ABSTRACT

INDIA is facing over whelming energy challenges that are likely to increase the over next few decades. Domestic gas supply for cooking in under developing countries is facing terrible insufficiency last few years. Use of renewable energy can help- the cause and also contribute for the energy generation. Solar energy is being used for various domestic applications. However, solar based smart electric stove is not included in those applications. Our goal is to design a project which involves the development of solar powered electric stove that would use sunlight to generate electricity. In this project, we have designed the heating coil for the available solar power. Normally it is not possible to regulate the DC current from the panels, here in our project we have implemented the use of rotary switch to regulate the flow of current to the coil form the panels. In addition to that, payback analysis is presented.

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Chapter 1

INTRODUCTION

1.1 Background

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 16 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. The contemporary solar cooking system movement began in earnest mid-century. In 1980's 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.

1.2 Literature survey

For the last 10 years in India, there has been an increased emphasis on alternate energy sources, which is mainly due to energy crisis and long planned/unplanned power outages in the country. The government of India is itself seeking opportunities to invest in renewable energies. One example of such government initiative is the state of the art of solar power plant to help increase existing power supply source of the country. Besides these state supported activities, steps need to be taken at grass root level. All individual consumers need to attempt to overcome their part of the shortfall by installing renewable energy projects at their premises. Installing a renewable energy project is a part of short term planning to quickly overcome the energy shortfall. The most common renewable energy technologies are hydro, wind and solar technology.

Development of smart electric single burner stove powered by pv energy project is an advancement for the cooking environment . 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. 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].

More than a century ago, technology was revolutionized with the discovery and use of the fuel in domestic and industrial machines improving the lifestyle of people by many steps in one go. Fast means of transportation, electrical and electronic accessories and an improved industrial yield to meet the increasing demands are among a few of the advantages people got straight away from this addition to their everyday life. As the time elapsed, rapidly dying fuel reservoirs and exponential rise of fuel demand overgrew the production, causing a significant short fall of the product. Here is when the problem arose first [1].

Demand of fuel became so high that fossil fuel reservoirs failed to meet it while fuel search is a costly and time taking process as oil companies have to conduct long surveys and then, if any traces of the fuel are found, heavy drilling deep down into the earth or in the seas is required. It is not a matter of months but several long years. This supply and demand gap has hiked the fuel prices as well. This situation has led the world to look for easy, immediate and cost effective alternatives like wind, solar, solar thermal and biogas [2].

India is facing a challenging energy crisis for almost past two decades. Despite large natural oil and gas reserves, India is unable to overcome the energy crisis due to lack of advanced technology and poor financial planning. Fuel prices on average have risen by as high as 175% from 1996 to 2014. Similarly the electricity prices have also increased roughly 200% from 2010 to 2014. Although, government of India is trying its level best to help overcome the crisis yet no significant positive results have been observed so far. Business conditions are getting worse due to short fuel supplies as well as hiked fuel prices .A vast majority of households is unable to afford electricity costs which is developing economic dissatisfaction among countrymen. In this critical situation, the need of the hour is the adoption of cost effective renewable energy alternatives to stabilize the household and industry as well as economy of the country [2].

1.3 Motivation for the project work

There has always been an imbalance between supply and demand of energy. Energy shortfall in India reached 5500 MW in 2015, which is almost 45% of the actual demand. On average, planned load shedding to balance the supply and demand is about 8-10 hours in every 24 hours. It has been 10-14 hours during last year [3]. With increasing market competition, prices of PV modules are decreasing with each passing day. Recent surveys and studies reveal that the average per watt cost of PV module which had been $1.61, has now reduced to $0.8 in a short span of four years, which is almost exactly opposite to the rise in the electricity prices in the country over the same period [4].

1.4 Problem statement

The next chapter is dedicated to reviewing wind and solar energy. Based on this research, it may be concluded in that wind energy in India is limited and only a few territories are able to produce energy from wind. Energy generation through wind is not feasible for individuals, whereas in this report we are working on solution for individual sites. Wind energy is feasible in India on city or district level. On the other hand, solar energy is abundant in India and most of the parts of the country receive an abundant amount of solar irradiations. Solar energy solutions are quicker and faster ways to overcome the energy crisis on individual level. This report offers a cost benefit analysis, with a focus on calculation of the payback periods for solar energy system [4].

