"Experimental Investigation of Photovoltaic Panel Cooling Using Passive Inserts"

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ABSTRACT

The performance of PV panel depends on the environmental factors, which is solar radiation and operating temperature. These environmental factors will be reduced the effectiveness of PV panel due to increase in operating temperature of PV panel. To improve the performance of Photovoltaic cell different types of augmentation technique are used which include active, passive and combine technique. The passive technique is widely used because it is not required extra power. In passive technique use twisted tape or wire coil different type of insert's which is placed in flowing fluid in tube then turbulence will create. Then laminar flows gets convert in to turbulent flow which result increases in heat transfer rate is used to overcome the problem of low efficiency of Photovoltaic panel with water flow to the backside of PV panel. This water cooling mechanism is one way for maintaining a low operating temperature during its operation period. The experimental results mentioned that the decrement of operating temperature and increase the power output of the PV panel with water cooling mechanism based on solar radiation.

Keywords: *Photo voltaic panel, Heat transfer, Augmentation technique, Insert, thermal efficiency, electrical efficiency, Operating temperature.*

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1. INTRODUCTION:

Nowadays, with the fast development of the global health, the energy crisis has developed into one of the principal issues. Total energy consumption Utilization of solar energy is very less In India the raise of residential area buildings amounts in India, the energy issue has been very serious. For the moment the environment issue brought by the conventional energy consumption structure (coal mainly) and the high solar energy consumption will certainly limit economic development in the future. The solar energy utilization for in the North of India occupies a large percentage of the whole solar energy consumption. The resource of Sun energy in India is abundant, and the annual sunlight hours are more than 2000 h. The solar energy is particularly huge in most heating region in the North of India, which makes the solar buildings possible. Photovoltaic cell is the direct conversion of solar energy in to electric energy by using the photovoltaic principle of semiconductor, is one of the most hopeful utilization technology of solar energy. The photovoltaic technology is rarely restricted by region because the solar energy that reaches the earth is spread out over a large area. Moreover, photovoltaic is a noiseless, pollution-free safe Eco friendly and reliable technology.

However, the photovoltaic effectiveness of common solar cells is between 4% and 17%, which is with sensitivity affected by working temperature. In practical applications, a large portion of solar energy will be stored by solar cells in the form of heat. This part of heat energy is very difficult to be removed from solar cells by natural convection and the resulting increasing working temperature of solar cells leads to a declining photovoltaic efficiency consequently. To improve the performance of Photovoltaic cell different types of augmentation technique are used which include active, passive and combine technique. The passive technique is widely used because it is not required extra power. In passive technique use twisted tape or wire coil different type of insert's which is placed in flowing fluid in tube then turbulence will create. Then laminar flows gets convert in to turbulent flow which result increases in heat transfer rate. is used to overcome the problem of low efficiency of Photovoltaic panel On the other hand, solar thermal is also common application of solar energy. Via heat collectors, the solar thermal energy can be used for heating working fluid. If water is used as the working fluid, the hot water can be produced for domestic use.

Generally, enhancement techniques can be classified in three broad categories:

A. Active Method

Active augmentation, which has been studied extensively, involved some external power input to bring about the desired flow modification for enhancement and has not shown much potential owing to complexity in design. Furthermore, external power is not easy to provide in several applications.

B. Passive Method

This method does not need any external power input and the additional power needed to enhance the heat transfer is taken from the available power in the system .Tube insert devices including twisted tape, wire coil, extended surface and wire mesh inserts are considered as the most important techniques of this group; in which, twisted tape and wire coil inserts are widely applied than others

C. Compound Method

A compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves the complex designs and hence it has limited applications.

2. LITERATURE REVIEW:

2.1 H. Bahaidarah , Abdul Subhan , P. Gandhidasan , S. Rehman

The performance of PV cell (photovoltaic) module is highly dependent relative on its operational temperature. The effect of cooling the module by incorporate a heat exchanger (cooling panel) at its rear surface is also investigated experimentally. With active water cooling, the unit temperature fall noticeably to about 20% leading to an increase in the PV panel efficiency by 9%.

2.2 Ming-Tse Kuo and Wen-Yi Lo:

In this paper, concentrator photovoltaic (CPVs) were used to integrate the removal of Sun light energy and thermal energy. The water cooling system that is proposed in this paper provides effective cooling by circulating cold water to remove heat from the photovoltaic's module.

