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Development and Testing of Sun Tracking System for Solar Cooker

Manoj Nehra, Sunder, Sanjeev
[1]Dept of Environmental Engineering and Technology
Guru Jambeshwar University of Science and Technology, Hisar

Abstract- **An automatic sun tracking system was designed, developed and then installed in a solar cooker. This solar cooker along with a manually tracked solar cooker were kept under observation in order to record temperature readings of both and compare the same. It was observed that the cooker with automatic tracker works more efficiently as compared to that of manually tracked solar cooker. A temperature difference of about 15^{0}C was seen which contributes in the success of the tracking system. Much better results were observed during morning and evening time this is because the difference in angle of tracking is more as compared to that in afternoon. The only disadvantage of installing this tracker is that it works efficiently only in clear sunny days. The following conclusions were made:**

- **Max. temperature difference between automatic and manual tracked Solar Cooker without load was 16.6^0 C**
- **Avg. temperature difference between automatic and manual tracked Solar Cooker without load was 10.4^0 C**
- **Max. temperature difference between automatic and manual tracked Solar Cooker with load was 12.3^0 C**
- **Avg. temperature difference between automatic and manual tracked Solar Cooker with load was 8.8^0 C**
- **Much efficient than manually tracked Solar Cooker**
- **Annihilates labour requirement**

By this we can conclude that installation of such circuits can prove beneficial for those having all day out of their homes and will also save labour and time. Moreover installation of tracking system leads to introduce modernization and awareness about new scientific techniques and equipments in rural areas which will lead to the development of the nation as a whole.

Keywords: Solar energy, solar cooker

I. INTRODUCTION

1. *General background*

Energy crisis is the most important issue in today's world. Conventional energy resources are not only limited but also the prime culprit for environmental pollution. Renewable energy resources are getting priorities in the whole world to lessen the dependency on conventional resources.

The major portion of energy consumption in developing countries is for cooking in the domestic sectors. It has been confirmed by a recent survey of domestic fuel use pattern in villages. It has been reported that 97% of energy consumption is purely for cooking in the rural areas of India. The demand for cooking in rural areas is met by fire wood (75%), cow dung cake and agricultural waste (25%). One third of Indian's fertilizer consumption can be met if cow dung is not burnt for cooking and instead is used as a manure the cutting of fire wood causes deforestation which leads to desertification .Fortunately, solar radiation is available in abundance in almost all ports of India and is maximum in the arid part of India, where it is 5.5 kWh/m^2 day on a horizontal surface.

Fossil fuels reserves are depleting at a fast rate are very costly and cause pollution of all types. There is need to find an alternate source of energy. So renewable energy is the best choice which is eco-friendly, easily available and has no cost. Among all, solar energy is best utilised as India is a tropical country where sun is available throughout the year.

Solar energy can be used for different purposes; maximum use is for cooking in rural areas. If we could use solar energy for cooking in rural areas then it would solve like indoor pollution, depletion of fossil fuels, deforestation and clean cooking. Conventional cooker is used in villages for milk simmering and feed preparation. The limitations of this are that it causes pollution and infection in eyes and lungs. For avoiding all these problems, solar cooker has been developed which can be used for above purposes. It was found that 25-28 % saving in fuel use per household per day can be achieved. These savings show that solar cooking could positively impact the lives of the people and surrounding environment.

The major constraints of single box type solar cooker (solar cooker) is the tracking of cooker as the presence of person required for tracking it during the time of operation. Solar energy is rapidly advancing as an important means of renewable energy resources. More energy is produced by tracking the solar panel to remain aligned to the sun at right angle to the rays of light. Solar tracking system is the most appropriate technology to enhance the efficiency of solar system by tracking the sun.

2. *Justification*

The presence of a person is required for tracking the solar cooker during the time of its operation. Therefore, it has been made essential to develop "automatic tracking system for solar cooker. The sun tracking system will increase the solar insulation and which is turn enhance the efficiency and working of solar cooker compared to the stationery one.

