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A Review: Comparative Study of Hybrid PV/T Water Collector

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Abstract

The objective of this paper is to review the collection of literature available on the Photo Voltaic and Thermal Solar Collector. The review paper is presented to show the comparison of findings obtained by various research works. In solar collector, the solar energy from the sun is converted in to electrical energy by means of Photo Voltaic panel and thermal energy by converting cold water into hot water. Nowadays, solar collector is preferred in many industries and house hold applications to reduce the demand of electricity by increasing the effective utilization of solar energy coming from the sun. The selection of collector design plays vital role in the development of heat energy and electrical energy. The input process parameters such as type of collector, time, mass flow rate, flow direction, flow pattern and size of the flow tube are normally considered for the research work and the output responses like thermal efficiency and electrical efficiency are appraised by using the Photo Voltaic Thermal Hybrid Solar Collector. Normally experiments are to be conducted based on the recommendation by the Traditional and Non-Traditional techniques. The output efficiency of the solar collector is purely based on the selection of input process parameters. Based on the literature review, an investigation is essential to improve the performance of the solar collector. The authors found that input process parameters plays vital role in the quality and efficiency of the solar collector.

Keywords: Solar Collector, Input process parameters, Output responses, Optimization techniques.

Introduction

Photovoltaic thermal hybrid solar collectors, sometimes known as hybrid PV/T systems or PVT, are systems that convert solar radiation into thermal and electrical energy. These systems combine a solar cell, which converts sunlight into electricity, with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module. and thus be more overall energy efficient than solar photovoltaic (PV) or solar thermal alone.[1] A significant amount of research has gone into developing PVT technology since the 1970s.[2]

Photovoltaic cells suffer from a drop in efficiency with the rise in temperature due to increased resistance. Such systems can be engineered to carry heat away from the PV cells thereby cooling the cells and thus improving their efficiency by lowering resistance. Although this is an effective method, it causes the thermal component to under-perform compared to a solar thermal collector.

Alibakhsh Kasaeian, and Giti Nouria**,** (2018), studied the solar collectors and photovoltaic as combined heat and power systems: the main method to increase the solar energy utilization efficiency is to combine heat and power generation together. Thus authors concluded that the solar collectors for combined CHP were focused on optimizing the performance of the maximum average useful power generation and minimum total heat transfer area, little environment impact analysis was conducted. Sobrina Sobria, and Sam Koohi-Kamalia,(2018) investigated the solar photovoltaic integration requires the capability of handling the uncertainty and fluctuations of power output. the authors conclude that solar photovoltaic power forecasting is a crucial aspect to ensure optimum planning and modeling of the solar photovoltaic plants. This paper investigates solar PV power generation forecasting techniques presented to date and describes the characteristics of various forecasting techniques.Yunfeng Wang, and Ming Li, Wenping.(2018) **presented** the experimental investigation of a solar-powered adsorption refrigeration system with the enhancing desorption: the solar adsorption refrigeration system prototype with activated carbon-methanol as working pair was designed and built. the authors conclude that, the results of experiments show that the novel system has improvements in the coefficient of performance, the mass of desorption and desorption rate, and the characters of the solar adsorption refrigeration system can be a benefit to further application. Xiaojiao Yang, and Liangliang Sun, (2017) studied the Experimental investigation on performance comparison of PV/T-PCM system and PV/T system: Photovoltaic/thermal (PV/T) panels are devices commonly used for the conversion of solar energy into heat and electricity. The use of phase change materials (PCMs) can efficiently decrease the temperature of a PV module. The total solar energy conversion efficiencies of the PV/T and PV/T-PCM modules were determined to be 63.93% and 76.87%, while their primary energy-saving efficiencies were 73% and 87.5%, respectively. Hasan Saygin and Raheleh Nowzari (2017) investigated the performance evaluation of a modified PV/T solar collector: It gets the excess heat produced by panel and cools it. Thus the authors conclude that the aim was to improve the electrical performance of PV module by cooling it and the use of excess heat for heating the air and improve the thermal efficiency. Pierre-Luc Paradis a, and Daniel R. **(**2017) studied the 2-D transient numerical heat transfer model of the solar absorber plate to improve PV/T solar collector systems A simple optical model is combined with the well-known five parameters PV module electrical model and the 2-D heat conduction equation to compute the temperature field of the PV plate and the electrical power generated for every time step of the simulation. Gang Wang and Yaohua Zhao, (2017) investigated the Application of a multi-function solar-heat pump system in residential buildings: The system could realize different functions by operating in different modes, such as heating in winter, cooling in summer, domestic water heating for a whole year, and part of household electricity demand. The experimental data could provide a reference for developing a practical solar PV/T-heat pump system.

