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Renewable Energy Technology: A Case Study of Solar Steam Cooking System at Shri Saibaba Sansthan Trust, Shirdi, MS, India

Dawange Sahebrao S

Head of Department of Electrical Engg, Sanjivani K. B. P. Polytechnic, Kopargaon, MS, India
Email: ssdawange99@gmail.com

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ABSTRACT

Many scientists have pointed out the relevance of alternate renewable sources of energy to overcome 'Energy Crisis'. Among the renewable sources of energy, solar energy offers a practical solution for the energy problem which is clouding the prospects of mankind. Much of solar energy research in India is concentrated towards developing solar cookers for domestic use. In this context we should concentrate our thoughts on utilizing solar energy for the cooking requirements at the large scale establishments for better future and energy security. For facilitating the quantity cookery in large establishments, Sheffler's reflectors are among the convenient, cost effective and operationally viable devices. In order to iron out all the queries such as the availability, cost benefit ratio, the mode of installation, and the financial support given by the Government for installation, an explorative research study has been undertaken at Prasadalaya of Shri Saibaba Sansthan Trust, Shirdi, Maharashtra where the world's largest Solar heating steam cooking system have been installed. The findings of this study bring forth the importance of the Sheffler's reflectors for quantity cookery that could be one of the emerging ventures for meeting the energy demands of the country.

Keywords: Energy crisis, Fossil fuels, Renewable energy, Solar energy, Thermosyphon principle, Sheffler reflector Solar heating steam cooking for Quantity cookery

INTRODUCTION

"Solar energy is the energy of the future, not just an alternative" was the message of the Second World Conference on Solar Cookers. It further stated that this energy will soon achieve great economic importance, not only in countries which lack primary energy resources such as coal, gas and oil but also in the industrialized countries. Solar energy would be the best and ready alternative to conventional fuels if harnessed through solar cooking devices. The rapid rise in population has resulted in constantly increasing energy needs. In order to cope with the increasing needs of the people, it put more stress and evokes higher demand on available energy.

This case study aims to understand Solar Heating steam Cooking System installed at Prasadalaya of Shri Saibaba Sansthan Trust, Shirdi to see that how conventional energy and expenses incurred on it could be saved by using the solar energy. Nowadays, solar heating cooking system is becoming more popular as the concerned organization can save lakhs of rupees by saving the conventional energy sources. It also aims that natural resources of energy have the limitations. However, it can be saved if we emphasize the use of non-conventional energy sources. It is also required to come to a particular conclusion that after installing this type of project, to find out the efficiency of steam generation system by using Scheffler's reflector and its payback period. A Scheffler type concentrating solar steam cooking system was commissioned at Shri Saibaba Sansthan, Shirdi on 30th July, 2009. This is the first of its kind in Maharashtra. It cooks food for about 3000 devotees. The 73 nos. of solar Scheffler concentrators raise the water temperature to 550°C to 650°C and convert it into steam for cooking purposes. This system is integrated with the existing boiler to ensure continued cooking even at night and during rainy or cloudy weather. The solar cooking system installed at Shirdi follows the thermosyphon principle and so does not need electrical power or pump.

SYSTEM DEVELOPMENT

German scientist Wolfgang Scheffler has devised a parabolic reflector set-up to harness solar energy using low cost set-up which can be used in rural areas in India. A concentrating primary reflector tracks the movement of the Sun, focusing sunlight on a fixed place. The focused light heats a very large pot, which can be used for heating, steam generation, cooking, baking breads, and water heating.

The solar steam cooking system installed at Shirdi has 73 parabolic concentrators / dishes (called Scheffler dishes after its inventor) placed on the terrace of Sai Prasad Building No.2.

The use of Scheffler reflectors can result in effective water heating by using the non-uniform distribution of solar radiation on the cylindrical absorber surface. In most of this system the part of the cylindrical absorber is thermally insulated in order to reduce storage tank thermal losses [5].

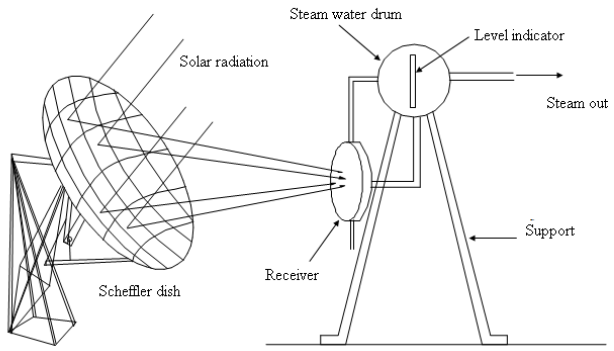

Fig 1. Schematic view of system installed at Sai Baba Sansthan`s Prasadalaya, Shirdi

They reflect and concentrate the solar rays on the 40 receivers placed in focus. Water coming from the steam headers placed above the header centers is received from bottom of the receiver, gets heated up to due to heat generated (about 550^0 C) due to concentration of solar rays on the receivers and get pushed up via top pipe of receiver into the header. The principle of anything that gets heated is pushed up is called thermosyphon principle. The advantage of thermosyphon principle is no pumping (thus no electricity) is needed to create circulation since the heated water is pushed into the header and water from the same headers come into the receivers for heating. The cycle continues till it reaches 100 ^{0}C and gets converted into steam.

