Solar Concentration Technology for Increasing Solar Energy: Review

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***Abstract*— One of the renewable energy resource available in abundance today is solar energy. As huge amount of solar energy is received (164 W/m^2 per day) by earth so the solar cells have become popular in the world. The solar energy can be utilized efficiently by converting the heat of sun in different form of energy. Many of the time parabolic reflectors are used to concentrate solar energy but they have limitations such as bulkiness, low efficiency. Now days the solar concentration technology using Fresnel lens can make the full utilization of sun energy. the ongoing research on concentrating sun's energy involves imaging and non-imaging system. Fresnel lenses are used for various application such as hydrogen-generation, solar lighting, pump laser, surface modification of metallic material etc. in present situation the application scale is small the outgoing work in this field suggests that Fresnel lens solar concentration technology will prove benefit in future. This paper mainly deals with the Fresnel lens its configuration, its type, review of different kind of concentrators and the advantage of using the Fresnel lenses on concentrating sun's energy.**

***Keywords*— Renewable energy, Parabolic Reflector, Fresnel lens, imaging, non-imaging system**

I. INTRODUCTION

The energy available in abundance is solar energy. The large rate of depletion of conventional energy source has necessitated the researches to invest in renewable energy source which can help to power the future. From many years there is a research going on for capturing and transforming the suns energy into electricity. Even through solar energy is available in abundance harvesting it is the major problem faced today. Solar energy can be used for various applications by converting photon energy of sun into energy needed. In photon thermal the photon of sun gets converted into heat energy. In photo chemical conversion the solar rays are converted into some chemical reaction. Such that plants and animal sustain through photosynthesis. In photovoltaic the solar cell is used, here the sun rays of 0.33 to 1.2 μm of wavelength can be converted into electricity. The refection and retraction phenomenon through mirror can be used for concentrated solar system. The mirrors can be plane or parabolic in shape. The parabolic dish concentrators are bulky and require more time to rise temperature. The reflectivity of the surface material constitutes in optical efficiency. Highly efficient reflector contributes in cost reduction of solar collector. To overcome some disadvantage such as bulky reflectors, low efficiency, more time to raise temperature have brought Fresnel lenses in picture. Fresnel lenses are thinner and require less material. They are highly efficient to raise temperature in small span of time.

II. SOLAR COLLECTORS

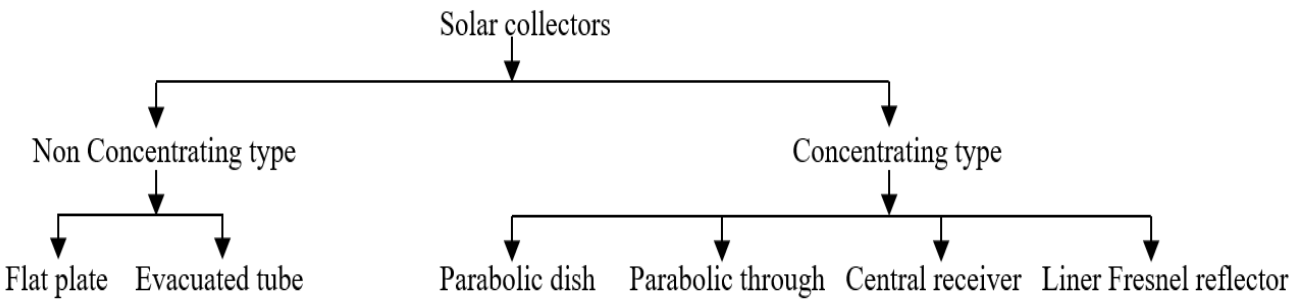


Fig.1 Types of solar collector

A. Non Concentrating type

In this type of collector, the area of collecting the solar rays is same of area for absorbing the solar radiations. The types of non-concentrated type of solar collectors are described below:

1) Flat plate type: The popular solar collector available commercially for domestic and industrial applications are Flat plate type collectors. A typical Flat plate collector consists of metal box with a Glass or plastic cover on upper side and at the bottom there are dark coloured absorber plates. Thin fins type absorber plates are connected with a series of tube and these tubes are further connected with a tube of larger diameter known as header as shown in fig.2 (a). The gain in temperature may be achieved is 80° [11].

