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Experimental Investigation on Solar Photovoltaic Thermal Collector Using Al_2O_3 Nano Fluid

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Abstract**: This work presents the most recent advances of nanofluids in thermal energy storage systems, solar collectors, solar stills and photovoltaic/thermal systems. With the application of nanomaterials, the efficiency of photovoltaic can increase substantially while reducing the production costs of electricity and manufacturing. The nanofluid used for this experiment is Al_2O_3. When we use the combine, system called photovoltaic thermal collectors the combined efficiency of system is increased. The initial temperature of water was 35 ̊C and it is raised by 6.2 ̊C after the experiment. The efficiency of solar photovoltaic cells was 27.96 % initially and after it is increased to 15 %. Which resulted in output of 51 volts which was 42 volts before passing Nano fluid.

Keywords—Solar photovoltaic thermal, solar energy, Nano fluid, PV/T, Al_2O_3

I. INTRODUCTION

As a kind of clean energy source with huge reserves, solar energy has been used in broad applications. Two most popular approaches of solar utilization, photovoltaic and photo thermal utilization can meet the principal energy demands in domestic life and industrial manufacture. In past few decades, numerous scholars have paid increasing attention to Photovoltaic/Thermal (PV/T) hybrid system. This is partially attributed to the obvious merits of its multipurpose use and high efficiency. In the conventional PV/T system, a cooling channel contacted with the back of the PV cell was designed to harvest heat generated by PV cell.
Meanwhile, the photovoltaic conversion efficiency of the cell is also improved owing to the declining cell temperature. However, the temperature of the heat collected by cooling fluid in the conventional PV/T system is generally only 40-50°Cbecause of the limitation of PV cells' operation temperature. This kind of low-grade thermal energy can hardly meet the requirements of most industrial applications nanofluid-based spectral splitting PV/T (PV/T) system has the advantages of less heat loss and high thermal efficiency owing to the volumetric heat absorption on the thermal side.
In addition, the PV/T system could attain a flexible adjustment of energy distribution ratio between and photo thermal units by changing the nanoparticles optical properties, thereby satisfying the versatile need of power and heat in extensive applications. Therefore, the PV/T system can provide electricity and medium-temperature heat for many applications, such as solar drying, solar refrigeration, and solar desalination, etc. In earlier work, Powell was likely the first to propose the liquid-based spectral splitting method. Sabry et al. developed a model to investigate the optical properties of ideal liquid filter for Si cell. Since nanofluids spectral characteristics could be modulated conveniently by = changing nanoparticles size, morphology, or even aggregation configuration, nano fluids drawing an increasing concern in solar energy field.

II. LITERATURE REVIEW

Ali H.A et al. conducted an experiment to evaluate the performance of PV/T system when using Nano fluid as working fluid. And said that the use of nanofluids improved the thermal conductivity of the base fluid, and hence the cooling of the photovoltaic cell which leads to higher power production [1]. Sadegh Aberoumanda et al. investigated the electrical, thermal and exergy efficiencies of a photovoltaic/ thermal (PV/T) system cooled by Ag/water nanofluid. The utilized nanofluid was prepared by a one-step method of electrical explosion of wire (EEW) and was tested for long-term stability and uniformity. The experiments were conducted at three different flow regimes of laminar, transient, and turbulent. The results indicated that by cooling the PV panels their thermal, electrical, and exergy efficiencies can be improved significantly.[2] Omid Mahian et al. concluded about Nanofluids are advanced fluids containing nano-sized particles that have emerged during the last two decades. Nanofluids are used to improve system performance in many thermal engineering systems. This paper presented a review of the applications of nanofluids in solar thermal engineering.[3]

Saber R. Abballah et al. give information on experimental investigation on the effect of using nano fluid (Al_2O_3- water) on the performance of PV/T system. also add that by increasing water flow rate the efficiencies of PV/T combined system increased and reached the maximum combined efficiency of 40.9 % and 32 % at flow rate of 1.2 l/min at the maximum radiation and average across the day respectively which was the maximum flow of the used pump.[4]

III METHODOLOGY

In conventional solar-powered hybrid system independent photo thermal and photovoltaic units are respectively adopted to collect solar energy. However, an integrated, compact and spectral splitting collector enables NSS-PV/T system to simultaneously harvest the electricity and heat. Through such a design, solar energy at a wide waveband can be efficiently collected, at the same time, the building cost of hybrid PV/T system can also be reduced considerably [5].

Generally, a NSS-PV/T system in CHP application is comprised of solar receiver, heat storage tank, pumps, and heat exchanger. A conventional trough concentrator can be used in the NSS-PV/T system. the solar receiver consists of a borosilicate glass tube with nanofluid flowing inside, a transparent quartz glass cover, two side insulation walls, and the silicon PV cells unit integrated cooling channel. The nanofluid in the glass tube works as not only a spectral splitting filter, but also a medium to absorb and transfer heat [6]. Working principle is shown in Fig.1.

