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Experimental Performance Analysis of Solar Photovoltaic Thermal Collector

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Abstract- A solar photovoltaic thermal (PV/T) is a hybrid combination of solar photovoltaic (PV) collector and thermal collector. In this research paper, experimental analysis of the oscillatory type (PV/T) water collector has been done to find the efficiency of this type of system and also comparison of its electrical efficiency with simple photovoltaic panel. In this experiment, 160W of polycrystalline solar panel and 0.127m diameter of copper pipe are used to build solar photovoltaic thermal collector. Fluent flow is 0.5 liter per minute. In this condition, electrical efficiency is found 600 Wm^{-2} heat flux, which is 9.5% and maximum value of hot water output is 311K. Average thermal efficiency is about 21.5% for same condition.

Indexed Terms- Photovoltaic-thermal collector, Heat Transfer, Electrical efficiency, Thermal efficiency.

I. INTRODUCTION

Generally, solar photovoltaic collector has the efficiency of 10~20% at its standard temperature about 25ºC. When the temperature is greater than its operation temperature, the efficiency will drop. The efficiency of the photovoltaic collector drops about 0.3% with cell temperature increased by 1ºC [1]. To solve this problem, researcher investigated the system of SPVT. Solar photovoltaic thermal collector (SPVT) is the modified technology of normal solar photovoltaic collector. The main function of this collector is to reduce the temperature of the cells and reuse this removed temperature as thermal energy in other pre-heating process. So, SPVT can change solar energy to electrical energy and thermal energy directly.

Two are the main benefits related to PVT technology: first, the efficiency of PV cells can be increased by actively cooling the PV laminate and the removed heat can be subsequently used. Second, incorporating a PV and a thermal system into a single unit, the total area dedicated to solar energy devices can be reduced. For these reasons, many studies concur that a well-designed hybrid system can achieve better performances compared to two separated systems. [2] There are two main types of collectors, water based solar photovoltaic thermal collector and air based solar photovoltaic thermal collector. Basically, thermal conductivity of water at 20˚C is 0.6 Wm^{-2}K^{-1} and air is 0.024 Wm^{-2}K^{-1}. Convection coefficient of water is 50-3000 Wm^{-2}K^{-1} (depend on flow rate) and air is 10-1000 Wm^{-2}K^{-1} (depend on flow rate). Thus, the most investigated PVT technology in recent time is based on systems using water as the heat transfer fluid, because they achieve higher overall efficiencies than air systems, due to the higher heat capacity of water. [3]

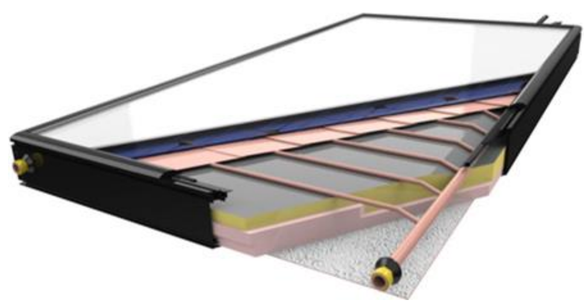

Figure.1 Water-based solar photovoltaic thermal collector

II. CONSTRUCTION OF PV/T

Solar photovoltaic thermal collector is constructed by using polycrystalline silicon solar panel is used as the energy collector from sun. that is 160W. Dimension of photovoltaic collector is 1.49m length and 0.67m width. Behind the panel 0.127m diameter of copper sheet and 1mm thickness of copper tube is attached. Copper sheet acts as an absorber, which absorbs heat from the panel and transfers it to coolant fluid flowing in copper tubes. In SPVT, cooling pipe design is oscillatory flow for it is easy to manufacture and low pressure drop than other design. According to the calculation results, width to diameter ratio is 6. Width to diameter ratio is the ratio of distance between cooling pipes and diameter of the cooling pipe. This system is installed at the roof top of the TRC building in the Yangon Technological University, Myanmar. A pump is used to circulate the coolant in the system. Water is used as a coolant in the system. For measuring electrical data, multimeter and Arduino kit are used as measuring devices. For measuring thermal data, thermocouples and data logger are used in this system. Figure 2 is the cooling pipe line of constructed photovoltaic thermal collector and figure 3 is the front view of constructed photovoltaic thermal collector.