Here in this project, the ratings of the available panels are considered. For these ratings we have calculated the open circuit voltage and current. The heating element is configured in a appropriate manner and resistance and current from each of the coil is calculated. With these voltage, current and resistance values, the maximum output power is determine.

Table 1: International cost of Solar Modules

Solar Panel Technology	**Cost per watt $**
Mono Crystalline	0.79
Poly Crystalline	1.73

1.5 Methodology

STEP 1 : Load calculations: Calculate the voltage, current, resistance of the coil for the available ratings of solar panel. For the available solar panel ratings calculate the length and diameter of the heating element.

STEP 2:System design: Configuration of the heating coil and appropriate mode of Connection of solar panels

STEP 3: Experimental Set up: Connection of all the components.

STEP 4: Results and discussion: Experimental results from the set up.

STEP 5:Pay back analysis : Comparative study

1.6 Organization of the Project work

This report is organized into five chapters and brief overview of each chapter is given below

Chapter 1: A brief introduction that includes solar system background, global interest, problem statement and review of literature survey

Chapter 2: It gives detailed information about types of solar panels and its application, and energy storage

Chapter 3: It shows up experimental set up along with block and connection diagram, complete description of the components used and their ratings.

Chapter 4: Results and discussion, output calculations, payback analysis and comparative studies.

Chapter 5: Implementation of complete single burner smart electric stove followed by conclusions and future of its work.

Chapter 2

SOLAR PV SYSTEM

1

2.1 Introduction

A Photovoltaic System / PV system, used generate electricity using solar PV modules. It consists of various components such as solar panels to convert sunlight into electricity, an inverter to change the voltage from DC to AC, as well as mounting, cabling, and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution, as prices for storage devices are expected to decline. Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarized as balance of system (BOS). Moreover, PV systems convert light directly into electricity and shouldn't be confused with other technologies, such as concentrated solar power or solar thermal, used for heating and cooling [1].

2.2 Types of Solar Panels

Solar modules are made from SiO2 (Silicon), which is abundant on earth and is inexpensively available. The raw sand must be purified up to 99.9999% or in words 1 part per million (1 ppm). The cost of purification of sand up to prescribed levels is significantly high. There are basically three types of solar panels.

1. Mono-Crystalline Based Solar Panels
2. Thin Film Based Solar Panels
3. Poly Crystalline Based Solar Panels

2.2.1 Mono Crystalline Solar Panels

All the solar panels have the same basic recipe and all are made from silicon. Mono crystalline solar panels are made from single crystal of silicon. As the word 'mono' (meaning “single”) suggests, mono crystalline solar panels are developed from a single crystal on silicon, thus having no such grain boundaries. Mono crystalline solar panels have highest efficiencies in the world. The most recent solar panels claim of having efficiency nearly 22% at laboratory scale. Because of their highest output efficiency monocrystalline solar panels are expensive than the other solar panels [1].

Figure 2.1: Mono Crystalline Photo Voltaic Module

2.2.2 Poly Crystalline Solar Panels

Poly crystalline solar panels (also referred to multi crystalline solar panels) are developed from multiple crystals of silicon and have different structure than mono crystalline solar panels. Their silicon crystals are less purified, hence cheaper in price. As a consequence of less purity, they have low efficiency. The most recent papers claim that poly crystalline solar panels have efficiency of 17%. This type of modules can sustain high temperature and can perform very well in hotter regions. That is why; poly crystalline modules are used in Africa, Australia and Gulf regions. [1]

Figure2.2: Poly crystalline pv module

2.2.3 Thin Film Solar Panels

Thin film solar panels are entirely different in structure from traditional solar panels. Mostly they are made of single or multi-layer of Cadmium Telluride, with glass used as a substrate. Flexible solar panels are also a subclass of thin film based solar panels. In flexible solar panels the plastic sheet is used as substrate and CIGS (Copper Indium Gallium Solenoid) is deposited on it to make it workable.

Previously, thin film solar panels had very low efficiencies of only 8-10%, but now the 3rd generation of this film solar panels, currently available in market claim to have an efficiency of 21%. [1]

Figure 2.3: Thin Film Solar Module

Thin film solar panels have the following distinct advantages over conventional solar panels.