3. *Review of Literature*

Vaughan (1979) recommended a typical hot box type solar cooker meant for villagers. A rectangular pit was dug in the ground, suitably insulated with hay or rice husk, and a flat box not taller than 10 cm made of a metal sheet is fixed into this pit, and then covered with two glass panes with about 0.5-2.5 cm space in between. Such a cooker work well at least during summer, in most parts of the country, but to increase the efficiency it was essential to add a flat reflector. Round aluminium boxes painted with black board paint acted

as cooking vessels and it gave satisfying results for cooking of rice.
Muzumdar (1980) made a similar design with cardboard, but the box had only a single polyester sheet as glazing the reflectors were also made of cardboard and coated with aluminized polyester.
Cheema (1984) designed double reflector cooker and both the reflectors reflected light into the box from a lower angle. The arrangement was interesting and a stagnation temperature of 206˚C was reported compared to 164˚C of ordinary box type cooker.
Knudson and Lankford (1998) conducted a solar cooker training programmed in Kenya. It was found that 25-28% saving in fuel use per household per day can be achieved. These savings showed that solar cooking could positively impact the lives of the people and surrounding environment.
Emad (2003) designed solar cooker in which the absorber is exposed to solar radiation from the top and the bottom sides. A set of plane diffuse reflectors is used to direct the radiation onto the lower side of the absorber plate. The performance of this new cooker and the conventional box type solar cooker was extensively investigated. The double exposure cooker reduced the cooking time by about 30-60 min. The taste and appearance of the food was quite good.
Negi and Purohit (2005) developed of a box type solar cooker utilizing non-tracking concentrator optics to enhance the solar energy availability in the box of the cooker for efficient cooking. A laboratory model of a box type solar cooker employing a non-tracking concentrator was designed and fabricated and its thermal performance was investigated experimentally.
Agravat *et al.* (2008) design, fabricate and test a truncated pyramid-type solar cooker. The truncated pyramid geometry concentrates the incident light radiations towards the bottom and the glazing glass surface on the top facilities the trapping of energy inside the cooker. One of the salient features of the proposed design is to completely eradicate the need for tracking the sun during cooking, as tracking of sun does not yield better performance. During testing the highest plate stagnation temperature, under no load condition, approached 140˚Cand under full-load condition, water temperature inside the cooker reaches 98.6˚C in 70 min. Two figure of merits, F_1 and F_2, were calculated and their values were0.117”cm^2/W and 0.467’cm^2/W, respectively, meeting the standards prescribed by the Bureau of Indian Standards for the solar box-type cookers. Minor modifications in design are recommended to achieve higher temperatures and reduce cooking times. The design also allows trays to be retained for use as a household dryer.
Barsoum (2009) described in detail the design and construction of a prototype for solar tracking system with two degrees of freedom, which detects the sunlight using photocells. The control circuit for the solar tracker is based on a PIC16F84A. Microcontroller (MCU). This is programmed to detect the sunlight through the photocells and then actuate the motor to position the solar panel where it can receive maximum sunlight.
Malouh *et al.* (2010) studied the effect of two axes tracking on a solar cooking system was studied. A dish was built to concentrate solar radiation on a pan that is fixed at the focus of the dish. The dish tracks the sun using a two axes sun tracking system. This system was built and tested. Experimental results showed that the temperature inside the pan reached more than 93˚C in a day where the maximum ambient temperature was 32˚C. This temperature is suitable for cooking purposes which was achieved by using the two axes sun tracking system.
Khan *et al.* (2010) developed a microcontroller based design methodology of an automatic solar tracker. Light dependent resistors were used as the sensors of the solar tracker. The designed tracker has precise control mechanism which provides three ways of controlling system. A small prototype of solar tracking system was also constructed to implement the design methodology.
Dicorato *et al.* (2010) investigated a concentrating solar-trough plant, having nominal power equal to 100 kWe and exploiting linear parabolic collectors, to generate electric energy by means of organic rankine cycle turbine. In particular, a model to estimate solar radiation on a sun-tracking surface was developed, in order to minimize the angle of incidence and thus maximize the incident beam radiation. A suitable inclination of the North-South rotation axis on the horizontal plane was examined. In this system electricity production was assessed through a statistical approach based on local meteorological conditions.

