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Hybrid Solar Cooker

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***Abstract*— The continuously increasing imbalance between the energy demand and supply, together with escalating cost of the conventional energy resources as well as growing environmental pollution are forcing people to invent newer methods either to reduce energy demands or to find alternative energy resources for cooking. The main intension behind this project is to employ concept of hybrid solar cooker with sensible heat storage. The system consists of thermal energy storage tank in which solar thermal energy is stored in the form of sensible heat by using different types of oils. Also auxiliary DC heater is installed in the tank which is operated by using PV panels and battery. This arrangement will help to cook the food even during deficiency of solar radiations. So the project deals with performance analysis of system with different oils.**

Keywords*— Solar cooker; Thermal energy storage; Parabolic concentrator type solar cooker.

I. INTRODUCTION

In today's era, energy is the primary and most universal measure of all kinds of work by human beings and nature. Everything what happens in the world is the expression of flow of energy in one of its form. Energy is required as an input to all the machines also very large amount of energy is required for cooking purpose and that energy is extracted from conventional energy sources which are limited. Cooking is an integral part of each and every human being as food is one of the basic necessities for living. An enormous amount of energy is thus expended regularly on cooking. Commonly used sources of energy for cooking are firewood, crop residue, cow dung, kerosene, electricity, liquefied petroleum gas (LPG), biogas etc. Half of the world's population is exposed to indoor air pollution, mainly the result of burning solid fuels for cooking and heating. Wood cut for cooking purpose contributes to the 16 million hectares (above 4% of total area of India) of forest destroyed annually. The world health organization (WHO) reports that in 23 countries 10% of deaths are due to just two environmental risk factors: unsafe water, including poor sanitation and hygiene; and indoor air pollution due to solid fuel usage for cooking. In under-developed countries, women have to walk 2kms on average and spend significant amount of time for collecting the firewood for cooking. The cooking energy demand in rural areas of developing countries is largely met with bio-fuels such as fuel wood, charcoal, agricultural residues and dung cakes, whereas LPG or electricity is predominantly used in urban areas [1].

Solar energy is considered a suitable alternative for cooking purpose. It is an abundant renewable resource, freely available everywhere in adequate amount, making it one of the most promising, clean, non-polluting sources. The rapid development of India and a growing population has led to increase the demand of energy for cooking. Therefore, solar cooking technology can be used very effectively for cooking purpose. Presently parabolic concentrator type solar cooker has gain maximum attention because its working temperature range is higher than other type of solar cookers [2].

In spite of these existing systems, cooking is not possible during cloudy atmosphere. This problem can be solved by storing the solar energy. So, there is need of solar cooker which can store the solar thermal energy when it is available and utilize this energy for cooking when there is deficiency of solar radiations. The solar thermal energy can be stored in the forms of sensible heat by using different types of oils [8]. For this project three types of oils are used for solar thermal energy storage and that are soyabean oil, olive oil and thermic fluid. The main intension behind the project is to use the concept of hybrid solar cooker with heat storage concept. Hybrid solar cooker can cook food with the help of thermal energy stored as well as with the help of DC heater. This DC heater is powered by the battery which is charged by using PV panel. This system is designed to cook 500gm rice in presence as well as in the absence of solar radiations.

Modern technologies comprise solar kitchens and cooking plants for community applications using high temperature solar concentrators. Nowadays a new geometry of solar parabolic concentrators with square or rectangular shape has gain more attention than traditional parabolic concentrators. This new design permits framed bowl structure with excellent transportability with higher efficiency [3]. This new designed concentrator can be used very effectively with solar thermal heat storage concept. So with this concept solar cooking will become more effortless than the present situation. Study focuses on the analysis of this solar cooker. Therefore observations are to be taken with different operating conditions and promising results are obtained with this experimental setup of hybrid solar cooker. These three different oils are having different properties therefore their performance will differ from each other. Performance of these oils is tested depending on the parameters like cost, life, temperature range and thermal properties of the particular oil.

