2v; total voltage was 131.87) and current was 3.78 amps from each. The stove which was bought from market was not covered with aluminum foil paper. Resistance of the wire of the stove was 33 ohm. Total amount of power which was being supplied was 498.5 watt.

Data analysis for the experiment done by DC Power Supply

Instead of the solar panel, DC power supply was used. It took 8minutes to boil 200 ml water with DC (Power supply) where the stove was covered with aluminum foil paper whereas without covering the stove it took 15.30 minutes to boil the water. Heat energy can be saved by covering the stove with aluminum foil or with any sort of paper which is bad conductor of heat and electricity. After these experiments, it was concluded that in order to save heat energy and save more time, it is better to use heat insulator.

With the National Grid Connection

The condition for the third experiment was for boiling water, AC (Power supply) which was connection from national grid. Voltage and current were being supplied from the grid. Voltage was 149.1 v and current was 4.25 amps. The stove which was bought from market was not covered with heat insulator. In this case rheostats were being connected with the wire of stove. Though resistance of the wire of the stove was 33 ohm, to increase the resistance from 33 ohm to 77 ohm rheostats were connected with the wire of the stove in series. However two rheostats were placed parallel to stable the resistance. Since the stove was for 1000 watt,if the stove is connected directly with the grid it would get 1000 watt. In order to get 500 watt power this change was done.

Measurements were taken with help of multi meter. Total amount of power **(P=V*I*Pf)** which was being supplied was 506.94 watt. Power factor (Pf) was 0.8.

Same conditions were for the forth experiment also the difference was the stove was covered both the side with aluminum foil wrapped box. The voltage coming from the national grid was 148.1v and current was 4.23amps and total power was 501.174watt power factor was 0.8. All these measurements were taken with help of multi meter.

Data analysis for the experiment done by the National Grid Connection

It took 7.5 minutes to boil 200 ml water with AC (Power supply) where the stove was covered with aluminum foil paper whereas without covering the stove it took 11.53 minutes to boil the water. Heat energy can be saved by covering the stove with aluminum foil or with any sort of paper which is bad conductor of heat and electricity. As the prime target of this experiment is save electricity, it is better the quicker the food cook the lesser electricity will be used. Thus it can be concluded that the covered stove should used with nation grid supply. The final experimental data is given below:

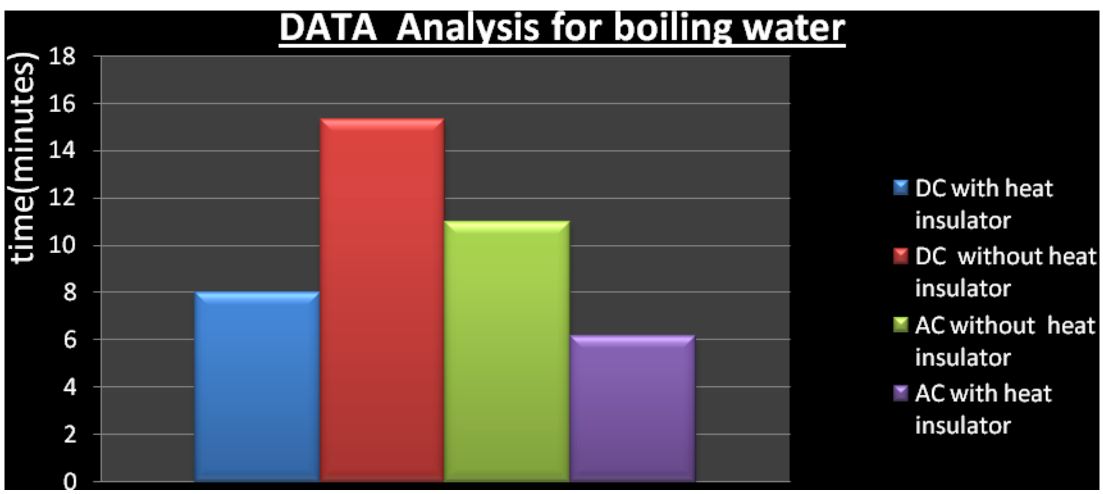


Fig4.3: Bar chart for comparative study for boiling water.

Experimental Analysis

After considering all the simulation results (instead of solar panel power supply was DC source), it can be said that the best design of the system is using the electric stove covered by aluminum foil paper in order to save heat energy that is being converted from electricity. More over within limited amount of time cooking can be done

4.3.2 Cooking 250 gm of Rice

Almost same experiment was done for cooking rice of 250 gram with 500 gram of water in it in lab. Five times experiment was taken, thrice covering the stove both the sides with aluminum foil paper as insulator DC (twice) and AC respectively and also DC and AC power supply (national grid supply) experiment was done without the aluminum foil paper. A data was also taken with the gas stove to compare the time duration. Data was taken in every 2 minute while the rice was in the stove till it was cooked properly. The temperature of the rice was being measured by thermometer and thumb.

With DC Power Supply

The condition for the first experiment was for cooking rice, 4 DC (Power supply) were connected in series. Voltage and current were being supplied from these power supplies. Each DC power supply was giving (33.3 v, 33.8v, 33.7v and 33.2v; total voltage was 134) and current was 3.78 amps from each. The stove which was bought from market was covered with aluminum foil paper both the side and as well as it was surrounded by the foil paper. Resistance of the wire of the stove was 33 ohm. Total amount of power which was being supplied was 506.52 watt. However multi meters were connected with the load to calculate the total amount of voltage and to calculate the amount of current was being supplied to the load from sources.

Repeating same experiment of rice cooking with DC power supply but power supply was different. Each DC power supply was giving (32.7 v, 33.2v, 33.3v and 33.2v; total voltage was 133) and current was 3.78 amps from each. The stove was covered with aluminum foil paper. Resistance of the wire of the stove was 33 ohm. Total amount of power which was being supplied was 502.74 watt.

Data analysis for the experiment done by DC Power Supply

Instead of the solar panel, DC power supply was used. It took 32 minutes to cook 250 gram of rice with DC (Power supply) and later on it took 33 minutes to cook properly. After these experiments, it was concluded that it is feasible for cooking rice with 500 watt. It could be a bit time consumer. When the experiment was done with DC source without covering the stove it took 35 minutes to cook 200ml rice.

With the National Grid Connection

In this case 250 gram of rice with 500 ml was being cooked by AC (Power supply) which was connection from national grid. Voltage and current were being supplied from the grid. Voltage was 153 v and current was 4.27 amps. The electric stove was not covered with aluminum foil paper. Again rheostats were being connected with the wire of stove to make the resistance 77 ohm since the stove was connected with national grid. Measurements were taken with help of multi meter. Total amount of power which was being supplied was 522 watt. Power factor was 0.8.

Same conditions were for the forth experiment also the difference was the stove was covered both the side with aluminum foil wrapped box. The voltage coming from the national grid was 152v and current was 4.24 amps and total power was 515.58 watt power factor was 0.8. All these measurements were taken with help of multi meter.

Data analysis for the experiment done by the National Grid Connection

Both the time it took almost same time. The duration for cooking rice electric stove covered with aluminum foil was 32 minutes and the duration of cooking rice without the covering was 41 minutes. And also it was not made that much difference from the DC power source experiments.

