Effects of Active Cooling Techniques to Improve The Overall Efficiency Of Photovoltaic Module- An Updated Review

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Abstract-Our scientists have struggled for the last few decades to save the nation from the harmful emission caused by burning fossil fuel and restore enormous solar radiation energy. Despite their hard labor in this field, only 12-16% ofsolar radiation is converted into electrical energy. The major part of it iswastage as heat thatcauses to rise of panel temperature and lowersits efficiency.The aim of the review isto findout the cost-effective and efficient active cooling methods of solar photovoltaic (SPV) cell to improve their overall performance.Therefore, thirty-two active cooling techniques are thoroughly studied, compared their results from more than a hundred papers. Cooling of the SPV panel is a function of optimum spraying timing, coolant flow rate, wind condition, the distance between flow points (nozzle) to the panel,and solar radiation.The major facts revealed that the efficiency of the PV panel is optimum within 25-30^{0}C, and the panel's performancedecreases by 0.5% for each 1^{0}C rise of panel temperature from standard temperature.The best active cooling method revealed thatthe electrical efficiency of the PV module could be increased by 57% with a lowering of module temperature by 32% in hot summer.

Keywords:Solar Photovoltaic cell, active cooling, electrical efficiency, ambient temperature, and hot summer day

1. INTRODUCTION

By using excessive fossil fuel, the change in the environmental condition, such as the increase of temperature of the atmosphere, emissions of toxic gases, and gradual thinning of the ozone layer, threaten the sustainability of life of living beings and their future in the world [1]. Burning of fossil fuels to generate power that usages in day-to-day requirement of human and theirsocietalneeds create severe environmental issues, one leading to another as heatwaves, drought [11] rising water levels, occasional flood, and different climatic wonders [31]; [7]. To get rid of it and to create a nonpolluting environment in which humankind can survive a healthy and happy life, researchers are continuously looking to use sustainable, clean, and renewable energy resourcesasan alternative to fossil fuel and their improved production processes. The generation of alternative clean energy with optimum overall efficiency to minimize cost has been the major challenge of scientists for the last few decades. Energy from natural resources such as solar, water, wind, waves, and tides in sea and river, bio-fuels, and geothermal can replace fossil fuels and have the potential to produce enough energy to fulfill the needs of a hygienic society. The literature revealed that solar photovoltaic (SPV) systems prove better than any other resources in the arena of power generation. As the sun is a resource of enormous energy, solar energy will be broadly accepted as a creator of renewable energy on behalf of its cleanliness, availability, sustainability, and infinite potential forthe generation of power [41].The key part of considering solar energy as a renewable energy source is the cause of enormous solar radiation than all other secondary energy sources, such as energy from wind, biomass, a wave of sea and hydropower, etc. [2]; [15].

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(a)Different PV technologies

Nowadays, Photovoltaic (PV) solar energy is utilizedfrom small rooftops to large integrated systems of vast commercial buildings with different capacities of several kilowatts. Mostly it is used for power generation of hundreds or more megawatts, and most of these large PV systems are connectedtothe grid. In a few cases, small stand-alonesystems work for domestic purposes. Now a day's, building-integrated photovoltaics (BIPVs) progressively utilizesolar panels indifferent places of new domestic and commercial buildingsto generate power as a main or auxiliary source of electricity The capacity rooftop PV systems for two purposes have small capacities of 5–10 kW in the range. On the other hand, commercial rooftop PV systems contributed to several hundreds of kilowatts. The electrical quantities of the PV modules related to the short circuit current (Isc) and open circuit voltage (Voc). The electrical power output (Pe) and efficiency (ηe) of every PV panel were evaluated as given equations 1 and 2:-

$$(Pe)=Isc\times Voc\times F.F. \tag{1}$$

Where (F.F.) = the fill factor of the PV panel.

$$\eta_e = P \div (A \times G) \tag{2}$$

Where, (G) = solar irradiation in the W/m2

(A) = surface area of the PV module in m2.

(b) Requirements of Cooling Techniques for improving the efficiency of PV module

The temperature of solar PV panels increasesat a hot ambient temperature, and their electrical performancedecreases. Hence cooling the panel is essential to improveitseffectiveness. The main motivation of the cooling is to decrease the panel temperature close to 25-30^{0}C, at which the panel performs its best. Therefore, to bring down the temperature of the PV panel on a hot summer day, scientists usedifferent cooling methods that could be applied in the Solar PV system, as shown in the Figs. 1 (a) and (b).

But here,the authors only considered varying active cooling techniques throughout the literature for review. The main aim of this research is to find out the best possible technique for cooling PV cells by which the cell can perform their best with the minimum cost incurred. A total of hundred and twenty-one (121) papers have been selected for this purpose, and based on that, different views of cooling and conclusions have been made.

