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FABRICATION AND PERFORMANCE ANALYSIS OF A SOLAR ELECTRIC STOVE (SES) AND PERFORMANCE ANALYSIS OF DEVELOPED STOVE

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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 in proportion with population increase, it will not take much time to finish all the resources that are available now. In this research, a Solar Electric Stove with an input power of 12V DC elegantly solves the issue of intermittent power by allowing seamless integration with small scale solar installations and solar-based micro-grids instead of a grid connection. The power will come from the national grid when, panel and battery are not giving sufficient power to the load. In this research an Electric Charge Controller will be developed to ensure safety of the system and store charge in the Battery. A Solar Electric Stove (SES) is considered as an amazing circuit which is capable of converting electricity into heat with utmost efficiency and without much loss. The SES is the first of its kind and represents a new contribution to both the field of induction heating and the field of clean cooking solutions for the developing world because it's not emits hazardous fumes and harmful GHG gas.*

Keywords: SES, Stove, Solar Panel, Battery, Charge Controller, Cooking

1. INTRODUCTION

The World Health Organization estimates that three billion people cook with biomass and coal causing 4 million deaths per year from breathing the associated emissions. In Bangladesh rural people uses firewood or cow dung that cause indoor air pollution and different diseases. Beside the dangers of indoor air pollution, cooking over open fire also results in deforestation and climate change emissions of CO2 and soot [1]. The negative effects of current cooking methods can be reduced but not eliminated by using fuel efficient stoves. We can overcome all of these problems using renewable energy. Everyone knows renewable energy is the energy for tomorrow. Still it is not affordable to use renewable energy to fulfill all our needs. All have to be smart with using renewable energy for different requirements. Cooking is one of the biggest sectors 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 solar electric stove can be an excellent replacement.

Moreover, Bangladesh government has 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 [2]. So, Solar Electric Stove will be a good fit to full fill the required demand of using solar energy. Weather condition in Bangladesh is also suitable for this research. The average sun shine data of Bangladesh clarifies the opportunity of the product in real life. In our country daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available in the month of April-May and minimum in December-January. The monthly average solar radiation in Dhaka is found to be $4.24 kWh/m^2$.A Solar Electric Stove is considered as an amazing circuit which is capable of converting electricity into heat with utmost efficiency and without much loss.

2. LITERATURE REVIEW

Cooking with solar energy is not a new notion. It had in fact started in the early period, in 1767 [3]. 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 [4]. 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 [5]. In [6] a study has been done on electric heating of an insulated chamber which was powered by solar panel and batteries. Advanced cookers like the induction cookers are very efficient but special pots are needed to operate those and there are health hazards due to electromagnetic emissions. The heating level of these cookers can be controlled and these can be turned on or off at desired temperature [7]. The Whirlpool sixth sense cooker can be set to the boiling point of the water [8]. Another induction cooker has employed mathematical modeling of temperature control [9]. A fuzzy logic based smart electric cooker has been designed in [10]. The model was designed for conventional AC electric cooker but not for solar based low voltage electric cooker.

3. DESIGN OF THE SYSTEM

3.1. Block Diagram of the System

Solar Electric Stove is comprised of four subsystems that transform electrical energy to heat energy during workout. The subsystems are solar panel, charge controller, battery and heating coil. During AC supply an additional inverter is used to convert AC to DC power. The basic block of Solar Electric Stove is given bellow.

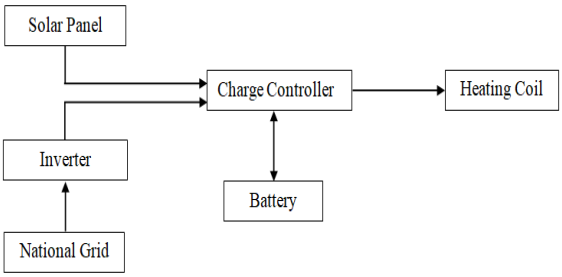


Fig. 1: Block diagram of Solar Electric Stove

In this context, solar panels and batteries will provide the opportunity to supply to designed stove according to the installed PV capacity level. The national grid will be used to cover the evening peak and complete the battery charge if required. The system will be designed to get the maximum energy and maximum cooking hours. It will be designed in sucha 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 comes 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 controllerwill charge the batteries in day time when the stove is not used.