4.3.3 Data of cooking rice in Gas stove

With the same amount of rice and water, an experiment was done in gas stove. Thermometer was used to check the temperature and with the help of thumb rice was checked whether it was cooked or not. In gas stove it took 30 minutes to perfectly cooked rice. It was obvious that heat intensity coming from stove was much better than electric stove, thus rice cooked a bit faster in gas stove than in electric stove. Besides heat can be controlled in the gas stove but it is quit impossible to control heat in the electric stove. Not only with 250 gram of rice was cooked but also 500 gram of rice was also cooked in the gas stove and it took 30 minutes . Since in all the experiment of cooking time was noted, a comparative study was done. As all the time was taken to compare which is better than other. A bar chart was made to easy the comparative study.

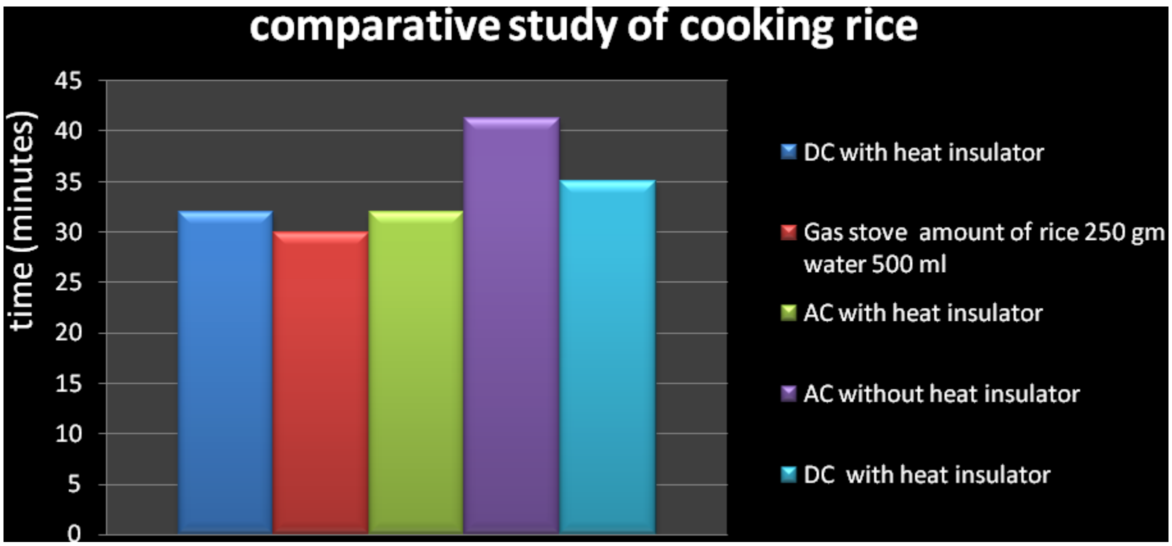


Fig4.4: Bar chart for comparative study of cooking rice

Experimental Analysis

Although the most effective and time consuming for cooking rice is in gas stove, for electric stove both with AC and DC when the electric stove is fully enclosed with aluminum foil paper give the same result. After considering all the simulation results (instead of solar panel power supply was DC source), it can be said that the best design of the system is using the electric stove by aluminum foil paper in order to keep heat energy that is being converted from electricity. Thus within limited amount of time cooking can be done.

4.4 Data collected After Re-designing the Stove

The electric stove was re designed for the experiment purpose. The coil of the stove was being divided and the connected in parallel. The resistance of each coil was 13.5ohm. The total resistance was 4.5 ohm. It was done so that when the electric stove is connected with the national grid, no more rheostats are required. As a result the voltage rating of the stove decreases from 134 volt to 48 volt.

The calculation of the resistance of the hybrid electric stove is given

$$R_p = 1/ [(1/R1) + (1/R1) + (1+R3)]$$

$$R_p = 1/ [(1/13.5) + (1/13.5) + (1+13.5)]$$

$$R_p = 4.5 \text{ ohm}$$

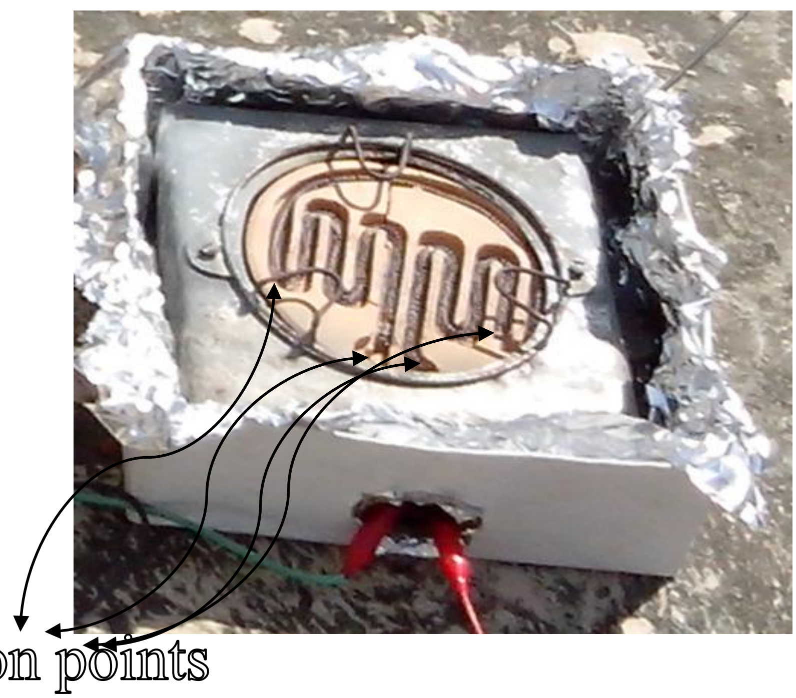


Fig4.5: re-design stove

The actual calculation was done in Export Dsch2. In Export Micro wind the circuit was design with 48 voltage source. The full figure is given below

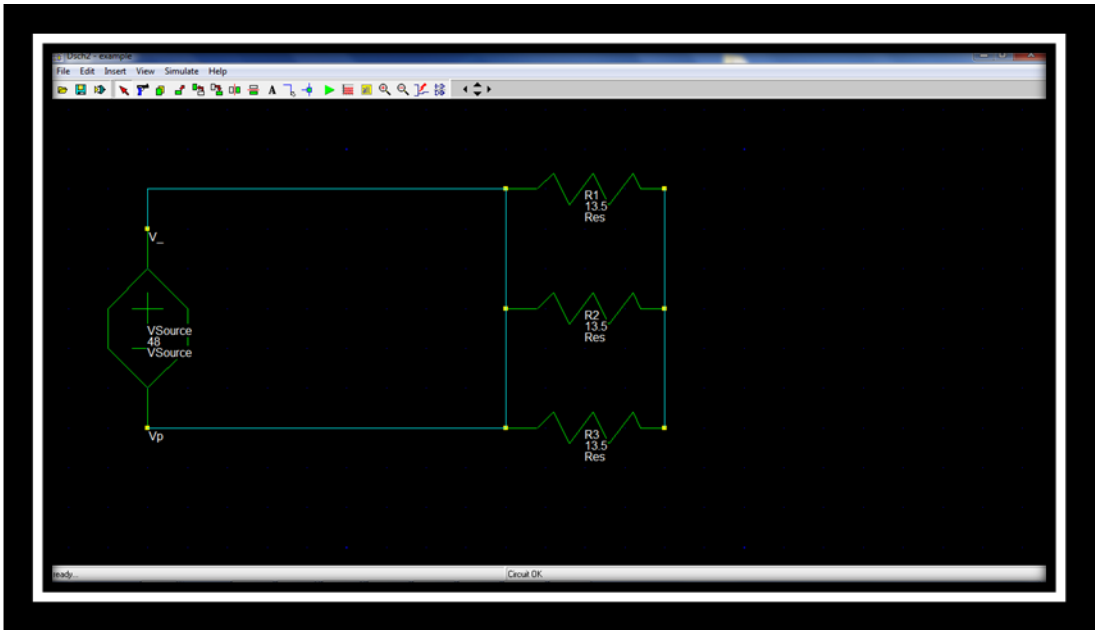


Fig4.6: circuit diagram of the hybrid stove in Export Dsch2.

