Solar Energy: An Alternative to Conventional Energy Sources

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Abstract: Solar is the first energy source in the world. Solar energy is one the alternative energy source that is used most widely across the globe. About 70% of the sunlight gets reflected back into the space and we have only 30% of sunlight to meet up our energy demands. Energy is one of the building blocks of the country. The growth of the country has been fueled by cheap, abundant energy resources. Solar energy is a form of renewable energy which is available abundantly and collected unreservedly. Solar energy have great potential, but it was left on the backburner whenever fossil fuels were more affordable and available. Only in the last few decades when growing energy demands, increasing environmental problems and declining fossil fuel resources made us look to alternative energy options have we focused our attention on truly exploiting this tremendous resource. With rising concerns about availability and the side effects of burning fossil fuels for energy, many homeowners have turned their attention to the sun for power. Many experts explained the main types of solar energy systems employed by alternative energy companies today — active and passive solar energy systems. Although several academic programs have focused on solar research in recent year, the need for developing energy alternatives is thus evident and considerable research and development work is needed in this direction.

I. INTRODUCTION

Since 1973, the word “energy” has been continuously in the news. There have been shortage of oil in many parts of the world and the price of this commodity has increased steeply. It is by now clear that the fossil fuel era of non-renewable resources is gradually coming to an end. Oil and natural gases will be depleted first, followed eventually by coal.

In India the energy problem is very serious. In spite of discoveries of oil and gas off the west coast, the import of crude oil continues to increase and the price paid for it now dominates all other expenditure. Every year the country is spending more than thousand crores for the import of oil. This amount forms a major part of India’s import bill. One of the promising options is to make more extensive use of renewable sources of energy derived from the sun. Solar energy can be used both directly and indirectly. It can be used directly in a variety of thermal applications like heating of water or air, drying, distillation, and cooking. The heated fluids can in turn be used for applications like power generation or refrigeration. A second way in which solar energy can be used directly is through the photovoltaic effect in which it is converted to electrical energy. Indirectly, the sun causes winds to blow, plants to grow, rain to fall, and the temperature differences to occur from the surface to the bottom of the oceans. Useful energy can be obtained for commercial and noncommercial purposes through all these renewable sources.

Solar energy is very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8×10^{11} MW which is many thousands of times larger than the present consumption rate on earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy sources. In addition to its size, solar energy has two other factors in its favour. First unlike fossil fuels and nuclear power, it is an environmentally clean source of energy. Second it is free and available in adequate quantities in almost all parts of the world where people live [1].

1.1 DEVICES FOR THERMAL COLLECTION

In any collection device, the principle usually followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid like air or water. When no optical concentration is done, the device in which the collection is achieved is called flat plate collector (FPC). The flat plate collector is the most important type of solar collector because it is simple in design, has no moving parts and requires little maintenance. It can be used for a variety of applications in which temperature ranging from 40^0C to about 100^0C are required. A simple, small-capacity natural circulation system, suitable for domestic purposes, is shown in Fig. 1. When high temperatures are required, it becomes necessary to concentrate the radiation. This is achieved using focusing or concentrating collector. A typical line- focusing concentrating collector is shown in Fig. 2. The term concentrator will be used for the optical subsystem which directs the solar radiation on to the absorber, while the term receiver will normally be used to denote the subsystem consisting of the absorber, its cover and other accessories. The concentrator shown is a mirror reflector having the shape of a cylindrical parabola. It focuses the sunlight on to its axis, where it is absorbed on the surface of the absorber tube and transferred to the fluid flowing through it [2].

