Design and Development of Low-Cost Solar Electricity Generation System with Heliostat to Ensure the Optimum Uses of Rated Capacity of Solar Cells

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ABSTRACT

Almost all solar electricity generation systems are now operated with flat plate solar panels. These flat plate solar panels have a lot of expensive collector area although still deliver only low-grade temperature which is a boundless problem for assuring the optimum uses of the rated capacity of solar panels. Using heliostats can reduce this problem significantly. Heliostats consists a single or a set of mirrors that track the sun's position and reflect the sun rays into a central receiving point. With the movement of the sun, these mirrors are adjusted accordingly to track the sun to ensure the highest amount of sunlight reflected onto the same collection point. The system is cheaper than any other solar tracking system presently used in our country. This paper describes an improved design of a solar electricity generation system having a capacity of $1W_p$ with heliostats on an experimental basis. It will also demonstrate a comparison of a generation of a $1W_p$ solar system with and without heliostats. Successful outcomes of this experiment will lead us to implement the heliostats-based tracking system into the large-scale solar electricity generation systems.

Keywords: Low grade temperature, Rated capacity, Heliostats, Solar tracking, and Economical feasibility.

INTRODUCTION:

Solar electricity generation systems are now operated with the flat plate solar panels. Flat solar panels have a lot of expensive but unutilized collector area and hence deliver very poor output. Heliostats can reduce this problem significantly. Heliostats consists a mirror or set of mirrors that track the sun position to ensure optimum sun ray reflection onto a central receiving point. By considering the incidental sunrays as parallel, mirror or mirror set is initially adjusted to ensure maximum light reflection onto the same spot (Deepak *et al.*, 2018). With the movement of sun, mirrors are adjusted by the required amount to track the sun. It is possible to calculate the tilt angle mathematically and it is applicable in anywhere in the world when reflecting on any spot (Ashok, 2020). In comparison with the flat plate collectors, mirrors are much cheaper and it ensures optimum sunlight presence in the collector area. It is also ensured that the actual collector can be fixed stationary on the

ground. The difference of heliostat and the conventional tracker is that in conventional tracking process the collector area need to be rotated angularly which increases the establishment cost as well as complexity.

Description of Solar Tracking System

A solar tracker is a device that orients a payload toward the sun. Payloads can be photovoltaic panels, reflectors, lenses or other optical devices (Naefa and Rahman, 2020; Arindam *et al.*, 2012). Trackers can reduce the angle of incidence significantly between the incoming rays and a PV panel. Total amount of energy produced from a PV based power generating system of certain capacity can be increased by proper solar tracking system (Rafique, 2004).

Working Principle of Heliostats

Heliostats consist of a reflector or set of reflector that track the sun and reflect the sunlight onto a central receiving point. Mirror can be used as reflector and it can collect optimum solar incident rays which is less expensive and having higher efficiency than normal flat plate collectors. Mirror can concentrate the energy on a relatively small collection point. The heliostats of this paper consist of only single mirror as it is on experimental basis. For 20ft² array of 1 element have been used, then the concentration factor will be about 10 to 1 (Saif Uddin, 2013). With this much concentration factor the relative thermal collection efficiency is about doubles that of a tracking flat plate collector (Mark Z. Jacobson, 2009).

Stasis Efficiency

Stasis temperature is the temperature recorded at collector point at ambient temperature which is required to calculate the stasis efficiency. It is inversely proportional of collector temperature to reference temperature. Maximum solar heat flow while the collector temperature is identical with the ambient temperatures (Islam *et al.*, 2020; HDC, 2017). It is due to that at higher temperatures less heat is available for transmission to a load (Islam *et al.*, 2020). With the increase of temperature, there may be some situation arrived when no heat transmission occurred (may captured by insulation or radiation loss) which resulting null stasis efficiency tem-

perature. The efficiency equation is determined on real measurements basis.

$$\eta = 1 - \frac{Tc - Ta}{(Ts - Ta) * CF} \text{ x } 100\%$$

Where,

η = Stasis efficiency
Tc = Collector temperature
Ta = Ambient air temperature
Ts = Stasis temperature.
CF = Solar Concentration Factor.

Experimental Setup

Experimental setup was equipped by a 1W peak to peak polycrystalline solar cell manufactured in china. The optimum efficiency was denoted 7% by the manufacturer. A flat mirror having diameter of 18x18x1.5 inch was used as heliostat. Tilt angle between the mirror and solar panel was 95 degree (approximately). Firstly, the setup was made without mirror and then the mirror added to the setup (act as heliostat).

The experiment was conducted on 5 successive days. Obtained data are shown in **Table 1**

Table 1: Obtained Data from output with and without mirror.

No of day	Output without mirror (V)	Output with mirror (V)
1	0.05	0.081
2	0.07	0.12
3	0.069	0.11
4	0.03	0.07
5	0.00	0.00

In day 2 and 3 there were plenty of sunlight but in case of day 4 it was almost dull. Day five was a rainy day. It was found that without mirror the max output was 0.07V and with mirror it was 0.12 V.

Output Efficiency

By the assumption of linear distribution of stasis efficiency, it can be concluded that using heliostat the static efficiency increased up to 2% then the previous setup. As the normal efficiency of commercial solar cells are on avg. 11 to 13 %, so using heliostat can be a good option for better energy harnessing.

Fig 1: Experimental setup without mirror.

Fig 2: Experimental Setup with mirror.

CONCLUSION:

In spite of some disadvantages, heliostat is a cheaper and easiest ways to increase the power output of a small solar panel. To reflect high amount of sun rays onto the solar panel more mirrors are needed but it may cause physical damage of PV collector on sunny very hot summer days. Placement of mirrors is also an important factor for harnessing optimum energy. However, it can be a cost-effective solution for small solar electricity generation plant or solar pumping system.

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CONFLICTS OF INTEREST:

The authors sincerely admitted no conflicts of interest to declare

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