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DESIGN AND FABRICATION OF SOLAR PARABOLOID CONCENTRATOR

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Abstract:
Concentrating Solar Power (CSP) is a unique renewable energy technology. CSP systems have the ability to provide electricity, refrigeration and water refining in one unit. The proposed technology is extremely helpful in improving the quality of life for many people around the world who lack the energy needed to live a healthy life. This project work is concerned with an experimental study under local climatic condition. It presents the designing of collector and performance of paraboloid collector. A spherical solar concentrator is fabricated with the easily available materials. From the test result and the collectors performance, the model is efficient for thermal applications.

Keywords:
Concentrator, Paraboloid Dish, Receiver, Temperature.

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I. INTRODUCTION

In 1973 a Greek scientist, Dr. Ioannis Sakkas, curious about whether Archimedes could really have destroyed the Roman fleet in 212 BC, lined up nearly 60 Greek sailors, each holding an oblong mirror tipped to catch the sun's rays and direct them at a tar-covered plywood silhouette 49 m (160 ft) away. The ship caught fire after a few minutes; however, historians continue to doubt the Archimedes story. In 1866, Auguste Mouchout used a parabolic trough to produce steam for the first solar steam engine. The first patent for a solar collector was obtained by the Italian Alessandro Battaglia in Genoa, Italy, in 1886. Over the following years, inventors such as John Ericsson and Frank Shuman developed concentrating solar-powered devices for irrigation, refrigeration and locomotion. In 1913 Shuman finished a 55 HP parabolic solar thermal energy station in Maadi, Egypt for irrigation. The first solar-power system using a mirror dish was built by Dr. R.H. Goddard, who was already well known for his research on liquid-fuelled rockets and wrote an article in 1929 in which he asserted that all the previous obstacles had been addressed. Professor Giovanni Francia (1911–1980) designed and built the first concentrated-solar plant, which entered into operation in Sant Ilario, near Genoa, Italy in 1968. This plant had the architecture of today's power tower plants with a solar receiver in the centre of a field of solar collectors. The plant was able to produce 1 MW with superheated steam at 100 bar and 500 °C. The 10 MW Solar One power tower was developed in Southern California in 1981. Solar one was converted to Solar Two in 1995, using molten salt as the receiver working fluid and as a storage medium until it was decommissioned in 1999. The parabolic-trough technology of the nearby Solar Energy Generating Systems (SEGS), begun in 1984, was more workable. The 354 MW SEGS was the largest solar power plant in the world, until 2014 and Solar steam engine for water pumping, near los angeles circa 1901 shown in figure 1. No commercial concentrated solar was constructed from 1990 when SEGS was completed until 2006 when the Compact linear Fresnel reflector system at Liddell Power Station in Australia was built. Few other plants were built with this design although the 5 MW Kimberling Solar Thermal Energy Plant opened in 2009. In 2007, 75MW Nevada Solar One was built, a trough design and the first large plant since SEGS. Between 2009 and 2013, Spain built over 40 parabolic trough systems, standardized in 50MW blocks. Due to the success of Solar Two, a commercial power plant, called Solar Tres Power Tower, was built in Spain in 2011, later renamed Gem a solar thermo solar plant. Gem a solar's results paved the way for further plants of its type. Ivanpah Solar Power Facility was constructed at the same time but without thermal storage, using natural gas to preheat water each morning. Most concentrated solar power plants use the parabolic trough design, instead of the power tower or

Fresnel systems. There have also been variations of parabolic trough systems like the Integrated Solar Combined Cycle (ISCC) which combines troughs and conventional fossil fuel heat systems. CSP was originally treated as a competitor to photovoltaic and Ivanpah was built without energy storage, although solar two had included several hours of thermal storage. By 2015, prices for photovoltaic plants had fallen and PV commercial power was selling for 1/3 of recent CSP contracts. However, increasingly, CSP was being bid with 3 to 12 hours of thermal energy storage, making CSP a dispatchable form of solar energy. As such, it is increasingly seen as competing with natural gas and PV with batteries for flexible, dispatchable power. Since the beginning of time, people have been fascinated by the sun. Ancient civilizations personified the sun, worshipping it as a God or Goddess. Throughout history, farming and agriculture efforts have relied upon the sun's rays to grow crops and sustain populations only recently, however, have we developed the ability to harness the suns awesome power. The resulting technologies have promising implications for the future of renewable energy and sustainability.