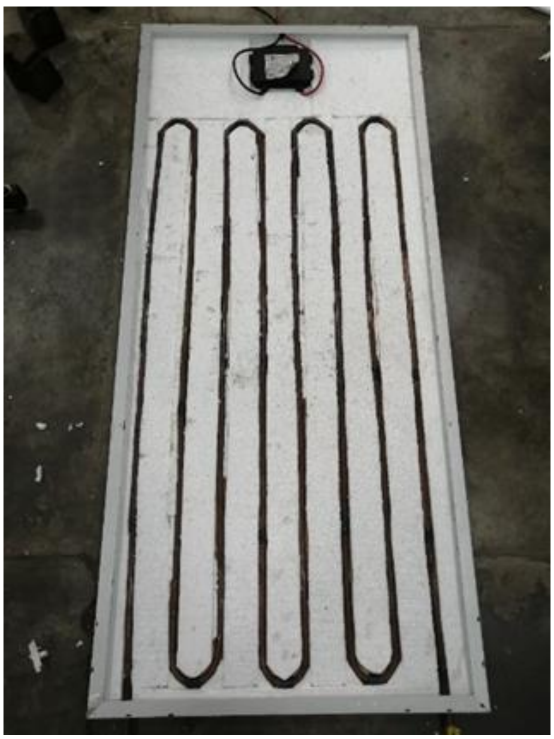

Figure.2 Cooling system of solar photovoltaic thermal collector

Figure.3 Front view of solar photovoltaic thermal collector

III. THEORY AND CALCULATION

In the experiment, the properties of water have been taken-
Density (ρ) = 998.2 kgm^{-3}
Specific heat capacity (C) = 4200 $Jkg^{-1}K^{-1}$
Viscosity (μ) = 0.001003 ($kgm^{-1}s^{-1}$).

Inlet water temperature is 300 K, and outlet pressure is atmospheric pressure. For the stagnant air, the free convection heat transfer coefficient on the PV panel is 10 $Wm^{-2}K^{-1}$(assume). Experiment is carried out on water Flow rate (Q) is taken 0.5liter per minute. The electrical efficiency of PV panel, as a function of cell temperature, is obtained by the following equation [4].

$$\eta_{el}=\eta_{ref}(1-0.0045(T_c-298))$$

Where η_{ref} is the efficiency of the PV module at the reference temperature [5], and Tc represents cell temperature.

The thermal efficiency of collector is obtained by the following equation [6].

$$\eta_{th}=\frac{\rho QC(Tout-Tin)}{IA}$$

Where A is the surface area of the PV panel;
T_{in}- inlet temperature of water (K);
T_{out}- outlet temperature of water (K);
I - heat flux (W/m2).

IV. EXPERIMENTAL ANALYSIS

In experimental analysis, there are two types of collectors are used. There are normal photovoltaic collector and solar photovoltaic thermal collector. Figure 4 shows the normal PV and PV/T.

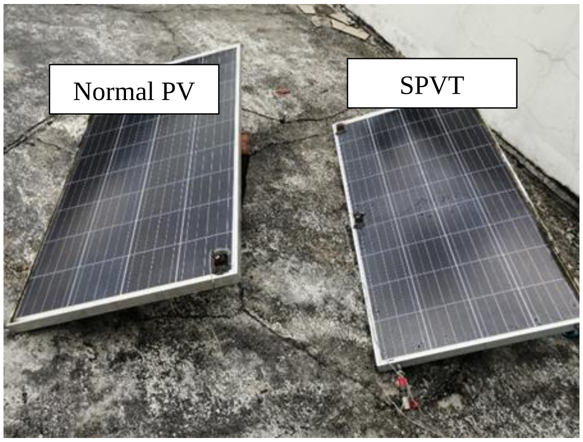

Figure .4 Front view of solar photovoltaic thermal collector

Solar radiation data and ambient temperature are received from weather station that installs in Yangon Technological University. Figure 5 is data logger of weather station.

Figure.5 Vantage pro 2 data logger

Arduino data logger is used for electrical data saving. Thermocouple and data logger is used for thermal data collection. Figure 6 is Arduino data logger and figure 7 is temperature data logger.