1. Have excellent working under low sun light conditions

2. Can be installed on any angle facing to sun.

3. Temperature coefficient is comparatively lower than conventional solar panels

4. Due to low temperature coefficients, they perform well in high temperature conditions.

2.3 Solar Power Applications

Now a day, solar powered appliances are in fashion; from mobile phone charger to mega power plants solar energy is being utilized. Solar energy is appropriate for mid-sized residential facility or small sized commercial facility. There are primarily 3 types of solar system configurations.

i. Off Grid Solar Systems

ii. On Grid Solar Systems

iii. Hybrid Solar Systems

2.3.1 Off Grid Solar System

In An off grid solar system is the one where primary source of power is solar energy only. In this system, the primary source of power is solar energy, the excess power is stored into battery bank, to be used in night time. The off grid solar system comprises of Solar Inverter, Battery Bank and Solar Panels.[3]

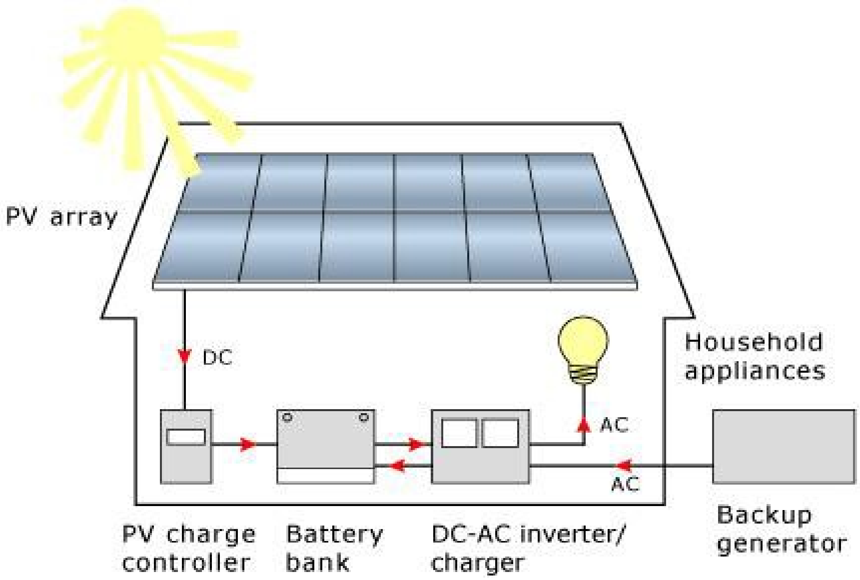

Figure2.4: Off grid solar system

2.3.2 On Grid Solar System

On grid solar systems are mostly installed in medium as well as large commercial units and are very popular in industrial sector. On Grid solar systems are well suited for any facility that has un-interrupted grid power. As this type of solar systems only use solar energy as primary source and grid as reference, there is no storing mechanism inside the system. The excess energy is fed back into the grid, which is calculated at the end of each month via Net Metering, Feed in Tariff or Power Purchase agreement, whichever is applicable [1].

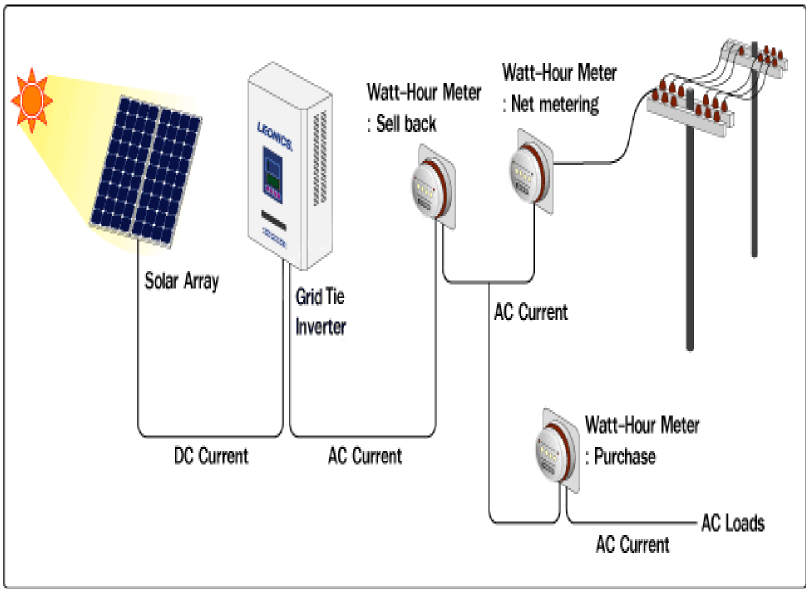

Figure 2.5: Schematic View of On Grid Solar System

2.3.3 Hybrid Solar Systems

The hybrid solar systems 'as the name suggests' are the mix of off grid and on grid solar systems. They use solar energy as primary source of energy and meanwhile they store excess energy into the battery bank. When battery bank are fully charged, the excess power is then fed into the grid for net metering.[1]