2.3 Karima E. Amori, Mustafa Adil Abd-AlRaheem:

In the existing work a effective study for thermal and electrical performance of different hybrid PV/T collector's designs for Iraq climate conditions have been carried out. Four various types of air based hybrid PV/T collectors have been produce and tested. The PV/T collectors consist of four important parts namely, channel duct, glass cover, axial fan to circulate air and two PV panels in parallel connection.

2.4 Tony Ho, Samuel S. Mao and Ralph Greif:

The solar concentration limit for densely packed, high-concentrated photovoltaic (HCPV) cells was analyzed for a novel two-phase cooling design. Eight working fluids were examined in the two-phase cooling analysis: R134a, R11, R113, R114, R123, R141b, water, and ammonia.

2.5 Feng Shan, Fang Tang, Lei Cao, Guiyin Fang:

Building integrated photovoltaic (BIPV), a new concept in solar power generation field, refers to integrating the photovoltaic array into the retaining structure surface of buildings to provide electric power. Photovoltaic (PV) is the key technology in the applications of BIPV, and how to improve the photovoltaic conversion efficiency has obtained more and more attention. In this paper, a brief review on the photovoltaic–thermal (PVT) solar collector and system using various working fluid was presented.

2.5 Jin-Hee Kim, Se-Hyeon Park, Jun-Tae Kim:

In this study, a PVT air collector with a mono-crystalline PV module was designed, and an experiment was performed in order to confirm its electrical and thermal performance in an outdoor environment. Therefore, it was concluded that the heated air taken from the PVT collector can be supplied into the ventilation system in building as pre-heated fresh air, and contribute to better electrical performance at the same time.

2.7 Alok Kumar, Manoj Kumar , Sunil Chamoli:

This paper focuses on comparison of some of the most commonly used insert geometries. Insert geometry selected for this comparison is collection of core fluid disturbance, surface modification and combination of both. Different geometries taken in this study include twisted tape, twisted tape with ring, circular band, multiple twisted tape, twisted tape with conical rings, and so on and used air under turbulent flow regime as working fluid..

2.8 Mohammad Sardarabadi , Mohammad Passandideh-Fard , Saeed Zeinali Heris:

In this research, the effects of using nanofluid as a coolant on the thermal and electrical efficiencies of a PV/T (photovoltaic thermal unit) are experimentally studied. Coolant fluids in the experiments are pure water and silica (SiO_2)/water nanofluid 1% and 3% by weight (wt %). When using the silica/water nanofluid of 3 wt%, however, the increase is 7.9%..

2.9 Shashank S. Choudhari

Studied wire coil of different material like as copper, aluminium and stainless steel. He concluded that Nusselt number for tube in which coil wire insert are higher than that of without coil wire insert tube. Because of coil wire insert it creates some disturbance between flowing fluid and it develop boundary layer near the wall of pipe. Then temperature of the fluid is increases because contact surface area is increases.

2.10 Mr. Amit Waghode ,Mr. M.D. Shende:

The present review paper is on the performance of tube in tube type heat exchanger with different types of inserts. Heat exchanger are widely used in many mechanical industries, power plant etc. it is required to optimize the performance of heat exchanger. Therefore augmentation technique is used which include active, passive and combine technique.

3. OBJECTIVES

- To calculate the heat transfer coefficient for three various twisted ratio of the twisted tape insert.
- To calculate the Nusselt number at various twisted ratio with increasing the Reynolds Number.
- To study the friction factor at various Reynolds numbers.
- To study the thermal efficiency and electrical efficiency of the solar panel.
- Calculate the thermal and electrical performance of the panel.

4. EXPERIMENTAL SET-UP

The experimental setup is PV module (poly-crystalline type 40W rated power) is shown in fig 1.The experimental setup consist of two sections. The pipe section and control section. The pipe section consists of twisted tape inserts made of copper material and well insulated test section pipe. The control section consists of the photovoltaic cell, centrifugal pump, water flow meter, thermocouple, digital temperature indicator, tube arrangement, insert, ball valve, gate valve, water storage insulating tank, body frame. A schematic diagram of the complete setup is also shown in fig. 2 the cooling system is attached to the rear side of the Solar panel and equipped with proper tubing arrangement inlet / outlet port for the water flow. The specification of the PV module is given in table no.1 respectively. The cooling water and heating water both are stored in an insulated tank connected to the PV system through pipes with twisted tape insert. A water pump is used to circulate the water through the tank to the PV panel. The maximum allowable flow regulates by using flow control valve. The water carrying the heat for the solar panel water get heated. The heated water back to the storage tank (with valve arrangement) has been added to ensure it does not exceed the pressure limit. To regulate the water flow inside the cooling panel, a flow-meter with maximum flow rate of 8 L/min is used. The cooling water flows through the solar system, captures the waste heat from the PV panel and produce hot water which is collected at the solar panel system outlet. The water temperature is measured using standard type – k thermocouples attached at the inlet on panel roof, on tubes and outlet of the cooling panel.