II. MATERIALS AND METHODS

Description of a single pot box-type solar cooker (solar cooker)
Single-pot box type solar cooker (solar cooker) consists of a rectangular enclosure insulated hot-box and outer lid having a mirror reflector fitted to its underside. The hot box consists of two trays having at least 5 cm spacing which is fitted with glass insulation. The upper tray is coated with black paint. The mirror reflector is adjusted in such a way that reflection falls into the enclosure. The solar radiation enters through the top transparent glass cover and heats up inside space in which item to be cooked is kept. The temperature obtained is more than 130℃ on sunny day. It can also be used for cooking of cattle feed and simmering of milk. Depending upon the intensity of radiation the time taken varies from one to three hours. When solar cooker is not in use, the lid enclosed down on the hot box thus providing protection to the mirror reflector as well as to the glass cover. While cooking, the solar cooker to be kept in a proper place to receiving sunshine.

Fig.1 Automatic Tracking System for Solar Cooker

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Components of Solar Cooker

The component of box type solar cooker includes the outer box, cooking box, the double glass lid, thermal insulation, mirror and cooking containers fan.

The Outer Box

The outer box of a solar cooker is made up of ply.

The Inner Box

The inner box is made from GI sheets of 26 gauges. All the four sides and the bottom of the inner box which are exposed to the sun are coated with black board paint which absorbs the solar radiation easily and transfers the heat to the cooking pots.

Thermal insulation

The space between outer and inner box including bottom is packed with glass wool, insulation to reduce the heat looses from the cooker. The thickness of the insulation is 5 cm.

Glass Cover

Generally double glass cover is provided for a solar cooker. These covers have length and breadth slightly greater than the inner box .The spacing between two glasses is 2.5 cm. The space contains air which acts as an insulator and is to escape heat from the top.

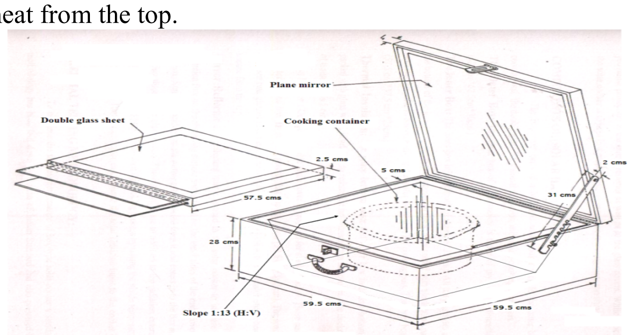

Fig 2 Components detail of Solar Cooker

Mirror Reflector

Reflecting mirror is used in solar cooker to increase the radiation flux on the absorbing surface and is fixed on the inner sides of the main cover of the box. Sunlight incident on the mirror gets reflected from it and enters into the box after passing through the glass covers. These radiation are in addition to the radiation entering the box directly and helps to quicken the cooking process by raising the inside temperature of the cooker. The use of mirror can enhance the solar radiation input to cooker by about 50 %.

Component of tracking system for solar cooker:-

A. Light Sensor (light dependent resistor):

A light sensor is the most common electronic component which can be easily found. The simplest optical sensor is a photo resistor or photocell which is a light sensitive resistor. The sun tracker system designed here uses the cadmium sulfide (CdS) photocell for sensing the light. This photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with capacitor. The photocell to be used for the tracker is based on its dark resistance and light saturation resistance. The term light saturation means that further increasing the light intensity to the CdS cells will not decrease it resistance any further.

B. Control circuit

The control circuit is basically a combination of three separate circuits whose functions are as:

- To track the solar cooker as per the sun revolve
- To control the speed of tracker
- To stop the working of tracking system when the solar insolation is less than the limit Selected.

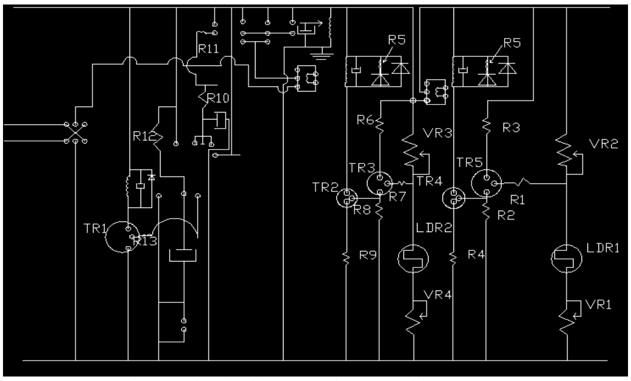

Fig.3 Circuit diagram of sun tracking system

C. Solar cooker base:

Solar cooker base is a rectangular frame on which solar cooker is mounted which is coupled with electric motor. The motor gives the drive to the solar cooker for its clockwise and anticlockwise motion.

