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Minimizing the Cosine Loss in a Solar Tower Power Plant by a Change in the Heliostat Position and Number

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Abstract*: Concentrating Solar Power (CSP) focuses sunlight in order to use the heat energy of the sun. In a central receiver system configuration, many mirrors (heliostats) individually track the sun and reflect the concentrated solar energy onto a receiver on top of a tower. The receiver contains the working fluid which is heated by the concentrated solar radiation. The useful energy that absorbed by the water flows through the receiver in solar tower plant depending on the angle between the solar rays and the position of heliostat in the region of work. Heliostat will reflect the incident solar radiation in the direction of the receiver founded in the top of the tower, in order to get a maximum incident solar radiation on the heliostat reflection area. Because of the cosine factor loss effect due to the sun position is variable along the day from sunrise to sunset, which must be in a minimum value, therefore an automated tracking system with dual axes as a control system with sensors had been built and used to stay the sunrays incident on the receiver, and enable the heliostat to flow the sun where it was.

Keywords: Cosine losses, Solar energy, Tower power plant, Heliostat position.

I. INTRODUCTION

Many people use solar power by harnessing the sun's energy to heat their homes and to run different appliances .It is an economical and earth-friendly way to bring power into the home and can cut external power consumption by 50 to 70%. For this reason, the world is thinking to transfer the energy sources to the green sources and technologies. The central solar tower is one of green technologies used to generate the electricity from sunlight by concentering the solar rays that directed to the receiver found on the top of the tower, this heat exchanger will absorb these rays and convert to the thermal energy then used to turn drive steam turbine. In solar power plant may heliostats installed to ensure the big amount of reflection the sunrays. This machine has a reflection area and a studied position in the field of the central solar, they follow the sun's motion by tracking system [1] and [2].

In this study, the main object is to maximize the efficiency and performance of the receiver which achieved by using the tracking system to minimize the effect of cosine factor and decreases the losses of the sunrays, therefore this will improve the performance of the solar power plant.

II. COSINE LOSS

In optics, the law cosines of Lambert said that the radiation intensity or the light intensity observed from a reflective surface is directly proportional to the cosine of the angle θ between the direction of the incident light and the surface normal sensor [3]. The law is also known as Lambert's emission law [4] or the cosine emission law. It is named after Johann Heinrich Lambert, from his Photometry, published in [5]. The cosine effect has been modeled follows in the Fig. 1.

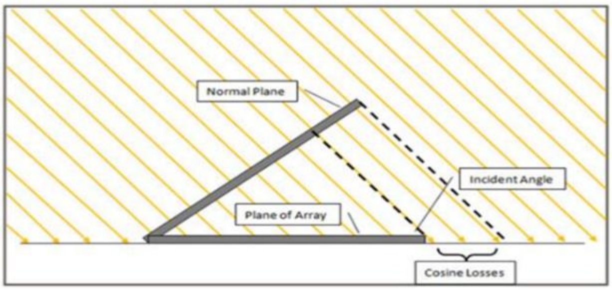

Fig. 1. Illustration of cosine losses [6]

Solar radiation descended on the heliostat mirror surface is proportional to the cosine of the angle between the light direction and the surface normal [6]. A significant wellspring of 'misfortune' in sun-based concentrators emerges from the way that mirrors can't generally be adjusted typical to the episode sun powered beams. At the point when a mirror is reflecting off-pivot, the evident territory of the mirror, as observed from the sun, is diminished by the cosine of the frequency edge. Accepting that the gap region of the concentrator to be equivalent to the mirror region, this decrease in evident zone at that point legitimately lessens the fixation proportion of the concentrator, consequently it is alluded to as a cosine misfortune, albeit carefully the vitality was never gathered in any case.

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This cosine misfortune impact happens in all types of sun-based concentrators. An endeavor to minimize normal cosine misfortunes is liable for the off-hub plan of most focal collector frameworks. End misfortunes are specific to trough and direct Fresnel concentrators. These allude to the radiation that is reflected from the mirrors however which, because of the sun not being straightforwardly overhead of the authority, misses the recipient, and rather is thought past the finish of the collector. Contingent upon the direction (east-west or north-south), these misfortunes may be available lasting through the year, or else just in the mornings and night times.

III. METHODOLOGY

A multi-turn solar power plant is a new concept of a focal point followed in two axes of concentration of the central solar energy (Fig. 2). This consists of several receivers mounted on a tower that stand so close to one another that the fields of the heliostat towers overlap in part. Consequently, in some regions of the total heliostat field, the heliostats are alternately directed to different points of sight on the different positions.

The field configuration of a heliostat in multi-turn solar power plant can be optimized to achieve a high annual efficiency for the use of available beam energy that would otherwise strike the ground or on the roof below. In this case the heliostats are not directed to the nearest tower; they are directed towards the receiver where the cosine effect will be the smallest. Multi tower solar array reduces the losses caused by the cosine effect of the heliostats in the solar field. In this work, the main idea based on the angle β (cosine effect) [8].