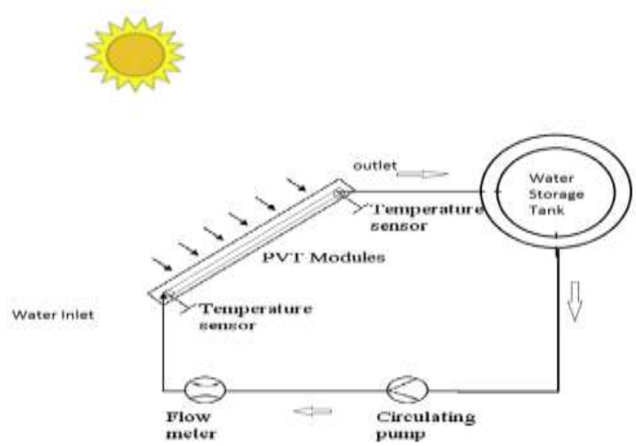

Fig.1.Schematic diagram of the experimental test setup

Fig.2 Experimental setup

Table 1: PV panel Specifications.

Electrical data	Value
Module type	NSA40
Maximum power (Pmax)	40 W
Maximum power voltage (Vmp)	17.84 V
Maximum power current (Imp)	2.25 Amp
Open circuit voltage (Voc)	21.95 V
Short circuit current (Isc)	2.44 Amp
Operating temperature	25 °C
Mechanical data	
Cell type	Poly-crystalline
No. of cells and cells arrangement	60 (6 * 10)
Dimensions (mm)	762 * 457.2 * 25 mm
Weight	7 – 9 kg
Front cover	Tempered glass
Frame material	Anodized Aluminium Alloy

5. PROCEDURE

Firstly the experimentation is performed without insert present inside the tube and back side of PV panel. Before start the Experiment to measure the temperature of roof and atmosphere as well as test section by using thermocouple. Then start the centrifugal pump the water flow is passed through the panel inlet to the without twisted tape insert with increasing flow rate (0.12, 0.24, 0.36, 0.48 lit/hr) to measure the temperature of atmosphere, roof, inlet, tube, outlet and test section by using thermocouple. Due to sun rays the temperature of solar panel increases for required cooling for solar panel to start the centrifugal pump. Water flow rate is measured by flow meter and flow is regulating by using the gate valve and note down the reading. In this phase, twisted tape insert with different twisting ratio (4, 3, and 2) fitted inside the tube and start the flow of water by increasing order and increasing the cooling rate of solar panel and enhanced the heat transfer rate and thermal efficiency. Take out the previous test without twisted tape insert and then replace it with the help of twisted tape insert with different twisting ratio. Start the pump the water is passed through the panel inlet to the panel by using twisted tape insert with increasing flow rate (0.12, 0.24, 0.36, 0.48 lit/hr) to measure the temperature of atmosphere, roof, inlet, insert, outlet and test section by using thermocouple. Take the reading of all the thermocouples (T1, T2, T3, T4, T5, T6, T7, and T8) at an interval of one hour. Calculate the heat transfer rate, heat transfer coefficient and thermal efficiency comparing with and without twisted tape insert. Start the set up and then follow the same procedure as above and note down the readings.

6. DATA CALCULATION AND ANALYSIS

1. Bulk mean temperature

$T_{mean} = (T_{b1} + T_{b2}) /2$

Where, Tb1 and Tb2 are the temperatures of base plate at two points in °C.

2. Cross sectional area of pipe

Acs = (3.14/4) * D*D

D = diameter of pipe in m.