Fig. 4 Solar Cooker Base

D. Working of sun tracking system

The sun tracking system consist of the automatic electronic circuit which keep the solar cooker base facing toward sun for getting maximum solar insolation falling on the surface of solar cooker.

The sun tracking system is based on light dependent resisters (LDR's) LDR1 and LDR2. The circuit containing LDR1 is so biased that as sun light falls on it up to some minimum insulation level the circuit get triggered and make the relay ON which gives supply to the circuit containing LDR2. The trigging minimum solar intensity can be adjusted by variable resistance VR1.

As the circuit containing LDR2 obtains power supply through LDR1 which is triggered by LDR1, the motor starts moving till the LDR2 get the maximum solar intensity. The solar cooker base where LDR's are mounted starts moving in the direction of sun and it facing in the direction where insulation falling on LDR2 are maximum.

Also the system is controlled by two limiting switches fixed on the base. As the rotation completes to certain limit as in evening time the motor circuit gets reversed and reaches to initial position. When sun rises and LDR1 receives minimum level of solar insulation the circuit starts functioning again.

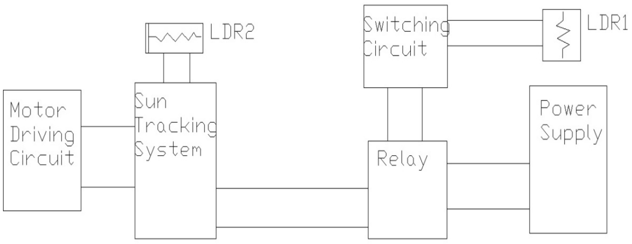

Figure 4 Block diagram of sun tracking system

1. Parameters to be measured:
   1. Ambient temperature measured by Digital Thermometer
   2. Solar isolation measured using Digital Solar Insulation meter
   3. Temperature inside the solar cooker using Digital Thermometer
      a. Three time manually tracking
      b. Automatic tracking
2. Thermal Efficiency Methodology

To evaluate the thermal performance of box type solar cooker a standard methodology has been laid down by the Bureau of Indian Standards. The thermal performance testing was carried out by using the following standard methods

3. Thermal efficiency test

To determine the efficiency of cookers, containers filled with known quantity of water are put in cookers noting down the initial temperature. The cooker is the exposed to sun and rise in temperature and solar insulation are recorded at regular interval of 1 hour.

The thermal efficiency can be calculated by using the following formula:

η_{Tav} = Total mass of water*C_p*(T_{av} – T_i)/Δt*I_{GA}*A

Where, η_{Tav} = Efficiency of cooker at temperature Tav

C_p = Specific heat of water (J/kg^{0}C)

A = aperture area of solar cooker(J/kg^{0}C)

I_{GA} = Average solar insulation (W/m^2)

Δt = Time interval in seconds between the time at which efficiency is calculated and starting time.

T_{av} = Average temperature of water at which efficiency is calculated

T_i = Initial temperature of water

III. RESULTS AND DISCUSSION

The experiments were conducted at Hisar (20°10' *N*, 75°24' *E*) using, a manual tracking and automatic tracking of solar cooker. The experimental tests were conducted following the standard testing procedure. The details of experimentation along with the test results are presented in this chapter. On the basis of test results, the performance of automatic tracking of solar cooker has been evaluated.

A. *Performance testing of solar cooker without load for manual and automatic tracking*

Hourly readings of both the Cooker were taken keeping it without load and it was observed that the maximum temperature attained in automatic tracking was 146.4°C corresponding to which the manual tracking was 134.6°C. The maximum temperature difference between automatic and manual tracked Solar Cooker without load was 14.0^0 C and Average temperature difference between automatic and manual tracked Solar Cooker without load was 9.98^0 C.