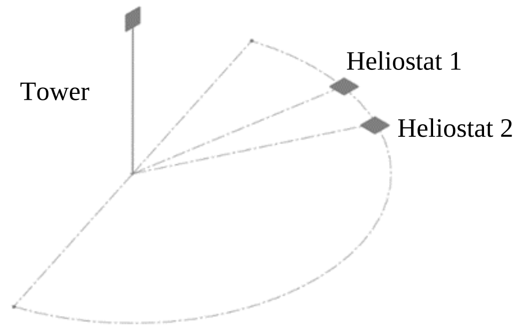

Fig. 2. heliostats positions according to the tower

The fixed parameters of the simulations are shown in table I. The following figure illustrates the image of a heliostat with the necessary parameters to determine the cosine effect.

Table- I: fixed parameters of the simulations

Hours	Day	Month	Tower Hight	Receiver Tilt	Mirror reflection coefficient	The surface of the heliostat
(07: 00 - 17: 00)	16	November	4.5 meters	vertical	0.88	(0.8*0.8) m

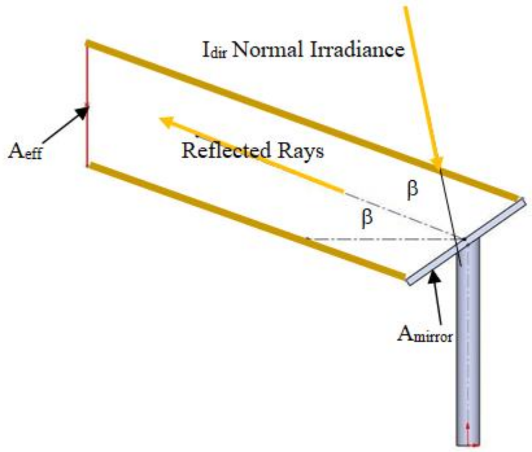

Fig. 3 Cosine loss Effect on radiant power reflected by heliostat.

The equation of the loss due to the cosine effect is given by:

$$Q_{(eff,\cos)} = 1 - \cos\beta \quad (1)$$

Where β is Heliostat normal zenith angle.

Radiation power is calculated by the following equation:

$$P_{\mathrm{rad}} = I_{dir} \times A_{eff} \quad (2)$$

Where I_{dir} is direct solar intensity

The effective area is calculated by the following equation:

$$A_{\mathrm{eff}} = A_{mir} \times \cos\beta \quad (3)$$

Where A_{mir} is surface area of mirror.

The sun and heliostat are in motion while the tower (the target) is fixed. The best solution to optimize the value of (β) angle is to change the position of the heliostat in the opposite technique used in [8] which fixed the heliostat and change the position of the tower. (β) angle varied throughout the day, therefore for maximum beam radiation incident on the mirror must make the beta angle always about zero (cosβ) = 1, in this way, the cosine effect can be reduced by change in the position of the heliostat.

IV. RESULT AND DISCUSSION

Fig. 4 shows the growth of the angle beta between the incident solar rays and reflects towards the receiver at the azimuth angle; this angle changed in the range of 0 and 20.3° during the recommended average day (16 November) and time of (8:00 am and 5:00 pm).

In the same manner, the Fig.5 explains the cosine evolution of the angle of Fig. 4 throughout the day.

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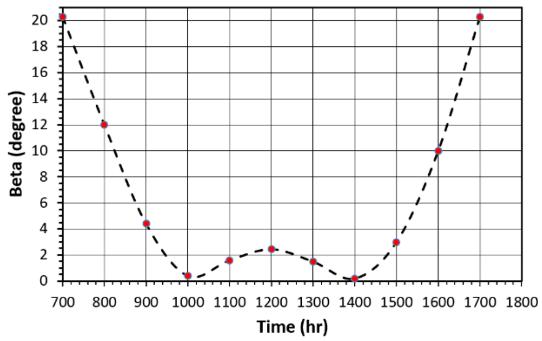

Fig.4. Variation of the beta angle throughout the day

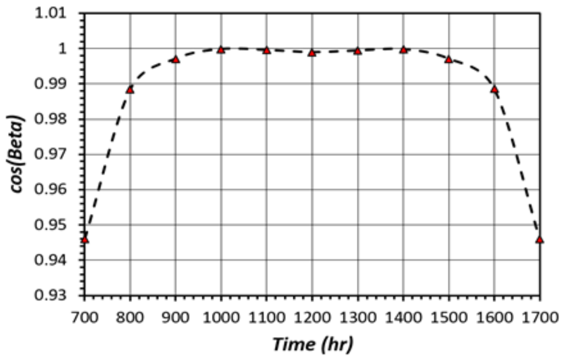

Fig.5. Variation of the cosine beta angle along the day

According to the results presented in the above figures, it is noted that the solution for decreasing the cosine effect in a solar power plant is to increase the number of receivers or to mobilize this position as a function of time day. Because the greater number of heliostats increases, the cosine effect decreased, and the efficiency of the plant increases which is also founded by [8].

V. CONCLUSION

In this work, it had shown the possibility of minimizing the cosine loss in a solar power tower; this technique is based on changing the position and the number of heliostats. It can be noted that several revolutions increase the cosine effect which means an increase in efficiency of a solar power tower plant.

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