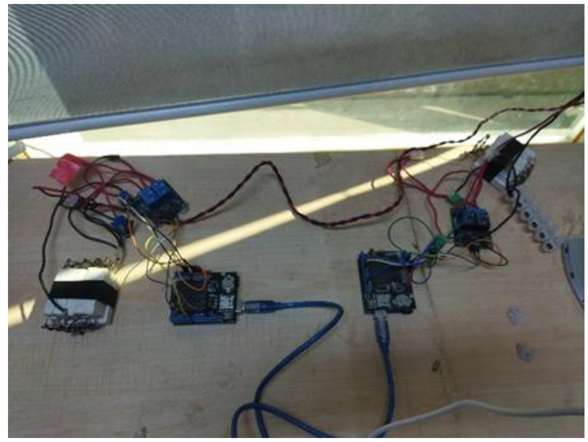

Figure.6 Data logger for electrical data

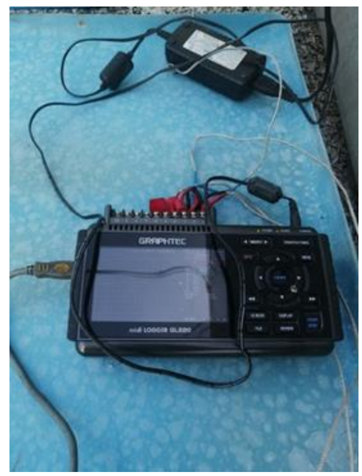

Figure.7 Data logger for thermal data

V. RESULTS AND DISCUSSION

Figure 8 shows the solar radiation data of the test day from 9 am to 3 pm. At 9 am, solar radiation is 400 Wm^{-2}. Solar radiation is sightly higher and highest point of solar radiation is about 850 Wm^{-2} that is at noon. And then, solar radiation is slightly down to 500Wm^{-2} at 3 pm. Between 1 pm to 2 pm is very low solar radiation because of cloudy situation.

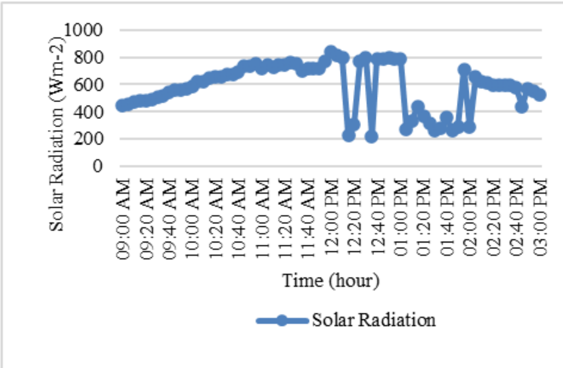

Figure. 8 Solar radiation data in test day

After experiment, inlet water temperature and outlet water temperature are received from the temperature data logger. Figure 9 is temperature of inlet and outlet water. At 9 am, the different between inlet and outlet water temperature is about 5 ºC. temperature difference is not highly change along the experiment. Average temperature difference is about 6 ºC.

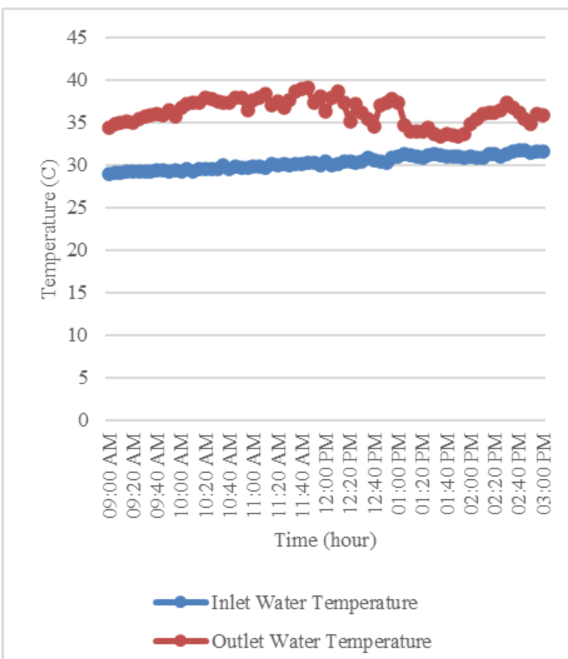

Figure. 9 Inlet and outlet Water Temperature of SPVT in test day

Figure 10 is current output of normal PV and SPVT. The difference between normal current output and SPVT current output is about 0.5A. In the cloudy situation, the current outputs are same.