3.2. Principal of Solar Electric Stove

The electric cooker follows the principle of electric heating. When electric current I flow through the electric coil which has a resistance R produces heat. This heat energy helps to increase the temperature of the electric coil. This heating should be controlled by choosing the appropriate material of the electric coil. The relationship between current I, resistance R, overall heat transfer co-efficient U and surface area of the coil A is-

$$q = I^2R = UA\Delta T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The resistance R of the coil is:

$$R = K\left(\frac{4I}{\pi D^2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In which K is resistivity in Ωm^{-1}. l is length of conductor in meter and D is diameter in meter. The surface area A of the coil,

$$A = \pi ID \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Combining 1, 2 and 3 we get,

$$D = 0.74\left(\frac{I^2K}{U\Delta T}\right)^{1/3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

This relationship gives minimum diameter of the coil of specific resistivity K which can be used to carry current I without increasing the temperature of the conductor to a value more than ΔT° C above the surrounding.

3.3. Design and Components of Stove

Following figure represents the designed Solar Electric Stove. The diameter of stove is 32 cm and height is 6 cm. The diameter of the plate is 26 cm. The coil plate is insulated from the side walls of the cooker by ceramic plates so that no heat is transferred to the body of the cooker. Two thermal fuses have been used with two coils in order to protect the coils from being damaged.

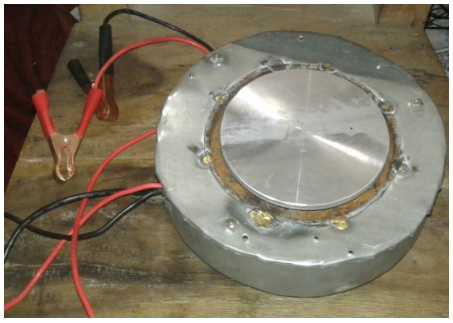


Fig. 2: Designed Solar Electric Stove

Coil: Solar Electric Stove using pure DC coil that use

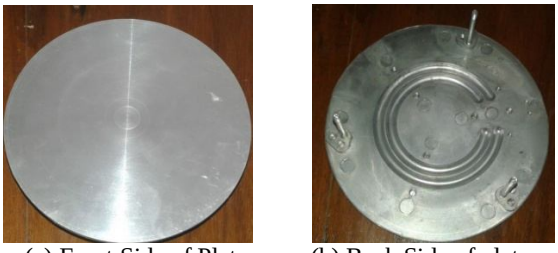
direct current without any converter. DC Coil is the heart of stove. It is using the solar energy or direct current to produce electromagnetic induction heat which is mainly responsible of heating process. Table 1 represents the specifications of coil and Fig. 3 represents the image of Coil.

Table 1: Specification of Coil

Coil Resistance	0.85 ohm
Length	10 Inch
Diameter	1.25 Inch
Voltage	12V
Current	11.76 Amps
Power	150 W

Fig. 3: Coil of designed Stove

Soul Plate: The soul plate is making with stainless steel 432. Basically, stainless steel has large surface resistivity. The diameter of soul plate is 12.4cm and thickness is 0.5cm.



(a) Front Side of Plate (b) Back Side of plate

Fig. 4: Soul Plate of developed Stove

PTC: Positive Temperature Co-efficient is as a thermostat. The thermostat does this by switching heating or cooling devices on or off. 110°C PTC is used in developed stove.

(a) Front Side of PTC (b) Back Side of PTC

Fig. 5: PTC in developed Stove

Table 2: Specification of PTC

Data Type	Value
Temperature	110°C
Resistance	0.027Ω
Voltage	0.5v
Current	15A

4. RESULT AND ANALYSIS

4.1. Boiling Water in Field Test

We boiled 500ml water with our developed stove in the field test. Both solar panels and batteries were connected to the system for power supply to determine the individual performance of stove. We used an aluminum pot with a lid for this process.