II. EXPERIMENTAL SET-UP

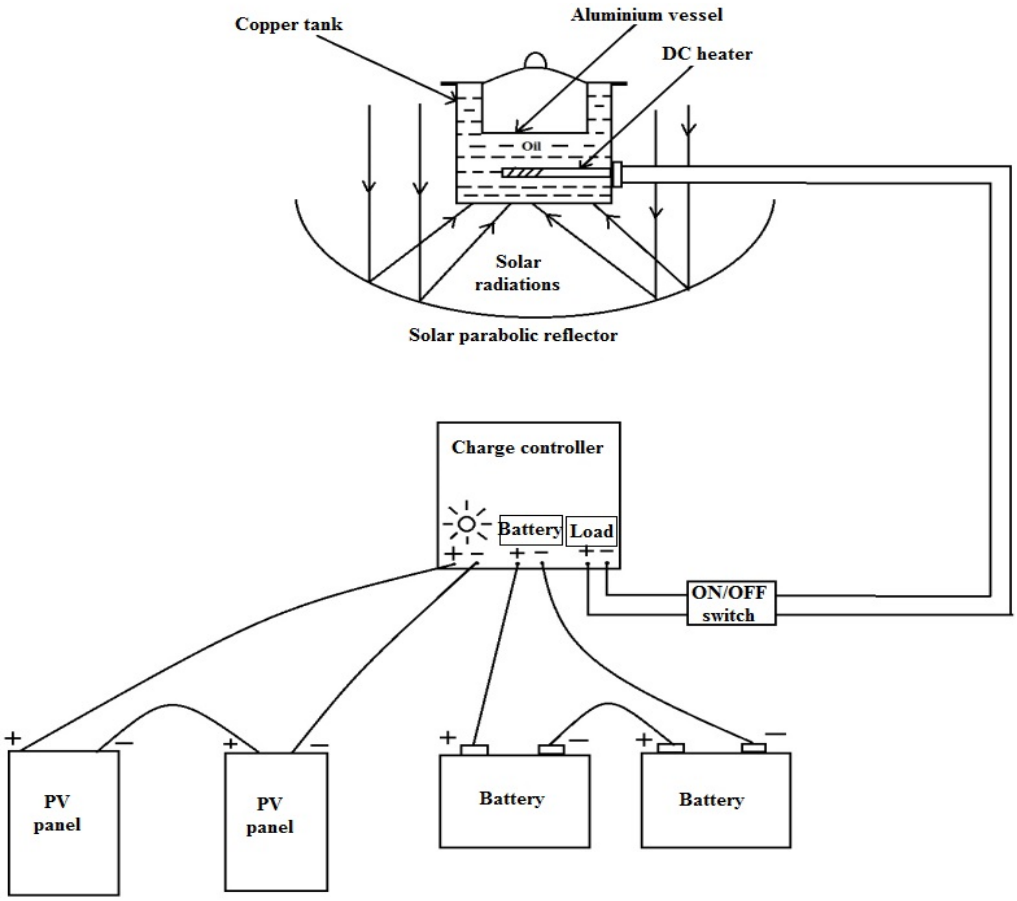

Fig.1 Layout of experimental Setup of hybid solar cooker

A. *Solar parabolic reflector*

As all the rays are coming on the collector are to be concentrated at focal point to achieve high temperature, so parabolic solar dish collector is more useful for this application. For getting maximum efficiency of reflection for dish, aluminium anodised sheets are used for the manufacturing of square parabolic dish collector. It is a parabolic concentrator with square or rectangular dish shape. This shape permits use of same sized strips to make bowl. This makes the bowl sturdy. As the members of the dish have same geometric shape interchange ability of support members is possible. This geometry permits the cooker design in DIY (Do It Yourself) kit and even novice people can assemble the cooker. Focal length of this design is kept at 400 mm as compared to 280 mm of SK-14. Size of the concentrator used during test was 1.25 m X 1.25 m. Other features like aperture area, tracking mechanism, framed structure are similar as that of parabolic dish [3].