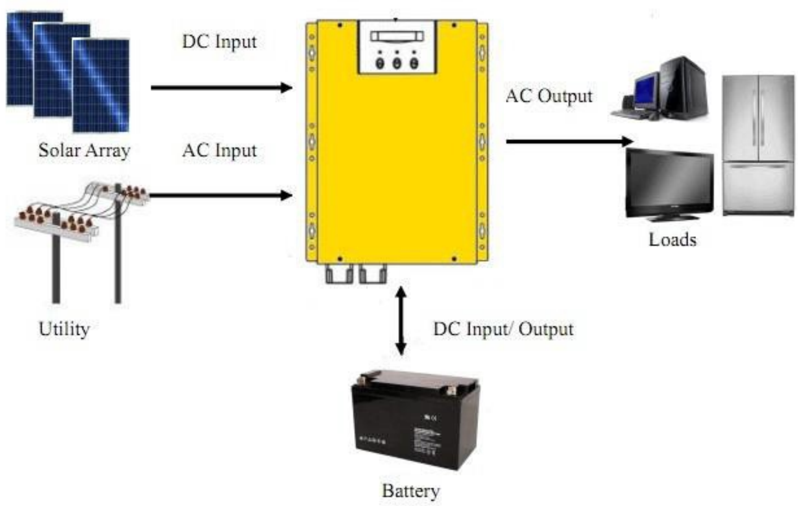

Figure 2.6: Hybrid solar system

2.4 Energy storage

Energy storage integrated net metering systems are also present. The producer stores some excess energy into battery banks and when the battery banks are fully charged, the excess power is fed into the grid. This system is more popular in the countries where the grid power is unstable. This is because the on grid systems only work if there is some reference sources present (i.e. grid or generator). If the reference is lost the system will shut down automatically. Energy storage helps the producer to store the energy at the time of grid shutdown during the sun hours. For storage purpose, batteries of various kinds are being used all over the world. Lead acid wet batteries are still used largely but they have small life cycle. Lithium Ion batteries and industrial deep cycle batteries are also being used and have an approximate life of 10 to 20 years . Ni-Fe batteries have the longest life span of approximately 40 years [3].

Chapter 3

EXPERIMENTAL SETUP

2

3.1 Block Diagram

Figure 3.1 shows block diagram of solar PV powered smart stove:it consist of solar panels, charge controller, rotary switch (heat controller) and stove.

