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A-Review for the Cooling Techniques of PV/T Solar Air Collectors

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HIGHLIGHTS

- Role of photovoltaic- thermal collector in providing heat and power was revealed.
- The profitability of utilizing photovoltaic-thermal solar systems was explored.
- Solar collector efficiency decreases the cell temperature rise and dust existence.
- The state of art of the solar systems and recent advancements were included.
- The cooling techniques of the solar photovoltaic soar systems were covered.

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ABSTRACT

A solar thermal collector is one of the most popular applications of solar energy. It is a photovoltaic (PV) cell system with a thermal collector system, this system is utilized in the production of electrical energy and many applications. The system is able to produce electrical energy directly from the sunlight using the photoelectric effect. Meanwhile, it also extracts heat from the PV and heats the fluid (airflow) inside the collector. In this review, the solar PV system and solar thermal collectors are discussed. Usually, solar collectors are exposed to damage and their efficiency decreases when the temperature rises. Need constant cooling. In addition, the methods utilized to cool the solar collector are presented, including cooling with air, water, and others methods. It has been shown that the water-based cooling system was at a rate of 48%, while the air-based cooling system was at a rate of 26%, and that cooling by other methods was at a rate of 26%. These methods were applied to the enhancement of the photovoltaic cell efficiency under different conditions. The study revealed the important role being played with the application of solar energy.

1. Introduction

Electricity and heating are the most important required energies in suburban for commercial and public services. At the present time, mainly about (80%) of the world's energy is produced by fossil fuel [1]. Massive utilization depletes these resources and poses an actual threat to the situation, which is manifested mainly during global warming and acidification of the water cycle. The most obtainable energy is solar. The sun is used for providing heat, electricity, light, etc. to domestic and industrial applications by solar technologies [1]. Photovoltaic (PV) cell is one of the solar technologies. The growth in photovoltaic installation is 24% between 2010 and 2017 in the world as illustrated in Fig. (1). In 2017 Europe's contribution to the total cumulative PV enterprise is 28%. Plant in China accounted for about 32% as illustrated in Fig. (2).

The PV module was first utilized as the primary electricity source in a space mission and satellite [3]. The expenditure for producing electricity for house application has dropped drastically and PV module has become more economically viable. New material has been residential and new technologies have formed PV modules at efficiency in many cases as 20% [3]. One relatively new type of PV module is the hybrid PV module. This kind of module converts the sun's radiation to electricity and provides heat to the system, which can be utilized for different purposes. This may be done by either fluid coolant or air. The most widely utilized fluid is water.

2. Photovoltaic Solar System

The widely used heat collection system is a flat module collector and solar cell for thermal and electrical applications. Generally, temperature Increment leads to a decrease in the efficiency of the solar cells [4]. The working temperature increases due to the fact that large parts of the solar radiations do not convert to electricity but are engrossed by plates as heat. Thus, the

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PV module should be cooled. The archetypal value of losses efficiency of the PV with temperature is 0.005 °C though this varies with cell type. Solar cells cooling can be achieved by water or air [4] [5] [6]. PV cell is arranged in a series / parallel circuit for generating higher current, voltage and power value. The photovoltaic array consists of one or more PV module. Each modules contains one or more PV cells wired in series/parallel for obtaining the required voltage and current as illustrated in Figs. (3) (4) [7].

The most common semiconductor material that is utilized to improve a solar cell is silicon. Other materials may be utilized in the construction of the solar cells, such as copper indium dieseline, gallium arsenide and cadmium Telluride. The silicon made solar cell may be classified according to the type of crystal as polycrystalline silicon, amorphous silicon, and monocrystalline silicon. [10].

The PV system is very reliable and has been chosen because of the low cost life-cycle particularly for Applications requiring need less than 10 kW, where the electricity grid isn't obtaining and the internal-combustion engine is costly [11]. Renewable energy is fine and consistent long life, Low recurs cost and economic benefit. The Photovoltaic module is silent and visually inconspicuous, easy to establish and take small size benefit of unutilized space on the rooftop of existing buildings. The PV still powers nearly every satellite circling earth because of its operation reliability for a long period of time with virtually no continuance. The drawbacks of the PV are initial cost is high, and low output in cloudy weather. Moreover, solar energy is rather more costly to produce than the conventional sources for energy due in part to the manufacturing costs for PV devices and in part to the efficiencies' conversion of the equipment. As the conversion efficiencies continue to increase and the manufacturing costs continue to come down, PV becomes gradually more cost competitive with conventional fuel.

Application of PV as:
Water pumps
Street Lighting
Electrification Village
Desalination
Powering of railway signals
Remote telecommunication repeater station

3. Effects of Weather Parameters on Performance of PV Solar Module

Many parameters affect the performance of PVT modules as temperature, solar radiation.