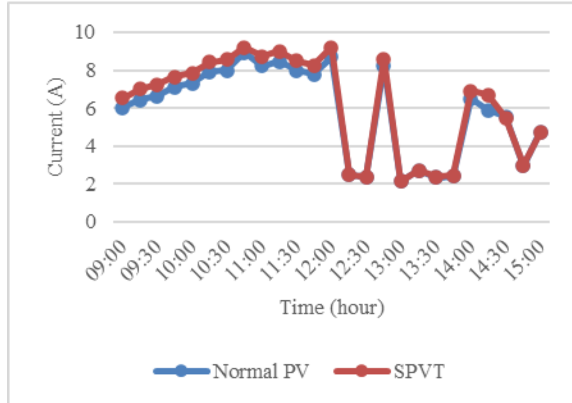

Figure 10 Short circuit current of Normal PV collector and SPVT collector

Figure 11 is open circuit voltage of normal PV and SPVT. After calculation, the results of power output are as shown in figure 12.

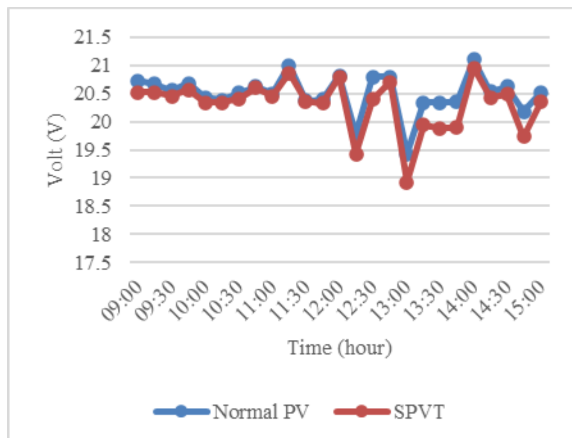

Figure 11 Open circuit voltage of Normal PV collector and SPVT Collectors

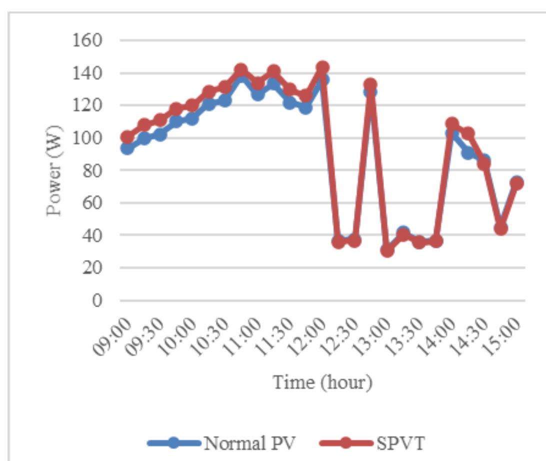

Figure 12 Power output of PV and SPVT

After calculations the output results, the overall efficiencies of normal PV and SPVT are shown in figure 13. The electrical efficiency of PV is 9% and SPVT is 9.5%. So, the electrical efficiency of SPVT is a little higher than normal PV. At the same time, there is no thermal efficiency of PV but thermal efficiency of SPVT is 21.5%.

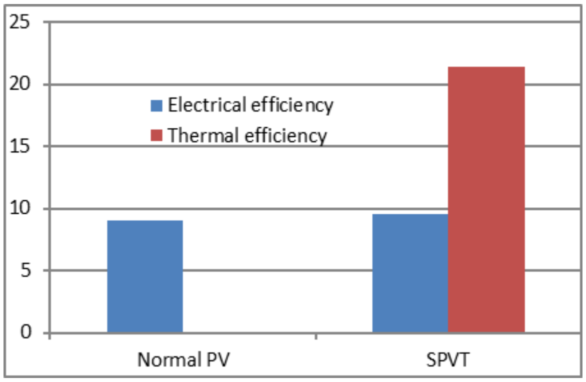

Figure 13 Overall Efficiency of Collectors

CONCLUSION

Experimental analysis of oscillatory flow SPVT collector was carried out. Along the experiment, weather condition is cloudy situation. PV panel surface and water outlet temperature were evaluated on heat flux 600 W/m^2.Water inlet temperature is 303 K, and flow rates is 0.5 L/min. In Experimental analysis, electrical efficiency is 9.5% and thermal efficiency is 21.42%. Overall efficiency is 30.92% and that is 21.92% higher than the normal PV.

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