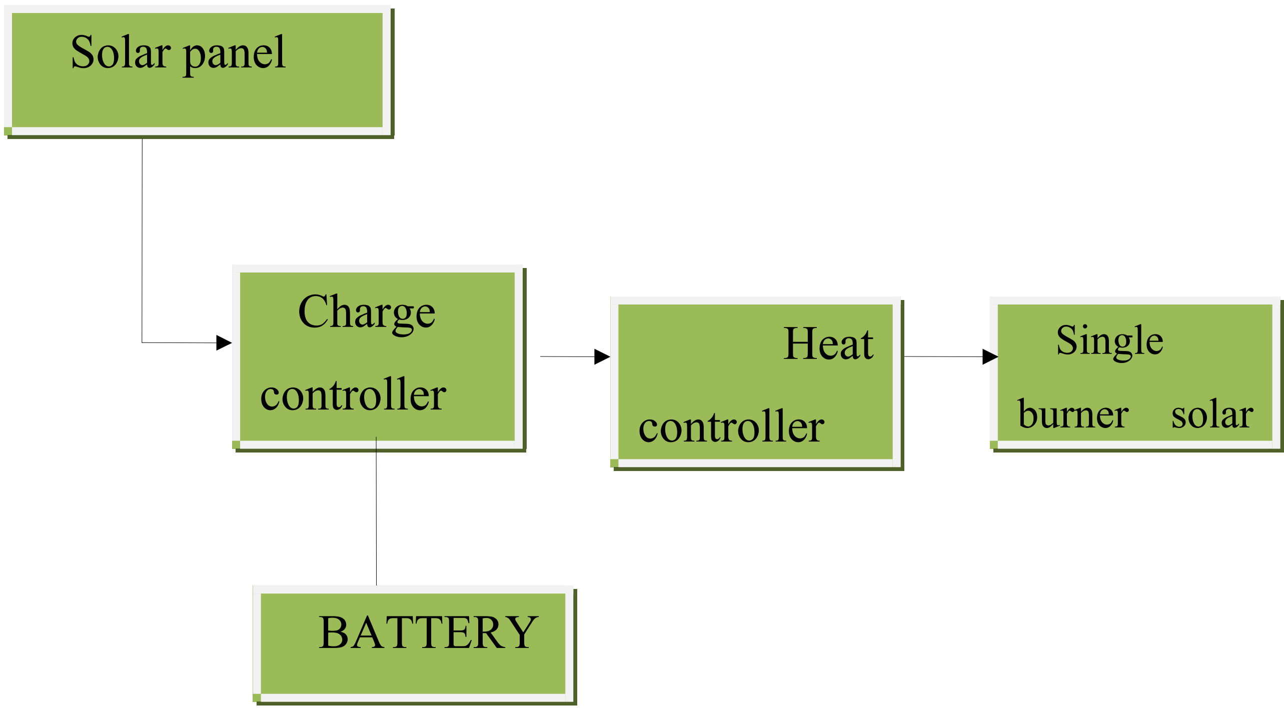

Figure 3.1:Block diagram of solar PV System

SOLAR PANELS: A photovoltaic (PV) module is a packaged, connect assembly of typically 6x10 photovoltaic cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications.

A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for storage, interconnection wiring, and optionally a solar tracking mechanism [2]

CHARGE CONTROLLER: Here Charge controller is used for multi function. The main purpose of charge controller is to give constant output current and frequency from the variable supply. Next it is used to convert DC to AC. 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.[1]

BATTERY: An electric **battery** is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, Smart phone's, and electric cars When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that when connected to an external circuit will flow and deliver energy to an external device. When a battery is connected to an external circuit, electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work. [1]

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. There is a knob for the controller by which the user can increase or decrease the heat according to their preference. Rotary switch of rating 16A is used.[1]

HEATING COIL: Nichrome 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 due to the resulting voltage from available resources. In order to achieve higher current the coil resistance was to be decreased. Later the coils are placed in the ceramic body.[1]

The power generated from solar panel is given to charge controller. The constant output from charge controller is given to heat controller. The controlled power is supplied to the stove through the heat controller thus control of the heat is achieved as shown in fig.1.

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.

3.2 Experimental set up

The main components of the single burner solar stove system are:

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

3.2.1 Solar panel

This is one of the most important components of the system. We used two 175W panels of rating 23V/9.8A, and three 75W panels of rating 17V/4.8A.The connection diagram of these panels is as shown. Photovoltaic solar panels absorb sunlight as a source of energy to generate electricity. Each module is rated by its dc output power under standard test conditions (STC), and typically ranges from 100 to 365 watts . The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module. There are a few commercially available solar modules that exceed

efficiency of 24% 17V

Model No.: ASPV12170

Maximum Power (P_{MP})	170 Wp
Open circuit voltage (Voc)	23.33 V
Short circuit current (I sc)	9.06 A
Voltage at maximum power (V_{MP})	19.84 V
Current at maximum power (I_{MP})	8.57 A
Maximum system voltage	600 V
Series Fuse Rating	15 A
Maximum Design load	2400 Pa
Application Class	Class A
Safety Class	Class II

Power measured in standard condition (STC) : Irradition 1000W/m², AM 1.5, cell temperature 25?C

Tested according to IEC 61215, IEC 61730-1&2

3.2.2 Charge Controller

A charge controller is an essential part of nearly all power systems that charge batteries, whether the power source is PV, wind, hydro, fuel, or utility grid. Its purpose is to

the basic functions of a controller are quite simple. Charge controllers block reverse current and prevent battery overcharge. Some controllers also prevent battery over discharge, protect from electrical overload, and/or display battery status and the flow of power. Let's examine each function individually.