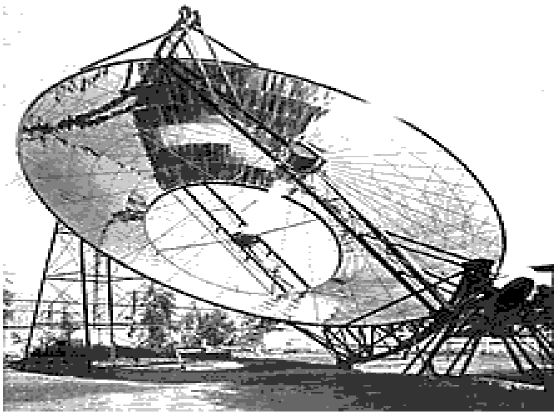

Fig. 1 Solar steam engine for water pumping, near Los Angeles circa 1901

A. Solar Energy

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power.

Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy.

Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light-dispersing properties and designing spaces that naturally circulate air.

B. Application of Solar Energy:

- Solar water heating
- Solar heating of buildings
- Solar distillation
- Solar pumping
- Solar drying of agricultural and animal products
- Solar furnaces
- Solar cooking
- Solar electric power generation
- Solar thermal power production

Cooking is one of the very important and necessary household chores in every society of the world. Energy consumption for cooking in developing countries is a major component of the total energy consumption, including commercial and noncommercial energy sources. In the rural areas of most developing countries cooking is usually done in open fires fuelled by firewood. In the cities, stoves are more common, fuelled by wood, charcoal, kerosene of sometimes fuel gas. In many regions, especially East Africa and West Africa (including Nigeria), oil-derived fuels are expensive and wood based fuels are becoming increasingly scarce, as rising demand presses hard on dwindling number of trees. In developing countries like Nigeria, cooking is the main source of demand for firewood and is an important cause of deforestation. There are four possible ways of remedying an insufficient supply of firewood for cooking. The first is to increase supply by promoting the planting of trees. The second is to decrease demand by introducing more energy-efficient stoves. The third is to develop indigenous alternative sources of fuel, such as biogas. The fourth is to promote the replacement of fuel-using techniques by solar cooking, the subject of this technical presentation.

Solar cookers are divided into four main categories:

- Concentrator cooker.
- Box cookers.
- Solar ovens.
- Indirect solar cookers.

The concentrating type of solar cookers is further sub-divided into parabolic dish/trough, cylindrical, spherical and Fresnel. This type of cookers usually employs mirrors/ reflectors to concentrate the total solar energy incident on the collector surface, so the collector surface is usually very wide and the temperature achieved is very high. Parabolic dish cooker has the highest efficiency in terms of the utilization of the reflector area because in fully steerable dish system there are no losses due to aperture projection effects. Also radiation losses are small because of the small area of the absorber at the focus. Additional advantages include higher cooking temperatures, as virtually any type of food can be cooked. and short heat-up times. In the present work a parabolic dish solar thermal cooker, PDSTC, is designed and constructed. The cooker can be used to cook food equivalent of 12 kg of dry (uncooked) rice per day for a relatively medium size family, with a designed efficiency of about 50%.

II. OBJECTIVES

i. To design and fabricate solar paraboloid concentrator by locally available materials.
ii. To evaluate the performance of the concentrator with water as heat exchanger.

III. METHODOLOGY

The objective of this project is to obtain maximum solar energy through the concentration of the solar radiations. There are many types of solar concentrators are available like parabolic trough, Linear Fresnel, Parabolic dish and Heliostat field tope concentrators. The parabolic dish was selected as it could be easily manufactured at the small scale and also turned out to cheap in terms of cost. It also provided us with point focus of the solar radiation which would lead to enhanced exposure of the absorber to the solar radiations. The absorber was designed such that it absorb maximum heat from the solar radiations and produce the steam in effectively.

The produced steam from the absorber is used for various applications in that we used steam for the cooking purpose. In normal solar cookers it is difficult to cook in outdoor condition. Our project is to design to solve this problem by providing the hot steam for cooking in kitchen itself.

IV. FINAL ASSEMBLY

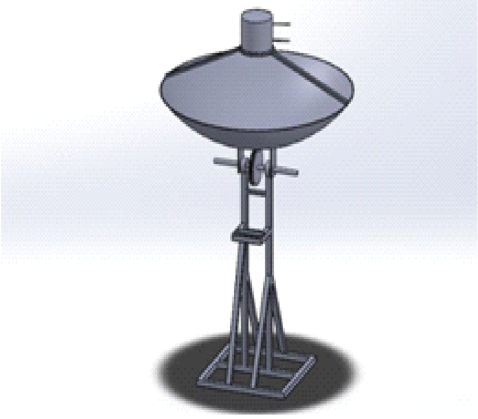

Fig.2 Final assembly

Working principle

In our Project, the type of concentrating system that is possible to use in a heating application is the parabolic dish. This has a bowl shaped reflector that focuses the sun onto a relatively small receiver. The glazing is chosen so that a maximum amount of sunlight will pass though it and reach the absorber for proximately sensor performance they require dual axis tracking and the receiver moves with the control unit. This complicates their practical application for water and space heating. Most parabolic dish systems are very sophisticated systems used for electricity generation or very simple systems for cooking food on a small-scale. Other types of concentrating systems have an array of reflectors that individually track the sun and focus sunlight onto a central receiver located on a tower. Development of these systems has focused on electric power generation.

