Energy Stored Sensible Hybrid Solar Cooker for Day and Night Cooking

Reshma Radhakrishnan[1] Vimi K Wilson[2]
[1,2]Nehru College of Engineering and Research Centre

Abstract— The continuously increasing imbalance between the energy demand and supply together with increasing cost of the conventional energy resources as well as the growing environmental pollution are forcing the people to invent new methods either to reduce energy demands or to find alternate energy resources for the cooking purposes. A hybrid solar cooker with oil as heat storage medium is designed and fabricated. Engine oil with high thermal conductivity is chosen as the sensible heat storage medium for the fabricated solar cooker. The system has two cook tops and two cook tops are used during day time and the parabolic dish collector is used for heating the oil in the receiver tank placed at the focus point of the dish. The primary cook top is placed under the oil receiver tank and the food is cooked by the concentrated solar energy falling on it. The oil circulation is done automatically using a 12 V reciprocating pump. The circulation starts when the oil at the receiver reaches to 700C. The pump can be worked in manual and automatic mode. The heat which left after cooking is transferred to the oil in the storage tank through the copper pipe. Here the copper pipe acts as a heat exchanger. The stored thermal energy in the oil is used for evening cooking purposes. A DC heater plug which is charged by a DC battery is used to heat the coil during night times and also when there is less solar radiation. Thus the cooker can cook food during day and night without any interruption. The energy stored sensible hybrid solar cooker is cost effective and is portable to use.

Key words: Parabolic dish collector, Hybrid solar cooker, Controlling Unit

I. INTRODUCTION

Sun is the primary source of energy and all the other forms of energy on the earth are derived from the sun The consumption of energy by human being has been increasing as rate of utilization has progressed. The people of the rural areas depends mainly on the natural resources around them to support their families, both for sustenance provided by food and monetarily provided by agriculture. Additionally, rural areas in India use wood as their main source of fuel for cooking. The fire occurs in the open and loses a great deal of energy to the environment. As a result of this inefficiency, the user must burn even more wood. Accumulating this wood leads to quicker deforestation of the surrounding areas, increased air pollution, and requires more time spent collecting wood. The lack of venting of the stove leads to increased risk for smoke induced health problems. The solar cooker only works for a few hours in the middle of a sunny day, but not at night or in the mornings when people actually want to cook. The total power that is incident on the earth's surface from the sun is equivalent to (1.5x10) KWh annually, which is equivalent to (1.9x10) ton coal equivalent. Compared to the annual world consumption of almost 10ton coal equivalent, this is a very huge amount and approximately 10,000 times greater than what is consumed on the earth annually. In rural India, energy demand for cooking is met by firewood, agricultural residue, biogas, kerosene and cow dung cake. Using these sources of energy for cooking creates indoor air pollution. Respiratory problems are common due to inhalation of hazardous gases from burning these fuels. LPG and electricity are the most preferred source of energy for cooking in suburban and urban areas. The 17.5% of Indian household or 33.6 million people use LPG as cooking fuel. The 76.64% of such households are from urban India which makes up 48% of urban Indian households as compared to a usage of 5.7% only in rural Indian households. In 2005, 27.2% of India's population lived in urban areas and by 2030 this figure is estimated to grow to 45.8%. Increase in crude oil price in the international market and increase in demand for LPG in India have caused the price of LPG to rise exponentially over the decade. This has forced the government to look for alternative source of energy. India has abundant amount of solar insolation in most of the regions making it most ideal for harvesting solar energy. With almost 300 sunny days each year, one can confidently rely on this source of energy. Since cooking is integral part of each and every household, cooking with solar energy will reduce the large difference between supply and demand of energy in future. With increasing population and economic growth, utilization of solar energy is must for sustainable living.

II. SYSTEM DESCRIPTION

Main Parts Description: Parabolic dish collector is used for collecting maximum solar energy. Steel with chromium coating is used as the reflecting material of the parabolic dish. The collector is shown in the figure 1

Fig. 1: Parabolic Dish Collector

A receiver tank and a primary cook top is placed at the focus point of the parabolic dish .The parabolic dish has an aperture area of .98m2. High fluid temperature is attained by the two axis tracking system in solar parabolic dish. The two axis tracking is done with the help of stepper motor attached to the dish. The receiver tank has an area of 0.069m2. The engine oil to get heated for the cooking purpose is stored in the receiver tank. The oil from the receiver tank is used by the secondary cook top and this oil is circulated by using a reciprocating pump. The receiver tank is shown in the figure 2. Engine oil (20W40) is used as the working fluid in the system. Heat transfer oils vary in terms of kinematics viscosity, operating temperatures, pour point boiling point and flash point. The parameters considered while selecting

available oils are density, specific heat capacity, flash point and thermal conductivity. Engine oil has high thermal conductivity, specific heat capacity and density than that of the edible oils. It eliminates all these complications along with issues of corrosion, scaling, fouling, and deposits in the heat transfer area.

