

Performance Evaluation of Parabolic Dish Solar Steam Generation for Low Cost Industries

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Abstract- Solar Energy is a renewable source of energy. Its uses do not contribute to emission of greenhouse gases and other pollutants to the environment. It is sustainable since it cannot be depleted in a time relevant to the human race. Concentrating solar power (CSP) is a unique renewable energy technology. Concentrated solar power has an ability to generate electricity, refrigeration and water purification in a single unit. This technology will be extremely helpful in improving the quality of life for many people around the world who lack the energy needed to live a healthy life. Solar parabolic dish is used for water heating and cooking application. An analysis is mainly concentrated on the steam generation. The values of mass flow rate of steam, hourly thermal efficiency are calculated and their variation with time and solar intensity are represented graphically. The result are encouraging to provide data for developing steam generation for rural application. The concentrated heat is absorbed by a copper tube which is made of spiral coil and the experimental results are taken on summer and cloud free days. Dish is equipped with manual tracking system. The maximum temperature achieved is 100 °C and maximum mass flow rate achieved is 0.1167×10^{-3} Kg/sec.

Index Terms- Focal point, Temperature, efficiency, concentrator, receiver, concentrated solar power.

I. INTRODUCTION

With the growing population and fast pace of development, energy is becoming more expensive and our cities and towns face a major power crisis. The reality is that resources like coal, oil and natural gas will not be around forever. We all realize today, that we need alternatives sources of energy that are renewable. Renewable energy is derived from natural resources such as sunlight, wind, tides and

geothermal heat. Solar energy is one of the most promising future renewable energy sources as reflector. Solar energy consists of light and heat emitted by the sun, in the form of electromagnetic radiation. Technology now a day helps to catch this radiation and turn it into usable forms of solar energy – for eg. heating or electricity.

The parabolic solar steam generation is an emerging device which has a great potential in India. However parabolic solar steam generation technology has to compete with prevalent steam generation devices in the country. The parabolic solar steam generation rest on the principle of the concentration of the rays. It is well known that parallel beam of rays of sun is reflected on the parabolic mirror and the ray of sun is reflected on the parabolic mirror and the rays converge at the same point, the hearth of the parabola. While running up against the dark plate placed at this point, the rays released their energy in the form of heat. Determination of the exact receiver size and the arrangement to provide insulation at the receiver are of prime importance to avoid thermal losses from the absorber to the environment. One or more transparent cover is employed to reduce the convective and radiative heat losses from the absorber to the environment.

Heat losses from a parabolic concentrator steam generator depend on the water tank temperature, the surface area of the absorber, the wind speed, and the orientation of reflectors. The heat losses are classified as optical losses and thermal losses. Optical losses are those which occur in path of the incident solar before it is absorbed at the surface of the absorber. While thermal losses are due to convection and radiation from the absorber. The thermal and optical performance of the parabolic concentrator was

evaluated by carrying out thermal tests by generating steam adjusting flow rate of water at different day timing.

In an attempt to find alternate sources of fuel, solar energy utilization is a big milestone as it is available for free everywhere and it cost nothing. The only things we need to do are to collect it in efficient way and convert it into required form. Solar steam generator is one which collects the light and concentrate it at small area so all thermal energy is utilized uniformly over blackened copper plate and pipe spiraled over plate which is specially designed for it. The advantages of using solar steam generator are, it emits no harmful gasses, no reason for global warming, clean energy, less maintenance, renewable source of energy, cost less operation. Mainly it is freely available and inexhaustible energy source. When a three dimensional parabola is aimed at sun, all the lights that fall upon its mirrored surface is reflected to appoint known as focus. If a copper plate with spiral pipe attached both black colored is placed at its focus it will absorb the light's energy and become very hot. A satellite dish is an example of a parabolic that can be made into a steam generator. Parabolic steam generator heats up quickly and are used for positive steam generation, vacuum steam, steam for cleaning, for moisturization in paper industries, pellets mill, humidification of air in confined space. They can also be used for power sterling engines, crack water to produce H₂ and even plasma matter. It is easy to see in today's world that this shape is successful in its use. The parabolic shape can be seen in satellite dishes, radio towers, solar cooker and yes, even in steam generators around the world. It is simple to say it works, and as just as simple to understand how it works.