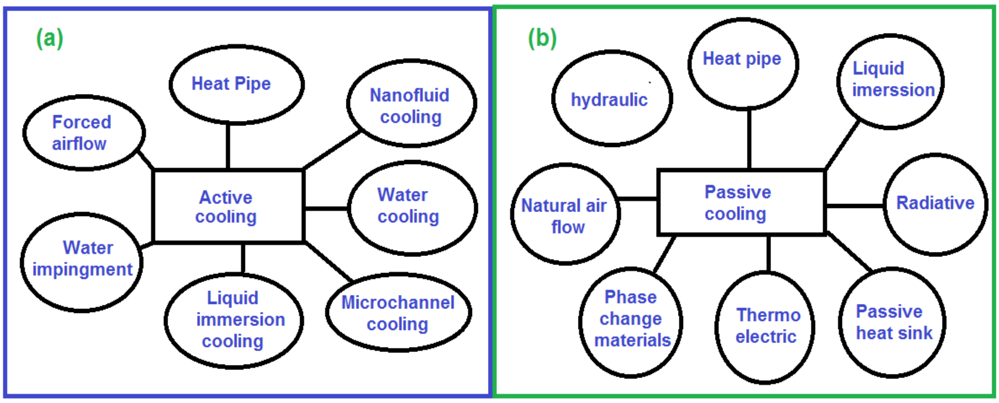

Fig.1. (a) shows varying types of cooling that reduce the temperature of PV panel very effectively and could be applied to improve the performance of the solar cell, and (b) demonstrate all passive cooling techniques generally usedto reduce the temperature of solar cellon hot summer days.

2.VARYING ACTIVE COOLING TECHNIQUES TO IMPROVE THE PANEL EFFICIENCY

(a) Cooling the photovoltaic panel using air as a coolant

An experimental setup to cool the back side of the solar PV module with the help of the number of DC fans was used by [6] as shown in Figs.2(a) and (b). They noticed that when the number of DC fansincreased, the solar PV module's electrical efficiency and output also increased. They achieved a better result when they used 2 DC fans, the increase of 37.17%in electrical power was measured by comparing conventional solar PV modules.Another experiment wascarried out by [23] as shown in Figs.2(c) and (d), in which they compared the performance of natural and forced convection to cool the solar PV module. Two solar PV modules were used, the first was a steel plate under the solar PV module to create an air channel underneath, and the second was a reference PV module. They studied the performance of natural convection with forced convection with the help of a centrifugal air pump. Experimental data shows that force convection resulted lowering of temperature by 150C of the solar cell,in which improvement of electrical power by 15 % took place with the comparison to natural convection.Another experiment that has been revealed in Figs.2(f) and (g) uses air cooling with a PVT collector investigated by [20].They narrated the improvement in electrical and thermal efficiency by 15% and 22%, respectively. As shown in Fig. 4(d), the Air Duct cooling procedure on the PVT system was incorporated for experimental investigation by [46] using Computational Fluid Dynamics (CFD) software.

They reported that an improvement in the electrical efficiency was 2.9% by reducing the PV panel temperature 300 C. At the same time,the airflow rate was maintained at 0.055kg/h, compared with conventional solar PV modules.The experimental result of cooling over an uncooled PV module is demonstrated in Fig. 8(c).The fourth experiment [22] used normal air to cool the solar PV module, as depicted in Fig.7(b). They also explained that the constraints that remarkably affect the cell's performance while cooling are the mass flow rate of coolant, ambient temperature, and solar irradiation. They found that increase in area is directly proportional to the lowering of the cell's temperature, and maximum cooling of the panel could be achieved by 160C in this method. Their result demonstrated that the maximum enhancement of thermal efficiency could be achievedby 15% and electrical efficiency by 10.5%, respectively. They also observed that when the airflow raterises from 0.03 to 0.15 kg/s, the electrical efficiency enhances due to high solar irradiation.The last cold air fromthe air conditioning system was passed through the rectangular duct mounted at the rear sideof the solar panel used for cooling the solar panel investigated by [30]. The experiment's result revealed a 7.2% increment in electrical efficiency and a 6% improvement in the cell performance compared to the module without cooling.

(b) An innovative Ground Coupled Central Panel Cooling System (GC-CPCS)

An innovativeGC-CPCS system was used to cool the solar PV module by [29],as shown in Fig. 2(e). In their setup, they used a single blower with nine PV modules (each 100 watts) to maintain normal airflow and cold air by forced convection to cool the PV modules effectively. An isolated solar cell was installed to run the blower in their system to avoid external energy.

(c) Performance evaluation of a PV panel by water active cooling

[9] investigated water cooling technique for lowering the temperature of solar cellsaccompanied byan aluminum radiator as a heat exchanger in which water had been circulated at the back side of the solar PV module, as narrated in Fig.2(h). He reported in his result that the improvement in electrical efficiency was by 57%,with a lowering of paneltemperature by 32%. Similar water cooling is also used with the help of a pump to cool the surface of the solar PV module [21]. The flow of water on the surface maintains a thin film of water over the panel that does not allow dust particlesto accommodate. As a summary of his results, he reported an enhancement of electrical efficiency by 9% in the pick hour. The details experimental setup is shown in Fig.2(j).