Fig.2: Oil Receiver Tank

The storage tank consists of copper tube for transferring of heat to the oil during the day time. The coil has length of 1m is used to transfer the heat to the oil in the storage tank. The storage tank is shown in the figure 2.

Fig. 3: Secondary Storage Tank

The storage tank is insulated with glass wool. Glass wool is a good thermal insulator which is cheaply available. During night time the heat stored in the oil is used for evening cooking. The proposed cooker contains mainly two cook top primary and secondary. Primary cook top is placed under the receiver of the parabolic dish collector. Here solar energy will directly concentrate on the cooking pot. This cook top is used to cook during the day time. Secondary cook top is placed above the hot oil storage tank. The primary and secondary cook tops are shown in figure 4 and figure 5

Fig. 4: Primary Cook Top

Fig. 5: Secondary Cook Top

The heat after the cooking is transferred to the hot oil storage tank. Engine oil is used as energy storage device for secondary cook top. Secondary cook top is a model of coil type heat exchanger. The heat from the hot oil is transferred to the copper coil. The outlet of the heat exchanger pumped back to the receiver tank. Galvanized Iron (GI) pipes are used for the flow of oil.GI pipes are manufactured using mild steel strips of low carbon steel coils. These pipes are cheaper, light weight and easy to handle. A 12V reciprocating pump is used for the pumping of the hot oil. The pump can work in automatic as well as in manual mode. In the automatic mode, the pump will start when the receiver temperature reaches to 700C. Automatic operation of the system is implemented with the help of embedded system. The embedded system used in the system is shown in the figure 6.

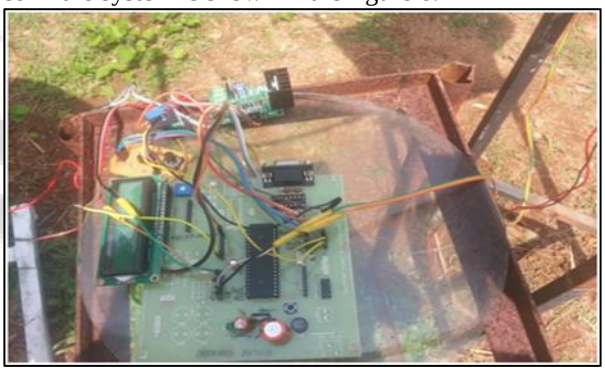

Fig. 6: Embedded System

Automatic operation helps to increase the system performance and hence reduces the human stress during the manual controlling. The embedded system is incorporated in the designed cooker is for the automatic pump operation, tracking control of the parabolic dish collector and also for sensing the temperature using temperature sensors. ATmega 16 microcontroller is used in the proposed solar cooker for the controlling of various components of the embedded system. The temperature sensor LM35 is used to sense the temperatures of the receiver and storage oil tanks. a and the oil temperature. The LM35 can be used to measure the temperature more accurately than that of the thermistors. The output of the sensor is proportional to temperature in degree Celsius. The operating temperature range of the sensor ranges from -55 to 150 degree Celsius. Relay circuit is used in the proposed solar cooker is to control the pump operation. The relay helps the pump on and off according to the temperature from the temperature sensors. The layout of the system is shown in the figure7