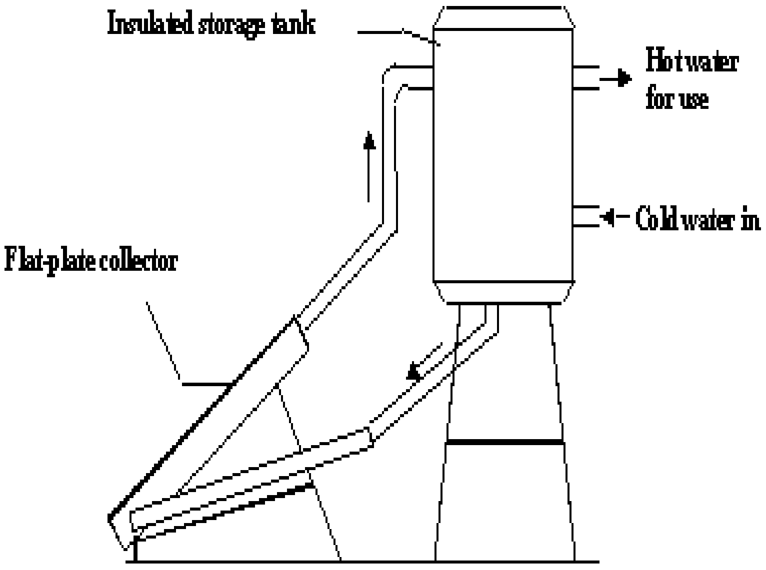

Fig. 1. Small capacity natural circulation water heating system.

Concentric glasses cover around the absorber tube help in reducing the convective and radiative losses to the surrounding. Fluid temperatures up to 400^{0}C can be achieved in cylindrical parabolic focusing collector systems.

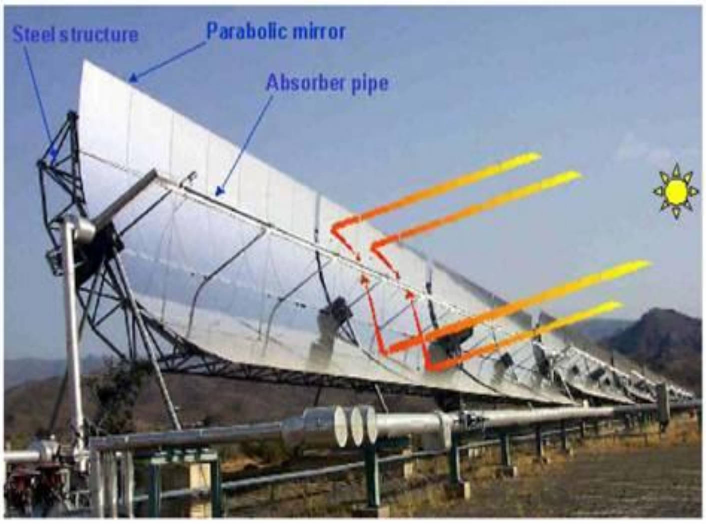

Fig. 2. Cylindrical parabolic concentrating collector

The generation of still higher working temperatures is possible by using paraboloid concentrating dish collector (Fig. 3) which have a point focus. These require two-axis tracking so that the sun is in line with the focus and the vertex of paraboloid [3].

