# Short Review on Recent Trends in Solar Photovoltaic/Thermal Water Collector Systems

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## Abstract

Energy obtained from the sun is known as solar energy. Various applications of solar energy include electricity production, water heating, distillation, drying of foods, cooking, etc. In this study we focused on reviewing literatures on hybrid solar photovoltaic thermal process and its performance enhancement. With an aim of improving performance further, numerous research works are conducted by solar photovoltaic thermal based researchers. Such highlighted works are consolidated in terms of electrical and thermal power output. In addition, this paper also highlights results of various machine learning based papers in the field of solar photovoltaic thermal system.
**Keywords: solar, PV/T, review, experimental and machine learning**

## I. INTRODUCTION

Among various sources of renewable energies, the energy obtained from the sun is considered as the principal source of all. A device which converts such energy from the sun into required mean is known as solar energy conversion devices (SECD). Photovoltaic (PV) module is an SECD which converts solar energy into electricity. Another SECD which converts solar energy into thermal energy is known as flat plate collector (FPC). Solar photovoltaic thermal (PV/T) water collector is a hybrid SECD which converts solar energy into thermal and electrical energy simultaneously. Fig.1 presents the schematic layout out of solar PV/T system.

## II. LITERATURE REVIEW

Ali et al. [1] the main function of such design is to provide cooling for the solar cell by absorbing its temperature High electrical and thermal efficiencies are associated with PV/ T's. In this study, mathematical analysis was used to examine the effect of the type of nanoparticles added (SiC, CuO, and Al2O3), and the type of base fluids (water, glycerin, and ethylene glycol) on the convection heat transfer of PV/T system The numerical results showed the base fluid and the added nanoparticles' thermophysical properties effect on the convective heat transfer and pressure drop. Glycerin showed the maximum pressure drop while water indicated minimal value. The numerical results showed a clear impact of the thermophysical properties of both the base fluid and the added nanoparticles. The addition of nano-SiC for any of the studied base fluids gave the maximum convective heat transfer compared with the other nanoparticles. The validation of the numerical results with the practical one showed a good agreement.

Hashim et al. [2] performance solar water heating for flat plate collector. Designed as lope square pattern, used the water as fluid flow working with two different flow rate (5.3 and 6.51L/min). The result shows that the water at flow rate 5.3L/min heated more than the flow rate 6.51L/min, which causes the higher efficiency and effectiveness of the collector, so the maximum temperature was (51.4°C and 49°C) at flow rate (5.3L/min and 6.51L/min) respectively.

Kazem, A. [3] the proposed PV/T shows superior electrical performance during the examination period, with consistent rises in electrical efficiency over conventional PV. The peak electrical power and voltage achieved by the system are around 67 Wp and 18.9V, respectively. The average power of the PV/T panel is 6% higher than average power of conventional PV panel. The voltage waveform is highly affected by cell temperature, which is highly influenced by heat transfer from PV panel to thermal collector. Increase in cell temperature causes an increase in short-circuit current of the PV, which is consistent with the literature. The use of rectangular absorber shape is very productive to reducing heat of PV panels as it covers more surface area and hence more heat transfer.

Al-Waeli et al. [4] examines existing evaluation criteria and proposes four novel methods for PV/T evaluation, namely yield per area/space, yield per weight, yield bias, and cost of yield. The tested systems are PV, Water-based PV/T and PV/T with Phase Change Material (PCM) and water as a coolant.

Abdullah et al. [5] this paper discusses experimental data utilizing in the MATLAB program with indoor experimental studies of the water-based PVT system and compare the results of the new design dual oscillating absorber of the PVT water system with a normal PV panel without a cooling system. The results show that increasing the mass flow rate and solar radiation leads to an increase in the thermal and total efficiency, but after the optimal value, the thermal and total efficiency decreases.

Hossain et al. [6] novel parallel serpentine pipe flow-based PV/T has been designed, developed and studied. The experiments were performed at different volume flow rates viz. 0.5-4 liters per minutes (LPM) to optimize the designed and developed PV/T. Maximum thermal efficiency of PV/T system was found to be as 76.58% at 2 LPM. Electrical efficiency of PV and PV/T-only was found to be 9.89% and 10.46% respectively. The maximum exergy efficiency of PV and PV/T system has been found 7.16% and 12.98% (0.5LPM) respectively.

Kianifard et al. [7] water PV/T collector with a serpentine half pipe instead of a full circle pipe has been evaluated. In this novel design, the thermal efficiency of 70% and electrical efficiency of higher than 11.5% is obtained. The thermal efficiency of the proposed model is greater about 10 to 13% and the electrical efficiency of about 0.4 to 0.6% compared to conventional models

Hamid et al. [8] an overview of Photovoltaic Thermal Combination system (PV/T Combo), with a combination of photovoltaic panel with air- and water-based systems as one unit. The combination of these two types of heat carrier is to cover the limitations and weaknesses of independent PV/T water and air heat collector systems. The configuration of the system also introduced low-cost cooling effect such as fins and ribs. The upgrading system by combining both types of heat carrier modes allows better performance of the PV/T technology as well as allows gaining higher efficiencies

Fudholi. et al. [9] proposed that the electrical and thermal performances of photovoltaic thermal (PVT) water collectors were determined under 500–800 $W/m^2$ solar radiation levels. At each solar radiation level, mass flow rates ranging from 0.011 kg/s to 0.041 kg/s were introduced. The performances of three PVT water collectors were observed. It was inferred that the efficiency of the PV module increases when the temperature decreases. The decrease in temperature is not proportional to the mass flow rate increase.