3.1 Solar radiation

Solar radiation is an essential factor that influences the performance of the solar photovoltaic unit as it is changing with time. Solar radiation changes during the day and this change results in a difference in the power output [13].

3.2 Temperature

Temperature is the main parameter affecting the power output of the PV module because the voltage is temperature dependent. Fig. (5) Illustrates the effect of the temperature on the PV power. It can be seen that when the temperature increased, the voltage decreased and consequently reduced the PV output power [14].

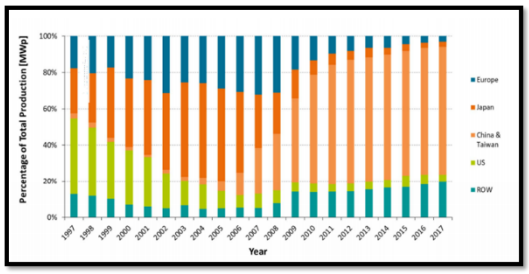

Figure 1: Power Production by solar cells from 1997-2017[2]

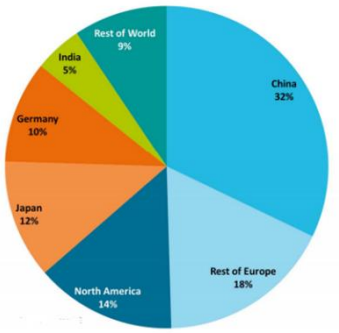

Figure 2: Percentages of whole global installation [2]

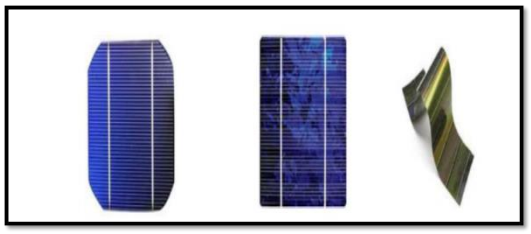

Figure 3: Types of solar cell [8]

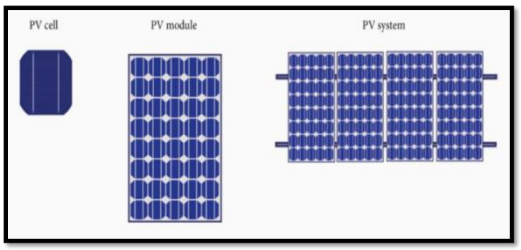

Figure 4: Typical PV cell, module, and system

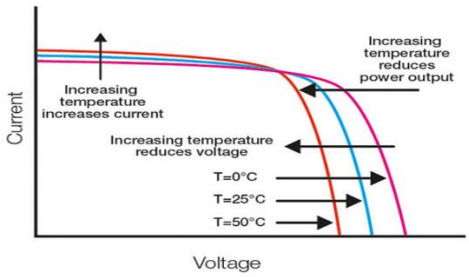

Figure 5: Characteristics of PV module with different temperatures [15]

4. Cooling Techniques for PV Module

The electrical efficiency of the PV cells decreases with the increment of the temperature. Cooling can improve the electrical production of standard flat module PV modules. The electrical efficiency increasing depends on the used cooling technique, types and sizes of the module, geographical location and season of the year generally, there are eight cooling methods including [16]:

1- Cooling method PV utilizing forced air
2- Cooling method PV utilizing water spraying
3- Cooling method PV utilizing circulation forced water
4- Cooling method PV utilizing the heat sink
5- Cooling method PV utilizing a phase-change substance
6- Cooling method PV utilizing immersion in water
7- Cooling method PV utilizing coating transparent
8- Cooling method PV utilizing thermoelectric cooling

4.1 Passive Cooling:

It can be classified into three main types:

4.1.1 Air Passive Cooling

PV cell utilized: one with aluminum fin as the heat sink, with thermal grease, apply and one without a heat sink. Illumination varies from 200 to 800 W/m2. Electric efficiency increased by 9 % usage passive cooling with heat sink [17].

4.1.2 Water Passive Cooling:

Water is characterized by a high ability of heat transfer. The water-cooling method is characterized by the high efficiency of the cooling method that improved photovoltaic cell efficiency. Many studies have been discussed front and back cooling [17]. A method for cooling is to reduce temperature is maintained at 30 °C that in turn yielded relatively efficiency increased as 20 %, but isolation intensity drops with depth at depth of 4 cm, efficiency increased by 11 %]18].

4.1.3 Conductive Cooling:

A particular type of passive conductive cooling is Phase Change Materials (PCM) cooling. The PCM may still be considered as a passive method mostly because there is no additional work needed to take away heat, Fig. (6), illustrates a diagram of PV cells attach at front surface of aluminum container full of PCM materials from back [18].

4.2 Active Cooling:

Using active cooling systems is a pump needed for maintaining fluid circulations. [19]. Fig. (7) Shows cooling by forced air [20].