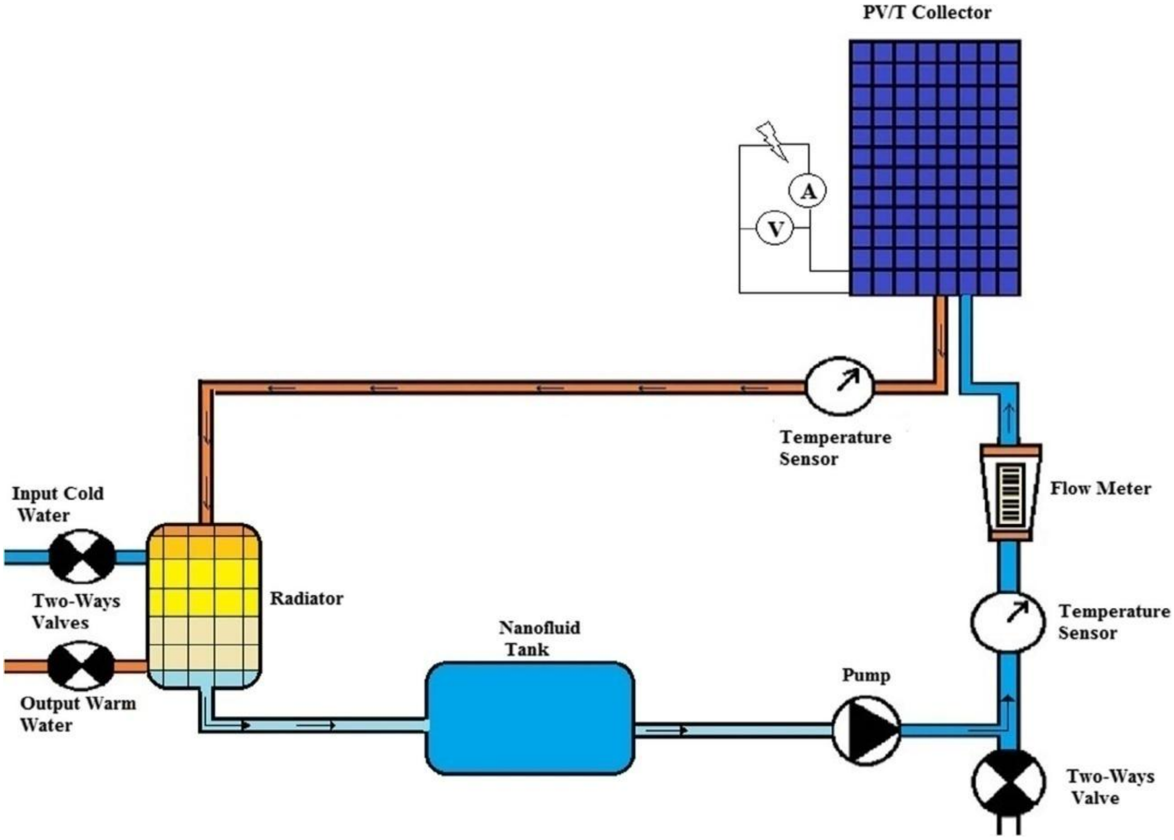

Fig. 1 Working principle

In such a system, concentrated light will pass through the semi-transparent nanofluid channel and reach the PV cells unit. To reduce heat loss of the receiver, the side insulation walls and the transparent quartz glass cover are installed on both sides and the bottom of the glass tube. The enclosure formed by the glass tube and these walls can be kept the vacuum to reduce the heat loss. The capacity of Photovoltaic Laminate is 32 W. the photovoltaic thermal collector is tilted at angle of 43º. Heat exchanger with the same size of PV laminate (650 mm × 550 mm ×10 mm) structure will be prepare from aluminium with baffles inserted inside it. Submersible cooler pump of 80 LPH capacity and head 1.58 m to circulate the water from the entire heat exchanging unit. Digital Temperature Indicator. Sensor will be attaching at inlet and outlet of observer tank, surface of solar laminate and one to measure atmosphere temperature. Experimental model is shown in Fig.2.

Fig. 2 Various views of developed experimental model.

IV. RESULTS AND DISCUSSION

The experiment was performed on the hybrid collector in the month of March and April 2019 at local atmosphere of Vadodara, Gujarat with latitude and longitude of 22.3072° N and 73.1812° E respectively. Readings were taken at the interval of every half an hour from 09:00 a.m. to 6:00 p.m. throughout the day time in real atmospheric condition as noted in Table-1. Local Wind velocity was measured by anemometer. Multi meter was also used for measuring electrical parameter to find power output. The maximum result is obtaining at 1 pm with the use of nanofluid we got 51 V.