Jee Joe Michael a and Iniyan selvarasan b (2017). presented the Economic analysis and environmental impact of flat plate roof mounted solar energy systems: a solar PV/T based water heating system was compared with a solar PV system and a flat plate solar water heating (SWH) system based on economic evaluation and environmental assessment. The authors conclude the presence of aluminum metal increases the embodied energy and embodied CO2 emission significantly. Mohammad Alobaid and Ben Hughesa**,** (2017) demonstrated the review of solar driven absorption cooling with photovoltaic thermal systems: The aim of this investigation is to evaluate the recent advances in the field of solar absorption cooling systems from the viewpoint of solar collector types. A review in the area of photovoltaic thermal (PVT) absorption cooling systems is conducted. The authors include experimental and computational work focusing on collector types and their efficiencies and performance indicators. Compared to vapour compression air conditioning systems, 50% of primary energy was saved by using solar absorption cooling systems and 10–35% maximum electrical efficiency of PVT was achieved. Hong bing Chen and Lei Zhang a(2017) demonstrated the Performance study of heat-pipe solar photovoltaic/thermal heat pump system: the paper discussed about a numerical and experimental study on the performance of aHPS PV/T heat pump system. A mathematical model, including a dynamic distributed parameter model of the HPS PV/T collection system and a quasi-steady state distributed parameter model of the heat pump system, is presented to assess the performance of HPS PV/T heat pump system.J. Sieckera and K. Kusakanaa (2017) demonstrated the review of solar photovoltaic systems cooling technologies: proper cooling of PV systems improves the thermal, electrical and overall efficiency, which in turn also reduces the rate of cell degradation and maximizes the life span of the PV module. Pierre-Luc Paradis a and Daniel (2017) studied the A 2-Dtransient numerical heat transfer model of the solar absorber plate to improve PV/T solar collector systems: This paper presents a genuine 2-D transient numerical model to evaluate the temperature field and the dependent electrical performances of different solar absorber plates. It can readily be adapted for solar thermal absorber plates, standard PV plates or thermally enhanced PV plates that can be used in PV/T solar collectors. The model can also be combined with the appropriate heat exchanger equations to simulate complete solar collector. Jun Ni, Jun Li, and Wei An, Tong Zhu (2017) investigated the Performance Analysis of Nan fluid-based Spectral Splitting PV/T System in Combined Heating and Power Application: Nano fluid-based spectral splitting photovoltaic/thermal (NSS-PV/T) system has attracted increasing attentions for its flexible adjustment of energy distribution between photovoltaic and photothermal units and the breakthrough on the temperature of collected thermal energy. In this work, a calculation model is developed to analyze the performance of the NSS-PV/T system in combined heating and power application which were reported by few literatures J.F. Chen, L. Zhang and Y.J. Dai (2017) presented the Performance analysis and multi-objective optimization of a hybrid photovoltaic/thermal collector for domestic hot water application: PV/T collector turns out to be a promising alternative for the traditional solar thermal collector for domestic hot water (DHW) application. In this paper, four comprehensive thermal and electrical models including unglazed PV/T, glazed PV/T, PV and flat plate thermal collector are established for the purpose of accurate long-term simulation and optimization. Qi Shi, Jian Lv, and Chunmei Guo(2016) presented the experimental and simulation analysis of a PV/T system under the pattern of natural circulation: The circulation velocities, electrical efficiencies, thermal efficiencies, overall efficiencies, and primary energy economic ratios are tested and analyzed under different radiation intensities. The authors concluded the overall efficiency of the system under the pattern of natural circulation is also calculated when used in hot summer and warm winter areas. The generated electricity is about 1281.5MJ/year; the heat collection is about 4639.6MJ; and the annual integrative efficiency is 60%.A.Khelifa and K. Touafek (2016) investigated the modeling and detailed study of hybrid photovoltaic thermal (PV/T) solar collector the efficiency of photovoltaic panel is sensitive to operating temperature and decreases when the temperature of the PV increases. Therefore, the PV/T hybrid systems are one means used to improve the electrical efficiency of the panel. In the study, the authors conclude that the photovoltaic panel temperature significantly reduced by 15–20% due to the flow of water through the manifold to the rear of the PV panel. S.Nizetic and F. Grubišic´-Cˇabo, (2016) demonstrated the Water spray cooling technique applied on a photovoltaic panel: experimental result shows that it is possible to achieve a maximal total increase of 16.3% (effective 7.7%) in electric power output and a total increase of 14.1% (effective 5.9%) in PV panel electrical efficiency by using the proposed cooling technique in circumstances of peak solar irradiation. Furthermore, it was also possible to decrease panel temperature from an average 54 °C (non-cooled PV panel) to 24°C in the case of simultaneous front and backside PV panel cooling. M.Shravanth Vanish, and J. Srinivasan, Sheela K. (2016**).** Studied the Performance of solar photovoltaic installations: Effect of seasonal variations. The main objective of setting up this solar photo voltaic system was to study the performance of solar plants under different seasons and climatic conditions. the authors conclude that The system has been producing an average daily yield of approximately 80 kWh for the past two years which translates to an annual yield of 28.9 MWh.

