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A comprehensive review of Scheffler solar collector

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ABSTRACT

A Scheffler collector is a fixed focus solar radiation concentrator. It has capacity to increase the temperature of the receiver up to 200 °C. It is being widely used in the various applications such cooking food, generation of power in the solar thermal power plant and etc. This communication presents a complete review of the Scheffler collector. The first part reviews a complete designing of a Scheffler collector with respect to the equinox by selecting a specific lateral part of a paraboloid. The next part compares the energy and exergy analysis of the Scheffler collector followed by the various applications of Scheffler collector and its recent developments.

1. Introduction

In today's world, the energy requirements are met by burning of fossil fuel which are not only limited but also release pollutants which intoxicate the world and affect its climatic pattern. To reduce this dependence on the fossil fuel, scientists are making effort to use other sources of energy – which are present in abundance and are inexhaustible like sun, water etc., to generate electricity. These non conventional sources of energy have the capacity to solve world energy crisis. Among the various non conventional energy sources solar energy contributes a large portion [1]. This history of using solar energy in daily life has been known since 1455 BC [2], still, complete utilization of this form of energy hasn't been possible. The total amount of energy received by earth, from the sun, in an hour is more than the energy consumed in one year. Solar energy striking the surface of Earth hits it directly or indirectly, through a number of reflections from the atmosphere. The key obstruction with solar energy is the erratic nature of its availability and the problem in capturing and storing it.Solar energy is also concentrated to limited parts of the world.

Solar energy can be converted into electricity by either using photo-voltaic cells or using concentrated solar power (CSP). Fig. 1. illustrates both photo-voltaic cell and different type of concentrated solar reflector [3].

Since its invention, photo-voltaic cells have resolved a significant portion of the world's energy crisis and now contributes around 177 gigawatt or 1% of the world's electricity demands [4]. These cells are mixture of semi conducting materials which are used to convert solar energy directly into electricity using photoelectric and electrochemical processes [5]. With recent technological advancements maximum efficiency extracted from the photo-voltaic cells was increased to around 40% but the average efficiency remains around 15% [6].Concentrated solar power, like photo-voltaic cells, uses solar radiation to generate electricity. When CSP can also combined with thermal storage capacity, CSP plants can provide flexibility for grid energy because of the large capacity of thermal storage to generate electricity even when sun is blocked by the cloud or sundown [7,8].

Depending on the use there can be different ways to concentrate solar power to a point. For commercial purposes, where the temperature at the focus point needs to be high, use of parabolic through, central tower. Parabolic through and central powers are widely used because of high temperature generation at the concentrated point. But, these are not practical as almost all parabolic concentrators have rigid structure and the focus. This motivated the Scheffer to come up with a design where hot focus is available at a fixed place so that solar energy can be contentedly used. He developed the Scheffler reflector in village workshops of India and Kenya so that this technology is in reach of everyone [9]. Scheffler [10] developed a special Scheffler reflector with 50 m^2 surface area to heat a 2 m long cremation chamber at 700 °C. Then different researchers started developing the Scheffler dish which finds its application in the households for boiling water, cooking food and in medical applications [11–15]. Scheffler dish reflects light in two dimensions concentrating it to a single point. This paper is attempted a review of progress of Scheffler dish. The first part reviews a complete designing of a Scheffler dish with respect to the equinox by selecting a specific lateral part of a paraboloid. The next part compares the energy and exergy analysis of the Scheffler dish followed by the various applications of Scheffler dish and its recent developments.

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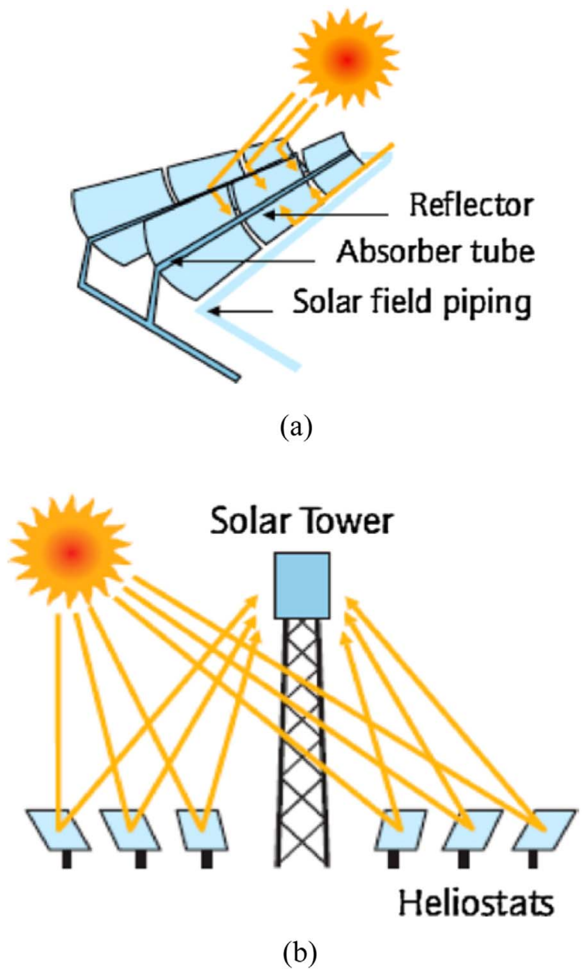