B. *Performance testing of solar cooker with manual and automatic tracking with load*

Hourly readings of both the cookers were taken with a load of 4 litres of water and it was observed that the maximum temperature attained in automatic tracking was 125.4°C corresponding to which the manual tracking was 114.4°C. The maximum temperature difference between automatic and manual tracked Solar Cooker with load was 12.3^{0}C and Average temperature difference between automatic and manual tracked Solar Cooker with load was 8.9^0 C

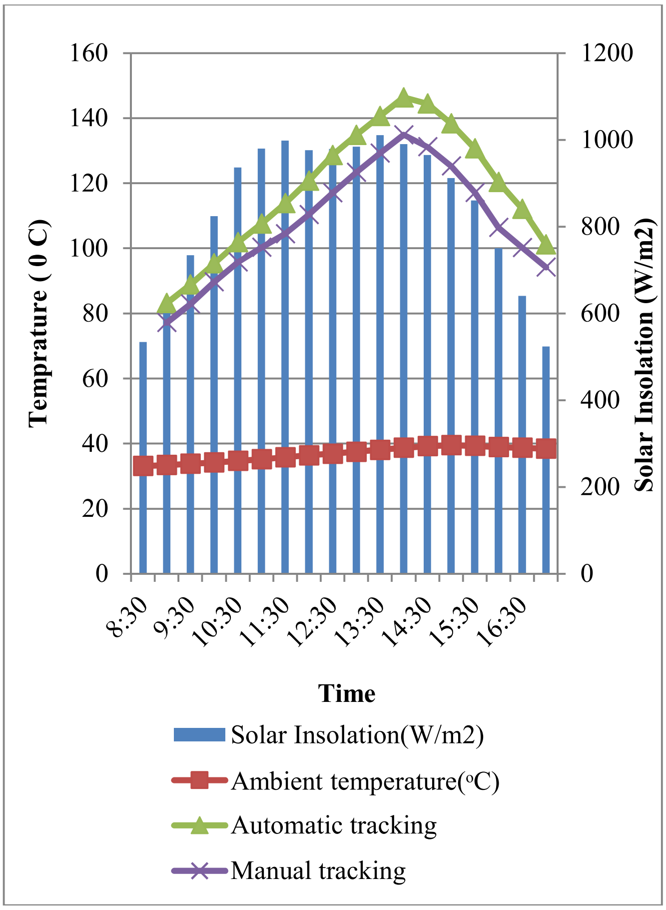

Fig. 5 Performance testing of solar cooker with manual and automatic tracking without load

C. *Thermal efficiency*

The thermal efficiency can be calculated by using the following formula:

η_{Tav} = Total mass of water (kg)*C_p*(T_{av} – T_i)/Δt*I_{GA}*A

Where, η_{Tav} = Efficiency of cooker at temperature Tav

A = aperture area of cooker(m^2)

C_p = Specific heat of water (J/kg^{0}C)

I_{GA} = Average solar insolation (W/m^2)

Δt = Time interval in seconds between the time at which efficiency is calculated and starting time.

T_{av} = Average temperature of water at which efficiency is calculated

T_i = Initial temperature of water

Thermal efficiency (η_{Tav}) =13.33%

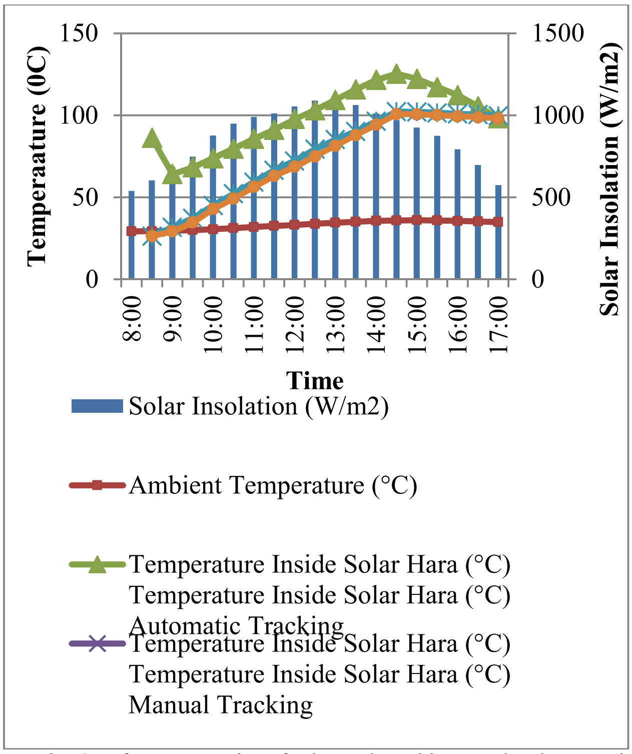

Fig. 6 Performance testing of solar cooker with manual and automatic tracking with load