B. *Thermal storage tank (Copper tank)*

As all the rays are going to focused at focal point so the storage tank should not act as an obstacle for heat transfer, so copper is selected as tank material because of its high thermal conductivity (401 W/m K). Tank is used to store the oil which will act as sensible heat storing material. Tank has 0.22 m diameter and 0.23 m height. Copper occurs naturally as native copper and was known to some of the oldest civilizations on record. It has a history of use that is at least 10,000 years old, and estimates of its discovery place it at 9000 BC in the Middle East. Copper becomes famous due to its amazing properties such as corrosion resistant, antibacterial, ductile, tough, etc.

C. *Heat storing material (Different oils)*

Solar thermal energy concentrated at the focal point is absorbed in the tank and stored as sensible heat by using oil. As project aims toward the analysis of solar cooker by using different heat storing materials so, three types of oils are used as heat storing material for the setup. Finally better oil is to be suggested depending on the performance of the oils. Role of heat storing material is to store the solar energy when it is available and utilize that energy when there is deficiency of solar radiations. Different types of oils used for analysis are Olive oil, Soyabean oil And Thermic fluid (Hytherm-500).

D. *Aluminium vessel*

This is the main cooking vessel in which actual cooking is to be carried out. This vessel is inserted in to the copper tank so it is continuously in contact with the oil. Therefore this vessel gets heat energy directly from the oil which can be

utilized for cooking purpose. Aluminium vessel has 0.20 m diameter and 0.10 m height. After iron, aluminium is now the second most widely used metal in the world. The properties of aluminium include: low density and therefore low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are amongst aluminium's most important properties. Aluminium is also very easy to recycle. Aluminium becomes famous due to its amazing properties such as formability, non corrosive, non toxic, non magnetic, etc.

E. DC heater (Nicrome heater)

DC heater is installed inside the copper tank such that it is continuously in contact with the oil. Heater is provided to operate the solar cooker even in the absence of solar radiations. When solar radiations are not available at that time heater will heat the oil inside the copper tank therefore we can cook the food. DC heater is made up of nicrome wire. This heater is operated on the battery which is charged by using the PV panels. DC heater (24volt & 300watt) requires 4 hrs to heat the oil upto 200^{O}C. Time required to heat the oil is depends on the wattage of heater. If we increase the wattage of heater then capacity of battery and PV panel is to be increased. Nicrome is the oldest documented form of resistance heating alloy. A common alloy is 80% nickel and 20% chromium, by mass, but there are many others to accommodate various applications. It is silvery-grey in colour, is corrosion-resistant, and has a high melting point. Due to its resistance to oxidation and stability at high temperatures, it is widely used in electric heating elements, such as in appliances and tools. Typically, nichrome is wound in coils to a certain electrical resistance, and current is passed through it to produce heat.

F. Ceramic wool insulation

Thermal storage tank contains heat storing material whose temperature is high. Therefore insulation is to be applied around the tank to restrict the heat loss from it. After detailed study of hot thermal insulating materials the conclusion is drawn that, ceramic wool is best insulation for this system. Ceramic wool with thickness of 25 mm is used for this application. In the 1950s, the term "Refractory Ceramic Fiber" was coined for the aluminium silicate fibres were developed at that time. On account of their chemical purity and resistance to high temperatures (classification temperature >1000 °C) as well as on the basis of their use in other applications, this definition was made to differentiate aluminium silicate wools from the conventional "mineral wools". Because of the ambiguity of the term "ceramic" and the development of new materials for the high temperature range, the nomenclature was changed to High Temperature Insulation Wool (HTIW) at the end of the 1990s.

G. Charge controller

A solar charge controller or regulator is a small box consisting of solid state circuits pcb which is placed between a solar panel and a battery. Its function is to regulate the amount of charge coming from the panel that flows into the battery bank in order to avoid the batteries being overcharged. Solar charge controller has mainly three basic functions:

- To limit the voltage from the solar panel and regulate the same so as not to overcharge the battery.
- Not to allow the battery to get into deep discharge mode while dc loads are used.
- To allow different dc loads to be used and supply appropriate voltage.

H. Photovoltaic panels (PV panels)

PV panel converts the solar light energy into the electrical energy. This electrical energy is stored in the batteries so that it can be used as input for the DC heater. PV panels of 200 watts are to be used for this application.