M.Y. Othman a, and S.A. Hamid b, M.A.S. a (2016) studied the Performance analysis of PV/T Combi with water and air heating system: Producing more thermal energy during the process contribute to poor performance on the electrical efficiency of the solar cells. Water and air can help by acting as the heat removal medium. M. Farshchimonfared and J.I. Bilbao, (2016) studied full optimization and sensitivity analysis of a photovoltaic–thermal (PV/T) air system linked to a typical residential building: This paper examines the optimization of a PV/T air collector with a fixed length and width (L = 5m,W= 3.6 m) linked to the mechanical air distribution system of a typical residential building. A methodology is developed for the full optimization of the rate of effective thermal output across a wide range of the air mass flow rate per collector unit areas (m_ =Ac = 0–0.07 kg/s m2). For the optimization methodology the air temperature rise (DT) was not restricted and several values of the weighting ratio of heat to electricity were compared. O. Sotehi a and A. Chaker b, (2016) studied the hybrid PV/T water solar collector for net zero energy building and freshwater production: The purpose of this work is to study the possibility of obtaining a net zero energy building and producing freshwater via a solar still by using a hybrid PV/T water solar collector. A solar prototype built in the city of studied under the climate of city to show the importance of the use of passive solar architecture. The results highlight the importance of using passive solar techniques to reduce heating energy needs. Energy savings are realized with passive techniques even before the use of active solar systems. Khelifa and Touafek K1 (2015) studied the Analysis of a Hybrid Solar Collector Photovoltaic Thermal (PVT): The study used to provide design and simulation data for this type of hybrid solar collector Photovoltaic thermal air. Several climatic parameters such as global radiation and wind speed also affect the performance of its types of systems. this study presents the heat transfer performance in a hybrid photovoltaic thermal solar collector from experimental data. The calculated coolant temperature is similar to the experimental results that are preceded already made. It is observed that cell temperature is lower resulting in a significant increase in the electrical performance of the system such as electrical and thermal efficiency.