Blocking Reverse Current: Photovoltaic panels work by pumping current through your battery in one direction. At night, the panels may pass a bit of current in the reverse direction, causing a slight discharge from the battery. (Our term "battery" represents either a single battery or bank of batteries.) The potential loss is minor, but it is easy to prevent. Some types of wind and hydro generators also draw reverse current when they stop (most do not except under fault conditions). In most controllers, charge current passes through a semiconductor (a transistor) which acts like a valve to control the current. It is called a "semiconductor" because it passes current only in one direction.It prevents reverse current
in some controllers; an electromagnetic coil opens and closes a mechanical switch. This is called a relay. (You can hear it click on and off.) The relay switches off at night.

If you are using a PV array only to trickle-charge a battery (a very small array relative to the size of the battery), then you may not need a charge controller. This is a rare application. An example is a tiny maintenance module that prevents battery discharge in a parked vehicle but will not support significant loads. You can install a simple diode in that case, to block reverse current. A diode used for this purpose is called a "blocking diode."[4]

Preventing-Overcharge: When a battery reaches full charge, it can no longer store incoming energy. If energy continues to be applied at the full rate, the battery voltage gets too high. Water separates into hydrogen and oxygen and bubbles out rapidly. (It looks like it's boiling so we sometimes call it that, although it's not actually hot.) There is excessive loss of water, and a chance that the gasses can ignite and cause a small explosion. The battery will also degrade rapidly and may possibly overheat. Excessive voltage can also preventing overcharge is simply a matter of reducing the flow of energy to the battery when the battery reaches a specific voltage. When the voltage drops due to lower sun intensity or an increase in electrical usage, the controller again allows the maximum possible charge. This is called "voltage regulating." It is the most essential function of all charge controllers. The controller "looks at" the voltage, and regulates the battery charging in response. Some

Controllers regulate the flow of energy to the battery by switching the current fully on or fully off. This is called "on/off control." Others reduce the current gradually. This is called "pulse width modulation" (PWM). Both methods work well when set properly. A PWM controller holds the voltage more constant. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then, it will drop the voltage lower, to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy).[1]

The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated patterns of usage, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. Some controllers have adjustable set points, while others do not. A circuit is overloaded when the current flowing in it is higher than it can safely handle. This can cause overheating and can even be a fire hazard. Overload can be caused by a fault (short circuit) in the wiring, or by a faulty appliance (like a frozen water pump). Some charge controllers have overload protection built in, usually with a push-button reset. Built-in overload protection can be useful, but most systems require additional protection in the form of fuses or circuit breakers. If you have a circuit with a wire size for which the safe carrying capacity (ampacity) is less than the overload limit of the controller, then you must protect that circuit with a fuse or breaker of a suitably lower amp rating. In any case, follow the manufacturer's requirements and the National Electrical Code for any external fuse or circuit breaker requirements.

Figure3.3: Charge controller

Specification charge controller:

- **Input** - 12 V
- **Output** - 12 V
- **Current** - 30A

Type - DC voltage

3.2.3 Battery

Simple dc coupled solar battery systems were once only used for remote power systems and off-grid homes but over the last decade hybrid (solar and battery) inverter technology has advanced rapidly and lead to the development of new AC coupled energy storage configurations. However the traditional DC coupled system is far from dead, in fact charging a battery directly from solar using DC charge controllers is one of the most efficient systems available.[3]

As solar battery systems became larger and more advanced AC coupled systems evolved as the preferred configuration due to the use of low cost, easy to install string solar inverters. Most modern AC coupled systems now use advanced bi-directional multi mode inverter coupled with one or more compatible solar string inverters [2].

In grid-tie solar generation system, the solar modules are directly connected to inverter not with load. The power collected from solar panel not in constant rate rather it varies with intensity of sunlight. This is the reason why solar modules or panels do not feed any electrical equipment directly instead they feed an inverter whose output is synchronized with external grid supply. Inverter takes care of the voltage level and frequency of the output power from the solar system it always maintains it with that of grid power level. As we get power from both solar panels and external grid power supply system, the voltage level and quality of power remain constant. As the stand-alone or grid fallback system is not connected with grid any variation of power level in the system can directly affects the performance of the electrical equipment fed from it. So there must be some means to maintain the voltage level and power supply rate of the system. A battery bank connected parallel to this system takes care of that. Here the battery is charged by solar electricity and this battery then feeds a load directly or through an inverter. In this way variation of power quality due to variation of sunlight intensity can be avoided in solar power system instead an uninterrupted uniform power supply is maintained. Normally Deep cycle lead acid batteries are used for this purpose. These batteries are typically designed to make capable of several charging and discharging during service. The battery sets available in the market are generally of either 6 volt or 12 volts. Hence number of such batteries can be connected in both series as well as parallel to get higher voltage and current rating of the battery system.

Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved additionally to include devices composed of a single cell. Primary (single-use or "disposable") batteries are used once and discarded; the electrode materials are irreversibly changed during discharge. Common examples are the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using mains power from a wall socket; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and smart phones. Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smart phones, to large lead acid batteries used in cars and trucks, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centres. According to a 2005 estimate, the worldwide battery industry generates US$48 billion in sales each year, with 6% annual growth.[2]

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. This is somewhat offset by the higher efficiency of electric motors in producing mechanical work, compared to combustion engines.

Figure 3.4: Tubular lead acid Battery

Specification of Battery:

- **Capacity** -150 AH
- **Voltage** - 12 V DC
- **Current** - 10A
- **Item -** Lead acid storage battery (factory charged).
- **Quantity-** 1 no.

Battery installation:

- Lift the battery cover.
- Install 1.5V AA size batteries as per polarity marked on the battery cover.
- Close the battery cover to avoid the electrical shock.

Caution:

- Do not apply power to P1 & P2, E1 & E2 terminals.
- Do not reverse the battery polarity while installing as this will damage the time switch permanently.

Hints on use:

- ❖ After programming the time switch remove the shorting across the terminals E1 & E2 where ever applicable. This facility will prevent the tampering of program setting.

3.2.4 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. There is a knob for the controller by which the user can increase or decrease the heat according to their preference. Rotary switch of rating 16A is used [1].

Figure3.5: Heat Controller

3.2.5 FILAMENT STOVE

Nichrome 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 due to the resulting voltage from available resources. In order to achieve higher current the coil resistance was to be decreased. Later the coils are placed in the ceramic body.[1]

Figure3.6: Filament Stove

Chapter 4

RESULTS AND DISCUSSION

3.

3

4.1 Design of the heating element

To design the heating element (nickle chromium) for supply voltage of V=40V and available power Wp=500W,with temperature T1=600 andT2=1000,radiating efficiency K=0.6,emissivity=0.9,

$$\left(\frac{l}{d^2}\right)=\left(\frac{\Pi V^2}{4\rho P}\right)=¿¿¿$$

¿

Nichrome coil is used as heating coil with gauge of 18mm .The 1000W coil is cut into 2 pieces each of 500W.One set of 500W is cut into 2 equal parts .These 2 coils are connected into parallel to decrease the resistance of the coil. Thus increasing the flow of the current. Later the coils are placed in the ceramic body. The final resistance of the coil was (13││16) Ω =7.1Ω.The parallel connection is shown in Fig 1

4.2 Parameters of solar PV panel

There are several parameters of solar that determine the effectiveness of sunlight to electricity conversion. The list of solar cell parameter is following:[4]

a. Open circuit voltage (Voc)
b. Short circuit current (Isc)
c. Maximum power point (Pmax or Pm)
d. Voltage at maximum power point (Vm)
e. Current at maximum power point (Im)
f. Fill factor (FF)
g. Efficiency (ɳ)

a. Open circuit voltage (Voc): It is the maximum voltage that a solar cell produces. The higher the Voc, the better is the cell. It is measured in volts (V).

b. Short circuit current(Isc): It is the maximum current a solar cell can produce. The higher the Isc better is the cell. It is measured in Ampere (A).

c. Maximum power point (Pmax or Pm): It is the maximum power that a solar cell produces under STC. The higher the Pm, the better is the cell. It is measured in terms of watt (W).

The expression Pm is given by

$Pmax \vee Pm = \Im * Vm$

d. Voltage at maximum power point (Vm): this is voltage which solar cell will produce when operating at maximum power point. The Vm is always be lower than Voc.

e. Current at maximum power point (Im): this is current which solar cell will produce when operating at maximum power point. The Im is always be lower than Isc.

f. Fill factor (FF): It is the ration of the area covered by Im-Vm rectangle with the area covered by Isc-Voc rectangle, whose equation is shown below. The FF is of the cell is given in terms of percentage (%).

$$FF=\frac{\Im*Vm}{Isc*Voc}$$

g. Efficiency (η) : The maximum efficiency of a solar photovoltaic cell is given by the following equation.

$$Percentage\, efficiency=\frac{Maximum\, power\, output\,(Pmax)}{incident\, r\, adiation\, flux\,(Pin)*collector\, area\,(A)}*100$$

Where

Pin = Incident radiation input power is converted into electrical power. Pin for STC is considered as 100 W/m2.