ENERGY CRISES

When talking about the energy crises, we should talk about the electrical energy and the other sources of energy which are responsible for the production of energy like, hydraulic, petroleum and natural gas, coal, etc., but for but for getting over this we need to use renewable energy and non-convention source of energy. An energy crises is one of the great bottleneck (or increase cost) in the supply of energy resources to an economy. In popular literature though, it often refers to one of the energy sources used at a certain time and place, particularly those

that supply national electricity grids or serve as fuel for vehicles. Because of industrial development and population growth there has been an enormous increase in demand for energy world wide. Supply of energy is, therefore, far less than actual demand.

Recent energy crises

South African electrical crisis. The South African crisis led to large price rises for platinum in February 2008 and reduced gold production. At the end of 2005 and also in early 2008 severe energy shortages has been experienced by china. During the latter crisis they suffered severe damage to power networks along with diesel and coal shortages. Supplies of electricity in Guangdong province, the manufacturing hub of china, are predicted to fall short by an estimated 10 GW of shortage of electricity supplies has been predicted in manufacturing hub of china, the Guangdong province. In 2011 China was forecast to have a second quarter electrical power deficit of 44.85 – 49.85 GW. It has also been predicted by economist that 2009 afterword's the United Kingdom will suffer an energy crisis due to the commitments for reducing coal-fired power stations, unwillingness of politicians to set up nuclear power stations to replace those that will be de-commissioned and unreliable sources and sources that are running out of oil and gas. like South Africa it has also predicted that UK will suffer regular blackouts. The July 2012 India blackout was the largest power outage in history, occurring as two separate events on 30 and 31 July 2012. Over 620 million people has been affected, the world population of about 9%, around half population of India, Northern, Eastern, and Northeast states of India spread over 22 states.

NEED OF SOLAR ENERGY

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. solar energy problem world now facing was solar heating, solar photovoltaic, solar thermal electricity, solar architecture and artificial. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques now a days uses photovoltaic panels and solar thermal collectors for harnessing energy. Passive solar techniques include orienting a building to the sun,

selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. In 2011, it is said by international agency that “the development of affordable, inexhaustible and clean solar energy technologies will have huge term benefits”. It will increase country energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, and lower the cost of mitigating climate change, keep fossil fuel price lower than otherwise. These things lead us to the idea of solar operated refrigerator, solar steam generator, and solar cooker and further took the form of a good and useful product for human being.

ADVANTAGES OF LOW PRESSURE SOLAR STEAM GENERATION

Using a free source. Sunshine is free and always will be free. By using a solar steam generating, you are saving fuel as well. Clean energy. Less maintenance. Renewable source of energy. Cost less generation. Not contribute to global warming.

APPLICATION OF SOLAR STEAM GENERATOR

First of all you may have realized that the energy from the sun is free. It uses none of our limited natural resources that are currently being used for other energy application in our modern world. One of the most important reasons for using solar steam generation: It is giving people around a world a hand up. It is a vital instrument for a more comfortable, better way of life by giving them feasible way of alternative to a costly Of Course, Solar steam generation is just a one choice in a multi-faceted field of alternative and options that comprise a solar energy domain. Below are some of the applications of low pressure steam generation-

Steam for Heating –

Positive Pressure Steam- Steam is typically generated and distributed at a positive pressure that means it is supplied to equipment at pressures and temperatures above 0 MPaG (0 psig) and higher than 100°C (212°F) respectively. Positive pressure steam can be used in food processing factories, refineries, and chemical plants to name a few. Saturated steam can be used for heating process fluid heat exchangers,

reboilers, reactors, combustion air preheaters, and many of heat transfer equipment.

