Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2013
(ICMERE2013) 1-3 May 2014, Chittagong, Bangladesh

ICMERE2013-PI-221

DESIGN AND FABRICATION OF A MODEL SOLAR CENTRAL RECEIVER HEATING SYSTEM

Banytosh Mazumder[1], Md. Kamrul Islam[2], Md Masudur Rahman[3], M M Kamal Bhuiya[4], Abdullah-Al-Mamoon[5] and Tahsin Ahmed[6]

[1] Gazi Auto Tyres, Bangladesh
[3]Bangladesh France Peru Engineers Limited, Bangladesh
[2,4,5]Chittagong University of Engineering and Technology, Bangladesh
[6]Khulna University of Engineering and Technology, Bangladesh
[1]banytosh06@yahoo.com, [2]kamrul.cuetme@gmail.com, [3]masudme039@gmail.com, [4]mkamalcuet@gmail.com, [5] sayem_027@yahoo.com, [6]saroj_2k6@yahoo.com

Abstract- *The concept of central receiver for solar energy concentration and collection is based on a field of individually sun-tracking mirrors that reflect the incident solar rays to a receiver at the top of a centrally located tower. Typically 80 to 95 percent of the reflected energy is absorbed into the working fluid which is pumped up the tower and into the receiver. Main objectives of the study were to design and fabrication of a model type solar central receiver heating system where solar energy concentration and collection is based on a field of heliostats that reflect the incident sun rays to the receiver which contains working fluid; and analysis of the amount of heat received and heat gained. The angle and position of the heliostats are controlled with respect to the stationary receiver to concentrate the rays, depending upon the time of the day. The highest efficiency is obtained in a particular period of time depending on the incident solar light density. The performance of the system can be advanced by placing more heliostats and focusing them more precisely to the center.*

Keywords: Central Receiver, Heliostats, Tower, Performance Analysis.

1. INTRODUCTION

Due to modern economic and population growth the solar energy is demanded as energy source for heating, cooling and transportation. Solar thermal electric generation system uses sunlight to heat fluids by terrestrial radiation. Of all the renewable energy sources, solar energy received the greatest attention and regarded as the solution for reducing the use of fossil and nuclear fuels and for a cleaner environment. It has been the optimistic predictions ranging from largely supplementing to eventually replacing all the current means of production of both electric-power and thermal-energy requirements.

In the United States, with 68 solar-thermal projects of various kinds taking place, the major activity in the late 1970 to 1980s was the development, construction and operation of Solar One, the 10MW(e) pilot plant which is situated in the Mojave Desert at Dagget, about 12 mi southeast of Barstow, California [3]. It is owned by Southern California Edison Company and is financed jointly by Department of Energy (DOE) and a group of utilities [1]. The plant uses water-steam as the heat-transport and working fluid with thermal storage using heat-transport fluid. It started operation in the summer of 1982. It reached a 10.4 MW(e) net output on 10 October 1982. The storage system, rated at 7 MW(e) maximum , had not met that goal at that time. The first two years of operation are devoted to operation experimental testing of the major subsystems and evaluating requirements and cost of operation and maintenance. This period will then be followed by full power tests to obtain long term operating, maintenance and reliability data [2].

In America, Spain, the International Energy Agency. Several European countries and United States have funded a 500 KW (e) plant that uses molten sodium as the heat-transport and thermal storage fluid. The sodium receiver exit temperature 975^0 F. The plant has 93 heliostats of 430 ft^2 each that are supplied by the Martin Marietta Corporation. It has a cavity receiver atop a 140 ft tower. The plant started operation in September 1981. An interesting feature of this plant is the installation of a parallel distributed system of 500 kW(e) using line focus receivers to compare its performance with that of the central receiver system. Another plant in Almeria, Spain, scheduled for completion in late 1982, is a 1.2 MW(e) central receiver system called CESA-1. It has 300 heliostats, 430 ft^2 each, a cavity receiver, water-steam at 975^0 F as the heat-transport and working fluid and a 3 MWh (th) thermal storage using Hytec as the storage fluid. It is funded by Spain and the United States, with heliostats built in France and Germany [4].