Wu et al. [10] a critical review on the essential thermal absorbers and their integration methods for the currently-available PV modules for the purpose of producing the combined PV/T modules. Compared to traditional thermal absorbers, such as sheet-and-tube structure, rectangular tunnel with or without fins grooves and flat-plate tube, these four types, i.e. micro-channel heat pipe array/heat mat, extruded heat exchanger, roll-bond heat exchanger and cotton wick structure, are promising due to the significant enhancement in terms of efficiency, structure, weight, and cost.

Suganthi et al. [27] identified the uses of fuzzy based modelling in renewable energy systems. Fuzzy logic controller (FLC) is being widely used in solar PV applications for MPPT. Also, FLC are predominantly used for controlling the intermittent energy flow from the renewable energy sources. Neuro-fuzzy logic controllers are being used in wind energy systems. In addition, it is found that other fuzzy based hybrid models such as fuzzy AHP, fuzzy DEA, fuzzy GA, fuzzy PSO, fuzzy honey bee optimization are being explored in the modelling of solar, wind, bio- energy applications.

Vafaei et al. [23] conducted experiments to evaluate a flat-plate solar collector performance of thermosiphon solar water heating system. A fuzzy inference system was developed to predict the efficiency of the solar collector. In our fuzzy inference system, we only utilize ambiance temperature, input and output temperature of the solar heating system. The predicted values were found to be in close agreement with the experimental counterparts with 0.9469,3.13, 6.96 coefficient of determination, root mean square error and average forecasting error respectively.

Zhai et al. [26] explored the role of consumer acceptance and model its effect on residential photovoltaic (PV) adoption develops a fuzzy logic inference model to relate consumer perception variables (inputs to the model) to their purchasing probability (output from the model). The peak of the purchasing probability distribution of adopters is at 100%, for non-adopters, it is at 20%. The difference between mean value of the probability is 30%.

Zainal et al. [11] conducted experimental study to maximize the PV panel output via the combination of the PV cooling system and FL-based MPPT. The main objective of this study is to develop an efficient stand-alone PV system with a cooling system using an FL controller-based boost converter. Applying FL to the CV method enabled MPP to be tracked easily and efficiently in a short time before the voltage was boosted twice as much as the input value. This increase in voltage output, VOUT of 1.96% led to an improved performance and enhanced stability.

Guenounou et al. [22] proposed an approach in which the fuzzy controller with an adaptive gain as a maximum power point tracker. The proposed controller integrates two different rule bases (fuzzy rules defined on error and change of error). The first is used to adjust the duty cycle of the boost converter as in the case of a conventional fuzzy controller while the second rule base is designed for an online adjusting of the controller's gain. Simulation results show that the proposed controller can track the maximum power point with better performances when compared to its conventional counterpart.

Farajdadian et al. [14] conducted experiments in symmetric and asymmetric fuzzy logic controllers. Fuzzy controller is optimized using Firefly Algorithm (FA) to generate the proper duty cycle. PV system with FLC-FA is compared with other methods like perturbation and observation (P&O) and fuzzy controller- Particle swarm optimization (PSO).

Shuvho et al. [25] conducted experiments on the heuristic models as well as grid connected PV systems which is important for power system operation and planning. Solar irradiation predict model based on fuzzy logic and artificial neural networks which aims to achieve a good accuracy at different weather conditions. As the results, the accuracy of fuzzy logic model was obtained 97.47% and the accuracy of ANN model was obtained 98.78% with the actual irradiation. So, performance of ANN model is better than the fuzzy logic model for solar irradiation prediction.

Zoukit et al. [12] designed a Takagi-Sugeno (TS) based performance prediction model. Indirect solar dryer prototype that can operate in both natural and forced convection modes, at various weather conditions. The predicted behaviours are identical to the experimental ones with an RMSE (RMSE%) that remains under 0.4 ℃ (0.81%) in natural convection and 0.52 (1.94%) in forced convection.

Rizwan et al. [24] conducted on experiments on smart grid applications, particularly for sizing the photovoltaic system and demand driven supply. The results obtained from the proposed fuzzy logic-based model are compared with reference data and it is found that the percentage error is within permissible limits that are about 5% for all stations considered in this work

Khairul et al. [13] the fuzzy logic expert system (FLES) for heat transfer performance investigation in helically coiled heat exchanger with spirally corrugated wall operated with water and CuO/water nanofluids. robust fuzzy knowledge-based rule has been formulated to predict heat transfer coefficient and friction factor characteristics in helically coiled heat exchanger with spirally corrugated wall operated with water and CuO water nanofluids and finally it is compared with the calculated data.

## III. CONCLUSIONS

The following conclusions are inferred from this review study

1) The solar PV module performance is more sensitive to its operating temperature [15] & [16].
2) Solar photovoltaic thermal water system (passive type) is a hybrid device which converts the principal solar energy in to thermal and electrical energy simultaneously [17] & [18].
3) Electrical output of the fully covered PV/T system is greater in comparison with partially covered PV/T system. While in thermal aspect, the partially covered system is higher [19].
4) Parallel and series connected solar photovoltaic thermal water system generates higher power output than the stand-alone photovoltaic thermal water system [28].
5) Parallel connected solar photovoltaic thermal water system generates 5-16% higher power output than the series-connected rig.
6) SECD is more sensitive to its atmospheric conditions. Therefore to predict the performance of such SECD, a cognitive model with high prediction accuracy is in demand [20].
7) Any photovoltaic thermal water system performance prediction model which requires lesser number of data sets and capable of predicting the performance of the SECD is also highlighted as a research gap [29].

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