In another experiment back surface,a water cooling technique was reported by [8], as shown in Fig.3 (d), where he used an insulated water tank to circulate the water with the help of a pump and heat exchanger at the back surface of the PV module. He reported a 20% reduction in the PV module temperature and a 9% improvement in electrical efficiency at the hot peak. Cooling PV modules by underground water with the help of a submersible water pump and a storage water tankwas investigated by [27] ,shown in Fig.3 (a). They circulated the water through the pump on the surface of the solar PV module and reported the data over one year.

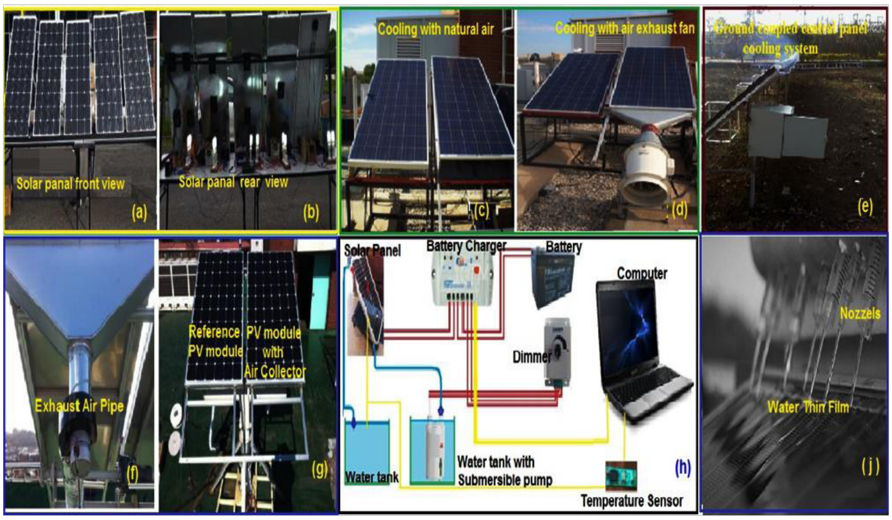

Fig.2(a)the outdoor experimental PV system with and without cooling (Front view) [6]. (b) The outdoor experimental PV system with and without cooling (Back view) [6]. (c) Cooling with natural air cooling [23] d) Cooling with forced air cooling with exhaust fan [23] (e)-Smoke flow visualization test conducted to test the GC-CPCS [29]. (f)- Back side of the PVT module with exhaust air pipe [20]. (g) Experimental setup withsurface cooling of PV module and non-cooled PV module ([20]. (h) Cooling PV moduleswith underground water with the help of a submersible pump [9] .(j) A thin film water cooling diagram created by nozzles on Solar PV modules [21].

In their experimental results, they observed that 15% improvement in the electrical output in hot summer days and a 5% improvement throughout the year . In these improvement in electrical power approx 50% enhancement of power had been achieved by the phenomenon of refraction of the solar beam within the water layer that increase the incident radiation and the rest due to dust free upper surface of PV module where continuous water flow is maintained).They also showed the gain in output power of the PV module by the different sources of cooling water, as shown in Fig. 8(d).Water cooling with photovoltaic thermal systems (PVT) was also investigated by [23] as shown in Fig.4(e), and the results were compared with solar PV modules without cooling. They reported that the electrical efficiency of the solar cell was only 8% duringthe day's highest temperature. Their experimental results illustrated that the active water PVT cooling system increased electrical and thermal efficiency by 2.1% and 51%, respectively. Cooling of PV module where water was used as coolant with the reflectors. The experimental result was compared with numerical model analysis by [44] as shown in Fig.4(f). They used a concentrated PV (CPV) module thatreached the critical temperature of 64.1^{0}C when the panel was with reflectors and 36.5 ^{0}C when the panel was water-cooling with reflectors. They also affirmed that electrical output power improved by 10.65% withoutreflectors and 24.4% when water cooling with reflectors and improved electrical efficiency by 2.8% with water cooling attached with reflectors.

Both numerical modelanalyses with ANSYS software and experimental technique were used by circulating water through porous media to increase the convective heat transfer of the PV module, investigated by [13], as shown in Fig.5(b). In their investigation, they confirmed that the average temperature of the PV module was reduced by 9-14^{0}C due to increasing porous media with an optimum flow rate of water. They also declared the result illustrated good agreement between the experimental values and modeling with ANSYS software. A comparison study was carried out to show the cooling effect of mono and polycrystalline panel of 50-watt capacity by[32], as shown in Fig.5(c). Their result reported that the mono-crystalline panel's performance provides a better cooling response than the polycrystalline panel. The improvement in electrical efficiency of poly and mono-crystalline PV panels was 3.8% and 4.2%, respectively.