2. DESIGN PARAMETER

There are some parameters related to this topics. But important parameters are describing as follows:

2.1 Central receiver

The central receiver containing heat transfer fluid placed at the top of a tower is located at a point where reflected energy from the heliostats can be intercept most efficiently. The length of the receiver is 0.8636 m. and diameter is 0.5842 m. The receiver (Fig. 1) is designed to intercept, absorb and transport most of the energy to a heat transfer fluid (water). Although radiation beams leaving the heliostat may be rectangular, the beam reaching the receiver is more circular because of the canting and focusing of the heliostat reflecting panels and because of the finite image of the sun.

Fig. 1: Central receiver.

2.2 Heliostat

This heliostat is composed of several mirror module panels rather than a single large mirror. The thin glass mirrors are supported by a substrate backing to form a slightly concave mirror surface. Individual panels on the heliostat are also canted toward a point on the receiver. The heliostat focal length is approximately equal to the distance from the receiver to the farthest heliostat. Subsequent “tuning” of the closer mirrors is possible.

The heliostats (Fig. 2) are steerable so that they can reflect the sun’s rays on the central receiver at almost all times during the daylight hours. In essence, they keep the sun stationary as far as the receiver is concerned. This angle depends upon both the time of day and the position of the individual heliostat with respect to the receiver. The heliostat is composed of a reflective surface or mirror, mirror support structure, pedestal, foundation, control and drive mechanism. Each heliostat has its own tracking mechanism to keep it focused on the tower to heat the transfer fluid. Height of the heliostat is 1.0141 m and 0.9144 m wide.

2.3 Tower

The height and weight of the tower depend on the receiver size and weight though the height of the tower is limited by its cost. The weight and wind age area of the receiver are the two most important factors in the design of the tower. Height of the tower is 1.6002 m.

Fig. 2: Heliostat.

3. WORKING PROCEDURE

The central receiver used in solar thermal system uses a large field of reflecting mirrors called Heliostat that reflect the sun’s energy and concentrate it on central receiver mounted on a tower. Individually each heliostat covers a large field. All energy from the sun it receives focused on the central receiver. In the receiver the concentrated solar energy is absorbed by a circulating fluid. The fluid could be water, which vaporizes into steam that drives a turbo generator in a Rankine cycle, or an intermediate fluid that transport the heat to the steam cycle [5]. Total experimental setup is shown in fig. 3.

Fig. 3: Experimental set up.

4. DATA ANALYSIS

Date: 12/07/2011

Table-1: Data on temperature of ambient air, receiver and heliostat surface.

Time	Ambient Air Temperature (	Working fluid (water) temperature (	Heliostat (1) surface temperature (	Heliostat (2) surface temperature (	Heliostat (3) surface temperature (
10.30 am	29	32	40	39.5	40
11.00 am	30	33	41	41	42
11.30 pm	31	37	41	39.5	39
12.00 pm	32	38	45	45	44
12.30 pm	34	38	45	42	44
13.00 pm	35	39	44	44	44
13.30 pm	33	40	46	45	48
14.00 pm	32	42	45	45	48
14.30 pm	31	43	45	44	47
15.00 pm	31	43	45	45	45

Calculation for receiver heat gain:

The useful formula is-

$Q = m\,c_p\,(T_2 - T_1)$…………………………………………..(1)

Where,

m = Mass of the working fluid (water) in the receiver. (Kg)

c_p = Specific heat of water. (J/KgK)

Rate of energy incident = $S \times A_h \times 3$………………………….(2)

= 1367×2.913×3

= 11946.213 watt

Therefore, $\eta = \frac{Heat\ gain}{Rate\ of\ energy\ incident} \times 100$………………..(3)