4.3 Thermoelectric Cooling:

Thermoelectric cooling is working from one side of the junction produces heating, and on the other side, cooling effect. The intensity of heating/cooling depends on temperature variation and intensity of voltage/current, cooling effect power consumes. The modeled PV cell cooling with Peltier elements Fig.(8) [15].

4.4 Heat Pipe Cooling:

Heat pipe cooling is the combination of phase change cooling and convention cooling medium. On one side cooling medium evaporate and expand taking up heat that is shown in fig. (9) [15].

4.5 Nanofluids Cooling:

Nanofluids are considered to be a discrete mixture of cooling fluids and solid nanoparticles. The most utilized particles are metal oxide, for instance, Al_2O_3 or CuO particles. The main compensation of Nanofluid is high heat capacity and thermal conductivity [21]. While the drawbacks are pumping processes and total change in flow regime [22].Many researchers applied methods for improving the performance of PV\T [23-24]. Many researchers have studied PV\T their application and cooling methods summarized in Table (1).

Figure 6: PCM

Figure 7: PV cooling by forced air.

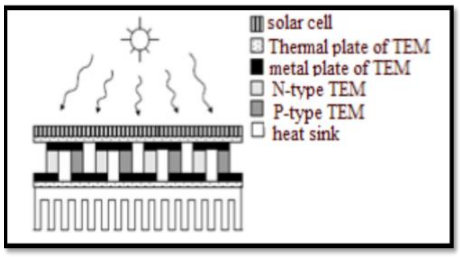

Figure 8: PV cooling with TEM attachment

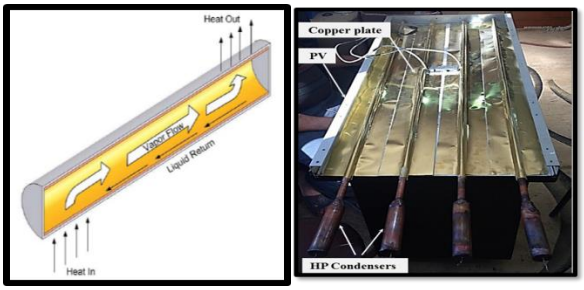

Figure 9: Heat pipe mechanism [15]

Table 1: Summarized of Literature Review

Author	Title	Results
Mohamed ElAmine Slimani et al. 2016 [25]	Study and modeling of energy performance of a hybrid photovoltaic/thermal solar collector: Configuration Suitable for an indirect solar dryer	The results illustrated the electrical, thermal and overall efficiency at 0.015kg/s were10.5%,70%, and90%correspondingly.
Poorya et al. 2016[26]	Performance of four air-based photovoltaic thermal collectors configurations with bifacial solar cells	It was observed that the double-pass in parallel flow type has the highest energy efficiency of 51% -67%,and the single -pass has the lowest energy efficiency of 28-49%, then thepackingparameterwas0.7.
Shyam et al. 2016 [27]	Analysis of series connected photovoltaic thermal air collectors partially covered by semitransparent photovoltaic module	It was concluded that type (A)excuses better than type(B)on thermal and electrical performance at0.04kg/s. This kind of systems can be utilized in thermal applications with decreasing dependency on electrical grids.