Vacuum Steam- The use of steam for heating at temperatures below 100°C (212°F), traditionally the temperature range in which hot water is used, has grown rapidly in recent years. In the same manner as positive pressure saturated steam when vacuum saturated steam is used, by adjusting the pressure the temperature of the steam can be quickly changed, such that precise temperature control of steam can be achieved. However, it is required to use vacuum pump with the equipment, as only reducing the pressure will not drop the pressure below atmospheric pressure.

Steam for Moisturization –

Steam is sometimes used to add moisture to a process while at the same time supplying heat. For example, steam can also be used in the paper industry, so that paper moving over rolls at high speed gets soften and does not suffer tears or microscopic breaks. Another example is pellet mills. Often mills that produce animal feed in pellet form use direct-injected steam to both heat and provide additional water content to the feed material in the conditioner section of the mill.

Pellet Mill Conditioner-

Due to moisturization the feed gets softens and firmer pellets can be obtain as the starch content of the ingredients gets partially gelatinized.

Steam for Humidification –

Many large commercial and industrial facilities, especially in colder climates, use low pressure saturated steam as the predominant heat source for indoor seasonal heating. HVAC coils, most commonly used with steam humidifiers, can be used for conditioning the air for indoor comfort, preservation of books and infection control, and records. When the cold air is heated by the steam coils, the relative humidity of the air drops, which must be taken to normal levels and downstream is injected with the proper amount of dry saturated steam.

AIMS AND OBJECTIVES –

Now a day's non renewable energy sources are depleting day by day and there is need to focus more attention on renewable energy sources such as sun, tide, wind etc. the aim is to design and fabricate Parabolic Dish Solar Steam Generator which operates on Solar energy. It should utilize renewable energy from sun during day and hot season. This parabolic Dish Solar Steam Generator should also be portable to operate in moving vehicle. The following are the aims and objective of this project. The average cost of solar steam generator decreases day by day on the contrary their power output and efficiency considerably increases. According to the global renewable energy scenario, proportion of the solar thermal applications will be about 480 million tons oil equivalent by 2040. Nowadays, solar steam generator are also available to use in the areas with limited solar radiation depending on the developments in solar power concentrating systems and material technology. In addition, the most challenging point of solar steam generator, unavailable to use when sun goes away, is overcome with thermal energy storage techniques. Briefly, it is anticipated that solar steam generated technology will be demanded by a huge group of people in the near future because of its outstanding features. To achieve energy security. To reduce carbon emission. To encourage indigenous solar manufacturing facilities in the state. To promote R & D in the solar energy sector and hybrid systems. To create skilled man power and employment in a new industry.

2 .TYPES OF CONCENTRATORS

There are varieties of geometry developed for the solar concentrator depending on the application addressed. The simplest one like SK14 which is intended for household cooking to the solar tower employed for MW level power generation plant have been demonstrated the capability of the solar concentrating technology. Adhering to the scope of the present article, the types of the solar concentrator that can be used for low pressure steam generation are listed in the Table 1.1 Each of the type can be employed in the process of solar concentrator system best suited for requirement of the application. Parabolic Concentrator, Hyperboloid concentrator, Fresnel lens concentrator, Compound parabolic concentrator, quantum dot concentrator are some of

the types of the concentrators that can be used for the steam generation application.

Table 1: Types of solar concentrator, their advantages and disadvantages

Type of Concentrator	Advantages	Disadvantages
Parabolic Concentrator	High concentration	Requires larger field of view.
		Need a good tracking system.
Hyperboloid Concentrator	Compact	Need to introduce lens at the entrance aperture to work effectively.
Fresnel Concentrator lens	Able to separate the direct and diffuse light - suitable to control the illumination and temperature of a building interior.	Imperfection on the edges of the facets, causing the rays improperly focused at the receiver.
	Requires less material than conventional lens.	
	Thinner than conventional lens.	
Compound parabolic concentrator	Higher gain when its field of view is narrow.	Need a good tracking system.
Quantum Dot Concentrator	No tracking needed.	Restricted in terms of Development due to the requirements on the luminescent dyes.
	Fully utilize both direct and diffuse solar radiation	