Date: 13/07/2011

Table 2: Data on temperature of ambient air, receiver and heliostat surface

Time	Ambient Air Temperature (	Working fluid (water) temperature (	Heliostat (1) surface temperature (	Heliostat (2) surface temperature (	Heliostat (3) surface temperature (
10.30 am	28	29	35	36	37
11.00 am	29	30	35	35	36
11.30 pm	29	31	37	38	37
12.00 pm	31	33	39	39	39
12.30 pm	32	35	39	38.5	38.5
13.00 pm	30	35.5	40	39	40
13.30 pm	33	36	42	41	41
14.00 pm	33	37	42	41	41
14.30 pm	33	39	44	43	42
15.00 pm	30	40	44	43.5	42.5

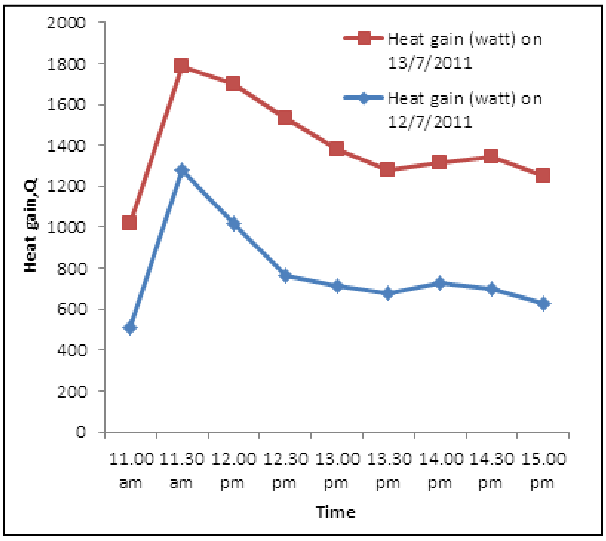

Fig. 4: Heat Gain vs. Time

5. RESULTS

On 12/07/2011

From 10.30 am to 12.30 pm obtained efficiency is 6.41%.From 12.30 pm to 14.30 pm efficiency obtained is 5.34%.Taking time difference from 10.30 am maximum efficiency is 10.68%.

On 13/07/2011

From 10.30 am to 12.30 pm obtained efficiency is 6.41%.From 12.30 pm to 14.30 pm efficiency obtained is 4.27%.Taking time difference from 10.30 am maximum efficiency is 6.40%.

Performance observation:

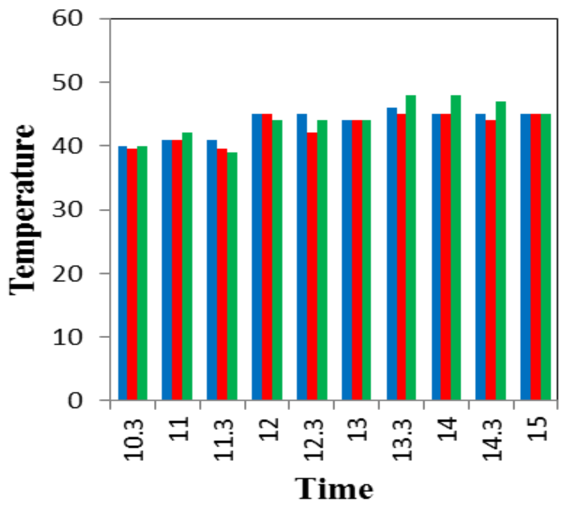

Fig. 5: Heliostats temperature in several times (Date-12/07/2011).