4.4.1 Boiling 200 ml Water in re-designed stove

Previously what was done with existing electric stove, same experiment was done with the re-design electric stove. As this re-design electric will be used both with solar power and national grid, it is named hybrid electric stove. With the hybrid electric stove 200 ml water was boiled and data was taken in every 30 second while water was in the stove till it was boiled up to 100 degree Celsius. The temperature of the water was being measured by thermometer. Four times experiments were done as it was done before.

With DC Power Supply

The condition for the first experiment was for boiling water, 4 DC (Power supply) were connected in series. Voltage and current were being supplied from these power supplies. Each DC power supply was giving (33.3 v, 32.2v, 33.7v and 33.2v); total voltage was 132.4) and current was 3.78 amps from each. The electric hybrid stove was covered with aluminum foil paper both the side and as well as it was surrounded by the foil paper. A box was used which was wrapped by aluminum foil paper and that box was used to cover the stove. Total amount of power **(P=I*V)** which was being supplied was 500.47 watt. However multi meters were connected with the load to calculate the total amount of voltage and to calculate the amount of current was being supplied to the load from sources.

When second time water was boiled, 4 DC (Power supply) were connected in series. Voltage and current were being supplied from these power supplies. Each DC power supply was giving (32.7 v, 32.3v, 33.5v and 33.2v; total voltage was 131.7) and current was 3.82 amps from each. The electric hybrid stove not covered with aluminum foil paper. Resistance of the wire of the stove was 4.5 ohm. Total amount of power which was being supplied was 503.09 watt.

Data analysis for the experiment done by DC Power Supply

With the DC power supply, It took 9 minutes to boil 200 ml water with DC (Power supply) where the stove was covered with aluminum foil paper whereas without covering the stove it took 15 minutes to boil the water. The electric hybrid stove can be work as oven as it was surrounded by aluminum foil.

National Grid Connection

For the third experiment was for boiling water in the electric hybrid stove was connected with AC (Power supply) or the national grid. Voltage and current were being supplied from the grid. Voltage was 148 v and current was 4.3 amps. The stove which was bought from market was not covered with aluminum foil paper. In this case rheostats were being connected with the wire of stove. The resistance the stove was 4.5 ohm. Measurements of all were taken with help of multi meter. Total amount of power **($P=V*I*P_f$)** which was being supplied was 506.94 watt. Power factor (P_f) was 0.8.

Same conditions were for the forth experiment also the difference was the stove was covered both the side with aluminum foil wrapped box. The voltage coming from the national grid was 148.1v and current was 4.23amps and total power was 501.174watt power factor was 0.8. All these measurements were taken with help of multi meter.

Data analysis for the experiment done by the National Grid Connection

It took 6 minute 30 sec to boil 200 ml water with AC (Power supply) where the stove was covered with aluminum foil paper whereas without covering the stove it took 11 minutes to boil the water. Heat energy can be saved by covering the stove with aluminum foil or with any sort of paper which is bad conductor of heat and electricity. As the prime target of this experiment is save electricity, it is better the quicker the food cook the lesser electricity will be used. Thus it can be concluded that the covered stove should used with nation grid supply. Besides the national grid would be connected in case if the battery is disable to supply.

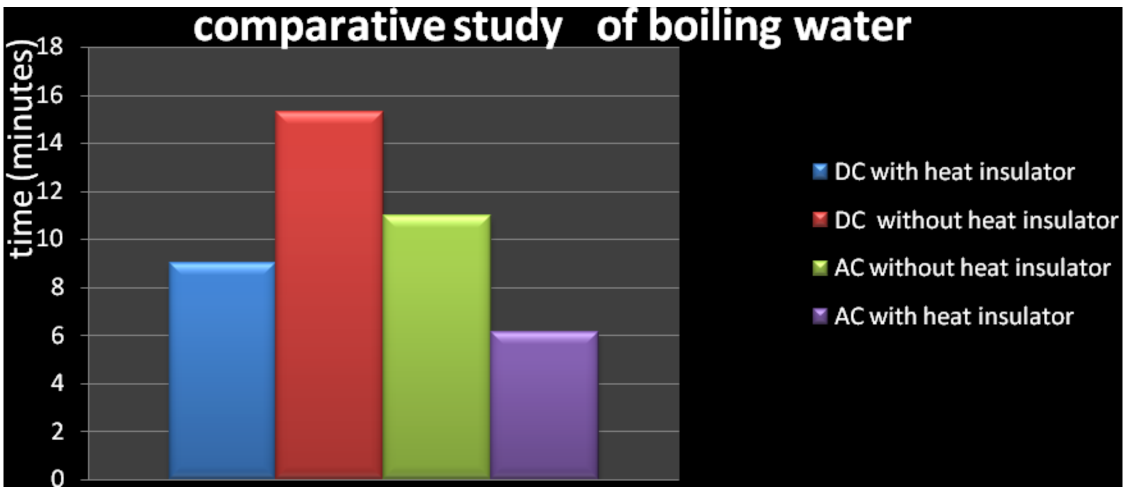


Fig4.7: Bar chart for comparative study of boiling water

4.4.2 Experimental Analysis

In this re-design electric hybrid stove, the most effective result was found in the experiment done with national grid covering both side but second best result was with DC power supply. Though with DC power supply water took a bit while to boil properly, it can be concluded that re-design electric hybrid stove was ready to use with solar panel.

CHAPTER 5

Field Test

5. Field-test

After completing the prototype and simulating it in the lab-condition, the whole system was set up on the roof top at BRAC University's 2nd building at 21st floor which is located at Mohakhali, Dhaka, Bangladesh to analyze its performance with the actual solar energy. Quite a lot of times, various foods were cooked at roof with the whole system. A few data were also taken specially for analyzing its performance and power efficiency. In this chapter, an overview of the field-test result will presented; the processed data will be interpreted in the figures and the system's efficiency over the throttle-controlled model of electric stove will be presented numerically. A data was also taken to know about the battery, how fast it going to discharge with load connected. A case was also studied to figure out the solar panel which are stored at roof top (now a days it is mandatory for all new building) how it going to be work with the stove and other electronics for house hold. Since main purpose of this experiment not only saves electricity but also it should be user friendly.

5.1 Objectives of the Field-Test

The major objectives of the field test were:

- To see how the whole system behaves with the connection of solar panel and batteries
- Efficiency of the stove (can a user use it as the alternation of gas stove or any other electric stove)
- To analyze if it is really user friendly or not.
- To see if the re-design electric stove with panel connection and battery connection works properly and safely (i.e. if any dangerous circumstances takes place.)
- To picture the energy-consumption trend in the current design

• A comparative analysis of cooking in lab and roof

• Calculating the efficiency of the design with respect to the previous model, in terms of the energy consumed during a time period.

