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Study and Analysis of different Types of Solar Concentrators

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Abstract: *Solar energy is one of the most widely used from of renewable energy. Concentrators of solar power use reflection, refraction or total internal reflection to trap and concentrate this solar energy. This provides greater efficiency than flat solar panels. There are different types of solar concentrators. This study compares three types namely compound parabolicand the Fresnel concentrator. Their efficiencies have been calculated and presented.*

Keywords: *Solar , Concentrators , Fresnel, Efficiency, Comparison.*

I. INTRODUCTION

In the last few decades the way people use the world's energy has completely changed. There is a huge emphasis to use renewable energy in today's world. Improvement of energy efficiency is the top priority of governments, academic institutions and industry. The constant pressure over different industries to reduce carbon emissions has motivated them to develop alternative sources of energy and reduce their dependence on fossil fuels.

Solar energy is a renewable source that has vast potential. It is also one of the most widely used forms of renewable energy. There have been numerous advances in this field but despite all the effort solar energy contributes to less than 1% of the world's energy demand. The main reasons for this are the high costs to set up solar power plants.

Solar concentrators trap solar energy using reflection, refraction and total internal reflection. These concentrators provide higher efficiency and help reduce costs.

II. TYPES OF SOLAR CONCENTRATORS

This study analyzes three types of solar concentrators namely the compound parabolic concentrator and the Fresnel concentrator.

Compound Parabolic Concentrator (CPC):

Figure 1 shows the geometry of the CPC. There are two parabolas on opposite sides AC and BD. We divide the CPC into three parts : a planar entrance aperture, an exit aperture and a totally internally reflecting side profile. Figure 1 is taken from [1]. CD is the entrance aperture and 2θ is its acceptance angle. The solar radiation will get concentrated at AB: the exit aperture. The size of the CPC depends on the acceptance angle and by varying the exit and entry aperture we can change the length of the solar concentrator.

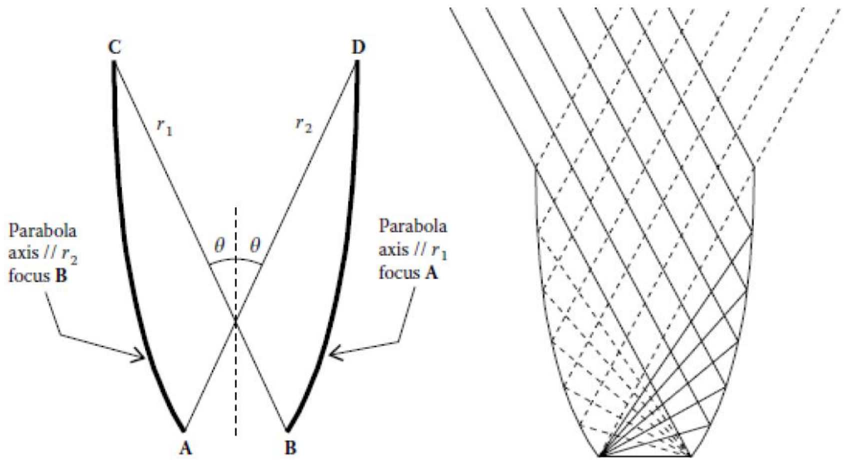

Figure 1.Geometry and trajectories of the edge rays inside the CPC

The efficiency is calculated using the following equation. Equation 1 is used to calculate the optical equation theoretically. This depends on the materials used in the construction of the CPC.

$\eta_o = \tau_a \tau_e \rho_m^{<n>} \alpha \text{ P } f_{ref}$ (1)

Here $\eta_o$is the optical efficiency, τ is the transmittance, ρ is the reflectivity, $<n>$ is the average number of reflections and αabsorbtance.

Fresnel Concentrator:

The Fresnel concentrator consists of a Fresnel lens. A Fresnel lens functions as a normal lens concentrating the sun rays at one focal point. A Fresnel lens however requires less material to fabricate as compared to a conventional lens. It has two components, a back surface that is made up of canted facets and a flat front surface.

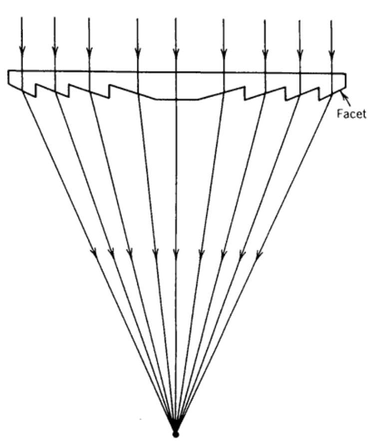

Figure 2. A Fresnel lens

We calculated the overall efficiency of the Fresnel concentrator by calculating the overall heat loss and heat gain using the following equations. Equation (2) calculates the heat loss per unit length due to natural convection and radiation. The heat loss due to convection from glass cover to ambient is given by equation (3). [2].

$q_l/L = h_{p-a} \pi D_o (T_P - T_c) + \sigma € \pi D_o (T_P^4 - T_c^4)$ (2)

$'q = h_{glass} A (T_{glass} - T_a)$ (3)

The useful heat gain is given by equation (4).