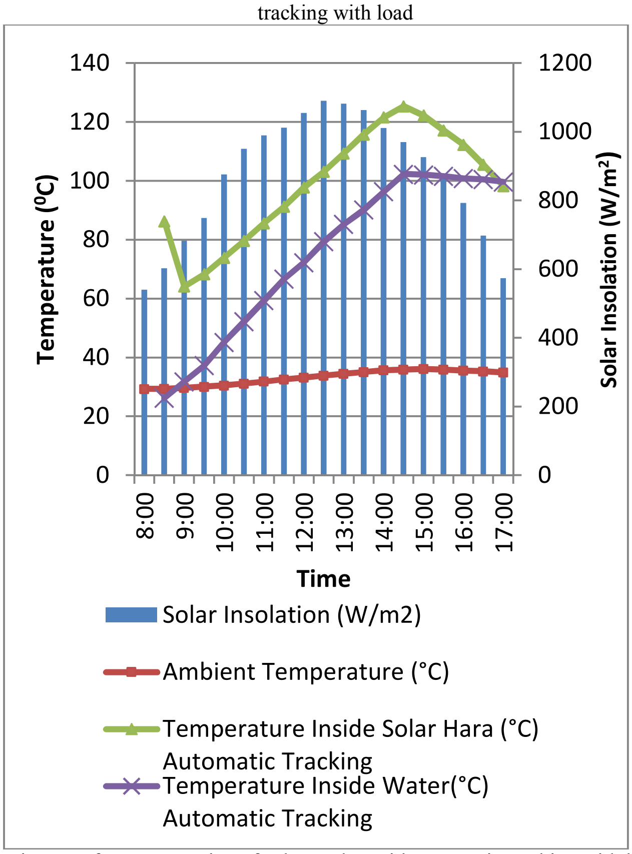

Fig. 7 Performance testing of solar cooker with automatic tracking with load for thermal efficiency

IV. REFERENCES

[1] Abu-Malouh R; Abdallah S; Muslih I M. 2011. Design, construction and operation of spherical solar cooker with automatic sun tracking system. Energy Conversion and Mgt., Vol. 52, 615–620

[2] Barsoum N. 2009. Implementation of a Prototype for a Traditional Solar Tracking System. Third UKSim European Symp. on Computer Modeling and Simulation, England.

[3] Cheema L S. 1984. 'Two step asymmetrical reflector solar cooker of box type'. Proc. of NSEC, Vadodara, Dec. 15-18, 1983.

[4] Dicorato M; Forte G; Pisani M. 2010. One-axis tracking optimization of Concentrating Solar Power plant for electricity production. UPEC 2010.

[5] Emad (2003). "Energy conservation and management", Volume 44,Issue 6,Sept. 2003,Page2651- 2663.

[6] Khan M T A; Tanzil S M S; Rahman R; Alam S M S. 2010. Design and Construction of an Automatic Solar Tracking System. 6th Int. Conf. on Electrical and Computer Engg., Dhaka, Bangladesh.

[7] Knudson B; Lankford B. 1998. Executive Summary of a Solar Oven Promotion Program Evaluation in Kenya._ Solar Cookers International, Sacramento, California.

[8] Muzumdar N N. 1980. 'Solar Oven' Muzumder Consultants, 13 Maitri Society, Dr. Radhakrishnan Road, Ahmedabad, Gujarat (India) - 380015.

[9] Negi B S; Purohit I. 2004. Experimental investigation of a box type solar cooker employing a non-tracking concentrator. Energy Conversion and Mgt. 2004.

[10] Vaughan B D. 1979. `Simple Solar Cooker from India' Appropriate Technology, Vol. 6(1), Page 12.