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ORIGINAL ARTICLE

Simulation Study of Cooling System for Photovoltaic Panel Using Ansys

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ABSTRACT – Photovoltaic or PV system are very important nowadays because of its functionality of absorbing energy of sunlight and convert it to electric energy. By applying the PV panel, it can cut the cost of billing for the users. It also called a green technology because it produces clean of the energy that can avoid from global warming and air pollutant. Despite of the benefits that it produces, the efficiency process of the system depends on how it been take care. The PV panel cannot be exposed to the high temperature of sunlight. If PV panel getting hot, the PV panel system cannot produce a full of its efficiency to user. By applying the cooling system on the PV panel, it can control and reduce the temperature of PV panel when the temperature increase. The simulation run was taken place in this research by using Ansys software. The result shows the reduction of the temperature of PV panel by applying mass flow rate of air and water. The inclination angle also plays a role in the simulation because if the angle of inclination of PV panel exposed more to sunlight it easily can make the PV panel hot. When the values of the mass flow rate increased, the lower the temperature of the PV panel can be achieved.

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INTRODUCTION

The exploration of photovoltaic (PV) modules is probably the biggest success in the history of solar energy utilization. The term "photovoltaic" is derived from the Greek "phos," which means "light," and "volt," which is the unit of electromotive force [1]. Alexandre-Edmond Becquerel, a French physicist, discovered the photovoltaic effect in the year between 1820 to1891. He constructed the 1st PV cell in the world at the age of 19. He saw voltage on the attached platinum electrodes while illuminating it. In his "Mémoire sur les effets électriques produits sous l'influence des rayons solaires," he detailed his discoveries [2].

Due to rising climate change concerns and ensuring energy security, renewable energy is the most popular zero-emission option for many energy applications throughout the world. Solar energy is abundant and entirely free everywhere on the planet. Hence, the rapid growth of solar energy application in both urban and rural areas. The most common use of solar energy for carbon–neutral power generation is PV systems. Nowadays, PV panel, i.e., known as solar panel is used to produce electricity by capturing sunlight energy. There are two types of PV panel system, which are the grid-connected system and stand-alone system. Grid-connected system is connected to the national grid, where electricity can be used directly from the grid. On the other hand, stand-alone system is not attached to the grid, where solar batteries are needed to use the electricity when there is no sunlight [3].

By using PV Panel as our main electricity supply, the pollution towards the nature can be reduced as PV panel provide a clean and green energy. PV technology also can supply an affordable sustainable energy and reduce the global warming that happen in the world caused by the carbon dioxide. PV panel can operate for 100 years and even longer period, where operating and maintenance cost is considered as cheaper than the costs of other renewable energy systems. The best part in using PV panel is it can help reduce the electricity bills. Moreover, there has been an experiment testing in efficiency of using PV panel which found that 40% of efficiencies is achieved in case of concentrating PV cells [4]. Furthermore, the efficiencies are even increased while mass-production costs are decreased [5].

Despite the benefits, there is also some drawbacks while using PV Panel. It was found that PV Panel cannot exposed to overheated sunlight. The longer period the PV panel is exposed to sunlight, the lower the efficiency of PV panel will become [6]. Specifically, high temperature of PV panel will decrease the performance of the PV panel to capture sunlight. To improve the efficiency of PV panel, cooling technique is of great importance. In this study, a cooling technique will be conducted to investigate its effects on the temperature reduction of PV panel. The technique will vary the water flow rate, air flow rate and panel inclination angle. A Computational Fluid Dynamic (CFD) approach will be applied by using Ansys software to conduct the investigation. Despite the benefits, there is also some drawbacks while using PV Panel. It was found that PV Panel cannot exposed to overheated sunlight. The longer period the PV panel is exposed to sunlight, the lower the efficiency of PV panel will become [6]. Specifically, high temperature of PV panel will decrease the performance of the PV panel to capture sunlight. To improve the efficiency of PV panel, cooling technique is of great importance. In this study, a cooling technique will be conducted to investigate its effects on the temperature reduction of PV panel. The technique will vary the water flow rate, air flow rate and panel inclination angle. A Computational Fluid Dynamic (CFD) approach will be applied by using Ansys software to conduct the investigation. Due to the global

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warming that we face every year in the country, it can be assumed that PV panel can expose to the overheated temperature of sunlight. Thus, PV panel will easily become less functioning [7]. Many houses, farms and factories that use PV panel system can get burden of overheated PV panels and thus increase the maintenance cost. Therefore, a solution to cool down the overheated PV panel must be developed to ensure the PV panel can be used optimally. According to previous studies, formation of dust is among the factors of the PV panel being less efficient. The efficiency of PV panel will reduce because the PV panel cannot work in maximum potential [7]. The energy conversion will be stuck as the PV panel is covered by dust.

LITERATURE REVIEW

The sun's energy to the earth is abundant and completely renewable. In a nutshell, the sun made human life possible in the planet that we couldn't imagine life if there no sun. Almost all of the earth's energy resources are derived directly or indirectly from the sun, including fossil fuels such as wind, waves, biomass, and so on. Ancient civilizations had already harnessed sunlight as a source of energy. Since then, many new technologies and breakthroughs have been made in this field [8].