2) Evacuated tube type: In this Evacuated tube collectors two concentric tubes are present which are made up of Transparent borosilicate glass material. The inner tube is coated with selective absorber coating and have low reflectivity and outer tube is transparent. As shown in the fig.2(b) The passage between tube is evacuated and have fused ends. The sun rays pass through outer transparent tube. It works throughout the year even during cloudy days hence providing good efficiency. Major drawback is they are costlier.

B. Concentrating type

A solar collector, which utilizes reflective surfaces to concentrate sunrays on smaller area, are referred as concentrating type solar collector. The solar radiation is concentrated with the help of reflector or lenses on an absorber surface. This type of collector is mostly used where high temperature or intensifier flux is required. Commercially available concentrates solar collector is discussed below:

1) Parabolic dish: This type of collector is point focus based. They are provided with full point dual axis tracking. The concentrated solar heat is absorbed using a turbine present at focus point. They are compact in size, no cooling water is required, low compatibility with thermal storage and hybridization are the key features of parabolic dish collectors. The Fig.2(e) shows the parabolic dish collector.

2) Parabolic through type: This type of collector consists of a parabolic through having inside reflector surface. Liner absorber is placed at focal line to absorb the solar energy as shown in Fig.2(f). Array of single axis tracking parabolic through usually aligned on a north-south horizontal axis are installed in a solar plant to get the desired level output [11].

3) Central receiver: Central receiver solar towers are also called as Heliostat solar tower. Thousands of small reflectors are placed on ground. These reflector concentrates the solar radiation on a central receiver placed at the top of a fixed tower as shown in Fig.2(d).

4) Liner Fresnel reflector: Liner Fresnel reflectors are the modification of parabolic through. Here to concentrate the solar flux, instead of using a voluminous through, the through is split up into long rows of flat or slightly curved mirrors approximate the parabolic shape of through which concentrates the flus similar to that of through. This concentrator flux is absorbed by downward-facing liner fixed receiver as shown in Fig.2(c). High operating temperature, multistage heating, direct stem generation are the key features which support its wide spectrum deployment [11].

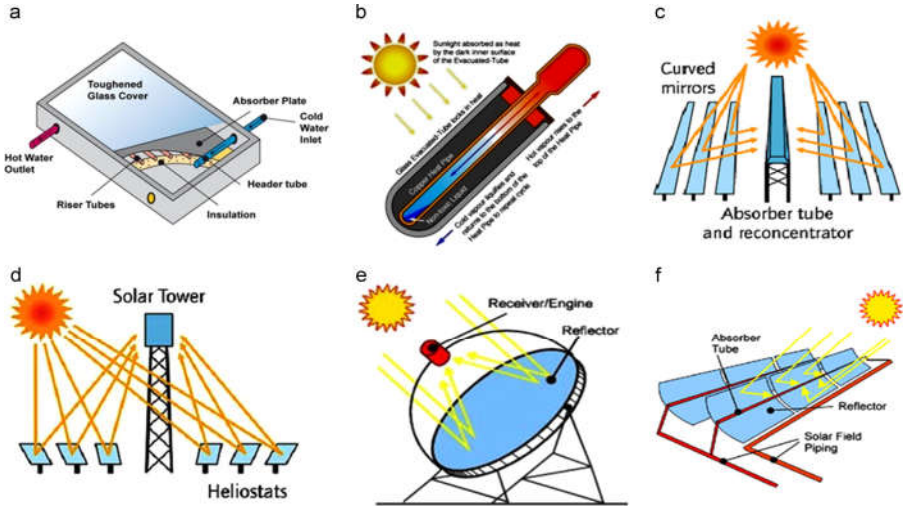


Fig.2 Types of Non-Concentrating and Concentrating collectors (a) Flat plate collector (b)Evacuated tube (c)Liner Fresnel reflector (d)Central receiver (e)parabolic dish (f)Parabolic through [11].