3. EXPECTED THERMODYNAMIC PERFORMANCE OF THE PARABOLIC DISH SOLAR STEAM GENERATOR-

Usefull energy for absorber-

$$\dot{q}_u = \eta I_b A_a$$

The efficiency range of most solar concentrators is 40% - 60% (Magal, 1993). Hence for Kaduna (Mohammed,2009):

$$\dot{q}_u = 0.5 \times I_b A_a$$

$$\text{assumption } I_b = 850 \text{ w/m}^2$$

$$\dot{q}_u = 0.5 \times 850 \times 0.536096$$

$$\dot{q}_u = 227.8408 \text{ W}$$

q_u is the energy available to the absorber for steam generation.

$T_{ambient\ water} = 32$ taken for designing purpose

$$q_u = \dot{m}_w \times L + \dot{m}_w C_{PW}(T_S - T_{ambient\ water})$$

$$q_u = \dot{m}_w \{L + C_{PW}(T_S - T_{ambient\ water})\}$$

$$q_u = \dot{m}_w \times 2544.24\ KW$$

By comparing above two values of q_u

$$\dot{m}_w = \frac{227.8408 \times 10^{-3}}{2544.24} kg/s$$

$$\dot{m}_w = 0.08955 \times 10^{-3} kg/s$$

$$\dot{m}_w = 0.08955 gm/s$$

$$\dot{m}_w = 5.373 gm/min$$

$$\dot{m}_w = 26.865 gm/ 5 min$$

$$\dot{m}_w = \frac{\rho_w V_w}{t}$$

$$t = \frac{\rho_w V_w}{\dot{m}_w}$$

$$\rho_w = 995.09 kg/m^3 \text{ at } 32^\circ C$$

$$t = \frac{995.09 \times \frac{\pi}{4} \times d_{ct}^2 \times L}{0.08955 \times 10^{-3}}$$

$$t = \frac{995.09 \times \frac{\pi}{4} \times (0.0045)^2 \times L}{0.08955 \times 10^{-3}}$$

For unit length i.e. 1m length of pipe time required for steam generation (L= 1m)

$$t = 176.72 sec$$

Let us take $t = 5 min = 300 sec$

$$L = 1.6975 m$$

$$= 169.75 cm$$

$$\approx 67 inches$$

Taken length of pipe is 70 inches = $70 \times 2.54 cm = 177.8 cm$

Rate of energy absorbed by the absorber (P_{abs}) –

η_o = optical efficiency

$$\eta_o = \frac{P_{abs}}{A_a \bar{I}_D}$$

$$P_{abs} = \frac{\eta_o}{\eta} (\eta A_a \bar{I}_D)$$

$\eta_o = 0.65$ (average of 0.6 and 0.7 & the bracketed

term is the same term as q_u as $\bar{I}_D = I_b$ taken)

$$P_{abs} = \frac{0.65}{0.5} q_u$$

$$P_{abs} = 1.3 q_u$$

$$P_{abs} = 1.3 \times 227.8408 W$$

$$P_{abs} = 296.1930 W$$

4. WORKING PRINCIPLE OF PARABOLIC DISH SOLAR STEAM GENERATOR

Experimental setup consist of two solar parabolic dish system, absorber, heat transfer fluid and manual tracking system. When sunlight rays are incident on the reflective surface they are reflected and conveyed to the surface of the tube at the copper plate & the copper tube to heat the water and to take change phase. 2 cm diameter & 2mm thick reflector glass is pasted to the dish act as reflector. The focal points of two dishes are found out and copper plate & the copper tube is placed such that the heat is distributed evenly over the coil.



Experimental setup



Experimental set up in working condition

Dual axis tracking system is used .Tracking System is helps to rotate the panel of dish from east to west and north to south. Solar tracking is process of varying the angle of panel on which two dishes are mounted to take advantage of the full amount of solar energy. The panel is rotated perpendicular to the sun angle of incidence. It increases efficiency by 30-40%. For rotating perpendicular to the sun angle of incidence mechanism of lead screw is used. Lead screw is used to get slower linear feed and locking arrangement (four bar kinematic link with one extendable link i. e.

of lead screw). Water storage is placed at some height from the coil so that no need of pump. Water is supplied to the coil under gravity through flow regulator valve by which the flow of water flowing under gravity force is regulated for steam generation under different point of time as we get different amount of radiation at different day time due to earth shape. As we get steam different temperatures readings is taken.