$(Q - q_L\text{-}q) = m c_p (T_{out} - T_{in})$ (4)

Where Q is given by equation (5).

$Q = I_b \times \rho_{reflector} \times \rho_{cpc} \times \tau_{glass}$ (5)

Here τ is the transmittance, ρ is the reflectivity, T is the temperature and $I_b$is the beam component of solar radiation.

III. CALCULATION AND RESULTS

The following results were obtained via computer software called PVSOL7.5. Figure 3 shows a sample page of the PVSOL7.5 software.

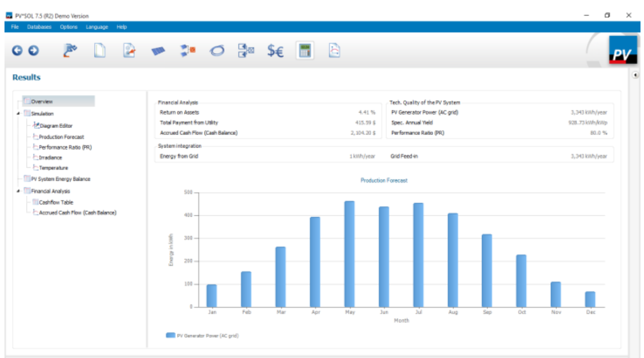

Figure 3. The home page of the software

The following results were obtained after evaluating the equations and obtaining the results through the computer software. All the variables were varied and an average value of optical and thermal efficiency was obtained.

The following values of each constant is was taken for the Fresnel concentrator equations

Reflectivity of mirrors: 0.92
Absorbivity of absorber tube: 0.92
Emissivity of absorber : 0.15 5.
Temperature of absorber tube: 200o C
Ambient temperature: 30o C,
Cavity Temperature: 80o C,

Reflectivity of CPC: 0.90,
Inlet temperature of thermic fluid: 25°C,
Glass covers temperature: 50° C,
Wind velocity: 3 m/s,
Mass flow rate of thermic fluid: 0.0162kg/sec,
Specific heat of thermic fluid at mean Operating temperature 1859J/kg K and
Transmissivity of glass cover: 0.95

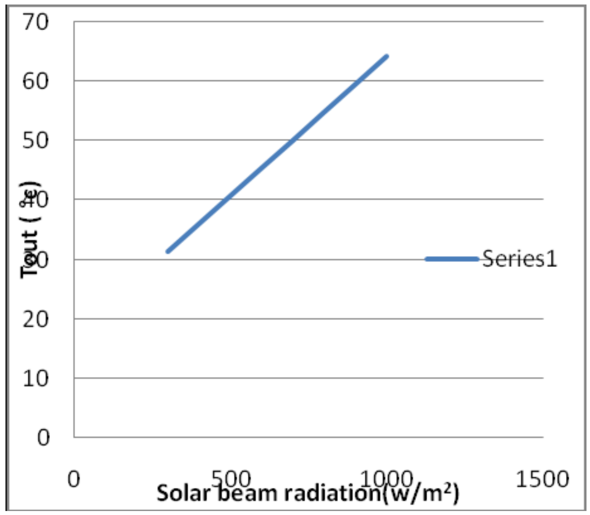

Figure 4. Solar beam radiation falling on the collector VS the outlet temperature (Fresnel Concentrator)

Using the Fresnel concentrator equations the values for heat loss due to radiation and convection within the cavity and the heat loss on the glass cover are respectively:

q_{cavity} = 155.84 w/m2
q_{glass} = 80 w/m2
These were in turn used to calculate the efficiency of the system with varying solar beam radiation and temperature. The results of which are given in table1. Figure 4 shows how the radiation varies with the outlet temperature. We notice an increasing trend in the overall efficiency of the Fresnel concentrator system with the increase in solar radiation as expected. The experimental values are obtained from [2].

Table 1. Normal radiation Vs efficiency

I_b (w/m2)	T_{out} (°C)	Overall Efficiency	Experimental efficiency
300	31.27	34.98%	30.05%
400	35.97	45.98%	45.95%
500	40.67	52.45%	51.98%
600	45.37	56.82%	57.06%
700	50	59.94%	60.74%
800	54.78	62.28%	61.10%

The CPC concentrator equations were also evaluated and the following values were obtained. The results of the optical efficiencies are given in table 2. Equation (1) is modified accordingly as we have a half acceptance angle of 4 degrees which derives the average number of reflections to be 1.4. Table 2 contains a list of various CPC modules and their optical efficiencies. The experimental values are taken form [3].

S.No	Module	Absorber Coating Type	Theoretical Estimation Of ηo	Experimental Values ηo
1	3-D CPC IA	Black paint	0.645	0.626
2	3-D CPC IB	Black Nickel- Tin	0.659	0.638

IV. CONCLUSION

The theoretical values of the efficiencies were successfully obtained by using the equations and are in agreement with the experimental values of the Fresnel and the compound parabolic concentrator. Our future study will include the cost analysis and determine the financial constraints of setting up a plant.

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