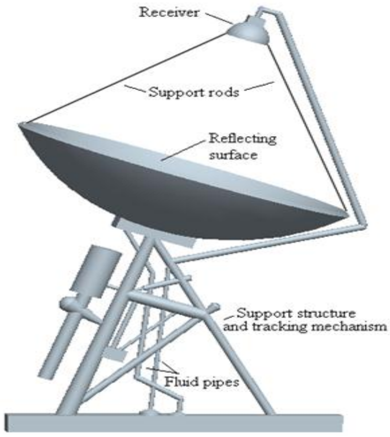

Fig. 3. Paraboloid concentrating collector

II. SOLAR COLLECTOR/CONCENTRATOR

The solar collector is the key element in a solar thermal energy system. The function of the collector is quite simple; it intercepts the incoming solar insolation and converts it into a useable form of energy that can be applied to meet a specific demand, such as generation of steam from water. Concentrating solar collectors are used to achieve high temperatures and accomplish this concentration of the solar radiation by reflecting or refracting the flux incident on the aperture area (reflective surface), Aa onto a smaller absorber (receiver) area, Ar. The receiver's surface area is smaller than that of the reflective surface capturing the energy, thus allowing for the same amount of radiation that would have been spread over a few square meters to be collected and concentrated over a much smaller area, allowing for higher temperatures to be obtained. These concentrating solar collectors have the advantage of higher concentration and are capable of much greater utilization of the solar intensity at off-noon hours than other types of solar concentrators. However, one of the major problems of using a 'dish-type' parabolic collector is that two-dimensional tracking is required. Most concentrating collectors can only concentrate the beam normal insolation (the parallel insolation coming directly from the sun), otherwise the focal region becomes scattered and off focus, as shown in Fig. 4, therefore requiring the concentrator to follow the sun throughout the day for efficient energy collection. For the parabolic concentrator, continuous tracking is needed; if oriented east-west, the concentrator requires an approximate ± 30°/day motion; if north-south, an approximate 15°/hr motion. This tracking also must accommodate a ±23.5°/yr declination excursion [4].

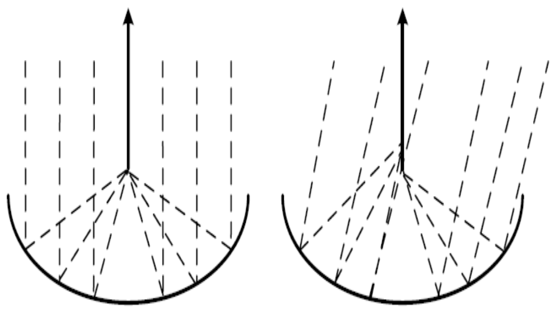

Fig. 4. Concentration by parabolic concentrating reflector for a beam parallel to the axis of symmetry, and at an angle to the axis.

The optical system directs the solar radiation on to an absorber of smaller area which is usually surrounded by a transparent cover. Because of the optical system, certain losses (in addition to those which occur while radiation is transmitted through the cover) are introduced. These include reflection or absorption losses in the mirrors or lenses, and losses due to geometrical imperfections in the optical system. The combined effect of all such losses is indicated through the introduction of a term called optical efficiency. The introduction of more optical losses is compensated for by the fact that the flux incident on the absorber surface is concentrated on a smaller area. As a result, the thermal loss terms do not dominate to the same extent as in flat plate collector and the collection efficiency is usually higher. Because of presence of an optical system, a concentrating collector usually has to follow or track the sun so that the beam radiation is directed on to the absorber surface. The method of tracking adopted and the precision with which it has to be done varies considerably. In collectors giving a low degree of concentration, it is often adequate to make one or two adjustments of the collector orientation every day. These can be made manually. On the other hand, with collectors giving a higher degree of concentration, it is necessary to make continuous adjustments of the collector orientation. The need for some form of tracking a certain amount of complexity in the design [5].

2.1 Paraboloid Dish Collector Receiver/Absorber

The purpose of the receiver in the solar-thermal system is to intercept and absorb the concentrated solar radiation and convert it to usable energy. Once absorbed, this thermal energy is transferred as heat to a heat-transfer fluid, such as air, water, ethyl-glycol, or molten salt, to be stored and/or used in a power conversion cycle. There are two main types of receiver designs that are found to be used with parabolic solar concentrator systems: external receiver, and cavity receivers, as shown in. External receiver (Fig. 5) is usually cylindrical in shape.

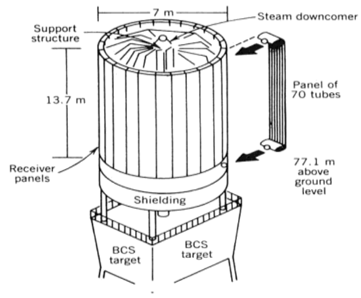

Fig. 5. External receiver

The solar flux is directed onto the outer surface of the cylinder consisting of number of panels and is absorbed by the receiver fluid flowing through closely spaced tubes fixed on the inner side. On the other hand, a cavity receiver has an aperture through which the reflected solar radiation passes. Once inside the cavity, internal reflections ensure that the majority of the radiation that has entered the cavity is absorbed on the internal absorbing surface (Fig. 6).