III. SOLAR CONCENTRATORS

From past few decades there has been development in designing solar concentrator. Concentrated solar power technology having significance due to its capability to fulfill electrical and thermal energy demand [1]. Solar concentrators are classified based on optical characteristic such as concentrator's factor, focal length, distribution of illumination and optical standard concentration. The solar energy can concentrate by following ways:

- Reflection Type: Here sun rays hitting the concentrator will get refracted to the photovoltaic cell.
- Refraction Type: Here the sun rays hitting the concentrator will get refracted to the photovoltaic cell.
- Hybrid of Both: Here the sun rays hitting the concentrator before hitting the concentrator will experience as well as refraction before hitting the photovoltaic cell. This type of concentrator provides better energy utilization.

Different concentrators with their merits and demerits are explained below:

- Parabolic Concentrator: Parabolic concentrator have high ability of concentrator sun rays but require large field of view and also need good sun tracking system.
- Hyperbolic Concentrator: Hyperbolic concentrator is compact but need to keep the lens at entrance aperture.
- Fresnel Lens Concentrator: Fresnel lens is thin in size require less material then conventional lens and also raise the temperature quickly. The demerit they possess is imperfection on edges causes the rays to get improperly focused on photovoltaic cell.
- Quantum Dots Concentrator: These are highly efficient concentrator which fully utilizes the direct and diffused solar radiation but they require luminescent rays.

The table 1 shows the summarization of different types of concentrators.

TABLE I
TYPES OF SOLAR CONCENTRATORS [12]

Type of Concentrator	Advantages	Disadvantages
Parabolic Concentrator	High concentration	Requires larger field of view Need a tracking system
Hyperboloid Concentrator	Compact	Need to ıtroduce ns to at the entrance aperture work effectively
Fresnel Concentrator lens	Able to separate the direct and diffuse light – suitable for controlling of illumination and temperature of a building interior	Imperfection on the edges of the facets causing the rays improperly focused at the receiver.
Compound Parabolic Concentrator	Higher gain when its field of view is narrow	Needs a good tracking system.
Quantum Dot Concentrator	No tracking needed Fully utilize both direct and diffuse solar radiation	Restricted in terms of development due to the requirements on the luminescent dyes

IV. FRESNEL CONCENTRATOR LENS

A. *Fresnel lens and types:*

Fresnel lens pronounced fray-NEL lens are used for light gathering application. They are used for concentrating the sun rays on the area of interest. Fresnel lens consist of a series concentric grooves etched into plastic. These lenses have high capability of gathering light which is useful for many of application. The driving principle behind the Fresnel lens is that the direction of propagation of light dose not changes within medium. Instead light rays are deviated at surface of more.

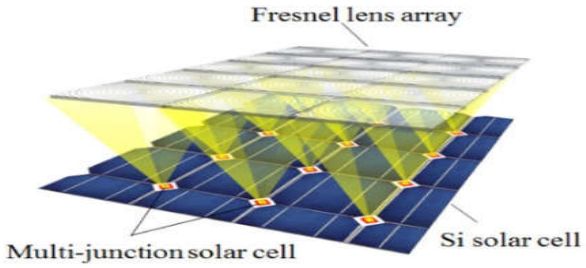


Fig.3 Concentrating sunrays on solar cell using Fresnel lens

Major studies conducted on concentrated solar energy application using Fresnel lens for various purpose can be grouped under too many field one is imaging Fresnel lens system and non-imaging system. The Fig.4 shows the difference between Conventional lens and Fresnel lens.