Fig. 1. Concentrating solar reflector (a) Parabolic through (b) Central tower [3].

2. Concentrating solar power

Concentrated solar power technologies can only utilize direct sunlight, concentrating it multiple times to reach higher energy densities at the focus point of the solar concentrating systems – and thus reaching much higher temperature when the light is absorbed by the material surface. The heat thus generated is used to operate conventional power cycle like a steam turbine or sterling engine which drives the generator [3]. CSP facilitates the generation of energy which uses a system that is non- toxic, noise free and less risky because of the use of nonflammable and safe materials. A concentrated solar power plant typically has a collector, tracking system, absorber, heat transferring liquid and a energy storage system. A reflecting type power generation system can be categorized into two general categories depending on their focus geometry as either a point focus concentrators, like Scheffler collector, parabolic collectors, etc, or line focus concentrators like parabolic trough and linear Fresnel collector.

3. Scheffler reflector

Invented by Wolfgang Scheffler, Scheffler reflector is a system of harvesting the solar energy. As depicted in Fig. 2, Scheffler collector is a collector which tracks the movement of the sun thus focusing sunlight on a focal point which is fixed [16]. A Scheffler fixed focus concentrators are successfully used for medium and high temperature applications in different parts of the world. It can concentrate sunlight in two dimensional angles to a “point”, which allows heat to flow without a specific mechanism and if position of the reflector is north or south of the focus point the Scheffler will track on a single axis as shown in Fig. 3. The focused light heats the receiver, and this heat is transferred by the suitable fluid which can be used for various purposes. The Scheffler reflector have the same principle as that of satellite collectors which uses the sides of a rotated parabola instead of the bottom [12].

Fig. 2. A scheffler type solar reflector [16].

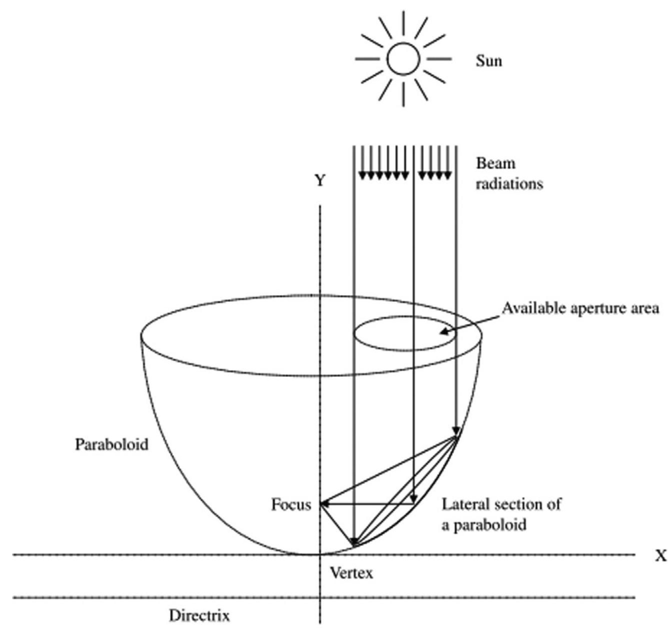

Fig. 3. A schematic view of the paraboloid type SD [12].

3.1. Design of reflector parabola and reflector elliptical frame

The first consideration in designing a Scheffler collector is to identify the parabolic equation and two extreme points of collector section for equinox. This information is defined in terms of the ratio of the area of the collector and the position of the focus with respect to the collector. Fixing this ratio helps in adjusting the dimension of parabola by scaling the area of the collector. The general equation of a parabolic collector with y intercept is given by Munir [12] as follows.

$$P(x) = mx^2 + C \quad (1)$$

where m is the slope of the parabola and C is the y intercept. The above mentioned curved is revolved around the y-axis to generate the paraboloid. By using the Eq. (1), calculation will be done on 2-D plane as shown in Fig. 4. It described the parabola and the equation of a line to represent the intersecting plane.E_1 and E_2 are the extreme ends of the collector section and 43.23° is the slope of the line.

The derivative of the above equation results in equation for the