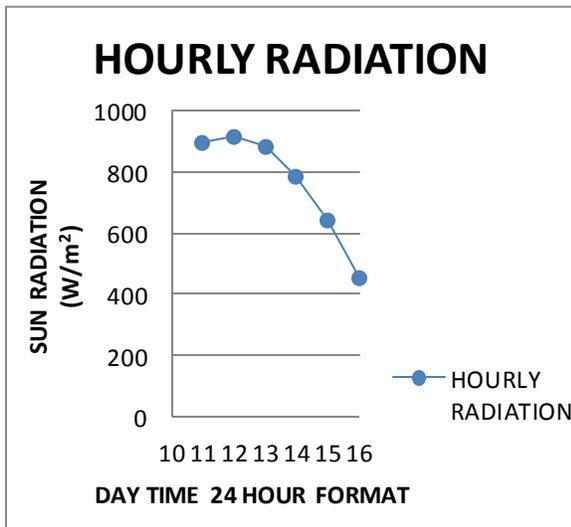
5. EXPERIMENTAL ANALYSIS

TESTING METHODOLOGY

Water storage is placed at some height from the coil so that no need of pump. Water is supplied to the coil under gravity through flow regulator valve by which the flow of water flowing under gravity force is regulated for steam generation under different point of time as we get different amount of radiation at different day time due to earth shape. As we get steam, different temperature readings is taken, and at that time mass flow rate is measured and thermal efficiency of the apparatus is find out. Below are the table for experimentation carried out of the apparatus.