Gang Wanga, and Zhenhua Quana, (2015) studied A novel solar PV/T-air dual heat source composite heat pump system was developed and the experimental platform was built to research the instantaneous performance. The experimental results show that the maximum instantaneous generating efficiency of solar PV/T collecting circulation of the system could achieve 15.0% and average heat collecting efficiency was 43.8% when average ambient temperature and solar irradiance were 6.5□ and 581.5W/m2. Heat distribution average ratio of solar, air and compressor at the run time were 28.1%, 35.7% and 36.2% respectively. Priyanju1 and Rashmi Kesarwani2(2015) studied the performance analysis of solar Photovoltaic and thermal (PV/T) hybrid water desalination system: This paper described that the desalination process supports to increase the electrical efficiency of PV/T system by 2% as compared to reference PV module and input water TDS is also reduced by 50% after the desalination process. This system also solves the problem of hardness of water in any climatic region and it can be also used.as a water heating system. However, this PV/T system has certain limitation of flow rate and solar radiation.This system is having good performance in those climatic regions where an average amount of solar radiation is always available. James Allan and Zahir Dehouche, (2015) demonstrated the Performance testing of thermal and photovoltaic thermal solar collectors: In this study, an experimental system that can be used to extract fundamental performance characteristics of solar thermal collectors has been detailed. The testing system has been designed to be adaptable and flexible so that different parameters can be isolated and the impact on performance measured. In the cases presented in this paper, the experimental system has been used to: characterize the performance of two different designs of collector; quantify the impact of using a cover to reduce heat loss; quantify the combined efficiency of a PVT collector. and JeeJoeMichaela,(2015)demonstratedFlatplatesolarphotovoltaicthermal(PV/T)systems:TheelectricalandthermalefficienciesofthePV/Tcollectorusingdifferentdesignsandheattransferfluids,theirapplications,limitations,advantagesandscopeforfutureresearcharediscussedtoenablethereaderto have a complete understanding of solar PV/T concept's. Saeedi, and A. Behzadmehr (2015) studied the Optimization of a PV/T (photovoltaic/thermal) active solar still: the optimization of PV/T active solar still has been carried out and the optimized value of mass flow rate, number of PV/T collector and the objective function have been obtained. Furthermore, the effect of various operating parameters on energy efficiency have been investigated. Anil Kumar n and (2015) demonstrated the Historical and recent development of photovoltaic thermal (PVT) technologies: The photovoltaic (PV) cells suffer efficiency drop as their operating temperature increases especially under high in solution levels. The overall electrical efficiency of the photovoltaic (PV) module can be increased by reducing the temperature of the PV module by withdrawing the thermal energy associated with the PV module.

F. Saeedi and F. Sarhaddi*,(2015**)** studied the optimization of a PV/T (photovoltaic/thermal) active solar still is carried out. Analytical expressions for glass cover temperature, basin temperature; brackish water temperature and fresh water productivity are obtained by writing energy balance for different components of PV/T active solar still. The output electrical power of PV/T active solar still is calculated by four-parameter IeV (current voltage) model. Objective function in present study is the energy efficiency of PV/T active solar still. A computer simulation program has been developed in order to obtain thermal and electrical parameters respectively. Niccolo Aste and Claudio del Pero (2014) studied the water flat plate PV–thermal collectors: A review: 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. The authors the performance evaluation of thin-films PV cells and the effect of thermal annealing even in hot climates should be carefully analyzed.

Ahmad Fudholi a, and Kamaruzzaman Sopian a, (2014) studied the performance analysis of photovoltaic thermal (PVT) water collectors: The electrical and thermal performances of photovoltaic thermal (PVT) water collectors were determined under 500–800 W/m2 solar radiation levels. At each solar radiation level, mass flow rates ranging from0.011 kg/s to 0.041 kg/s were introduced. The authors concludes the results show that the efficiency of the PV module increase when the temperature decrease. This result is due to the increase in the cooling factor of the PV module cells when the mass flow rate increases. Therefore, mass flow rate indirectly contributes to the increase in PVT water collector temperature.F. Sobhnamayan a, and S. Farahat a, J. (2014) studied the Optimization of a solar photovoltaic thermal (PV/T) water collector based on exergy concept: the optimization of a solar photovoltaic thermal (PV/T) water collector which is based on exergy concept is carried out. Considering energy balance for different components of PV/T collector, we can obtain analytical expressions for thermal parameters (i.e. solar cells temperature, outlet water temperature, useful absorbed heat rate, average water temperature, thermal efficiency. Suhaila Abdul Hamid and Mohd Yusof Othman (2014) investigated that overview of photovoltaic thermal combination (PV/T combi) technology: Photovoltaic panel converts sunlight to electricity, while thermal collector converts solar energy directly to heat. The synchronization led to the development of PV/T air-based and PV/T water-based systems. this paper presents an overview of Photovoltaic Thermal Combination system (PV/T Combi), with a combination of photovoltaic panel with air- and water-based systems as one unit. This bi-fluid concept not only generates electrical energy, but also produces hot air and hot water, simultaneously. From the literature, this concept was seen to achieve better overall energy efficiency, especially in electrical production.