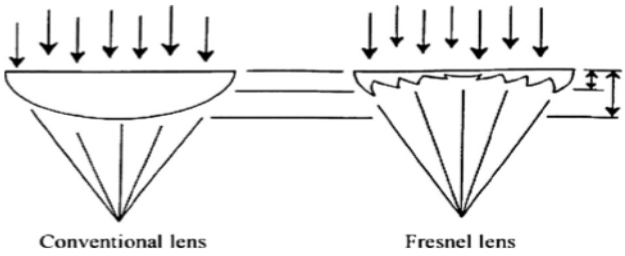
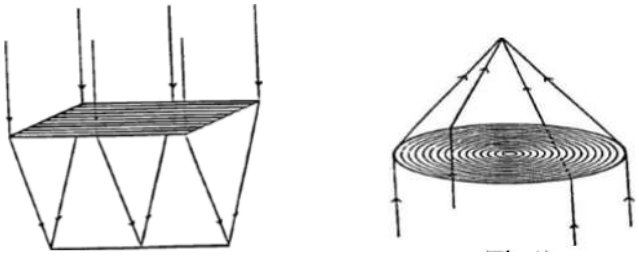


Fig.4 Difference between conventional lens and Fresnel lens

In Fresnel lens the bulky material is eliminated and flat optical lens is obtained with many concentric grooves. Hence every groove acts as individual prism. Two Configuration of Fresnel lens are available Liner and Circular. The liner Fresnel lens there is parallel grooves and focus is a line. In the circular Fresnel lens there are circular grooves and focus is small circle. The Fig.5 depicts the liner and circular Fresnel lens configuration. Modern plastic Fresnel lens cheaper and lighter than a conventional lens of same size, has high optical quality and no spherical aberration [2].



(a) (b)

Fig.5 (a) Linear Fresnel lens (b) circular Fresnel lens

Major studies conducted on concentrated solar energy application using Fresnel lens for various purposes can be grouped under two main fields: Imaging Fresnel system and non-imaging Fresnel system. In imaging optical concentrator, the image is formed on receiver by optical concentrator and in non-imaging optical concentrator the receiver is not concentrated with the formation of image by optical concentrator.

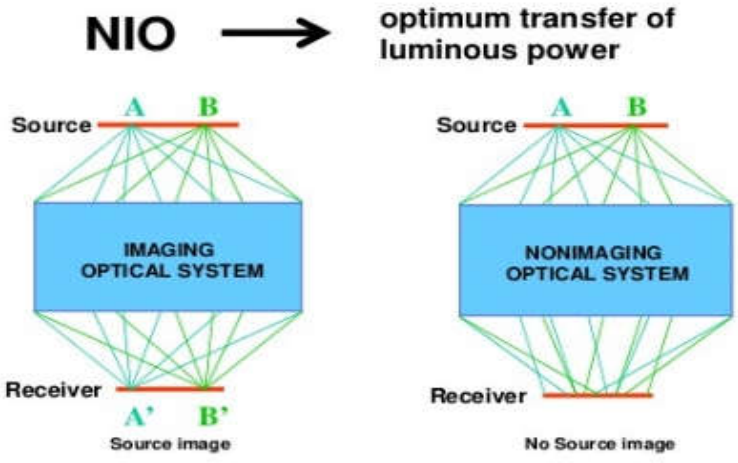


Fig.6 Imaging and non-imaging optical system [11].

1) Imaging Type:

- *Spherical:* A spherical Fresnel lens resembles like simple spherical lens having ring shaped segments each capable to focus light on single point. A shape image is produced by this type of lenses but not as clear as simple spherical lens due to difference at edges.
- *Cylindrical:* A cylindrical lens resembles like simple cylindrical lens having strength segment with circular cross section and focuses light on single line. It also shares same drawback as spherical lens.