Table 1. Result table

TIME	NORMAL AIR	WATER	WATER WITH NANOFLUID
9 AM	42 V	43 V	43 V
10 AM	42 V	44 V	45 V
11 AM	43 V	46 V	48 V
12 AM	44 V	47 V	49 V
1 PM	45 V	48 V	51 V

2 PM	45 V	47 V	51 V
3 PM	44 V	47 V	50 V
4 PM	43 V	45 V	48 V
5 PM	42 V	44 V	48 V
6 PM	39 V	40 V	45 V
TOTAL	**42.9 V**	**45.1 V**	**47.5 V**

TIME VS POWER

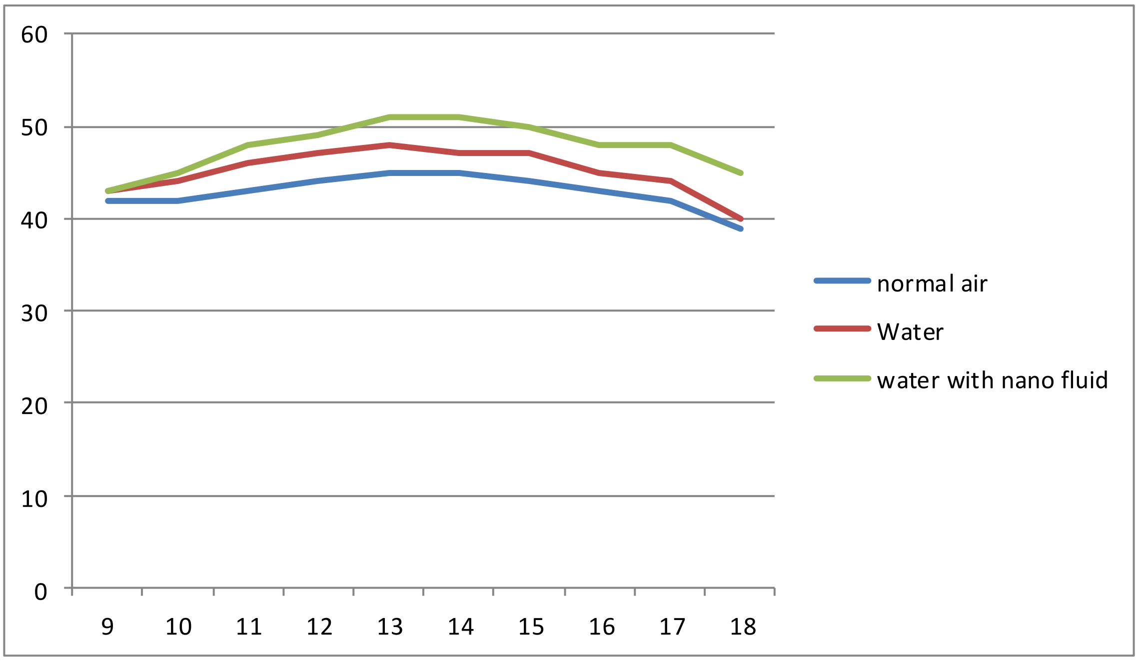

Fig. 3 Time vs Power Graph

V. CALCULATIONS

Here in hybrid PVT solar collector system, it is required to calculate electrical output and efficiency of PV laminate, thermal efficiency of solar collector system independently and after all we need to find overall efficiency of hybrid set up. So, from this we can compare the performance of solo PV module and solar collector with hybridized PVT solar collector system.

R=19 ohms (Ω) and I =0.51399 amp.
IR=897 w/m² AT PV and AREA OF PV =0.02 m

Electrical Power Output of PV module
$P = I^2 \times R = (0.51399)^2 \times (19) = 5.0196$ watts (1)

Electrical Efficiency,
$\eta Electrical = Power / IR \times Area\ of\ PV = (5.0196) / (897\times0.02) = 0.27979 = 27.979\ \%$ (2)

Thermal efficiency,
Mass flow rate=0.001599 kg/sec
Cp=4287 J/kg k, $\Delta T = 6.2$
$Q = m \times Cp \times \Delta T = (0.001599) \times (4287) \times (6.2) = 42.5202$
$\eta Thermal = Q / A\times IR = (42.5202) / (0.1367 \times 87) = 0.3467 = 34.67\ \%$ (3)
Total efficiency $= \eta Electrical + \eta Thermal = 27.979 + 34.67 = 62.64\ \%$ (4)

VI. CONCLUSIONS

- Efficiency of PV panel can be increased by maintaining the standard temperature of solar cell. It is efficient and flexible the combined efficiency is always higher than using to independent system.

- The Nano fluid used for this experiment was Al_2O_3. The initial temperature of water was 35°C and it is raised by 6.2°C after the experiment.
- The efficiency of solar photovoltaic cells was 27.969 % initially and after it is increased to 15 %. Which resulted in output of 51volts which was 42 volts before passing Nano fluid.

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