R.K. Mishra and G.N. Tiwari **(**2013) presented the Energy matrices analyses of hybrid photovoltaic thermal (HPVT)
water collector with different PV technology. To evaluate and compare the energy matrices of a hybrid photovoltaic thermal (HPVT) water collector under constant collection temperature mode with five different types of PV modules namely c-Si, p-Si, a-Si (thin film), CdTe and CIGS. The authors conclude analysis is based on overall thermal energy and exergy outputs from HPVT water collector. The temperature dependent electrical efficiency has also been calculated. Kamran Moradi and M. Ali Ebadian, (2013) demonstrated the review of PV/T technologies: Effects of control parameters: the effects of the major control parameters on the thermal/electrical performance of PV/T collectors are compiled and reviewed.
Mustafa Kaya (2013) presented the thermal and Electrical Performance Evaluation of PV/T Collectors: Photovoltaic Thermal/Hybrid collectors are an emerging technology that combines PV and solar thermal collectors by producing heat and electricity simultaneously. In this paper, thermal and electrical performance of PV/T collectors are analyzed and presented for the climate of RAK, UAE. Thermal performance evaluation is done following the collector output model presented in European standard EN12975-2 and electrical performance evaluation is done by analyzing the effect of water circulation on the performance of PV/T collectors.

V.V. Tyagia and S.K. Tyagib (2012) studied the Advancement in solar photovoltaic/thermal (PV/T) hybrid collector technology: Different types of solar thermal collector and new materials for PV cells have been developed for efficient solar energy utilization. The solar energy conversion into electricity and heat with a single device (called hybrid photovoltaic thermal (PV/T) collector) is a good advancement for future energy demand. H.D. Fu a, and H. Long b, T. (2012) studied the Experimental study of a photovoltaic solar-assisted heat-pump/heat-pipe system: the system operates in an optimal mode. A series of experiments were conducted in Hong Kong to study the performance of the system when operating in the heat-pipe and the solar-assisted heat-pump modes. Moreover, energy and exergy analyses were used to investigate the total PV/T performance of the system. Pei Gang* and Ji Jie*(2012) studied the Performance study and parametric analysis of a novel heat pipe PV/T system: A novel heat pipe photovoltaic/thermal (PV/T) system that could simultaneously supply electrical and thermal energy was proposed. Compared with a traditional water-type PV/T system, the heat pipe PV/T system can be used in cold regions without becoming frozen. A dynamic model of the heat pipe PV/T system was presented, and a test rig was constructed. Experiments were conducted to validate the results of the simulation.

Pei Gang a and Fu Huide (2012) studied the Annual analysis of heat pipe PV/T systems for domestic hot water and electricity production: Heat-pipe photovoltaic/thermal (HP-PV/T) systems can simultaneously provide electrical and thermal energy. Compared with traditional water-type photovoltaic/thermal systems, HP-PV/T systems can be used in cold regions without being frozen with the aid of a carefully selected heat-pipe working fluid. The current research presents a detailed simulation model of the HP-PV/T system. using this model, the annual electrical and thermal behavior of the HP-PV/T system used.