In contrast, the gain of electrical power was 13.7 and 14.8 watts in poly and mono-crystalline panels when the water flow rate was maintained at 0.01 kg s^{-1}. Both surface cooling of PVT modules, which cool with a thin film of water at the upper surface of the PV module added with water flow through coconut fibers pith at the back surface, have been seen. Water used for cooling both surfaces was taken from normal water and water from the earthen clay pot for comparison by [29] as shown in Fig.7(c). They revealed overall and electrical efficiency improvement when cooling with earthen clay pot water was recorded at 64% and 9.9%, respectively, compared with normal water cooling. They also explained that evaporation in clay pot during hot period maintain the temperature by 5-8^{0}C less than the ambient temperature.In a numerical investigation carried out by [40], water was used as a coolant to cool the PVT system. They design a 3D physical model and assess the effect of the coolant's mass flow rate, the solar radiation's intensity, the height of the water channel mounted on the top of the PVT system, and the temperature. They observed that heat transfer by convection at the bottom surface of the PVT module was better than that of the top surface for almost all cases. Their result showed that improvement in electrical and thermal efficiency is directly proportional to the mass flow rate. They also found that maximum exergy efficiency improved by 13.8%.

(d) Performance evaluation of a PV module by spray cooling technique

An experimental evaluation of cooling has been carried out by [3] using the spray cooling technique, as shown in Fig. 3(e). They concluded that circulating water creates a thin film on the solar PV module and maintains the optimum temperature of the surface of the PV module. They showed a reduction in the temperature by 37.67% and an enhancement in electrical power by 13.45% with a normal PV module. The resultis shown in Fig.8 (b), which shows the relation between temperature and time.

To overcome water scarcity in the hot region, a new technique of cooling PV panels, i.e., pulsed spray water, was experimentally reported by [14] as shown in Fig.3 (f). They reported steady spray water cooling provides the best result with a 33.33% improvement in electrical efficiency, whereas pulsed spray water cooling with duty cycle 0.2 offers 25.79%. They also mentioned that pulsed spray water cooling saves the water 11.11% compared to steady spray water cooling. A novel spray cooling technique was examined by [42], as shown in Fig.5(d).In their experiment, they suggested optimum spraying timing, spray flow rate, nozzle air flow rate, the distance between the nozzle to panel, and solar radiation to enhance the efficiency of the PV module. As a result, they stated the optimum values of electrical efficiency were obtained in the following experimental condition as 49.9 s for spraying time, 0.018 m^3/h of spray flow rate, 2 m^3/h of nozzle air flow rate, 50 cm of the nozzle to panel distance and 700 W/m^2 of solar irradiance.

Fig.3 (a) Cooling of PV module by water cooling test rig [27] (b) Photograph of the experimental setup with BHE arrangement. [10] (c) The structure of BHE arrangement underneath. [10] (d) Front view of the PV module's experimental setup of the water-cooling system [8].(e) Experimental setup with the nozzle to cool the front surface of the PV module (PV) setup[3]. (f) Arrangement of pulsed spray water cooling setup [14]. (g) Experimental setup of cooling of PV module with water fountain [33]

(e) Fountain cooling method to cool Photovoltaic Module

The water fountain cooling technique was experimentally carried out by [33], as shown in Fig.3(g).They used two panel one is used a reference panel and onher is used for water coolingt. They revealed in their result an improvement in panel efficiency by 34% and 28% at no load and loaded conditions, respectively.

(f) The performance of a buried heat exchanger system for PV panel coolingunder elevated air temperatures

An innovative PV cooling technique based on the buried heat exchanger (BHE) method was reported by[10], as shown in Figs.3(b) and (c). To evaluate their experiment, they used ambient air of varying temperatures of 35, 40, and 45 °C with airflow rates of 0.0228m3/s,0.0248 m3/s,0.0268m3/s, respectively which is given to the buried heat exchanger(BHE) arrangement. In this process, the pre-cooled air from (BHE) regulates the temperature of the rear surface of the PV module to improve its electrical efficiency.

