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Low Pressure Steam Generation by Solar Energy WithFresnel Lens: A Review

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ABSTRACT :*Fresnel lenses of imaging and non imaging designs are one of the best options for solar energy concentration. Compared with imaging systems, non-imaging systems have the merits of larger accept angles, higher concentration ratios with less volume and shorter focal length, higher optical efficiency, etc. Therefore, non imaging design can offer the possibilities needed for a breakthrough of Fresnel lenses in commercial solar energy concentration, both in photovoltaic and thermal power conversion. Fresnel lens solar concentrators continue to fulfill a market requirement as a system component in high volume cost effective Concentrating Photovoltaic (CPV) electricity generation as well as steam generation. This paper reviews the possible applicability of Fresnel lens based concentrators for application in low pressure steam generation.*
Keywords** -Solar concentrator, Fresnel lens, Reflecting materials, Solar tracking, Renewable sources.**

1. TERMINOLOGY

ω - hour angle
α -inclination angle
β-prism angle
f -focal length
R -width of Fresnel lens
d -is the path of ray in the lens
δ –deviation

2. INTRODUCTION

The continuous increase in the level of green house gas emissions, limited resources of the conventional fuels and the increase in the fuel prices are the main driving forces behind efforts to more effectively utilize various sources of energy. The use of renewable energy for the purpose is the best option and has been the topic of research worldwide [1]. In many parts of the world direct solar radiation is considered to be one of the most prospective sources of energy. The solar energy as renewable energy can be harnessed mainly in the following three different ways[2]. i) Photothermal - the system in which the incident radiation is absorbed and turned intoheat. ii) Photochemical- in which radiation between 0.3 and 1.0μm of wavelength can cause chemical reactions,sustain growth of plants and animals and through photosynthesis convert exhaledcarbon dioxide to breakable oxygen and. iii) Photovoltaic - in which part of the radiation in the band between 0.33 and 1.2 μm of wavelength can beconverted directly into electricity by photovoltaic cells. Photothermal processes are the most efficient systems developed to harness solar energy into the directly usable form. In concentrated solar system concentration is achieved by reflection or refraction through mirrors.Parabolic dish type concentrators become bulky and transportability is a problem and rising in temperature is slow. To overcome this, the change in materials for concentrators and use of Fresnel lenses shall raise temperature more than conventional one. The review presented here is divided into two parts, first the selection of solar concentrator system and the second being the applicability of Fresnel lens based system for low pressure steam generation.

3 .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.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.

Parabolic trough collectors can also be used for steam generation, which are single-axis sun tracking collectors that are used both in solar process heat plants and in large power plants for solar thermal electricity generation. Temperatures up to 300 °C can be obtained with good efficiency using parabolic trough collectors.

Table 1: Types of solar concentrator, their advantages and disadvantages [3].

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	

4. THEORETICAL ANALYSIS OF FRESNEL LENS SYSTEM

4.1 Principle of Fresnel Lens

There are two types of Fresnel lens, namely refractive lensand refractive mirrors. The refractive Fresnel lenses are mostly used in the photovoltaic applications where as reflective mirrors are used in the photo thermal applications. Fresnel lenses are more flexible as far as optical designs are considered and can produce uniform flux density on the absorber. Figure 1 shows the schematic view of Refractive Fresnel Lens and Reflecting mirror Fresnel concentrator systems.

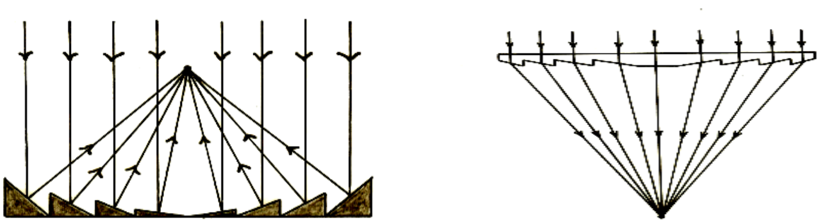

Fig. 1:(a) reflective Fresnel lens, (b) refractive Fresnel lens [4]

The Fresnel Lenses are also classified as ‘imaging’ and ‘non-imaging lenses. In case of imaging Fresnel lens, image of the sun is formed at the focal point where as in case of non-imaging form, sun’s image on the focal plane is a line along the axis of cylindrical parabolic reflector. Here we are concerned more with the non-imaging Fresnel lens for generating process heat.

Fig.2 (a) Point focus fresnellen, (b) line focus fresnel lens [5]

5. LITERATURE SURVEY

Joshua Folaranmiet al. [2]presented experimental investigation tothe design, construction and testing of a parabolic dish solar steam generator. Using concentrating collector, heat from the sun is concentrated on a black absorber located at the focus point of the reflector in which water is heated to a very high temperature to form steam. It also describes the sun tracking system unit by manual tilting of the lever at the base of the parabolic dish to capture solar energy. The whole arrangement is mounted on a hinged frame supported with a slotted lever for tilting the parabolic dish reflector to different angles so that the sun is always directed to the collector at different period of the day. On the average sunny and cloud free days, the test results gave high temperature above 200°C.