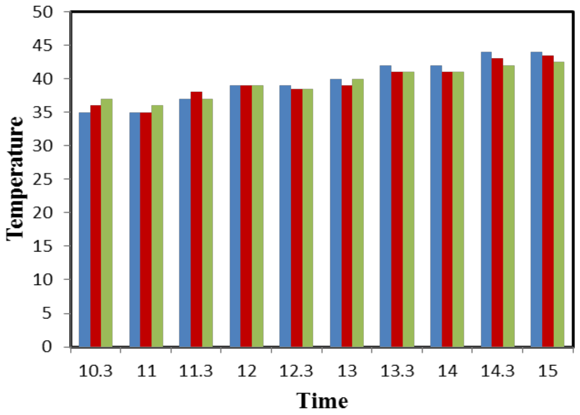

Fig. 6: Heliostats temperature in several times (Date-13/07/2011).

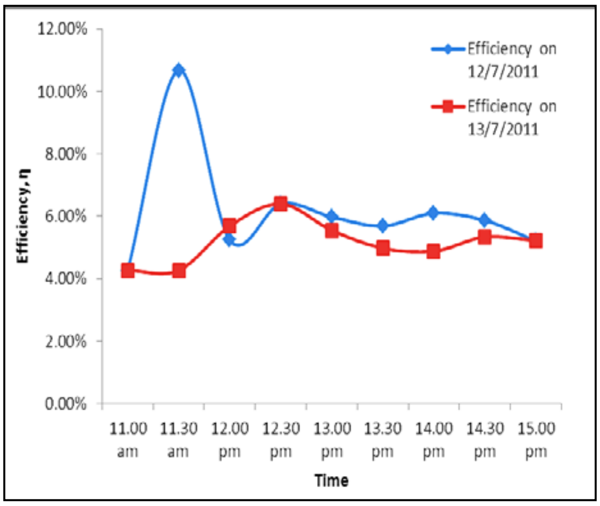

Fig.7: Efficiency of solar central receiver heating system

From the Fig.7 it is seen that highest efficiency is obtained at 11.30 am on both days. But the efficiency is decreases sometimes due to change of weather condition.

6. DISCUSSION

Adjusting the heliostat position more sun rays can be concentrated to the central receiver which will increase the temperature of the working fluid and better performance will be obtained. So in future sun tracking system will be useful to concentrate more sun rays to raise the temperature adjusting the focal length of heliostat from the central receiver.

7. CONCLUSION

Solar thermal technologies have a promising future and could become an economically valuable energy source. Solar energy has some disadvantages also. Sunlight is a free and renewable source of fuel. Solar thermal energies have minimum impact on the environment. Solar thermal energies are not fully commercialized, because of its some disadvantages. Fabrication of heliostat is costly. From the study of the solar central receiver heating system the maximum temperature of heliostat is found 48^0C at 13.30 pm (Date-12/07/2011) maximum efficiency is found 10.68% and it varies with several times due to weather conditions.

8. REFERENCES

[1] S. A. Kalogirou, "Solar thermal collectors and applications," *Progress in Energy and Combustion Science*, vol. 30, no. 3, pp. 231-295, 2004.

[2] V. Quaschning, "Solar Thermal Power Plants -Technology Fundamentals," Erneuerbare-Energien-und-Klimaschu.de, Renewable Energy World pp. 109-113, 2003.

[3] M. M. El-Wakil, Powerplant technology, McGraw-Hill Education, 1984

[4] T. R. Mancini, “Catalog of Solar Heliostats”, Albuquerque, USA, Technical Report, no. III - 1/00, 2000

[5] M. Romero, R. Buck, and J. E. Pacheco, “An update on solar central receiver systems, projects, and technologies”, *Journal of Solar Energy Engineering*, vol. 124, no. 2, pp. 98-108, 2002.

9. NOMENCLATURE

Symbol	Meaning	Unit
Q	Heat gain	Watt(W)
m	Mass of fluid	kg
C_p	Specific heat of water	J/kgK
T_1, T_2	Temperature of working fluid in different time	K
S	Solar constant	m^2
A_h	Area of Heliostat	W/m^2
η	Efficiency	Dimensionless