(g) Closed-loop nano-fluid cooling of photovoltaic thermal collector

A new experimental study wascarried out by [17] as shown in Fig.4(a). Their experiment used Al_2O_3 nanofluid as a coolant to circulate in the two different patterns. The first one was named PVT/A, and in this system, cooling nano-fluid was circulated through a copper coil tube used as a heat exchanger at the back surface of the solar PV module and the second one, named PVT/B, in this system,coolant nano-fluid was circulated through polyamide channel structure placed at the back surface of the PV module. To avoid the main electrical supply, a separate 50-watt mono-crystalline panel was used to circulate cooling nano-fluid in both Panels during the experiment. The result revealed that electrical performance in PVT/A & PVT/B increased by 40.17 and 78.27%, respectively. Experiments show that channel cooling is more efficient than coil tube cooling as the channel extended larger area than the coil. In another experiment combined, PVT cooling with the nano-fluid and phase change material (PCM) was used experimentally by [5], as shown in Fig.4(b). In this system, a tank attached at the back of the solar PV module, filled with paraffin wax as PCM and Si-c as nano-fluid, was circulated to cool the PV surface. This mixture was passed through the copper tube attached to the PV module's rear surface. In their result, they exposed the reduction in the temperature by 30^0C during the peak solar radiation period (12:30 PM-01:30). The improvement in the open circuit voltage (Voc), electrical output power, and electrical efficiency from 13V to 21V, 61.1W to 120.7W and 7.1% to 13.7% respectively. They also observed that the overall thermal efficiency gained by their systems was 72% when the flow rate of nano-fluid was maintained at 0.17kg/s. [12] experimented with a cooling procedure shown in Fig.6(d) where an unglazed PVT system using water and copper oxide-based nano-fluid asthe coolant passes through an integrated twisted coil organize sheet to cool the PV module. In their result, they narrated that cooling with only water and nano-fluids reduces the temperature to 15^0C and 23.7^0C, respectively, from 68.4^0C, and enhancement of overall efficiency by nano-fluids was recorded by 21% compared with normal water cooling only. In the same way, a numerical investigation of the PVT cooling technique with three different working fluids: pure water and two different nano-fluids with alumina (Al_2O_3) and silver (Ag) nano-particles were reported by [47]. Results depicted an improvement in electrical and thermal efficiency by 1.83% and 3.43%, respectively, with alumina water nano-fluid but an improvement in thermal efficiency and electrical efficiency by 3.9% and 7.64%, respectively, with Ag- water nano-fluid. The result was vivid that the higher volume fraction of Ag nano-fluids is better than Al_2O_3 nano-fluids for improving the electrical efficiency of the PVT system.

(h) Cooling using brine from the discharge ofreverse osmosis (RO) units

A novel cooling technique in which brine was used from the discharge of reverse osmosis (RO) unit was experimentally investigated by [36], as shown in Fig.7 (c).As the discharge water of RO comes in contact with the surface of the PV module, the temperature of water increases and the salinity level of brine also increases, improving the taken away heat of the PV module. They also reported that improvement in electrical efficiency by 20%, compared with an uncooled PV module.

(i) Hybrid photovoltaic module to optimize the efficiency

A novel hybrid photovoltaic thermal system with a heat pump (HPVTHP) used in the hospital in the tropics area to improve the room temperature of naturally ventilated wards/rooms as well as the generation of electricity was experimental investigated by [5] as shown in Fig.5(a).A heat pump was used to improve the PVT system's efficiency, and overall efficiency was recorded as 60%. Another experimental PVT system in which a serpentine tube attached to the rear surface of the solar PV module and water was used as a coolant was investigated by [43] as given in Fig.6(a).

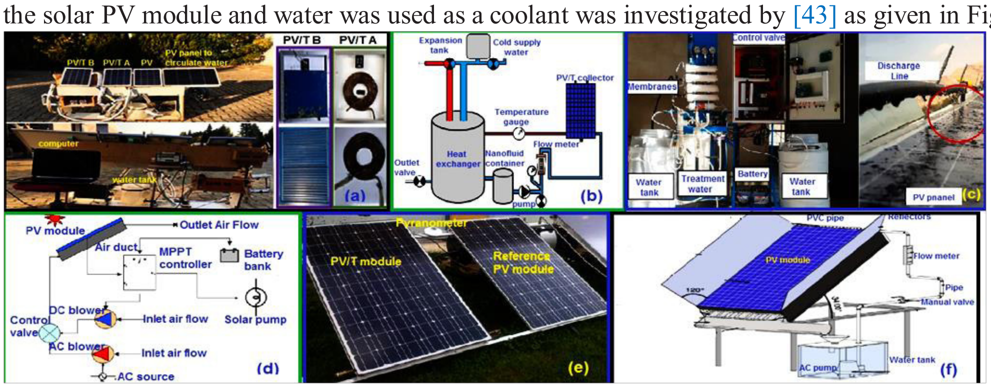

Fig.4 (a) Experimental setup of PVT A & PVT B front and back views. [17] (b) Schematic diagram of the experimental rig of nano-fluid and PCM- nano-fluid cooling system. [5] (c) Photographs of the RO system & the cooling process of the PV module used in this study. [36] (d) A schematic diagram of the experimental set-up of the air duct PVT cooling system. [46] (e)An arrangement of PV and

PVT test units. Left side collector is PVT, and the right-side collector is PV only. [23] (f) Detail layout of the experimental water cooling setup with reflectors. [44].

The data was collected in three different intervals of time in a day from 08-10:59 AM, 11:00-02:59PM, and 03:00-05:59PM. They narrated a reduction in operating temperature by 11.42% and an improvement in electrical and thermal efficiency by 1.25% and 23.5%, respectively, compared to conventional Solar PV modules.