V. RESULTS AND DISCUSSION

Day 1 Graphs

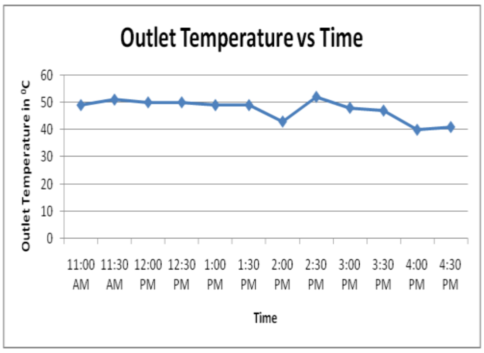

Fig.3 Graph showing outlet temperature v/s time

Fig. 3 shows temperatures of outlet water at different times of day 1. The temperature readings are taken from morning 11:00 am up to evening 4:30 pm. Max temperature is 52 °C at 2:30 pm and Min temperature is 40°C.

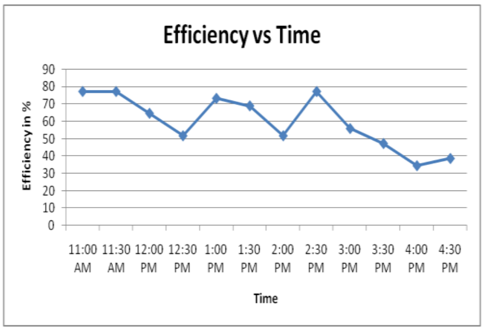

Fig.4 Efficiency of heat transfer v/s time.

Fig 4 shows efficiency of Heat transfer at different times of day 1. The Efficiency of Heat transfer values are plotted from morning 11:00 am up to evening 4:30 pm. Maximum Efficiency is 77.33 % and Minimum Efficiency is 34.54 %.

Day 2 Graphs

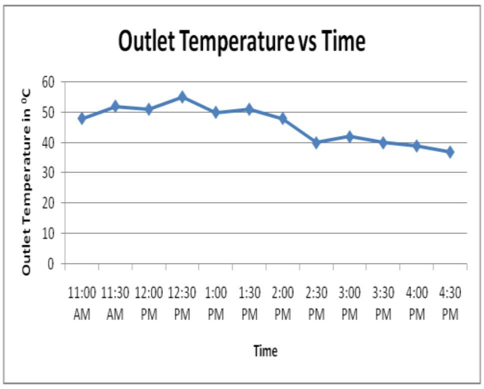

Fig.5 Graph showing outlet temperature v/s time

Fig. 5 shows temperatures of outlet water at different times of day 2. The temperature readings are plotted from morning 11:00 am up to evening 4:30 pm. Maximum temperature is 55 °C at 12:30 pm and Minimum temperature is 37 °C at 4:30 pm.

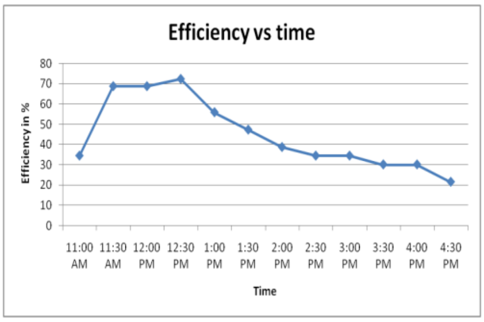

Fig.6 Efficiency of heat transfer v/s time.

Fig. 6 shows efficiency of Heat transfer vs Time. It shows efficiency of Heat transfer at different times of day 2. The efficiency of Heat transfer values are plotted from morning 11:00 am up to evening 4:30 pm. Maximum efficiency is 72.47 % and Minimum efficiency is 21.52 %.

VI. CONCLUSIONS

Concentrating solar technologies are in different stages of development most of them have passed the testing and power production phases and are being commercialized. Yielding the most power per area among all the solar concentrators is the paraboloid dish and the latter was selected as our low-budget prototype of choice. The steps towards the final paraboloid dish concentrator made with reflecting aluminum have been enumerated. To convert the paraboloid dish to a solar paraboloid concentrator, its surface has to be lined up with a reflective material so as to focus energy optimally. The choice of the solar concentrator along with the building materials, reflecting aluminum was also fully justified in accordance with the ease of production and tight budget. The analysis of concentrator is done and its average efficiency is 59% on full sunny day and 37% on partly cloudy day condition.

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