• How quickly the battery discharges (without the solar power)

5.2 Experiments with solar panel

4 solar panels among them two are of 200 watt and two of them are 180 watt. Solar panels of 200 watt were connected in series and solar panels of 180 watt were connected in series. Later on they are connected in parallel. From one end of solar panel of 200 watt and another end from 180 watt connected in charge controller. 4 batteries with 12 volt were used which were connected in series. From one positive end of one of the batteries and from other negative end of another battery together insert in the charge controller. Lastly from the load connection of the charge controller, stove was connected. all the measurements of the voltage and current gaining from solar panel, batteries and amount of obtained voltage and current of the load (electric stove) was taken with the help of multi-meter.

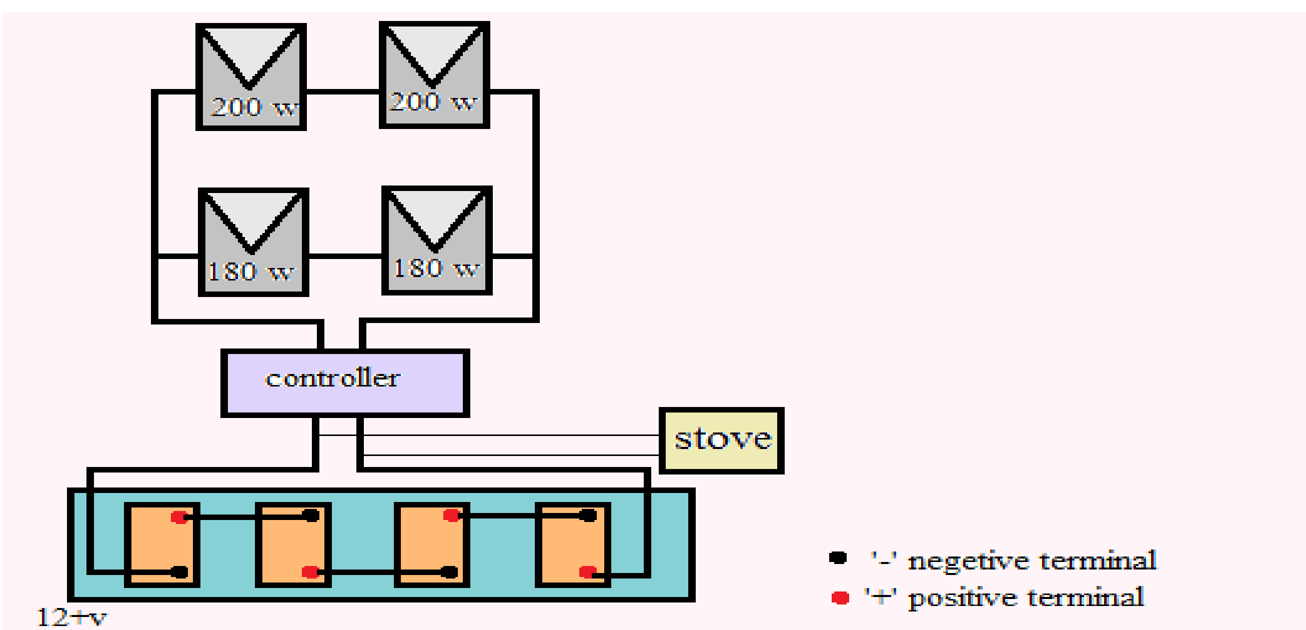


Fig5.1: circuit diagram with the solar panel

For the first time the whole system was set up at the 21st floor at 2nd building of BRAC University at 23rd September, 2013. It was a bright sunny day. After giving the set up water was boiled to this stove. Later on, at the same month rice was cooked in there. Back in 23rd September, 2013, this picture of the whole system was taken.

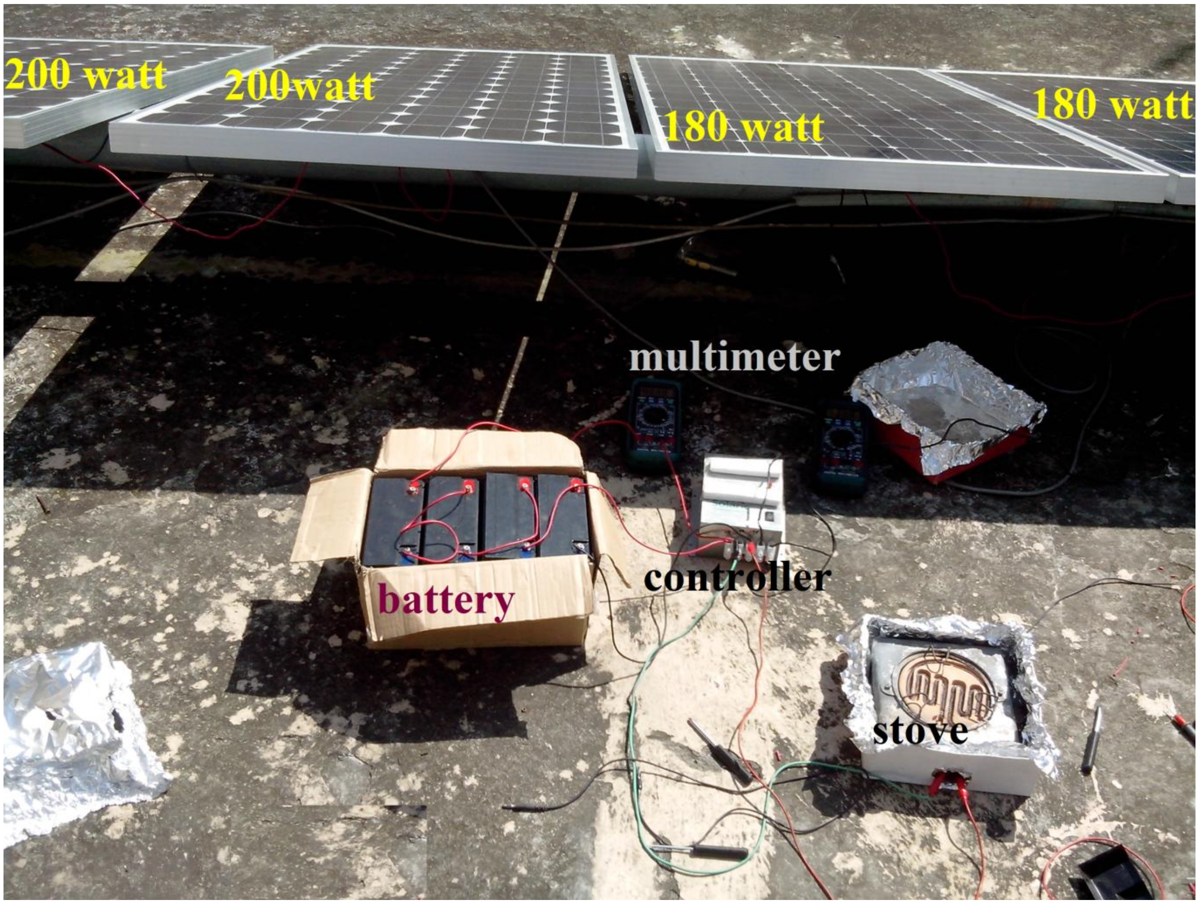


Fig5.2: setup of whole system with the solar panel

5.2.1 Data of boiling water at field test

With 200 ml of water was boiled again as an experiment. Since it will be compare with the previous data which was taken in lab same condition was used. For this reason, data was taken in every 30 second while water was in the stove till it was boiled up to 100 degree Celsius. The temperature of the water was being measured by thermometer. This experiment was done covering the stove both the side with aluminum foil. Since the power of load was varying, the accurate data, along with the time, the amount of power gained by load from solar panel and batteries is given below:

Time(PM)	PI	Pv	power from panel	BI	Bv	power from battery	Lv	LI	power of load
12.05	7.31	67.2	491.232	2.39	46	109.94	50.3	9.95	500.485
12.07	7.02	58.8	412.776	2.8	45.2	126.56	46.8	9.99	467.532
12.9	6.97	54	376.38	2.9	46.2	133.98	46.2	9.89	456.918
12.13	6.7	53.2	356.44	3.5	47.6	166.6	48.1	9.63	463.203
12.15	6.87	58	398.46	3.7	46	170.2	47.6	9.72	462.672
12.17	6.6	46.9	309.54	3.9	51.9	202.41	48.6	9.89	480.654

Table 5.1 data of boiling water on the field

The data which is showing below was taken during the experiment

Time	Temperature
0	33
0.3	38
1	41
1.3	43
2	47
2.3	54
3	58
3.3	61
4	65
5	72
5.4	79
6	80
7.2	84
8	89
9	92
9.4	96
10	97
11	98
12	100

Table 5.2 Time consumption data for boiling water

5.2.2 Comparative study

With the same re-design electric stove at roof with the solar panel electricity supply, the most effective result was found in the experiment done with national grid covering both. It took 12 minutes to boil 200 ml of water properly when the whole system was connected with the solar panel and batteries.

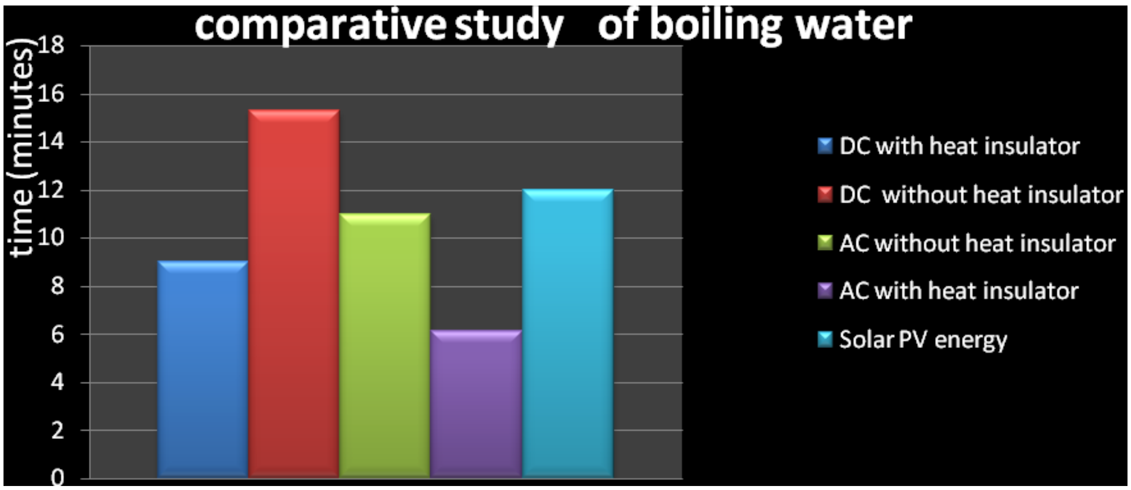


Fig5.3: Bar chart for comparative study of boiling (solar panel connected)

5.2.3 Experimental Analysis

Though with the solar panel power supply 200 ml of water took a bit while to boil properly than national grid supply, it can be state that the system works properly and it is user friendly too. Later on when rice and other food which were cooked at roof top were also cooked there. Boiling water is not the target to achieve by this stove. The main target is to cook food for an optimum number of family members in Dhaka city.

5.3 Data for other experiment in field test

5.3.1 Overview of experiments

All these experiments were done in the basis of daily food requirement. The prime target was the common people who live with an optimum number of family members (e.g. number of family members 4 to 5). Though the experiment was done for 3 people with a small fry pan frying food were done (fried items: chicken, fish, eggs etc) and with a pot rice and vegetable for 2 to 3 people were cooked.

The time duration of each item is given bellow:

Number of item	Name of item	Duration (minutes)
1	Chicken fry	14
2	Ilesha fish fry	7
3	egg fry	5
4	Rice	35
5	Vegetable	25

Table 5.3 Time consumption record for on field cooking

5.3.2 Comparative studies of the Data

After cooking all the items in the stove these data were compare with the normal time duration. An experiment with same amount of item with same quantity was also cooked in gas stove.

The comparative data is given below:

No. of item	Name of item	Duration in experimental stove	Normal Duration gas stove
1	Chicken fry	14	12
2	HIlsha fish fry	7	6
3	egg fry	5	5
4	Rice	35	30
5	Vegetable	25	20

Table 5.4 comparison in time consumption

5.3.3 Data analysis of experiments in field test

It is clearly seen from the above data that this experiment was a success. Though it took a bit while to cook food but all together cooking was don within 3 hours so that's the normal time period for cooking. Time was not consumed that much. Cooking can be done with this stove.

5.4 Calculation of Percentage of power from panel

Each time experiments were done at the roof, power calculation was taken. Every time the power supply from load and power supply from batteries were calculated. While boiling the water in the stove, the power percentage data is given below:

power from panel Percentage	power from battery Percentage
98.15119	21.96669
88.28829	27.0698
82.37364	29.32255
76.95114	35.96695

86.12149	36.78632
64.39976	42.11137

Table 5.5 load sharing between panel and battery

Bar chart of the percentage of power from panel and battery while water was boiling inside the stove is given as follow

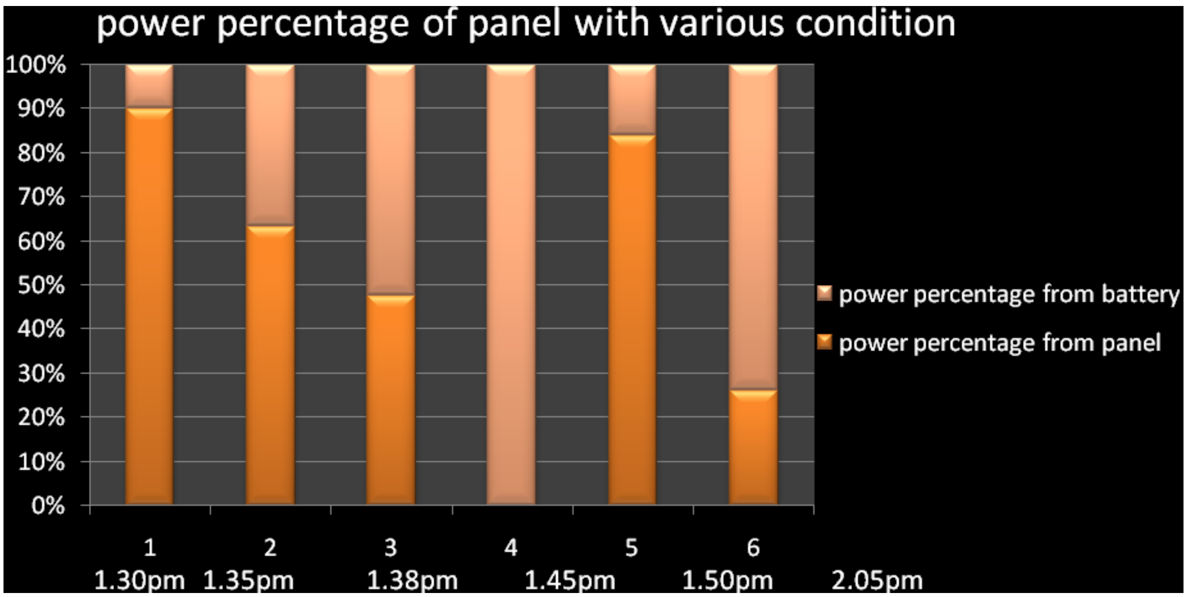


Fig5.4: Bar chart percentage of power from panel and battery (while boiling water)

Later on, with several terms and condition data was taken. As this project is fully weather dependent, experiment was done in consideration of the weather. Though stove was connected for while, no cooking was done. It was done within same day.