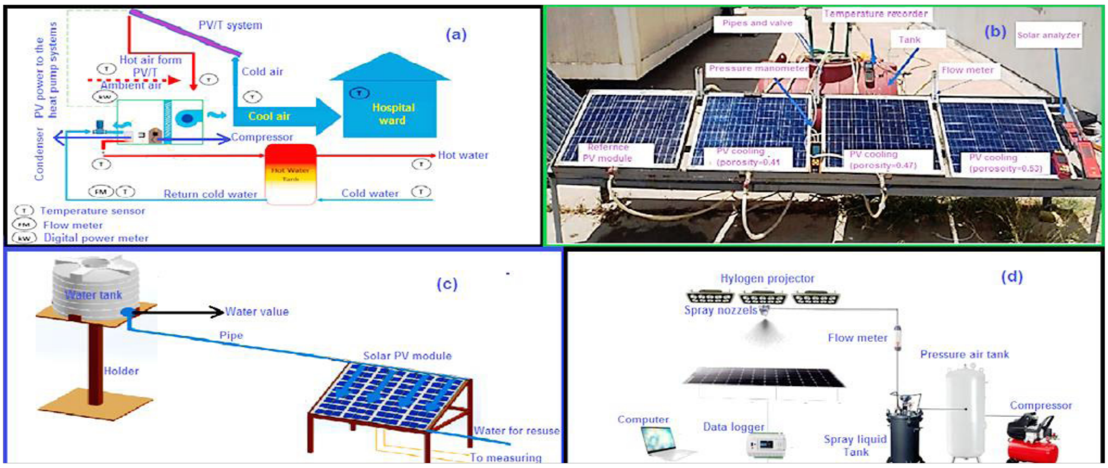

Fig. 5(a) Design of a hybrid PVT system with a heat pump to increase the combined efficiency of the system [5] (b) Experimental setup of PV module with porous media coolant supply to maintain the coolant at low temperature. [13] (c) Detail set up gravity feed water cooling of PV module [32] (d) Experimental setup with spray water cooling technique for cooling PV cell [42]

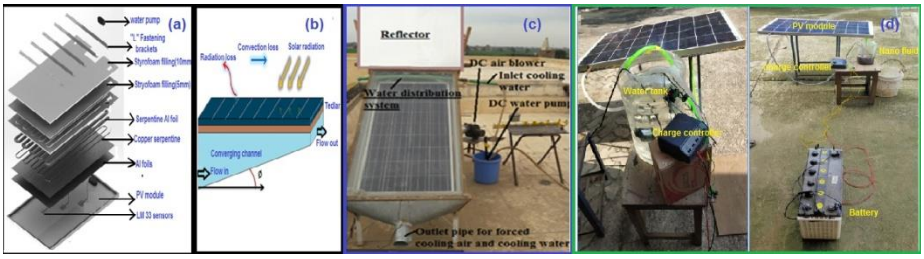

Fig.6 (a) layout of the solar module and water pump for cooling the systems [43] (b) Detailed picture of converging channels heat exchanger with heat transfer modes. [45] (c) Experimental setup with reflectors and cooling technique. [18] (d) Experimental setup with water cooling and cooling with nano-fluids of PV module. [12].

(j) Converging channel heat exchanger for PV cooling

An advanced cooling technique named converging cooling technique, experimentally and numerical investigation has been done by [45], a complete demonstration of the experiment is shown in Fig.9(b). They did the experiment in Saudi Arabia in June and December, and they learned that 2^0 (degree) converging angle systems had given the best result in their experiment. They reported in their results a lowering of temperature to 45.1^0C from 71.2^0C and36.4^0C from 48.3^0C in June and December, respectively, compared to the conventional PV module. Power output and conversion efficiency improved by 35.5% and 27.5%, respectively. The average improvement of electrical efficiency and output was achieved by 27.5% and 35.5%.

(k) Combined air-water cooling to improve PV panel efficiency

The combined cooling techniques of air, water, and both were reported by [18] , as shown in Fig.6(c).In their experiment, they used the solar PV module with reflectors for studies the three different cooling methods separately and compared their results with the reference PV module. Water cooling was the best of all three cases, as shown in the comparison plot in Fig.8 (a).