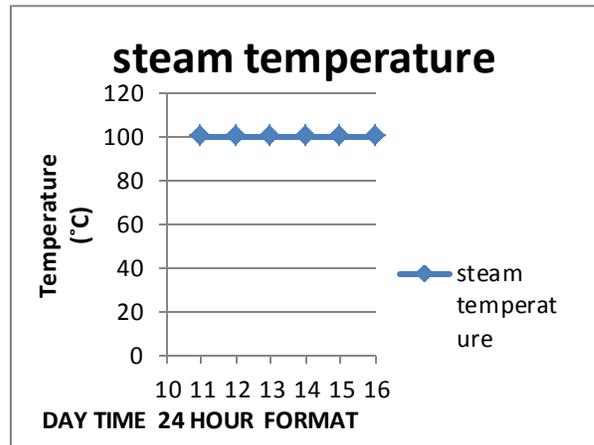
6. RESULTS AND DISCUSSION

DAILY RADIATION OF SUN –



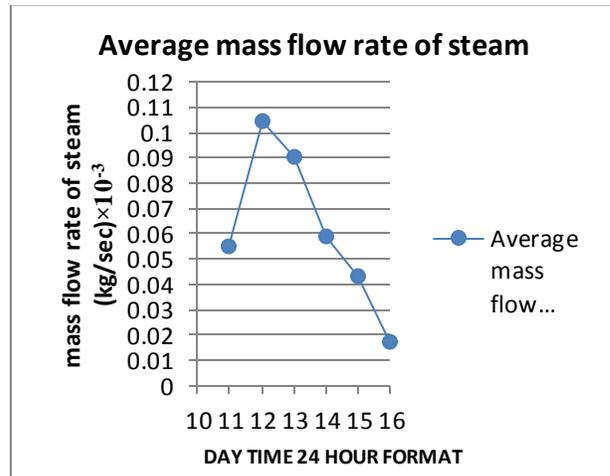
Graph 7.1.1 Daily Solar Radiation

TEMPERATURE OF STEAM FOR ALL READINGS –



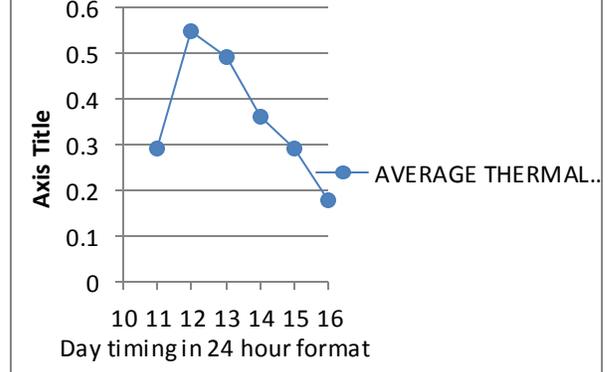
Graph 7.2.1 Steam Temperature variation with day time

AVERAGE DAILY MASS FLOWRATE OF STEAM ON HOURLY BASIS –



Graph 7.3.1 mass flow rate of steam on hourly basis

AVERAGE DAILY EFFICIENCY OF STEAM GENERATION –



Graph 7.4.1 Thermal Efficiency variation with Day Time

It is seen from the graph No. 2 that the steam temperature is fixed and not increases more than 100 °C, as steam outlet is open to atmosphere. Steam is at atmospheric pressure and from all four graph it is seen that as the day time increases up to 12 pm sun radiation increases thus mass flow rate of steam increases and thermal efficiency of apparatus also increases. After 12 pm as sun radiation starts decreasing thus mass flow rate of steam and thermal efficiency of apparatus both starts decreasing. Also from the graph it is seen that maximum average mass flow rate reaches is 0.1047×10^{-3} Kg/sec.

7. CONCLUSIONS

As the purpose of our project is to build a solar concentrator for steam generation for low cost industries where steam is used at atmospheric pressure. Thus we built the apparatus such that we get the steam at 100 °C, and its performance analysis is carried out, efficiency and mass flow rate is also measured. By result we have seen that the temperature of steam is 100 °C constant at various time of the operating condition.

The following objectives are fulfilled by this project.

1. Easy to handle.
2. Model is solar operated.
3. The model is environment friendly.
4. We get best efficiency and mass flow rate between 12 Pm – 14 Pm.
5. Maximum efficiency of apparatus is 60.76%.
6. Maximum mass flow rate achieved is 0.1167 gm/sec.
7. Analysis of various Parameters is plotted on graph as time on X-axis and solar radiation, steam temperature, mass flow rate of steam, thermal efficiency on Y-axis. The analysis of various graph indicates that –
 - a) Operating condition of the apparatus is between 11 Am – 16 Pm.
 - b) optimum condition is achieved at 12 PM.
 - c) As the sun moves from east to west from 9 AM to 4 PM intensity of sun radiation increases up to 12 PM and then goes on decreasing, so our apparatus efficiency and mass flow rate also.

8. SCOPE FOR FUTURE WORK

Solar thermal electricity Association, and the International Energy Agency's Solar group investigated that the potential and future of concentrated solar power. The study found that concentrated solar power could account for up to 25% of the worlds energy needs by 2050. The increase in investment would be from 2 billion Euros worldwide to 92.5 billion in that time period. Spain is the leader in concentrated solar power with more than 50 projects approved government in the works. Also, it exports its technology further increasing the technology's stake in energy worldwide. Because of the nature of the technology needing a desert like area experts predicted the biggest growth in places like Africa, Mexico, the southwest United States. Energy saving is one of the key issues not only from the view of energy conservation but also its support for global environment. With correctly concentrating the sun light on to the focus line of the Parabola, It will be possible for us to generate the steam that will be useful for running the Steam Engine. And It can be used for preheating purposes in Power plants. In future I can modify this Automatic Tracking system for the change of the face of the parabolic surface according to the Sun's position. So that the maximum temperature will be obtained. In the upcoming future, widespread use of this technology is expected hopefully not Only in developing countries but also throughout the world. Renewable energy resources will play an important role in the world's future. Briefly, it is anticipated that solar steam generation technology will be demanded by a huge group a industries in the near future because of its outstanding features.

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