3. Mass flow rate

m = rAV

r = Density Kg/m^3

A = Area m^2

V = Velocity m/s

m = mass flow rate kg/sec

4. Heat transfer rate

$Q = m*cp*(T_{b2} - T_{b1})$

Q = heat transfer rate, W

m = mass flow rate kg/sec

Cp = specific heat of water J/Kg –K

$T_{b1} =$ bulk temp at inlet °C

$T_{b2} =$ bulk temp at exit °C

5. Heat transfer coefficient

$h = Q/ As*(T_w - (T_{b1+} T_{b2})/2)$

h = heat transfer coefficient W/ $m^{2\,k}$

Q = heat transfer rate, W

As = Heat transfer area =3.14* D* L= m^2

D = diameter of tube in m.

L = length of tube in m.

Tw = wall surface temp °C

= (T4+T5+T6+T7)/4

T_{b1} = bulk temp at inlet °C

T_{b2} = bulk temp at exit °C

6. Pressure drop

$\Delta P = \rho \times g \times h$

r = Density Kg/m^3

g = acceleration due to gravity m/s^2

h = height in m

7. Reynolds's Number

$Re = (\rho * D * v) / \mu$

r = Density Kg/m^3

D = diameter of tube in m.

V = velocity in m/s

μ = Absolute viscosity $N\text{-}s/m^2$

8.Nusselt Number

$Nu = h*D/ k$

h = heat transfer coefficient $W/ m^{2\,k}$

D = diameter of tube in m.

K = thermal conductivity W/m-k

9. Friction factor

$f = \Delta P \times 2 \times D / Lt \times \rho \times v^2$

ΔP = pressure drop N/m^2

D = diameter of tube in m

Lt = length of tube in m.

r = Density Kg/m^3

V = velocity in m/s

10. Thermal efficiency

η_{th} = m Cp (To-Ti)/ Gap

m = mass flow rate kg/sec

Cp = specific heat of water J/Kg-K

T_o = outlet temperature

T_i = inlet temperature

Gap = solar panel area

11. Electrical efficiency

e = Ppv /Gap

P_{pv} = PV module power

G_{ap} = solar panel area

Comb = η_{th} + e

th = thermal efficiency

e = electrical efficiency

7. RESULT AND DISCUSSIONS

The performance of PV system depends on several climatic factors such as solar radiation, ambient temperature and wind speed since the maximum power point on the current – voltage performance factors. The module temperature is linearly proportional to irradiance. In case of without cooling, the module temperature reached to about 45°C and with cooling the module temperature is reduced to 34°C due to heat absorbed by water. Hence they used twisted tape insert on increasing cooling heat transfer rate and efficiency.