The data with the term is given below:

23rd september 2013

P_I = panel current
B_I = battery current
L_I = load current

P_V = panel voltage
B_V = battery voltage
L_V = load voltage

time	PI	Pv	power panel	BI	Bv	power battery	Lv	LI	power load	power per(	power percentage from	
1.30pm	7.18	48.1	345.358	1.42	50.2	71.284	50.2	9.99	501.498	68.86528	14.21421	
1.35pm	6	49.6	297.6	3.73	46	171.58	46	9.73	447.58	66.49091	38.33505	
1.38pm	4.28	47	201.16	4.91	45.2	221.932	46.2	9.72	449.064	44.7954	49.42102	
1.45pm	0	48.2	0	9.53	46	438.38	47.3	9	425.7	0	102.9786	giving shadow at 200w panel
1.50pm	7.83	69.6	544.968	2.2	47.6	104.72	48	10.1	484.8	112.4109	21.60066	
2.05pm	2.34	48	112.32	6.9	46.3	319.47	46.3	9.71	449.573	24.98371	71.06076	removing shadow
2.12pm	1.8	46.7	84.06	7.6	48	364.8						no load
2.17pm	1.9	50.956.3	1.9	7.8	51.9	404.82						
2.19pm	7.3	56.3	410.99	2.36	56	132.16						no shadow
2.21pm	4.8	53.8	258.24	4.6	56	257.6						small portion shadow in one panel
2.23pm	4.12	52.7	217.124	5.2	55.1	286.52						a bit more than previous one in single panel
2.26pm	0.84	58.6	49.224	8.6	55.5	477.3						small portion of shadow in both panel
2.29pm	0	46.1	0	9.1	58.347.3	9.1						more shadow in both panel
2.40pm	7.1	53.5	379.85	0	54.7	0	charging					

Fig5.5: Percentage of power from panel and battery(with several conditions)

Terms and conditions while taking the data were:

- Giving shadow at 200watt
- Small portion shadow in one panel
- removing shadow
- Small portion of shadow in both panels
- A bit more than previous one in single panel
- No load no shadow
- No load.

On 30th September, 2013 without any terms and condition a data was taken to determine the percentage of the power coming from panel and batteries toward the load.

It was to note that without the interruption how much power can the load obtained from the solar panel and from the batteries. The table of the percentage data is given below:

power percentage from panel	power percentage from battery
112.4109	21.60066
98.15119	21.96669
91.82493	29.52768
88.28829	27.0698
86.12149	36.78632
82.37364	29.32255
71.06076	24.98371
76.95114	35.96695
68.3788	30.72216
68.86528	7.644108
66.49091	38.33505
64.39976	42.11137
57.50628	57.36376
51.00399	67.30561
44.7954	49.42102

Table 5.6 load sharing between panel and batteries

In the bar chart it is showing as follow

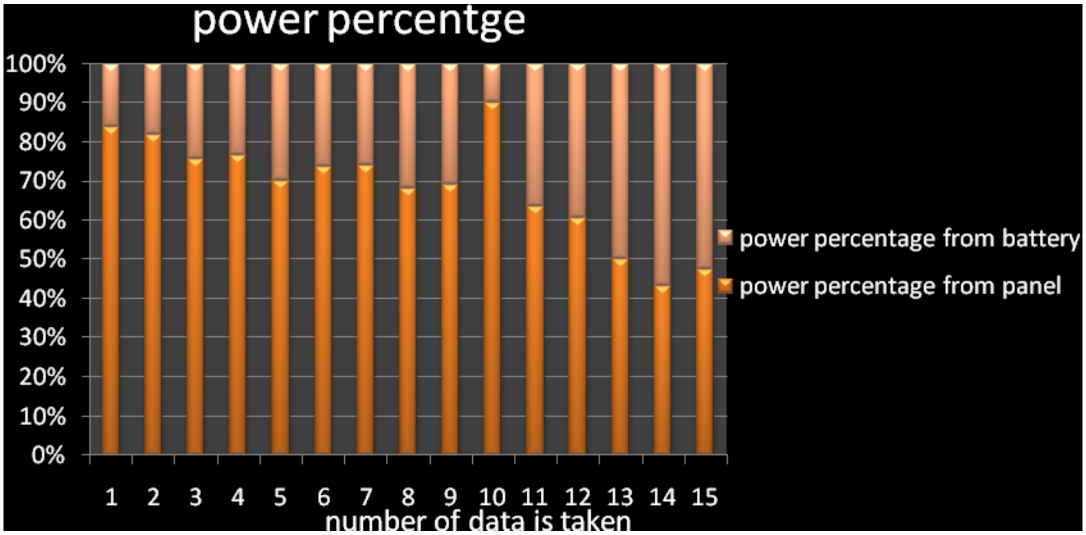


Fig5.6: Bar chart percentage of power from panel and battery

5.4.1 Analyzing result of percentage

It can be said that from, after analyzing all the results of the data- in a bright shiny day most of the time power is being supplied from the solar panel towards the load and less amount from batteries. Average of power percentage coming from solar panel rice is 75.24% and rest of the power coming from batteries. Furthermore when the load is not being used during that time the solar panel will charge the batteries.

5.5 Battery Discharges

4 batteries used for this system. Each battery is of 12v and all together it is 48 volt. It was necessary to take the discharge data to how long without the supply of the solar panel, the system can be run. About 70 minutes it can be run. Though in general cooking in the households can be done within daytime, in case of emergency or snacks making item at evening can be done with the batteries power. Solar panel was not connected. The whole system was designed without solar panel for this purpose. Only batteries were supplying the power to the load. Not only battery, charge controller was also used.

Data is given as follow

TIME	Voltage	current	Power
0.55	48.6	9.75	473.85
6.14	48.3	9.69	468.027
10	48.1	9.86	474.266
15	47.8	9.81	468.918
20	47.6	9.7	461.72
25	47.4	9.64	456.936
30	47.2	9.64	455.008
35	47.3	9.63	455.499
36	47.6	9.52	453.152
40	46.5	9.52	442.68
45	46.4	9.48	439.872
50	46.2	9.48	437.976
55	46	9.44	434.24
60	45.76	9.43	431.5168
65	45.4	9.4	426.76

Table 5.7 batteries discharging record

Since the load was connected with the batteries, while taking the data, rice was cooked in the stove.