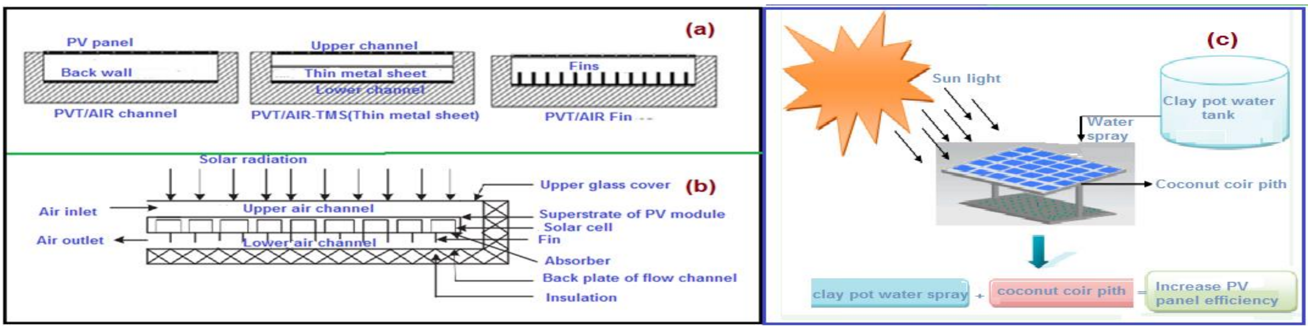

Fig.7 (a) Pictorial view of forced air cooling of PVT systems with fins to increase the PV section's cooling rate [22] (b) Cross-sectional view of double-pass PVT solar air heater with fins. [22] (c) Experimental setup of a clay pot water cooling with coconut coir pith at the rear surface cooling. [28].

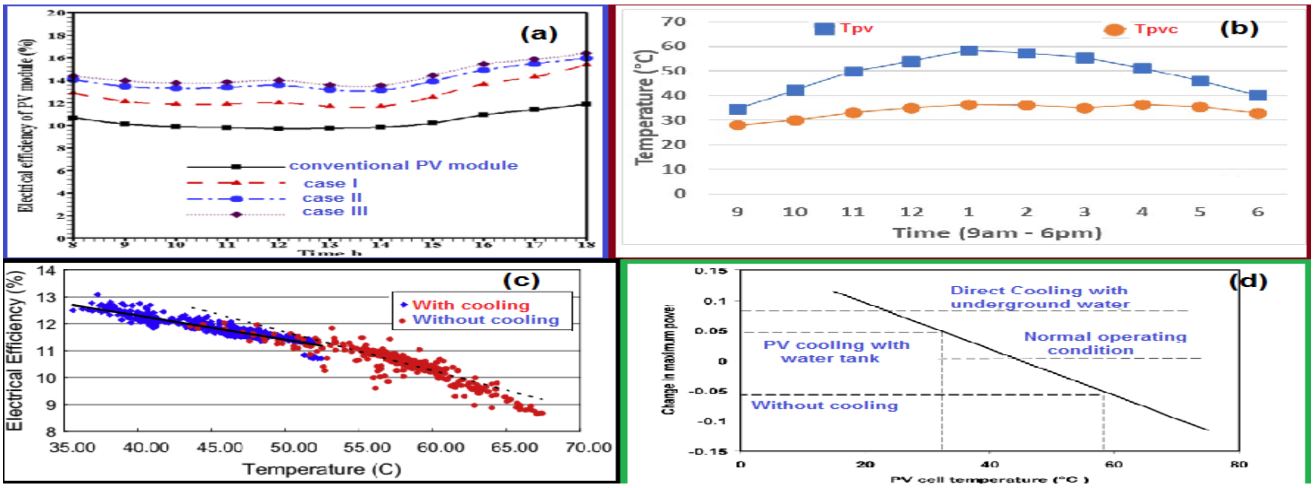

Fig.8 (a) variation of electrical efficiency along the day for all cases. [18] (b) Variation of the temperature of reference photovoltaic (PV) panel from morning 09:00A.M.-06:00P.M. of a day [3] (c) Electrical efficiency as a function of PV temperature. [46] (d) Effect of using different sources of cooling water with the temperature of the PV module[27].

3.COMPARISON TABLE OF DIFFERENT COOLING TECHNIQUES.

Sl. No.	Method of experiment/surface cooling	Reduction of panel temperature (%)	Improve in electrical efficiency (%)	Remarks
1	Al_2O_3 nano-fluid as a coolant to circulate in the two different conditions /rear [17].	--	40.17 &78.27	Electrical performance in PVT/A (Coil cooling) and PVT/B (channel Cooling)
2	Cooling of unglazed PVT system using water and copper oxide-based nano-fluid [12]	23.7	--	--
3	Novel water spray cooling/front [42]	--	--	The optimum electrical efficiency was obtained in 49.9 s for spraying time, 0.018 m^3/h of spray flow rate, 2 m^3/h of nozzle air flow rate, 50 cm of the nozzle to panel distance, and 700 W/m^2 of solar irradiance.
4	Discharge of reverse osmosis (RO) unit as coolant/front [36]	--	20	