Table 1 Continued

Author	Title	Results
RaviKantRavi et al. 2016 [28]	A review on different techniques utilized for performance enhancement of double pass solar air heaters	It was found that using a double-pass solar collector over single-pass cautilized increasing the convective heat coefficient between thermal collector and medium fluid by improving the area of heat transfer. Also, the thermal modeling of double pass type has been analyzed by applying the energy balance equations
Abhay Lingayat et al .2017 [29]	Design, improvement and performance of indirect type solar dryer for banana drying	The average collector efficiency and drying efficiency were observed 31.50% and22.38%
Rehan Ali, et. al (2017)[30]	Effect of Cooling on Solar Module Performance	The results further illustrateed that the cooling of photovoltaic system using water over the front surface enhances the performance even more as compared to air cooling of solar module
Biplab Das et al. 2017 [31]	Performance analysis of single glazed solar pvt air collector in the climatic condition of ne india	The maximum energy efficiency was observed to be83%. Consequently, the enhancement of the thermal performance was obtained By increasing the air flow rate
Roonak Daghighetal.2017 [32]	Design and fabrication of abi-fluid type photovoltaic-thermal collector	The temperature is the thermal efficiency of water mode were19.1_C and0.45at700 W=m2. It was concluded that the water mode system was completely optimized.
Essalhi Hajar et al. 2017 [33]	Conception of as olaraircol- lector for an indirect solar dryer. Pear drying test	The results of thermal performance demonstrated that the maximum temperature of outlet air was 57_C with natural mode and the temperature of air in First tray was higher than othertrays. Inaddition,the mass removal from pear was from997.3g to 135.13gafter24 hours of drying process,and the average dryer efficiency was11.11%
Zeyad A. Haidara et.al (2018)[34]	Experimental investigation of Evaporative cooling for enhancing photovoltaic modules efficiency	The effectiveness of the method were conducted and analyzed. More than 20 °C reduction in PV module temperature and around 14% increment in Electrical power generation efficiency were achieved compared with a referent PV module
Sumit Tiwarietal. 2018 [35]	Pvt air collector integrated green house dryers	The average thermal, electrical,and overall efficiency forthePV/T system was indicated to be26.68%,11.26%,and56.30%, correspondinglyat0.01kg/s.
Mohamed A.Eltawil et al. 2018[36]	Energy analysis of hybrid solar tunnel dryer with pv system and solar collector for drying mint(menthaviridis)	The results stated that the time of drying was changed from 210 to 360 min for the enhanced dryer, while changed from270to420minforopen type dryer. The average efficiency of the PV module and dryer system were9.38% and30.71%, correspondingly.
M. Fterich et al. 2018[37]	Experimental parametric study of a mixed mode forced convection solar dryer equipped with a pv/t air collector	The highest efficiency of the dryer system was recorded as28.49and34.29%,when air flow was0.0786kg/s.
Ahmed Zoukitetal. 2019 [38]	Takagi sugeno fuzzy modeling applied to an indirect solar dryer operated in both natural and forced convection	The experimental structure comprises solar collector, drying room, trays, chimney, and with or without fan according to the convection mode.
Meraturefun et al. 2019[39]	Effect of cover design on moisture removal rate of a cabinet type solar dryer for food drying application	It was noticed that the natural draft was the best type and attic type was worst. It was also observed that the moisture removal content of crops after1p.m.was higher than before, because of the higher solar radiation.
Patria Julianto ,2020 [40]	Dynamic Economic Load Dispatch by Introducing Compressed Air Energy Storage for Solving Duck Curve	In this paper, the dynamic economic load dispatch (DELD) is carried out on thermal generators and CAES to determine optimal output of thermal generators and CAES operation pattern to meet the load demand for 24 hours and the Quadratic Constrained Programming (QCP) on the DELD integrated with CAES problem is solved by using the CPLEX solver to prove the effectiveness of the proposed system.
Abdullateef A. Jadallah, 2020 [41]	The hybrid(PVT) double-pass system with a mixed-mode solar dryer for drying banana	This gives an indication that the highest reduction was 68% of banana weight at a high mass flow rate of airflow. The critical parameter such as temperature distribution of the PVT with dryer room, useful heat gain, The highest heat gain and thermal Efficiencies were 423.7 and 52.98%, correspondingly, at 1:00 PM when the mass flow rate 0.031 kg/s

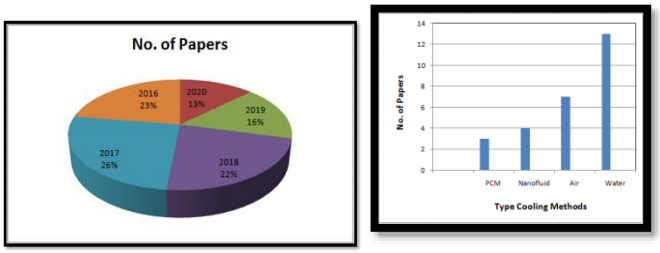

Figure 10: No. of Paper of PVT

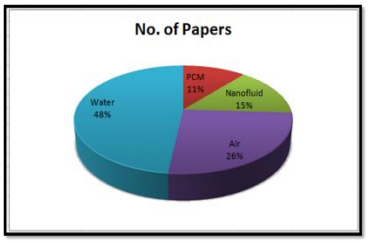

Figure 11: No. of paper with cooling technique

5. Discussion

Figure (10) illustrates the number of papers illustrated in Table(1) that show many studies that applied for improved performance of PV by using the cooling technique. The Result of this study shows that papers using PVT with air for years (2016 to 2020), while Fig.(11) illustrates the number of papers dealing with the cooling techniques of PV. From this paper can be concluded that solar energy has played an important role in recent years.

6. Conclusion

Increasing demand for clean energy sources, including solar thermal collectors. A photovoltaic cell system is utilized in the production of electrical energy and many applications. The system is able to produce electrical energy directly from sunlight using the photoelectric effect. Meanwhile, it also extracts heat from the PV and heats the fluid (airflow) inside the collector. In this review, the solar PV system and solar thermal collectors are presented. These collectors are exposed to damage and their efficiency decreases when the temperature rises, so they need constant cooling. In this review, the methods utilized to cool the solar collector are presented, including cooling with air, water, and others. The conclusions made it clear that the number of researches that utilized water was at a rate of 48%, while the research that utilized air was at a rate of 26%, and that cooling by other methods illustrate was at the rate of 26%.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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