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Low Cost Compound Parabolic Concentrator for the Photovoltaic System

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Abstract:

Keeping in view the importance of solar energy in modern physics, the development of solar energy panels has become crucial. This research has attempted to design and develop a compound parabolic concentrator for the commercial use which will be low in cost. The compound parabolic concentrators are used with fewer solar panels, which makes them economical. This research demonstrates a PV panel with a compound parabolic concentrator. The analysis of the performance of the PV system with concentrator shows that the power increases two times when compound parabolic concentrator is used for the purpose. Somehow, as the temperature of the panel rises, the output power decreases. To control the rise in temperature, a cooling system was designed which was mounted at the back of the panel. The output power with and without a cooling system was recorded and it was concluded that a substantial increase in output power can be obtained by using the concentrator and the cooling system.

Keywords: Low Cost Compound Parabolic Concentrator, Photovoltaic System

1. INTRODUCTION

In modern day physics, solar energy has earned reputation as renewable and eco-friendly source of energy as it helps the world to meet its energy demands more efficiently. This type of energy is cheaper than the other energy sources. Its commercial use is preferred throughout the world due to its little cost. According to its utility and usage, it is categorized into two classifications i.e the thermal system which is used to change the solar energy into thermal energy and the photovoltaic (PV) system, which transforms the solar energy into electrical energy directly. There has been an increasing trend, in the past recent years, to use the photovoltaic technology due to its efficiency in improving and increasing the photoelectrical conversion rates. Due to the high initial cost, the wide range application of photovoltaic system is limited, yet it is still possible to make it cost efficient either by improving the performance efficiency of the solar cells or by using the concentration photovoltaic (CPV). An improved and cost effective concentration photovoltaic system can be obtained by producing same amount of power through the usage of less number of cells in contrast to the conventional number of cells. Researches reveal that a low concentration photovoltaic system (LCPV) helps to decrease the cost up to forty percent as compared to plane flat photovoltaic system. In modern physics, many attempts have been made to decrease the practice of expensive solar cells by using the CPC and it has dropped the rates of PV power output. Concentrators are used to decrease the material cost and also to increase and improve the efficacy of the solar cells through concentrating a huge peripheral part of light of sun and its consequential heat on a minor solar cell, enhancing its voltage of open circuit by restricting entropy creation when radiation is being absorbed and emitted [1, 2]

Fresnel lens, a lens concentrator, is being used most widely and commonly since 1950 when plastic was used for lenses. In past, due to current constancy and transitivity, plastic were considered to be more effective as it equals the solar range and their index of diversion that is same to that of the glass. [3, 4].

A substrate having an interference layer and a reflective layer, which reflects the solar energy, is used to design most of the mirror based concentrators. Usually, a parabolic arrays of solar mirrors or a planar mirror are utilized to get a concentrated reflection factor for Photovoltaic system. To study the testing of solar concentrator and their designs, various investigations have been conducted, which, in result, have created a number of multiple concentrating solar collector design including V-trough Concentrator, the flat planar, , polygon concentrator and many more including Compound Parabolic Concentrator. However, CPC is considered as the supreme static concentrator for solar collection radiation among all concentrators,. The CPC is preferred over other concentrating systems due to its higher optical effectiveness and the ability of collecting both direct and diffuse radiations. Yet, due to non-uniform clarification, the usage of CPC is still restricted to professional utilizations. There are many factors which influence the performance of V-trough collector and CPC for PV applications, but the performance mainly depends upon the optical effectiveness and distribution of solar flux along the PV module. It is a challenge to manufacture curved reflectors and high concentration ratio CPCs. However this task can be carried out by developing simple V-trough style concentrators that are easily fabricated. The usage of V-trough solar concentrators in solar desalination systems and for heating water have been recently demonstrated. These demonstrations have shown a considerable decrease in the cost. [5, 6].

The Photovoltaic systems are more effective for future energy generation. Presently, they are used without a concentrator. The Compound Parabolic Concentrator (CPC) based concentrator has been reported for thermal application. The output power of a PV system can be enhanced using a concentrator. However, a low cost compound parabolic concentrator design is locally unavailable and needs an investigation.

II EXPERIMENTAL SETUP

The experimental setup of this study consists of a PV system which is silicon based. The system is combined with concentrator and cooling system. This system is comprised of the following design:

A) Design of Concentrator.

Fig. 1 shows the concentrator is a non-imaging device having two parabolic mirrors with tilted axis which are used to create an acceptance angle of $\theta a = 2\times\theta c$. In this equation the half acceptance angle θc is the measure of the received and rejected solar radiation. The following equation shows how the CR of the Compound parabolic concentrator is related to its θc [5]:

$$CR = 1/\sin \theta c$$

By solving the above equation, the value of θc is 30 if concentration ratio is 2. The focal length F of a full CPC is shown in the following mathematical expression: [5,7]

$$F = W'(1 + \sin \theta c)$$

By putting $W' = 7$ and $\theta c = 30$ in the above equation, we get the value of focal length of full CPC as 8.5.

Where W' Depicts the half-width of the outlet aperture. The following equation can be used to calculate the height of a full CPC:

$$h_{full} = F \cos \theta c / \sin^2 \theta c$$

By solving the above equation, the full height of proposed CPC is 29.445cm.

The following equation gives the inlet aperture half-width W,

$$W = W' / \sin \theta c$$

By solving the equation, the inlet aperture half-width W of proposed CPC is 14cm.