I. Battery

Battery stores the electrical energy provided by the PV panel and gives supply to the heater. 70 ampere-hour of battery is used for this experimental set-up.

J. Tracking mechanism

The tracking mechanism is necessary because to achieve higher temperature, all the solar radiations should concentrate at a focal point and this is possible only when, the incident solar radiations are perpendicular to the face of solar collector. Therefore simple nut and bolt arrangement can be made for this purpose. When the shadow of upper nut is exactly on the bottom nut, then the solar rays are perpendicular to the face of collector and rays are concentrating focal point, if shadow deviates from its position adjust the angle of the collector to bring it in correct position. So for this setup manual tracking mechanism is used.

K. Temperature measuring instrument

Temperature measuring instrument is very important component because it is necessary to examine condition of heat storing material for analysis purpose. For this purpose K type thermocouples are used for this setup. Total eight thermocouples are installed in this setup for measuring the variation of temperature across the system. These thermocouples are attached to temperature indicator which will indicate temperature digitally on the display.

III. WORKING

There are basically two steps are involved in the working of solar cooker Heat storage & Utilization of stored heat for cooking.

A. Heat storage

Solar collector is used to concentrate solar energy at focal point on the thermal storage tank. Thermal storage tank has arrangement as shown in figure. Heat storing fluid is heated to its highest temperature based on several variables including area of the collector, emissivity, absorptivity, reflectivity and boiling/smoking temperatures, among others. As the oil near focal point is heated its density decreases so this heated oil moves up in thermal storage tank and this space is occupied by cold oil. In this way total quantity of oil available in tank is heated by using natural circulation phenomenon. When solar intensity decreases during 5pm-6pm then insulation is applied to the tank to restrict the heat loss from the tank to the atmosphere.

B. Utilization of stored heat for cooking

This solar cooker is very useful concept as per as evening and early morning cooking is concerned. This solar cooker is able to cook the food anytime throughout day irrespective of the atmospheric conditions. In this system solar thermal energy is stored in sensible heat storing material like oil. So cooking is done during daytime and also during evening period by using the heat energy stored in the oil. As per construction aluminium vessel is dipped in oil all the time so due to high temperature stored in the oil cooking vessel gets high temperature for cooking. If atmospheric conditions are not good for cooking because of deficiency of solar radiations then also cooking is possible by using auxiliary DC heater which is dipped into the oil. This heater is operated on the batteries which will get charged by using PV panels. For improvisation in the heat storing capacity different types of oils are to be used for experimentation.

IV. CONCLUSION

The problem with existing solar cooker is that, it cannot be used during cloudy conditions. This limitation of existing solar cooker is overcome by this system. By using concept of thermal heat storage and auxiliary heater, cooking can be done in presence as well as in absence of solar radiations. This method of cooking is more useful in rural areas where sunrays are efficiently concentrated to the focal point because of availability of more open land. Cutting of trees for cooking is also minimized by using our system which is more useful to reduce pollution.

Thermal energy storage (TES) is a key technology for renewable energy utilization and the improvement of the energy efficiency of heat processes. Sectors include industrial process heat and conventional and renewable power generation. TES systems correct the mismatch between supply and demand of thermal energy. Thermal energy storage is now the need of the future. In the coming couple of years we will strongly require the need of the solar thermal energy because, the conventional energy sources are now reducing day by day. By using solar thermal energy storing materials the energy which is available at the day time due to sun can be stored and it can be utilized in the night time also. As mentioned above different materials are having different capacity of thermal storage so, according to application suitable alternative can be selected amongst them.

The complete spectrum of high temperature storage technologies like various types of sensible and latent heat storages is being developed. Different concepts are proposed depending on the heat transfer fluid (synthetic oil, water/steam, molten salt, air) and the required temperature range. The aim of project is development of cost effective, efficient and reliable thermal energy storage system. Research focuses on characterization of storage materials, enhancement of internal heat transfer, design of innovative storage concepts and modeling of storage components and systems. This aim is achieved by using solar thermal energy storing materials.

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