Area of solar panel (A) in square meter.

4.3 Efficiency Calculation

Ideal condition

As per standard specification of solar pv panel:-

tage at maximum power point (Voc) =.23.33 volts

Current at maximum power point (Isc) =9.06 amps

Light input power (standard) (Pin) = 1000W/ sq meter.

Area of solar panel (A) = 0.98 sq meter.

We know that

$$Pmax=Voc*Isc = 23.33 * 9.06 = \mathbf{211.36\ Watts}$$

Therefore

$$\%\, Efficiency=\frac{Pmax}{Pin*A}*100=\frac{211.36}{1000*0.98}*100= \mathbf{21.56\%}$$

- 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

Record of batteries' discharging data.

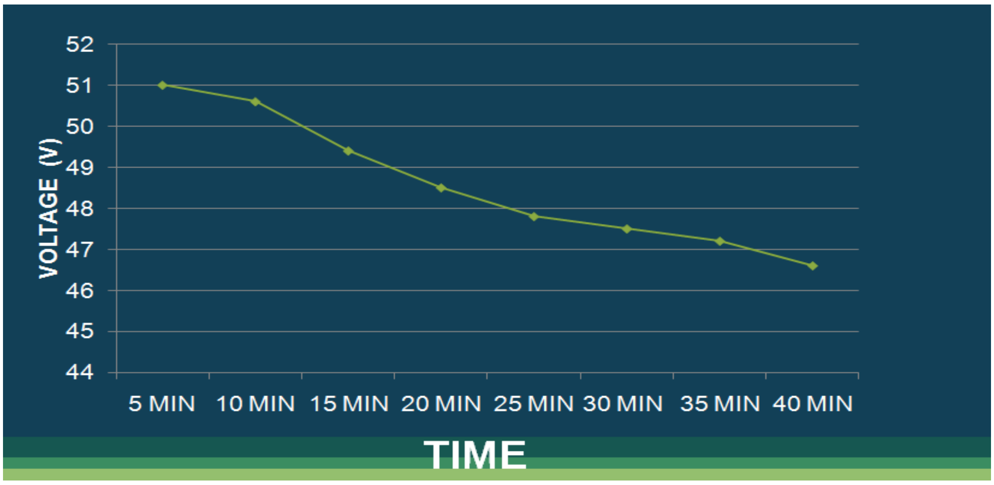

Figure 4.2: Graphical representation of rate of discharging battery.

I=8A.

R=7.1ohms.

So, power P = (8^2*7.1) W

= 454.4W.

V= (454.4/8)V

=56.8V.

So it was decided that the voltage for the stove will be 57v.

4.4 Comparative Studies

Table 2 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	750rs	1500rs	18,000rs
Moderate(5-7 people)	1.5	750rs	1,125rs	13,500rs
Small(2-4 people)	1	750rs	750rs	9,000rs

Table2: Cost Calculation of Gas Cylinders.

Single burner solar stove installation cost:-

Solar panel: 175W=8000rs. 75W=3000rs.

Two 175W panel=16000rs.

Three 75W panel=9000rs.

Total=25000rs.

Rotary switch=100rs.

Charge controller=1000rs.

Stove body making cost =3000rs.

Heater Coil, wires & other costs: 400rs

Total cost: 29,500rs.

Pay Back Period

PAY BACK PERIOD = Initial installation cost of smart solar stove/cost of LPG per year

=29,500/12360

=2.3 year.

Chapter 5

CONCLUSIONS AND SCOPE FOR FUTURE WORK

5.1 Conclusions

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. In this project we have designed a project which involves the development of solar powered electric stove that would use sunlight to generate electricity. In this project, we have designed the heating coil for the available solar power. Normally it is not possible to regulate the DC current from the panels, here in our project we have implemented the use of rotary switch to regulate the flow of current to the coil form the panels. In addition to that, payback analysis is presented.

5.2 Scope for the Future Work

1. Converters can be connected to use the stored power for ac loads.
2. We have used rotary switch for heat controlling, any automatic heat controllers can be used.
3. Our design id for single burner solar stove ,two or more burners can be used
4. Single burner solar stove has input power only from solar panels it can modified to power exchange model, which can be connected to utility grid when any problems occurs in solar panels.

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