Table 1: Details of system development.

Sr. No	Particular	Remark
01	Cost of Project	Rs. 1.33/- Crores
02	Financial aid Ministry of Renewable Energy, New Delhi	Rs. 58.40/- Crores
03	Project Completion period	150 days
04	Area of Project	2500 Sq. mtr
05	Total solar dishes	73 Nos.
06	Area of each dish	16 Sq. mtr
07	Total dish collection area	1168 Sq. mtr
08	Energy creates by one dish during 8 Hr period.	37,840 kcal
09	Total energy created from all dishes per day	2762320 kcal
10	Steam generation capacity per day	3500 kg/day
11	Fuel used at present	L.P.G.
12	Calorific value	10,500 kcal
13	Total calories generated from solar project	2762320 kcal (10500 calorific value of gas)
14	Saving of gas	263.08 Kg/day
15	Commercial gas rate	Rs. 40.27
16	Saving per day	Rs. 10,594/-
17	Saving per month	Rs. 3,17,825/-
18	Carbon credit from project = 1956.1 MT CO_2 x 150	Rs. 2,93,425/-
19	Subsidy of carbon credit from International organization	Rs. 2,93,415/-

The header is only filled and thus steam generated gets accumulated in the upper half of the steam header. The temperature and pressure of steam generated keeps on increasing and heat is stored till the steam is drawn for cooking into the kitchen.

All the 73 dishes rotate continuously along with the movement of the sun, always concentrating the solar rays on the receivers. This movement of concentrators is called tracking, which is continuous and is controlled by the fully automatic timer mechanism.

Only once during the day i.e. in the early morning the dishes have to be turned manually onto the morning position, subsequently the automatic tracking takes over.

WORKING OF SOLAR STEAM HEATING COOKING SYSTEM

In the focus of each pair of Scheffler Concentrator (dishes), the sleeping dish and standing dish, are placed heat exchangers called receivers.

The Solar rays falling onto the dish are reflected and concentrated on the receivers placed in its focus. Due to concentration the temperature achieved is very high (between 450-650^{o}C) and thus the water in receivers comes to boiling and becomes steam.

Above the receiver is an insulated header pipe filled half with water. The cold water enters the receiver through inner pipe, gets heated due to the high temperature of the concentrated rays and the heated water goes up. The cold water again enters through inner pipe and the cycle continues till steam is generated. The steam gets stored in the upper half empty portion of the header pipe and pressure keeps on rising. The steam is then drawn / or sent to kitchen through insulated pipe line.

TESTING PROCEDURE AND EXPERIMENTATION

The Scheffler reflector used here has an area of 16 m^2. The sunlight that falls onto this reflector is reflected sideways to the focal point away from the reflector. The axis of daily rotation is located exactly in north-south direction, parallel to earth axis and runs through the centre of gravity of the reflector. Thus the reflector always maintains its gravitational equilibrium and the mechanical tracking device (clockwork) can be moved easily in position with the sun. The focus is located on the axis of rotation to prevent it from moving when the reflector rotates.

During the day, the concentrated light is rotated around its own center but not in sideways. Thus, the focus stays fixed. At the focus it has a receiver to hold 20 liter water. The parameters measured were: ambient temperature, water temperature, solar radiation and wind speed. The built in thermometer is used to measure water temperature which has a range of - 200^{0}C to 1250^{0}C. Wind speed is measured by battery operated digital Anemometer with a range 0.3 to30 m/s and with a facility to show ambient temperature. A pyranometer is used to measure the radiation. The experimentation was carried in the month of October, November and December 2017. The readings were taken between 9 AM to 10:35AM for 21 Dec, 2017. All readings were taken at the interval of 5 minutes. The sample observations are shown in Table II.

Table 2: Readings of various parameters in solar steam generation system.

Date	Serial Number	Time [hour]	Generated water Temperature [^{o}C]	Wind speed [kmh^{-1}]	Ambient Temperature [°C]	Radiation falling [Wm^{-2}]
21 Dec. 2017	1	9	25	16	28	700
	2	9.05	28	16	28	750
	3	9.1	34	16	28	750
	4	9.15	40	15	28.5	750
	5	9.2	45	16	28.5	750
	6	9.25	52	15	29	750
	7	9.3	58	15	29	750
	8	9.35	66	17	29	750
	9	9.4	73	17	30	750
	10	9.45	80	17	30	750
	11	9.5	86	17	30	750
	12	9.55	87	15	30	750
	13	10	90	15	31	775
	14	10.05	91	15	31	775
	15	10.1	93	14	31	775
	16	10.15	94	15	31	775
	17	10.2	96	15	31	775
	18	10.25	97	16	31	775
	19	10.3	98	16	31	775
	20	10.35	98	16	31	775