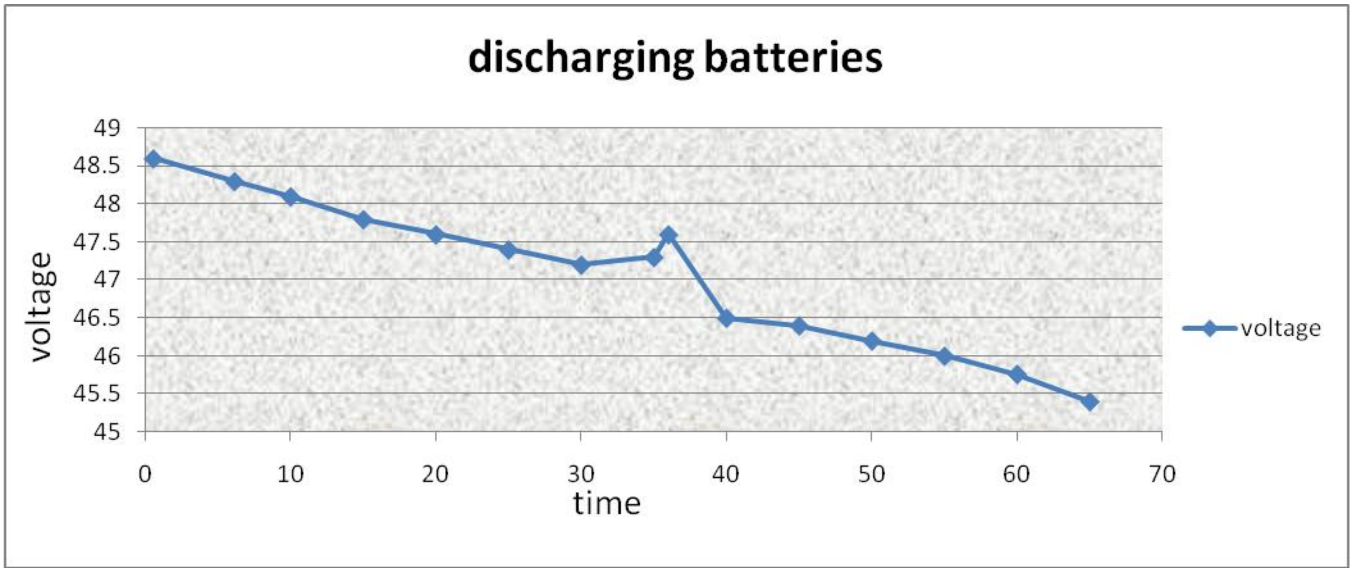


Fig5.7: Graphical representation of rate of discharging battery

Note: Reason for pick in the graph is described in chapter **2.2.1(**comment**)**

5.6 Qualitative Analysis

During the three hours of test, no hazardous condition took place like losing the control over electric stove and nonstop performance was taken from the system. From the user point of view, it is user friendly and one can easily cook with it at anytime of the day and also during night time. Although the stove once was broken in first experiment later on in all other experiments it was attached properly. Moreover any electronics for cooking purpose of 500 watt like sandwich maker or toaster can be use instead of the electric stove.

5.7 Confirmation

Cooking can be done with the solar panel along. Furthermore it can be run along with the other electronics (light, fan, heater and so on). With all the evidence it can be proved that energy can be saved after cooking.

CHAPER 6

Comparative Study

6.1 Cost Comparison with Gas Stove.

A large number of urban dwellers are waiting to be connected to the national gas network in Bangladesh. "The total number of which is reportedly close to one hundred thousand."[**11**]. Also new apartments will not get the connection either in recent time. In these circumstances people are getting involved with cylinder gas. The gas is not cheap either. "TotalGaz sells a cylinder at Tk 2,000, which will go up by Tk 500." [**12**]. So each cylinder will cost 2500Tk. Table below helps to understand further about cost of cylinder gas for cooking.**[13]**

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

Table: 6.1 cost calculation at present rate.

On the other hand, this project utilizes solar energy which is free of cost. In fact, it has the potential to earn some money by saving additional energy to the batteries. It also promises to sell extra energy to grid connection in near future. Though the initial cost for set up is high, but it can be met with government's subsidies to this sector.

6.2 Government's Policy to Renewable energy.

Bangladesh government is looking for alternative for energy source because of declination of natural gas reserve in the country. The country also could not meet the target of reserve of natural gas in the year of 2010. As a result several strategies were undertaken to mitigate the reliance on natural gas. Solar energy project came in this regard as a promising one. To establish the project government imposed some policies for the new buildings. "This policy requires that all newly constructed buildings must include a rooftop solar power unit with an output not less than 3% of the buildings total peak load."[**14**] So, this project will be a good fit to full fill the required demand of using solar energy. One must buy solar panels to get electricity connection and the major part of the cost of this project is due to panels. So, this project can easily become a good choice for utilizing panels.

6.3 Case Study Analysis.

Recently a meeting was held in a developer company named "ejab" and the meeting was with their Deputy Manager (Electrical), Engr. Liton Sarker. According to him since it was mandatory to have 3% of total peak load from solar panel, ordered by "DESCO" (Dhaka Electricity Supply Co.), they put solar panel at their roof top. It was about amount of power supply from solar panel for their residential house with 8store. Relative data was taken. With the help of those data, an approximation calculation was prepared.

Total Peak Load	**195 kW**	
Panel Load	**4.4 kW**	Supposed to be 5.8 kW
Battery	**600 Ah**	
Controller	**12/24 V**	

Table:6.2 Data of 'ejab' developer project.

With the help of these data[**15**] of their system, the analysis is presented below.

Total Energy Produced by Panels.

4400×10×.41 [4400= panel wattage, 10= hours exposed to sunlight, .41= avg. co-efficient using SWERA data]

=18.04 Kwh

Energy consumed during cooking:

7×465×3× [7= no. of stove, 465= stove wattage, 3= hours exposed during cooking]

=9.765 Kwh

Energy stored in the battery:

(18.04-9.765) Kwh

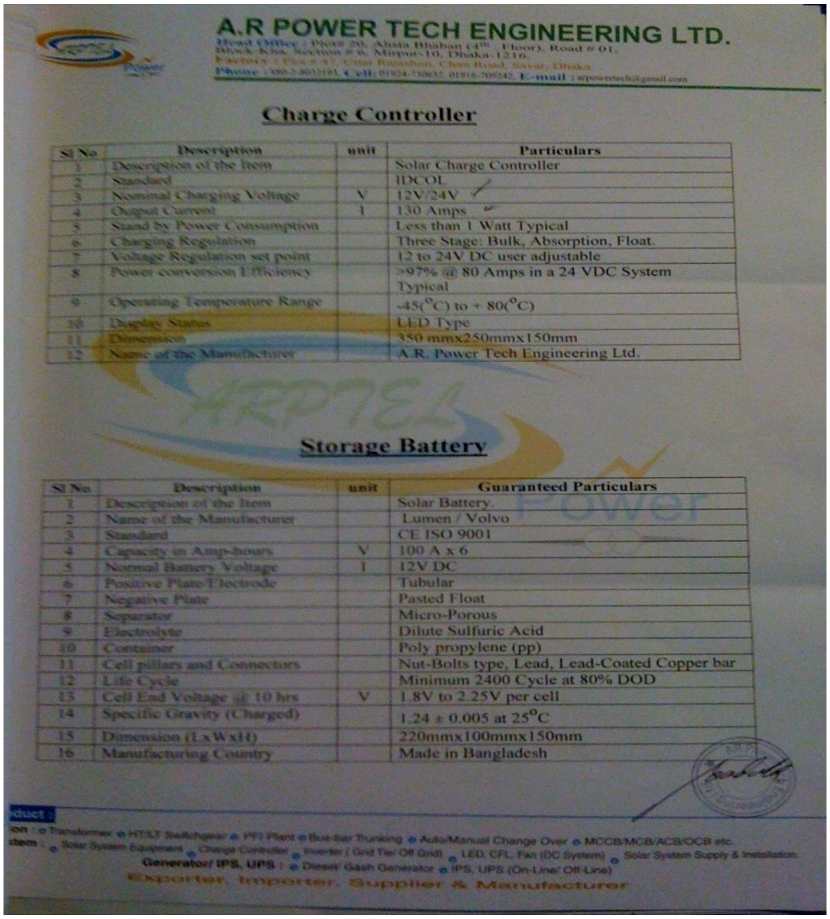
=8.275 Kwh

If 75% is discharged from the battery, battery supply = (8.275×75%) Kwh

= 6.21 Kwh

This amount of energy can be extracted from the batteries after it being charged.

Now 1.395 Kwh energy is needed for cooking. So, while discharging batteries people can cook or do whatever, with that limited energy.



A.R POWER TECH ENGINEERING LTD.

Charge Controller

Sl No	Description	unit	Particulars
1	Description of the Item		Solar Charge Controller
2	Standard		IDCOL
3	Nominal Charging Voltage	V	12V/24V
4	Output Current	I	130 Amps
5	Stand by Power Consumption		Less than 1 Watt Typical
6	Charging Regulation		Three Stage: Bulk, Absorption, Float.
7	Voltage Regulation set point		12 to 24V DC user adjustable
8	Power conversion Efficiency		>97% @ 80 Amps in a 24 VDC System Typical
9	Operating Temperature Range		-45(°C) to + 80(°C)
10	Display Status		LED Type
11	Dimension		350 mmx250mmx150mm
12	Name of the Manufacturer		A.R. Power Tech Engineering Ltd.

Storage Battery

Sl No	Description	unit	Guaranteed Particulars
1	Description of the Item		Solar Battery.
2	Name of the Manufacturer		Lumen / Volvo
3	Standard		CE ISO 9001
4	Capacity in Amp-hours	V	100 A x 6
5	Normal Battery Voltage	I	12V DC
6	Positive Plate/Electrode		Tubular
7	Negative Plate		Pasted Float
8	Separator		Micro-Porous
9	Electrolyte		Dilute Sulfuric Acid
10	Container		Poly propylene (pp)
11	Cell pillars and Connectors		Nut-Bolts type, Lead, Lead-Coated Copper bar
12	Life Cycle		Minimum 2400 Cycle at 80% DOD
13	Cell End Voltage @ 10 hrs	V	1.8V to 2.25V per cell
14	Specific Gravity (Charged)		1.24 ± 0.005 at 25°C
15	Dimension (LxWxH)		220mmx100mmx150mm
16	Manufacturing Country		Made in Bangladesh

Exporter, Importer, Supplier & Manufacturer

Fig 6.1: Specification of controller and storage of battery at "ejab"

CHAPTER 7

Conclusion and Future Work

7.1 Digest

The project is based on solution of real life problem. Such system can be beneficial in our life not only because it saves money but also because it is an application of utilizing solar energy which is renewable. Modification in the coil is an on-demand innovation. The project did not change the mud insulator to sustain simplicity in the design. Effective heating technology is just the demonstration of the importance for introduction of this technology to this kind of product. Battery backup can also store energy to be utilized for other purposes rather cooking, provided the systems are for DC. Versatility in execution of experiments shows the effectiveness of the product in different conditions. As time consumption is one of the biggest issues of this project, several tests were implemented sincerely to support the product. Cost analysis explains its financial advantages. The case study is a great evidence for believing in the implementation of this product in real life. It has opened a new era for cooking environment which seems to be the solution of the problems for tomorrow.

7.2 Proposed Home System

The apartments those are newly built or are building, falls in the obligation to have solar panels of a significant load. In most cases for Bangladesh, people buy the panels to get over with the obligation and do not utilize those panels properly. Hence, a home system can be a good fit to that system loss. It proposes to implement this modified stove and its system for the entire building in cooking purpose. With the help of the case study one can easily understand the possibility of implementation. It will help the owners of those buildings to get the most out of the panels. Since panels last for 30 years or so, it may provide earning to the owner. Also in the community cooking system (shelter centers, tribe unities) this system is applicable.

7.3 Prospective Development

This thesis opens a new field for the manufacturers to develop the product. More compressed design of the stove can easily draw the attention of the consumers. Development is also possible in the coil design which can improve its performance. Insulation inside the stove can be improved to develop effective heating. Double stove is possible for faster cooking.

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Appendix

200Wp Mono crystalline solar module

Electrical Characteristics

Maximum power at STC（Pmax）	200W
Optimum operating voltage（Vmp）	34.4V
Optimum operating current（Imp）	5.81A
Open-circuit voltage（Voc）	43.2V
Short-circuit current（Isc）	6.5A
Short-circuit current temperature coefficient	（0.065±0.015）%/℃
Open-circuit voltage temperature coefficient	-（80±10）mV/℃
Peak power temperature coefficient	-（0.5±0.05）%/℃
NOCT (Air 20℃; Sun 0.8kW/m wind 1m/s)	47±2℃
Operating temperature	-40℃ to 85℃
Maximum system voltage	1000V DC
Power tolerance	±3%

STC: Irradiance 1000W/m^2, Module temperature 25℃, AM=1.5

Features

- Nominal 24V DC for standard output.
- High efficiency.
- Outstanding low-light performance.
- High transmission tempered glass.

Dimension

Tariff Rate

This is for information of all concerned that in accordance with the BERC Order# BERC/ Tariff/ BST-05/Bubo/2012/2441 Dated: 20 September 2012, new tariff rates with respect to retail sales of electricity of Dhaka Electric Supply Company Ltd. (DESCO) has been made effective in case of electricity usages from 01 September 2012 as the followings :

SL	Consumer Category		Per Unit Rate (Tk.)
1	Category-A : Residential		
	a.	First Step : From 00 to 75 units	3.33
	b.	Second Step : From 76 to 200 units	4.73
	c.	Third Step : From 201 to 300 units	4.83
	d.	Fourth Step : From 301 to 400 units	4.93
	e.	Fifth Step : From 401 to 600 units	7.98
	f.	Sixth Step : Above 600 units	9.38
2	Category-B : Agricultural pumping		2.51
3	Category-C : Small Industries		
	a.	Flat Rate	6.95
	b.	Off-Peak Time	5.96
	c.	Peak Time	8.47
4	Category-D : Non-Residential (Light & Power)		4.53
5	Category-E : Commercial And Office		
	a	Flat Rate	9.00
	b	Off-Peak Time	7.22
	c	Peak Time	11.85
6	Category-F : Medium Voltage, General Purpose (11 KV)		
	a	Flat Rate	6.81
	b	Off-Peak Time	5.96
	c	Peak Time	9.33
7	Category-H : High Voltage, General Purpose (33 KV)		
	a	Flat Rate	6.48
	b	Off-Peak Time	5.87
	c	Peak Time	9.14
8	Category-J : Street Light and Water Pumps		6.48