Michael J. Wagner [6]gives an idea about the technical formulation and demonstrated model performance results of a new direct-steam-generation (DSG) model in NREL’sSystem Advisor Model(SAM). The model predicts the annual electricity production ofa wide range of system configurations within the DSG LinearFresnel technology by modelling hourly performance of the plant in detail. The quasi-steady state formulation allows users to investigate energy and mass flows, operating temperatures, andpressure drops for geometries and solar field configurations of interest.The model includes tools for heat loss calculation using either empirical polynomial heat loss curves as a function of steam temperature, ambient temperature, and wind velocity, or a detailed evacuated tube receiver heat loss model. Thermal losses are evaluated using a computationally efficient nodal approach, where the solar field and headers are discretized into multiple nodes where heat losses, thermal inertia, steam conditions (including pressure, temperature, enthalpy, etc.) are individual.

Steve Ruby et al. [7]gives an idea about the viability of producing high temperature industrial processheat from the sun’s energy by using parabolic trough solar collection. The installation of a large scale industrial solar thermalsystem provides an opportunity to evaluate the technical and economic hurdles ofsimilar systems in California.The research was performed through the design, construction, operation, and analysis ofa high temperature solar thermal system at a Frito‐Lay snack food plant located inModesto, California. In this installation, high temperature water in excess of 232°C(450°F) is produced by a concentrating solar field, which in turn is used to produceapproximately 300 pounds per square inch (20 bar) of process steam. The solar thermalsystem is intended to improve plant efficiency with minimal impact on day‐to‐dayproduction operations. Process steam in the plant is used for cooking, which includes heating edible oil for frying, and heating baking equipment. Steam is also converted into hot water for cleaning and sterilization processes.

6. THEORETICAL ANALYSIS OF ARC FRESNEL LENS

The focal length f>> d where d is the path of ray in the lens. From Fig. 3, following two equations can be derived [8, 9].

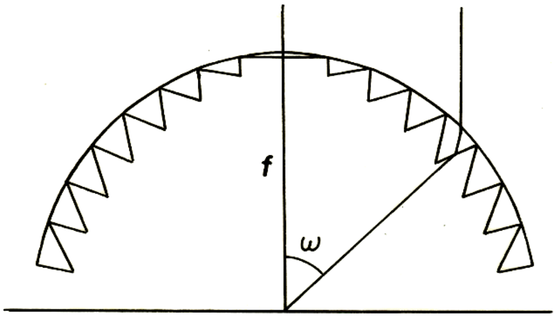

Figure3: Arc fresnel lens

sin α = n sin(α-) (1)
n sin (β + γ) = sin (β + ω) (2)
Similarly, for α = ω
From equations (1) and (2)
sin ω = n sin (ω - γ)

$$\omega - \gamma = arc\sin(\frac{\sin\omega}{n}) \quad (3)$$

$$\gamma = \omega - arc\sin(\frac{\sin\omega}{n}) \quad (4)$$

$$n = \frac{\sin(\beta+\omega)}{\sin(\beta+\gamma)} \quad (5)$$

$$\frac{n+1}{n-1} = \frac{\sin(\beta+\omega)+\sin(\beta+\gamma)}{\sin(\beta+\omega)-\sin(\beta+\gamma)} \quad (6)$$

$$\sin x + \sin y = 2\sin\frac{x+y}{2}\cos\frac{x-y}{2} \quad (7)$$

$$\sin x - \sin y = 2\cos\frac{x+y}{2}\sin\frac{x-y}{2} \quad (8)$$

$$\frac{n+1}{n-1} = \frac{2\sin\left(\frac{2\beta+\omega+\gamma}{2}\right)\cos\left(\frac{\omega-\gamma}{2}\right)}{2\cos\left(\frac{2\beta+\omega+\gamma}{2}\right)\sin\left(\frac{\omega-\gamma}{2}\right)} \quad (9)$$

$$= \tan\left(\beta + \frac{\omega+\gamma}{2}\right)\cot\left(\frac{\omega-\gamma}{2}\right) \quad (10)$$

$$\beta = arc\tan\left[\left(\frac{n+1}{n-1}\right)tan\left(\frac{\omega-\gamma}{2}\right)\right] - \left(\frac{\omega-\gamma}{2}\right) \quad (11)$$

the deviation δ of beam is given by,

$$\delta = \alpha + \beta = arc\tan\left\{\frac{\sin\omega}{n\cos\left(arc\ \sin\left(\frac{\sin\omega}{n}\right)\right)-1}\right\} \quad (12)$$

Using above equations, one can design Fresnel lens for given focal length and aperture [8].

7. CONCLUSION

The need for the construction of a Fresnel lens collector solar steam generator arose as an alternative to solve the thermal energy needs of the populace. This will also reduce the total dependency on fossil fuels and other non-renewable and exhaustible energy source which have be known to be depleted with ages to come as they are being used up. As such, deforestation and other environmental populations are reduced to a minimum temperature above 200°C was obtained at base of the absorber. Water boiled faster using the generator than when using ordinary charcoal or kerosene stove. The Fresnel lens collector solar steam generator is very efficient heating equipment to fulfil this requirement.

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