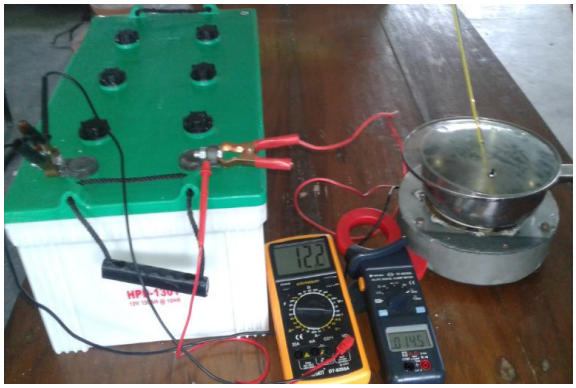


Fig. 6: Experimental setup of developed stove

Table-3: Data of boiling water

Time (Min)	Temperature (^{0}C) during Battery Power	Temperature (^{0}C) during PV Power
0	27.10	27.12
3	43.60	46.10
6	59.80	58.10
9	75.80	71.30
12	89.80	82.30
15	98.10	94.80
18	100.00	98.80

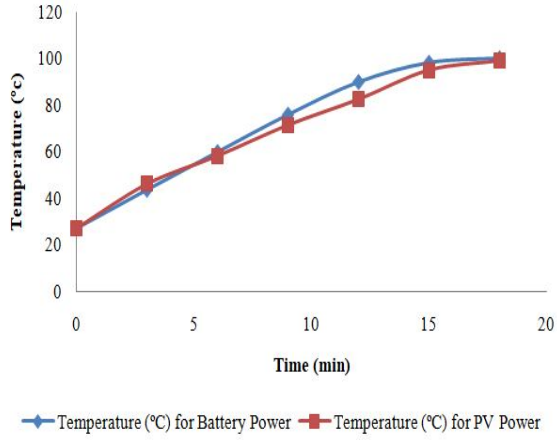


Fig. 7: Temperature variation for Battery and PV Power

4.2. Cooking Rice in 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.

Table-4: Data of Cooking Rice

Time (Min)	Battery Power			PV Power		
	V (Volt)	I (Amp)	P (Watt)	V (Volt)	I (Amp)	P (Watt)
0	12.28	14.45	177.45	12.7	14.40	182.88
5	12.27	14.43	177.06	12.7	14.40	182.88
10	12.26	14.42	176.79	12.7	14.41	183.01
15	12.25	14.41	176.52	12.7	14.40	182.88
20	12.24	14.40	176.26	12.6	14.40	181.44
25	12.23	14.39	175.99	12.5	14.23	177.88
30	12.22	14.38	175.72	12.4	14.20	176.08

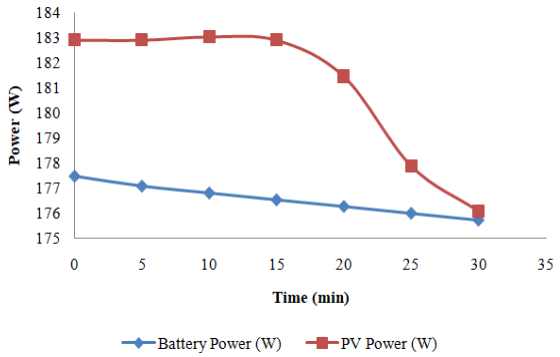


Fig. 8: Power variation for Battery and PV Power during cooking rice

From fig.8 it is clear that, battery power is almost constant and gradually decreases with the increase of time. But PV power is depended with solar radiation and hence it is vary with time.

4.3. Time Duration for Cooking Different Items

Table 5 shows the times required for cooking different items of food on the designed Solar Electric Stove.

Table-5: Times required for cooking different items

Item No	Item Name	Quantity	Time (Min)
1	Boiling Water	500 ml	18
2	Cooking Rice	0.5 Kg	30
3	Boiling Egg	2 piece	20
4	Noodles	1 packet	10
5	Fried Egg	1 piece	4

5. FUTURE RECOMENDATION

To ensure the best thermal efficiency we may use different types of thermal conductive plates. The temperature controller of the electric cooker can be improved by using PID controller or advanced microcontroller. On the other hands, Micro- controller based LED system can be developed with heat controller to let the user know about the current, voltage and temperature of the load side without using any multi meter.

6. CONCLUTION

This Solar Electric Stove 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. This project also includes battery backup which will help on cooking during gloomy days. As future availability of nonrenewable resources for cooking is a burning task, this product is a great solution introducing by the nonpolluting and renewable solar energy.

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8. NOMENCLATURE

Symbol	Meaning	Unit
T	Temperature	(^{0}C)
K	Specific Resistivity	(Ωm^{-1})
U	Heat transfer co-efficient	W/(m^2°C)