5	Spray water cooling. Technique /Front [3]	37.6	13.45	--
6	Pulsed spray water cooling /front[14]	--	33.33	Optimize pulsed spray water cooling with duty cycle 0.2 offers 25.79%, and water saving 11.11%
7	Fountain cooling technique/front [33].	--	34 & 28	At no load and loaded conditions, respectively
8	Cold air from buried heat exchanger (BHE) /rear[10]	--	--	Improve the electrical efficiency of the panel
9	Cooling by cold air of air -conditioning /rear[30]	--	7.2	6% improvement in the performance ratio compared to the module without cooling.
10	Both front and rear surface cooling [28]	--	9.9	Evaporation in clay pot during hot period maintain the temperature by 5-8^0 C less than the ambient temperature.
11	PVT systems in which serpentine tube is used [43]	11.20	1.25	--
12	Air cooling by 2 DC fans /rear [6]	--	37.2	Two fans prove the best result than more numbers of fan
13	Water cooling with the aluminum radiator as heat exchanger /rear [9]	--	57	Decrease in surface temperature of PV module by 32%.
14	Nano-fluids cooling {water with alumina (Al_2O_3) and silver (Ag) nano-particles/front [47]	--	7.64	A higher volume fraction of Ag nano-fluids is better than Al_2O_3 nano-fluids for improving electrical efficiency
15	Converging cooling method /front([45]	35	27.5	2^0 (degree) converging angle systems gave the best result
16	Cold air by GCCPCS with smoke flow visualization/rear[29]	--	--	Highest conversion efficiency at 35 degrees of panel temperature
17	Forced convection of air cooling/front[23]	15	15	Forced convection is better than natural convection.
18	Back surface water cooling technique [8]	20	9	--
19	Normal air to cool the solar PV module/front[22]	16	10.5	The mass flow rate of air increases from 0.03 to 0.15 kg/s the electrical efficiency enhances
20	Combined PVT cooling with the nano-fluid and phase change material (PCM)/rear [5]	--	7.1& 13.7	Paraffin wax as PCM and Si-c as nano-fluid were circulated to cool the PV cell

4. CONCLUSIONAND FUTURE SCOPE OF WORK

The study of active cooling of the solar PV module is very important in the present scenario as global energy production is moving towards solar energy as an alternative to fuel energy by using solar photovoltaic cells. Therefore, to optimize its efficiency throughout the day and in a year, the functioning of the PV module is to be taken care of. The PV module's cooling increases its efficiency by lowering panel temperature on hot summer days. The literature survey depicts that the researchers have been working on this issue approximately from 1979 to date to finda cost-effective,highly efficient cooling technique to generatethe energy of PV cellson hot summer days. Based on the review, the following conclusions have been made that are mentioned below:

- In cooling PV modules, the active cooling method plays a major role compared to passive cooling.
- In the DC fan cooling process at the PV module's rear surface, when the number of DC fansis increased, the electrical efficiency and electrical output of the solar PV module also increase. Still,using two(2) DCfans proved the best. Asaresult, theyachieveda 37.17% increase in electrical power compared tothe conventional solar PV module.
- In the air cooling method, force convection resulted in a 15^0 C reduction in temperature of the solar PV module by improving 15% of the electrical power compared to natural convection.
- Different parameters affect the system's cooling efficiency, such as coolant temperature, coolant, and solar irradiation mass flow rate, wind flow, ambient temperature, and the panel's material.
- Maximum enhancement in the electrical efficiency was achieved by 57% with a lowering of 32% in panel temperature when back surface water cooling of the PV module had been carried outwith the help of an aluminum radiator.
- In an investigation, they confirmed that the average temperature of the PV module was reduced by 9-14^0C due to increasing porous media with an optimum flow rate of water.
- CoolingPV modules by underground water with the help of a submersible water pump and a storage water tank resulted ina 15% improvement in the electrical output on hot summer days and a 5% improvement throughout the year.
- In the process of water cooling, 50% enhancement of power is achieved by the phenomenon of refraction of the solar beam within the water layer that increases the incident radiation and the rest due to the dust-free upper surface of the PV module where continuous water flow is maintained.
- Continuous spray water cooling provides the best result with a 33.33% improvement in electrical efficiency, whereas pulsed spray water cooling with duty cycle 0.2 offers 25.79%. It is also clear that pulsed spray water cooling saves 11.11% of water compared to steady spray cooling.
- The water fountain cooling technique improved the panel efficiency by 34% and 28% at no load and loaded conditions, respectively, to the base panel.
- The study showed that channel cooling is more efficient than coil tube cooling as the channel extended larger area than the coil.
- In the process of water cooling, where discharge water from RO comes in contact with the PV module's hot cell surface, the temperature of water increases, and the salinity level of brine also increases, improving the taken away heat of the PV module. This method's improvement in electrical efficiency by 20%is observed compared with an uncooled PV module.

As a future scope of work, the following can be doneto better understand the cooling parameters of PV modules on hot summer days.

- The study can be made with more than these many papers in the active cooling process.
- Active and passive methods of cooling can be studied for better comparison.
- The experimental procedure could be conducted to find the reality of getting maximum efficiency.

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