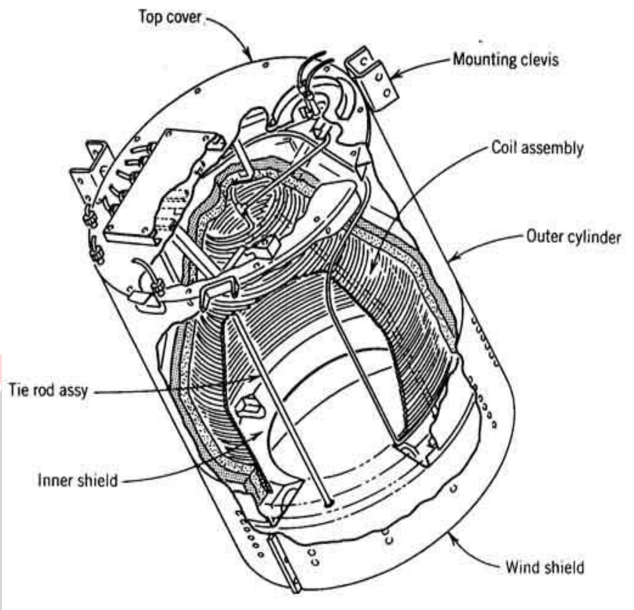

Fig. 6. Cavity Type Receiver

The cavity contains a suitable tube configuration through which the receiver fluid flows. In large scale solar concentrator projects, and commercially available solar concentrators, it is found that the cavity type receiver is most commonly used. This is due to the lower heat-loss rate compared to that of an external receiver; however, they are more expensive than external receivers. The concentrated solar radiation entering the aperture of the cavity spreads inside and is absorbed on the internal walls where the heat is then transferred to a working fluid. Any radiation that is reflected or re-radiated from the walls inside the cavity is also absorbed internally on the cavity walls resulting in a higher absorptance value of the receiver. This spreading of the solar radiation causes a reduction in the incident flux within the cavity, thus helping to prevent thermal cracking or smelting of the internal walls. Also, because of the design of the cavity receiver, it is easier to insulate to aid in avoiding radiant and convective heat loss to the environment [6].

III.NEED OF STUDY

Developing solid engineering design requirements is crucial to the success of any design project. An engineer must spent a lot of time at the beginning of the design process reviewing research, talking to people in the industry, and discussing how their research could be translated into measurable design requirements. In addition to cost requirements, the engineer had to create ambitious but achievable technical requirements. While there are many methods for developing constraints and design requirements, one straightforward method is to simply identify gaps in current solutions [12].

India is currently the second fastest growing major economy and is the fourth largest in the world in purchasing power parity (PPP) terms, with steady progress achieved since the start of economic liberalization reforms in 1991. The International Monetary Fund predicts 8.3 % growth for India for the year ending 31 March 2011. The Eleventh Five-Year Plan (2007-2012) predicts an energy demand of 547 Mtoe in 2011-12 and between 1,350-1,700 Mtoe by the year 2030. The per capita primary energy consumption in India in 2008 was about 540 kgoe/year, which is well below that of developed countries. While the country's per capita energy consumption will remain much lower than that of industrialized countries for the foreseeable future, India's total energy consumption is expected to continue to increase significantly for many decades as it continues to develop [7].

The industrial sector is the second largest energy consuming sector in India after the residential sector. Industrial sector demand was 114.8 Mtoe of energy in 2008, which is 28% of the total energy demand of the country5. Growth in industrial energy demand is projected to grow at a rate of 4.7% per year during the period of 2005-2015. International Energy Agency (IEA) projections are that the industrial sector's energy demand will increase to 34% of India's total energy demand in 2030. Electricity is a relatively smaller constituent of industrial energy demand compared to other major economies; in 2008, only 21% of industrial energy demand was in the form of electricity (Fig.1.7). The rest of the demand was met by fuels – coal, biomass, oil products and gas, which indicate that a large amount of energy in the industrial sector is used to provide thermal energy/heat. Oil products accounted for 20% of total industrial demand [8].