Todd Otanicar a and Robert A. (2012) presented the Prospects for solar cooling – An economic and environmental assessment: Producing refrigeration and/or air conditioning from solar energy remains an inviting prospect, given that a typical building's cooling load peaks within 2 or 3 h of the time of maximum solar irradiation. The attractiveness of "free" cooling obtained from the sun has spawned a wealth of research over the last several decades, as summarized in a number of review articles. Obstacles—especially high initial costs—remain to the widespread commercialization of solar cooling technologies. It is not clear at the present time if thermally driven systems will prove to be more competitive than electrically driven systems. Sujala Bhattarai a and Jae-HeunOhb, (2012) studied the Simulation and model validation of sheet and tube type photovoltaic thermal solar system and conventional solar collecting system in transient states: In this paper, the comparative performance of PV/T systems and conventional solar collecting systems was studied through simulation and experiments. The thermal efficiency of the PV/T and conventional solar collecting systems were 58.70% and 71.50%, respectively, under steady state conditions. The electrical efficiency of the PV/T system was found to be 13.69%. G.N. Tiwari and R.K. Mishra ⇑, S.C. Solanki (2011) studied the photovoltaic modules and their applications: A review on thermal modeling: PVT systems to improve their overall thermal and electrical efficiency and reducing their cost, making them more competitive in the present market

R. Daghigha, and M.H. Ruslana, (2011) presented the Advances in liquid based photovoltaic/thermal (PV/T) collectors: The liquid based photovoltaic thermal collector systems are practically more desirable and effective than air based systems. The authors concluded temperature fluctuation in liquid based PV/T is much less than the air based PV/T collectors which subjected to variation in solar radiation levels.G.N. Tiwari and S.C. Solanki (2011) studied the Photovoltaic modules and their applications: A review on thermal modeling: it is clear that PVT modules are very promising devices and there exists a lot of scope to further improve their performances particularly if integrated to roof top. Henrik Davidson and Bengt Perers (2010) studied Performance of a multifunctional PV/T hybrid solar window: The simulation program was calibrated against measurements on a prototype solar window placed in Lund in the south of Sweden and against a solar window built into a single family house. The results from the simulation shows that the solar window annually produces about 35% more electric energy per unit cell area compared to a vertical flat PV module.

M.K. Gaur (2010) studied the Optimization of number of collectors for integrated PV/T hybrid active solar still: of PV/T collectors connected in series has been integrated with the basin of solar still. The optimization of number of collectors for different heat capacity of water has been carried out on the basis of energy and exergy. Expressions of inner glass, outer glass and water temperature have been derived for the hybrid active solar system. A.S. Joshi a,b,1 and A. Tiwari a, **(2009)** presented the In this paper, an attempt is made to evaluate the thermal performance of a hybrid photovoltaic thermal (PV/T) air collector system. The two type of photovoltaic (PV) module namely PV module with glass-to-tedlar and glass-to-glass are considered for performance comparison. The results of both PV modules are compared for composite climate of New Delhi. Analytical expression for solar cell, back surface, outlet air temperatures and an overall thermal efficiency are derived for both cases. It is observed that hybrid air collector with PV module glass-to-glass gives better performance in terms of overall thermal efficiency. Parametric studies are also carried out. P.G. Charalambous a and G.G. Maidment a, (2007) presented the Photovoltaic thermal (PV/T) collectors: A review The parameters affecting PV/T performance, such as covered versus uncovered PV/T collectors, optimum mass flow rate, absorber plate parameters (i.e. tube spacing, tube diameter, fin thickness), absorber to fluid thermal conductance and configuration design types are extensively discussed. based on an exergy analysis, it was reported that the coverless PV/T collector produces the largest available total (electrical + thermal) exergy.

CONCLUSION

In this present work, a comprehensive review on the flat-plate solar PV/T technology is carried out. The electrical and thermal efficiencies of the PV/T collector using different designs and heat transfer fluids, their applications, limitations, advantages and scope for future research are discussed to enable the reader to have a complete understanding of solar PV/T concept. From the literature review, it is observed that the PV/T system is a promising device with maximum solar energy utilization and a few inherent drawbacks. Several researches are being carried out presently to improve the efficiency of the solar PV/T collector and make it competitive with the solar PV module and solar thermal collector. The electrical efficiency decreased with the increased in cell temperature. Adding heat absorber will definitely increase both the electrical and thermal efficiency. Increasing mass flow rate will improved thermal performance but electrical efficiency only shows high performance at certain mass flow rate.Based on the review work, the authors found that mass flow rate, inlet temperature, out let temperature and flow patterns absorption material are normally considered for the output responses.

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