2) Non Imaging Type:

- *Spot:* They consist of ring shaped segment with cross section of straight line instead of circular arcs. They focus light on small spot but does not produce shape image shown in Fig.6. This type of lens finds its application is solar power for focusing sun rays on solar panel
- Liner: These type of Fresnel lenses uses straight segment with cross section of straight line instead of arcs. The focusing light into narrow band. Liner Fresnel lens fined its application in focusing sunlight on pipe to increase temperature of water shown in Fig.6.

B. Factor affecting performance of Fresnel lenses:

There several factors affecting the performance of Fresnel lenses which are listed below:

1) Fresnel losses: Due to some surface irregularities some fraction of light rays which enter from rarer medium to denser medium or from denser to rarer medium are reflected at the interface. Fig.7 shows percentage reflectivity losses w.r.t. radial position of square and circular lens for 100mm focal length lens. It is evident that relative losses increase drastically as radial distance increase in square lens, but the loss is moderate of circular lens [11].

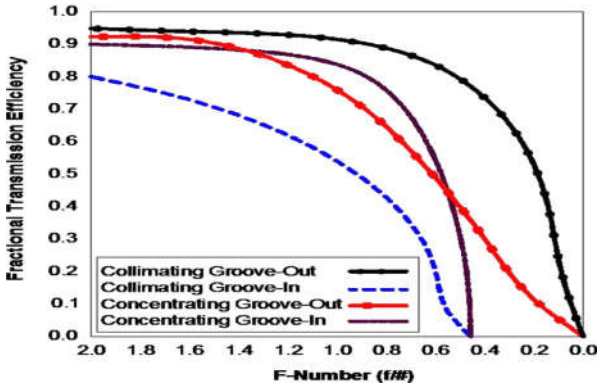


Fig.7 Transmission efficiency of lens in various mode of operation [11]

2) Lens efficiency: Lens efficiency corresponding to the f-number below 1.0 is very poor therefore not useful for concentrated solar power application.

3) Draft angle: The grooves structure of Fresnel lens adds to losses of substantial portion of incident light rays.

4) Facet corner rounding: Due to manufacturing constraints Facet corner rounding also causes losses in incident light rays.

C. Losses in Fresnel lens:

1) Geometric losses: The losses caused by the geometry of the lens are referred as geometric losses. Geometric losses are caused due to design and manufacturing drawbacks like chromatic dispersion, surface, roughness etc.

2) Absorption losses: The light rays get absorbed due to the solid filled in material of lens. This loss is insignificant as in Fresnel lens the excess material is removed while preserving the contour profile on thin sheet which have functional importance.

3) Reflection losses: When there are two mediums with different refractive index, the light rays passing through this medium gets reflected and the losses are dependent on the angle of incident.

D. Solar energy application in various field:

1) Solar Cooking: A variety of non-renewable resources like coal, kerosene, cooking gas, firewood is used for cooking. Due to the energy crisis, these resources are deteriorating. This caused the necessity to the use of solar energy for cooking purposes and the development of solar cookers. A simple solar cooker is the flat plate box type solar cooker.

2) Solar Electric Power Generation: The photovoltaic cells or solar cells can be used to produce electricity from solar energy. Photovoltaic cells convert these photons of sun's energy into electricity. Solar cells are made of semi-conductors which the light rays are made incident i.e. absorb the photons received from the sun, which generates free electrons with high energies.

3) Solar Water Heating: Here the sunlight from sun is converted into heat for water heating using solar thermal collectors. A solar water heating system consists of a blackened flat plate metal collector The transparent glass cover is present above the flat plate collector and a layer of thermal insulation beneath it. The metal tubing of the collector is connected by a pipe to an insulated tank that stores hot water during cloudy days. The collector absorbs solar radiations and transfers the heat to the water circulating through the tubing either by gravity or by a pump.

4) Solar furnaces: In solar furnace solar energy is used to generate the high temperatures required for industrial processes. Here the high temperature is obtained by concentrating the solar radiations onto a specimen using a number of heliostats arranged on a sloping surface.