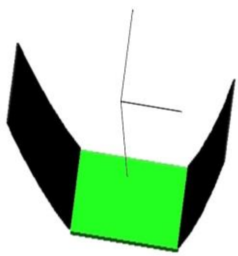

Fig. 1 the concentrator design

Fig.2 PV with Concentrator

B) Design of Cooling System.

The concentrator raises the temperature of the PV, consequently the PV requires a cooling system to decrease the temperature. The back cover of the PV was removed to install the cooling system. A coper plate was chosen for the cooling system as it has good thermal conductivity. The copper plate of the size of the PV was cut and fixed at the back of PV. A copper pipe was bent on the copper plate and used for the circulation of water.

III. Measurement

The readings were noted with and without cooling system.

1) ***Concentrator without cooling system***

The fig. 4 describes the experimental setup which consists of an easily available and accessible poly crystalline solar panel. The PV was of 3.8 watt. The number of the photons falling on the concentrator per unit area was increased via a mirror which was associated with the solar panel. The experiment was executed without cooling system.

Fig. 3 PV panel without back cover and cooling copper plate

The output of the PV solar panel was connected to a 12 volt 8 watt load bulb. A UT 33B series digital multimeter was connect and used for reading and measuring the efficiency of the concentrator. The short circuit current (Isc) through load and the vulnerable circuit voltage (Voc) of the panel was recorded for each value of input power using solar power meter TES 1333. A digital thermos meter of K-type was used to measure the temperature.

Fig 4 Experimental set up with and without cooling system.

2) *Concentrator with cooling system*

The experiment was performed, then, with a cooling system. This helped to compensate the degradation of the output power due to increase in temperature. Using a cooling system, the Isc and Iop were recorded for the system with concentrator. The values were noted for a period of one hour i.e. from 12:05 to 01:05.

IV. RESULTS AND DISCUSSION

Fig 5 & 6 show the results of output power attained from the panels with the concentrator without and with cooling system. The results show that the performance of the system without cooling system reduced with time compared to system with the cooling system

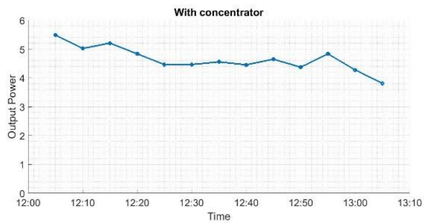

Fig.5 Output vs time graph of PV with concentrator without cooling system.

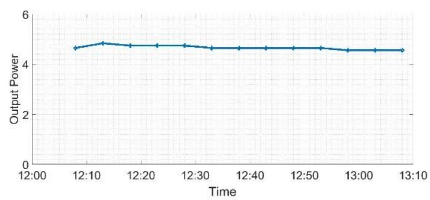

Fig 6 output power vs time graph of PV with cooling system

The graphs in figures 7 and 8 show comparison of results of output power vs temperature performance of the system without and with cooling system. The results shown in graph 7 and 8 make it evident that the PV panel with contractor and cooling system maintains a stable level of output.

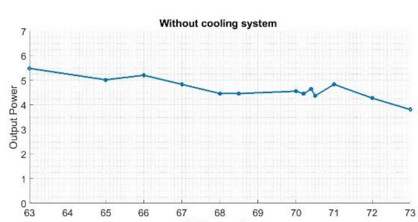

Fig.7 Output power vs temperature graph of PV without cooling system

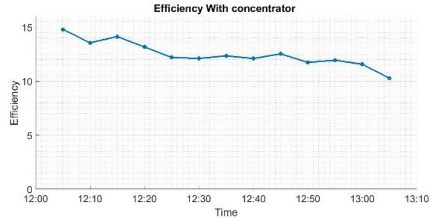

Fig 8 output power vs temperature graph of PV with cooling system

The results depicted in the graphs shown in fig 9 and 10 display the efficiency vs temperature performance of the system without and with cooling. The fig 9 shows the efficiency of the pv panel with concentrator and without cooling system compared to the fig 10 which expresses that the efficiency of the PV panel with concentrator with cooling system remain constant.

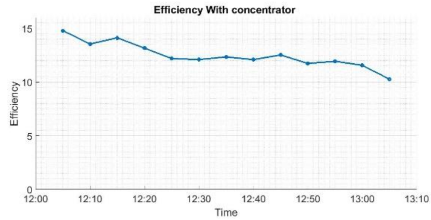

Fig.9 Efficiency vs time graph of PV with concentrator without cooling system.

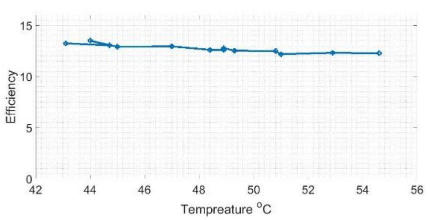

Fig 10 efficiency vs temperature graph of PV with cooling system

V. CONCLUSION

In contemporary physics, solar energy has gained a standing as renewable and eco-friendly source of energy as it assists the world to meet its energy demands more proficiently. This type of energy is cheaper than the other energy sources.

During this research, we have attempted to develop a concentrator based photovoltaic system. A commercially available PV and compound parabolic concentrator was used to design the system. The study gives a comparison of measurement of the output power of the system with and without concentrator. The results show that the power increases apoximatley two times when a compound parabolic concentrator is used for the purpose. Somehow, as the temperature of the panel rises, the output power decreases. The temperature was controlled by using a cooling system based on copper plate with a wave shape pipe. The cooling plate was fixed on the back of the panel which helped to maintain the moderate temperature of 40ºC. This system can be utilized to decrease the cost and space in energy production PV systems.

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