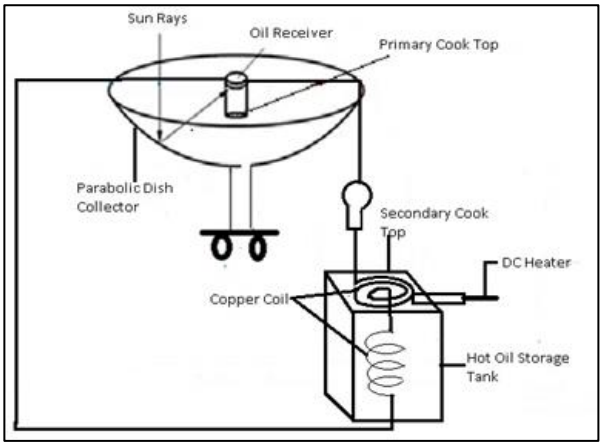

Fig. 7: Layout of the Cooker

Working Principle: The solar cooker consists of two cook tops. The position of primary and oil receiver is designed at top and bottom of the focal point, so that the concentrating radiations are mutually divided. The primary cook top is made portable and is placed under the receiver of the parabolic dish collector using wire mesh to hold the pot. Here the solar energy will directly concentrate on the cooking pot and thus used to cook during the day time. The position of the cooking pot is designed to be below the focal point of the concentrator, so as to receive the radiations over the cylindrical and the bottom surface of the pot. The secondary cook top is made up of copper coil. The secondary cook top is used for day time as well as evening cooking. The parabolic dish collector is used to concentrate solar energy into working fluid, engine oil (20W40). The receiver is designed at the diverging section above the focal point, where the radiations focused to a point and later diverges over the bottom surface of the receiver. This positioning of primary cook top and receiver gives the advantage of operation of cooking and heating of oil. The secondary cook top collection subsystem consists of two parts: two oil reservoir tanks and the solar collector that is used to heat the oil. The fluid is heated to its highest temperature depending on several parameters like flow rate, reflectivity, operating and smoking temperature. The oil is heated inside the oil receiver tank made of mild steel. The receiver tank is situated at the focal point of the parabolic collector. The hot oil is pumped automatically using the temperature sensors. Two sensors are placed inside the receiver tank and inside the secondary storage tank filled with oil. The oil pumping starts when the temperature at the receiver tank reaches to 50 degree Celsius.

The secondary tank is filled with oil (2litres).Copper tube is inserted inside the secondary oil tank. The hot oil is passed through the copper coil inside the tank and through the cooking area and then to the receiver tank. This process will continue till the temperature of the oil in the secondary tank becomes greater than that of the receiver tank. During the cloudy time, the oil at the receiver tank temperature will be less than that of the secondary tank. At this time the pump stops working. At this time a heater plug which is connected to the heater coil will work and heats the coil. Thus the heat loss inside the oil tank is very less and retains its heat for a long time. The secondary tank is insulated with glass wool to prevent the heat loss. Thus the heated oil can be used for evening cooking and during night time, the heater plug connected to the secondary cook top helps to heat the coil and thus helps to cook food during night time.

Fig. 8: Fabricated Energy Stored Sensible Hybrid Solar Cooker

III. RESULT AND DISUSSION

Several experiments were conducted to analyze the performance of the cooker. Maximum intensity receiving area should be chosen for the installation of the equipments. For finding out the maximum solar intensity, solar intensity survey was conducted in various area. The experiments were conducted in the month of March to April 2017. The maximum solar intensity obtained during the day was 998W/m2. No load test was conducted and obtained the oil tank bottom temperature and copper coil temperature. The maximum oil temperature was found out with and without tracking of the parabolic dish collector. The tracking of the system is expected to have maximum gain compared to non tracking mode. The experiment is conducted at an average wind velocity of 0.2m/sec. The maximum oil temperature obtained during the tracking of parabolic dish with tracking is 990C. . The oil temperature obtained during tracking is more than that of non-tracking. The maximum oil temperature obtained parabolic dish without tracking is 910C. Various food items were prepared in the primary cook top and secondary cook top and measured the temperatures of food items. Three batches of food items were prepared in the primary cook top. The oil temperature at the storage tank was found out and cooking was done with the oil and measured the food temperature. Evening cooking takes more time to prepare the food than that of day time cooking.

IV. CONCLUSION

An efficient cost effective solar cook stove has designed and fabricated. The selection of oil as working fluid gives an advantage of storing the solar energy even after the sunset, for few hours. This model works with dual mode of operation by which primary and secondary is used alone and simultaneously. The loss heat after cooking is stored in the oil of the storage tank. Therefore the heat loss is used for storing energy during evening time. The usage of DC heater helps to cook food during night time and also when there is less solar radiation. Thus the cooker can work without any interruption in the presence and absence of the solar radiation. The design fabrication and performance analysis of the system are studied and various food items are prepared. As the cost of operation of the system is very less, it gives the

advantage over the conventional models. Thus existing smoke type cook top using wood can be substituted by solar based cook stove and the usage of LPG, wood, kerosene can be reduced, but it cannot be completely replaced by solar energy. Fuel savings can be achieved and the related health issues can be reduced. This technology can be further developed by creating various modifications in the design to increase the effectiveness of cooking.

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