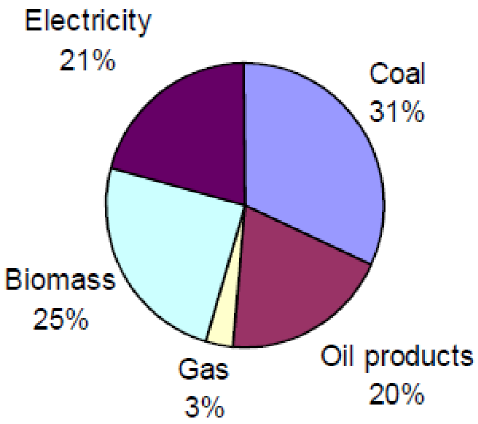

Fig. 1.7 Indian Industrial Demand by Fuel Type, 2008

India is endowed with a vast solar energy potential. About 5,000 trillion kWh per year of solar energy is incident over India's land area, with nearly all of India receiving an average 5-7kWh/m2/day11 (Fig. 1.8). The abundant solar radiation, clean character of solar energy, high cost of fossil fuels and negative emission consequences of fossil fuel consumption along with large requirements for process heat below 250°C are the key drivers of the strong focus on the development of solar thermal applications in India. The solar water heating industry in India is fairly well developed and is already on an accelerated growth path. The use of solar concentrators to meet the process heat requirement of community, industrial and commercial establishments (concentrated solar heat – CSH) is an emerging and exciting market opportunity in India [9].

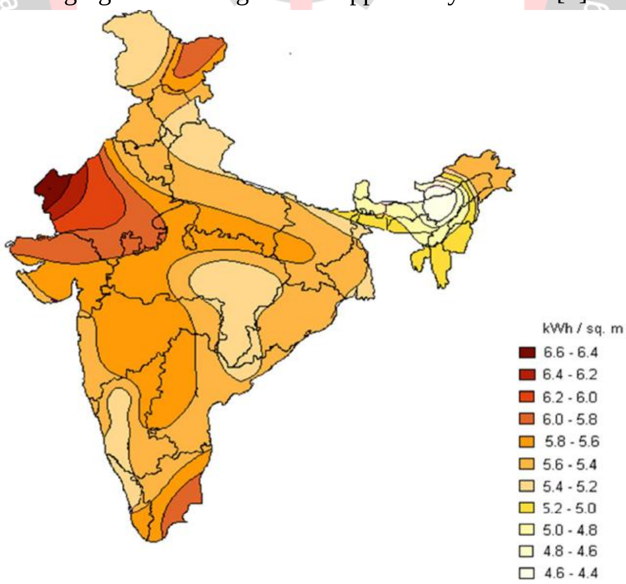

Fig. 1.8 Global Solar Radiation in kWh/m2- India

In addition to its size (inexhaustible source of energy, 1.8 X 10^{11} MW), solar energy has two other factors in its favour. First unlike fossil fuels and nuclear power, it is an environmentally clean source of energy. Second it is free and available in adequate quantities in almost all parts of the world where people live.

The heat losses from the receiver include three contributions: conductive heat loss from the receiver walls and radiative and convective heat losses through the receiver aperture. Among these contributions, natural convective heat loss contributes a significant fraction of energy loss. The natural convective heat loss in the receiver is an important factor for determining the performance of a fuzzy the overall focal solar dish concentrator. In order to improve system efficiency, natural convection characteristics need to be studied extensively[13].

The important energy loss for the receiver originates from convection and radiation heat transfer to the surroundings. These losses depend on the design of the receiver, its heated (or aperture) area, and its operating temperature. Additional factors include the local wind velocity, ambient temperature, and the orientation of the receiver. The design of central cavity receiver need to be analyzed to reduce heat losses [10].

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