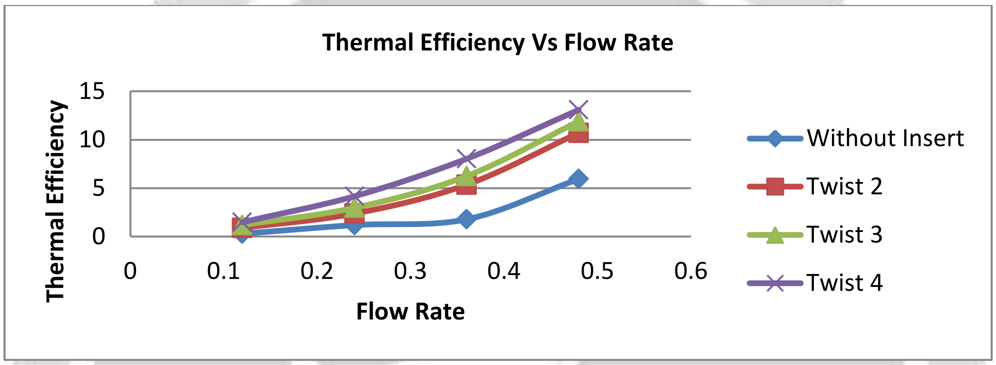

Fig 1 The variation of the thermal efficiency with flow rate

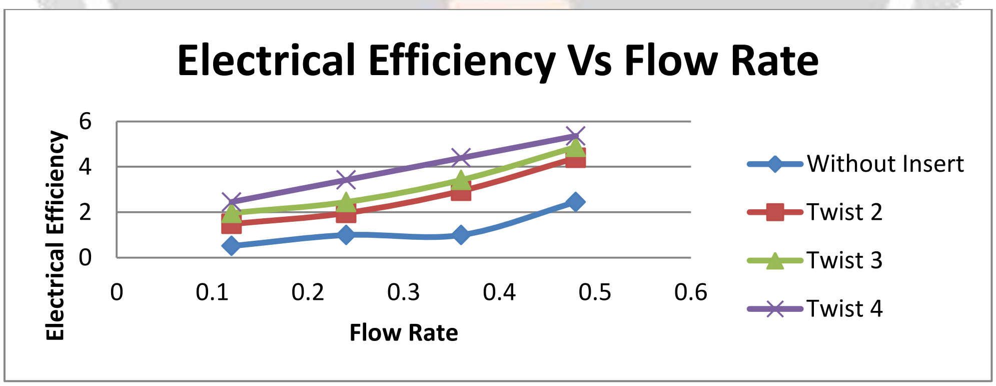

Fig 2 The variation of the electrical efficiency with flow rate

Case I - The first time carried out the experiment without insert the roof temperature of the panel is obtained the time water is circulate to the system is on without insert with different flow rate (0.12, 0.24, 0.36, 0.48 Lit/hr) heat the thermal efficiency is 0.69% obtained same operation performed in gradually increasing flow rate then thermal efficiency and electrical efficiency is improved gradually. Fig.1 and fig. 2 the higher flow rate with thermal efficiency. The water passing to tube the heat transfer rate also increased with increasing flow rate. The water circulation to the system the small water inlet and outlet temperature difference 1^0 -2^0 obtained. Flow rate is increase the temperature difference of water is increased.

Case II - Experiment is carried out with twisted tape insert. The roof temperature is when Twisted tape twist ratio 2 twisted insert placed inside the water tube with different flow rate and start the water circulation system due to twisted tape turbulence is increased in the water flow. The heat transfer rate increased with used in twisted tape insert the temperature difference of the inlet and outlet is small higher than the without insert is 4^0-5^0 C water-circulation cooling system can be turned on to perform the water cooling operation, which helps improve the solar cell's Thermal efficiency and electrical efficiency by 8.29%–2.37%.

Case III - The water-circulation cooling system with twist ratio 3. The water temperature difference between the inlet and outlet is quite higher than the twist ratio 2. Temperature difference is 6 - 8^0C also heat transfer enhancement is also quite higher than above two conditions. When the twist ratio of the twisted tape is increased the turbulence of the flow is increased the heat transfer of the panel is more. When decrease in solar cell temperature of around 1 °C leads to a increase in efficiency of about 0.45%. The solar cell's Thermal efficiency and electrical efficiency is 10.29%–3.37%.

Case IV - The experiment carried out twist ratio is 4 with different flow rate water is flowing through the panel due to twisted tape with twist ratio is four more turbulence is created and the heat transfer enhancement is increased at the time. If the results of the analysis using twisted tape the water-circulation cooling system are used, with twist ratio 4 the thermal efficiency and electrical efficiency is can achieve an improvement of 15.85%–5.39879% in terms of the overall efficiency.

The performance of the PV panel is improved and due to heating of panel hot water also obtained for the outlet of the panel.

8. CONCLUSIONS

The experimental analysis of a PV-water cooled with twisted tape insert system studied regarding its thermal performance. The system is tested under the climatic conditions of Nagpur, (Maharashtra). Based on the results obtained, the following conclusions are drawn:

1. A detailed experimental set up (coupled thermal) capable of predicting the thermal performance of the water cooled PV system is carried out using different mass flow rate with twisted tape insert of different twist ratio (y/W = 2, 3, 4 etc.) and A solar PV panel (cooling panel) is fitted underside of the PV panel which captures the waste heat from the panel producing hot water and increased performance of PV panel.
2. The effect of twisted tape insert and water as a cooling medium for solar PV panel studied experimentally. The efficiency of PV panel sensitive to the panel temperature, as temperature increases the efficiency of the PV panel decreases. The passive cooling technique, the operating temperature of the module reduced significantly to about 10-$11^0$and an increase the thermal and electrical efficiency about 13% & 5%ewas observed respectively.
3. An increase in solar cell temperature of around 1 °C leads to a decrease in efficiency of about 0.45%.To prevent decreased efficiency due to heating, a visibly transparent silica crystal layer can be applied to a solar panel.
4. Friction factor reduces, as the Reynolds number increases. This is because with increase in Reynolds number, velocity increases. As friction factor is inversely proportional to velocity, friction factor decreases. This friction factor is found to be more in higher twisted tape Ratio(y/w =4).
5. As the velocity increases friction factor decreases because friction factor is inversely proportional to velocity of water.

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