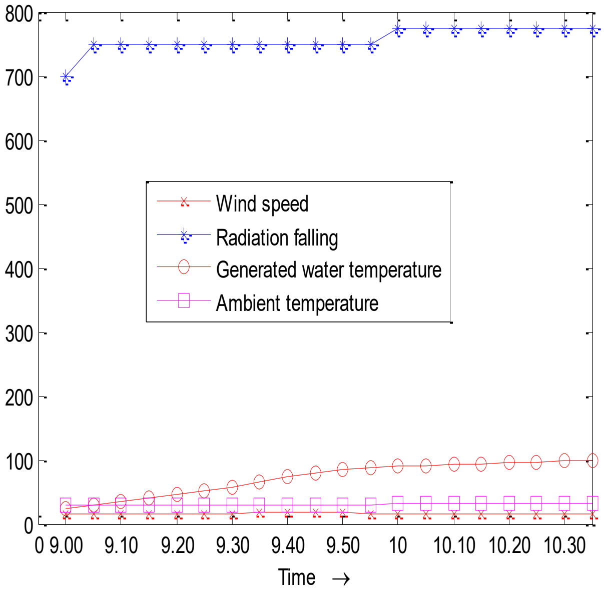

Fig 2: Variation of different parameter depending on time hours.

PERFORMANCE EVALUATION

A. Model formulation for performance analysis

The efficiency was calculated with the following equations:

$$\eta = \frac{10^{s} * Ep}{\int_{t=0}^{tp} [Gbave * As]dt} x100 \quad (1)$$

Where,

Ep : The total heat energy,

t : The time;

Gbave : The beam radiation at time t,

As : The aperture area of the Scheffler reflector which is also a variable function whose value can be determined for any day of the year by the following formula.

Aperture area = Reflector Area × cos (43.23° − seasonal angle deviation of the sun / 2) (2)

Funk [18], described the procedure for evaluating different types of solar cookers and his research was focused on the influence of test conditions on results minimization if uncontrolled variables are held to certain ranges. He has used water for the evaluation of the cookers in terms of power. For the performance test with water only, the following equation was used:

$$Ep = m_w * c_w * \Delta T / 3600 \quad (3)$$

Where,

m_w is the mass of water used,

c_w is the specific heat at constant pressure (for water 4.187 [kJ kg^{-1} K^{-1}]) and

ΔT [K] is the change in temperature for a specific time.

The average power available, Pave, during the experiment is given as

$$P_{ave} = \frac{Ep}{tp} \quad (4)$$

Where,

tp is the total process time.

In between the beam radiation range of 700 to 800[Wm^{-2}], Scheffler reflector showed that about half of the solar power collected by the reflector becomes finally available in the cooking vessel.

B. Calculation:

Here,

Number of solar reflectors=73

Solar reflector area= 16 m^2

Total reflector area=73*16 m^2

ΔT=(98-25)+273=346 ^{o}K

E_p=(73*20)*4.187*346/3600

E_p= 587.53 KW

Aperture area= (73*16) × cos (43.23° − 1.5^o / 2)

Aperture area= (73*16) × cos (42.48°)

Aperture area=861.71 m^2

$$\eta = \frac{10^{s} * 587.33}{\int_{0}^{1.35} [757.50 * 861.71] dt} x100$$

$$\eta = 66.67\%$$

C. Cost benefit ratio

Total cost spent on the installation of the system (Rs) = 1.33 cores.

Cost of L.P.G fuel saved per year (Rs) = 38, 13, 900.

Carbon credit (Rs) = 2, 93, 425.

Subsidy (Rs) = 50 %

Net saving (Rs) = 41, 07, 325.

Payback period = Total cost / Net saving per year
= 6650000 / 4107325
= Approximately 2 years

USEFULLNESS OF SYSTEM

The Sansthan has a Prasadalaya where it offers food (prasad) to the devotees at subsidized rates. Thousands of devotees partake food at a nominal rate of Rs.4/- per meal for grownups and Rs.2/- per meal for children. The Sansthan is always on the lookout for innovative ways to reduce its overhead costs. They have installed hot- water- systems at its dharmashalas / dormitories, providing staying facilities for devotees. The Sansthan have also installed solar streetlights in its pumping complex. Thus, it was found to be the ideal place to introduce the new solar steam cooking technology for its proper take-off in Maharashtra state. Before the installation of the solar cooking system, the steam for cooking at Sansthan was being generated by LPG gas firing in the boiler.

CONCLUSION

The main goal of the system was to reduce LPG gas consumption by 50 %. Another important goal beside financial benefits due to saving LPG gas was to use as much natural energy as possible to promote environment protection, its conservation and rejuvenation by using renewable and clean energy. To promote and popularize use of solar energy. MNES and MEDA have supported this project towards realizing this objective.

Conflicts of interest: The authors stated that no conflicts of interest.

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