5) Solar Green House: Solar energy can be used to grow plants using green house. A green house is a structure covered with transparent material like glass or plastic that acts as a solar collector. They also have heating, cooling and ventilating devices for controlling the temperature inside the green house.

V. RELATED WORKS ON FRESNEL LENS

The design, construction and performance test of parabolic Fresnel concentrator cooker using locally available material is carried out in [3]. The cooker design was based on Fresnel principle with concentric parabolic rings. Here reflective material used was glass mirrors. The sun tracking was manual adjustment at 20 minutes' time interval encouraging and satisfactory results were obtained on series of water boiling and cooking tests carried out. Renewable and sustainable energy is reviewed in [4]. The Fresnel lens is best way to use the sunlight of sun in solar energy concentration technology. The research and development going on includes Imaging and Non- imaging systems. These both systems have its own merits and demerits. The non-imaging systems have large acceptance angles, high concentration ratio, short focal length and high optical efficiency. The performance evaluation of Fresnel lens concentrated solar water heater cum distillation unit is carried in [5]. Here, two insulation tanks with glass cover we used in which one was for water heating and second tank for condensation for water vapours. The efficiency obtained after experimentation for water heater was 42.38 % and 27.48 % for distillation unit. Designing and optimization of Fresnel lens for high concentration photovoltaic system is given in [6]. Here, the solar direct light spectrum and multi-junction cell response are taken into consideration for optimized design. The experimental result shows that using Fresnel lens achieves an increase in efficiency of about 10 % compared with conventional lens. The performance of Fresnel lens solar concentrator is studied in [7]. Use of solar concentrator can lead to generation of low pressure steam using low cost technology involves study of Fresnel lens solar concentrator. The overall efficiency of Fresnel lens solar concentrator is 51 % and can generate process steam required for the industrial application. The study comes to conclusion that Fresnel lens solar concentrator system has a very good potential for generation of low pressure steam. Design of modular Fresnel lenses for concentration PV system in [8] provides design of Fresnel lens for PV solar concentration. They used Fresnel lens for concentration of sun light on photovoltaic cells. The improved efficiency of 70 % is obtained in the experimentation. The Experimental investigation and analysis on concentrating solar collector using linear Fresnel lens is carried in [9]. Here the Fresnel lens is used to concentrate solar radiations on flat collector. The experimental work shows that thermal efficiency is increased by 50%. Application of Fresnel lens for stove and solar heating is presented in [10]. The solar radiation is concentrated with the help of Fresnel lens to obtain high energy concentration.

VI. UNSOLVED ISSUE

Till date solar energy is concentrated by using conventional lenses or Fresnel lenses for increasing the intensity of solar energy for the application of solar water heating, solar cooking, solar power generation etc. Since Fresnel lens concentrating technology is not used in the application like refrigeration and air conditioning, so this technology of increasing the utilization of solar energy can be the promising alternative in near future.

VII.CONCLUSION

From this review paper we are concluding that different environment issues like reduction in conventional energy resource and energy saving has been a problem faced all over the world. Today the concentrated photovoltaic has become the need as they are capable of producing electricity with the high efficiency .concentrating solar energy using Fresnel lens is one of the emerging technology .According the applications the imaging and non- imaging Fresnel lens system can be used to the studies the overall efficiency of different applications using Fresnel lens concentrator is increased as compared to conventional lens, Fresnel lens ,its configuration type are explain in the paper. The Fresnel lens can rise more temperate than conventional lens which can be used for furnace heating or other heating applications. Use of solar energy concentrator with Fresnel lens is cheap and environmentally friendly.

ACKNOWLEDGMENT

The authors would like to express their sincere thanks to Prof. S.Y. Nagwase for his valuable references and support. We thank him for complete support, co-operation and valuable suggestions.

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