Solar's first applications were mostly in the realm of architecture. 6000 years ago, the Neolithic Chinese people had a single aperture pointing south in their buildings to gather wintertime low sun rays to help keep their homes warm. The homes were protected from the hot summer sun by a suspended thatched roof. The ancient Egyptians and Greeks employed this technique thousands of years later. Aristotle (384 BC-322 BC) was a Greek philosopher who taught how to harness the winter sun for heating and how to keep the home cool in the summer. This method was the forerunner of today's passive heating and cooling methods [8].

More traditional methods of fructifying the sun's thermal energy were also used in that era's architecture. Insulation, south-facing windows, and expansive floors and walls were all incorporated into meticulously engineered passive systems that naturally aid with heating, cooling, and lighting. In more elaborate active solar heating and cooling systems, liquids or air were pushed through pipes or channels to convey heat to the desired location [9]. Numerous advances in the collection, storage, and control of solar energy were shown, due to a greater understanding of the glass's propensity to trap solar heat [9].

Despite the many benefits that photovoltaic (PV) panel can provide to the users, there are also weakness that cannot be avoided. PV panel is one of the green technologies that has helped reducing global warming in the world. Using it can also reduce cost of electricity and save money for the maintenance [10]. However, as the temperature of the PV panel rises, it has a greater impact on the operating parameters and lowering the efficiency of PV performance. It's worth mentioning that every 1°C rise in ambient temperature, PV performance efficiency can be reduced by 0.4 to 0.5 percent [10]. Experimental study conducted in the past [10] has been set up by using Pulse Code Modulation (PCM) integrated natural water circulation cooling technology during summer days. The main objective of the investigation was to record the performance of the solar PV panels.

Furthermore, according to the previous study from by Fahad Faraz Ahmad et al., they stated that during summer at UAE the temperature can increase up to 70°C. It's very dangerous and may affect the safety and efficiency of PV panel. Around 20% of power loss have been recorded and caused the efficiency drop drastically [11]. The temperature coefficient of power, which is technically known as the relative efficiency, normally decreases by 0.45% when the working temperature rises by 1°C. According to their reports, every 10°C rise in the solar photovoltaic (SPV) panel's working temperature twice the deterioration rate. Furthermore, temperature deterioration and soiling are two key issues that SPV systems confront in the UAE. Other losses in the system, such as optical and ohmic losses, were also found to play their role. However, the thermal impact was found to be the most significant contributor to the degradation of the solar system's performance among all system losses [11]

Formation of dust on PV panel becoming one of the reasons why the temperature of the PV increases and decrease in efficiency. The formation of dust on surface PV module will minimize the quantity of solar irradiation reaching the cells by lowering the glass cover transmittance. In Tehran, Iran, Asl-Soleimami et al. observed that the energy production of solar modules was decreased by 60% and advised a 30° tilt angle as the best for grid-connected applications. Simulated sandstorms were also tested to see how they affected PV module efficiency [12]. The solar cell characteristics of a solar cell decreased owing to the combined influence of shade and dust, according to Ibrahim.

A long-term exposure of PV modules to Dhahran's real-world outside conditions reveals that performance declines as dust accumulates except if the modules were cleaned by rain or human intervention. If no cleaning is conducted on modules for more than six months, the power output might drop by more than half. Dust collection causes a reduction in power production that is dependent on the time of module exposure, frequency as well as severity of dust [12]. Here, a cleaning tool installed on PV modules can helps to clean the PV modules right away when sandstorm happen. Although rain can help to enhance the power output of dusted solar modules, it is not fully efficient since raining seldom happen in the Dhahran region.

Due to humidity, dust adheres to the glass covers of modules, necessitating a thorough but gentle cleaning to return them to their original power outputs. By minimizing the dust impact by 50%, the tracker increases the power output of the PV modules. The backside temperatures of modules on the solar tracker were greater than those on the fixed stand. When compared to monocrystalline modules subjected to the same circumstances, polycrystalline modules had a significantly higher backside temperature. The elemental composition of the collected dust derived through EDS analysis demonstrates that oxygen is the most abundant element in the dust at the solar PV module installation location [12].

Additionally, Omer Khalil Ahmed and Zala Azizi Mohammed publish research on the influence of dust on the performance of hybrid photovoltaic panels and thermal collectors [13]. According to their analysis, the greatest electrical efficiency was 10.24 % in the case of a clean collector, while the maximum electrical efficiency was 5.67 % in the case of a dusty collector. Additionally, as compared to the clean collector, the hybrid collector's total efficiency was lowered by 17.5% for the dusty collection [13]. The disadvantage of these cells is that they develop in temperature, especially in hot, bright weather, such as that found in Iraq, and that they spend the bulk of the year exposed to a heated environment. Additionally, when the temperature of the cell increases, its efficiency increases [14].

Along with high temperatures, especially during the summer, the Middle Eastern countries have dusty climates. Therefore, the primary challenge facing academics working in the field of solar energy in Iraq and other similar countries is the prevalence of dust and the subsequent need to clean sun energy equipment. According to current research, a buildup of around 4 g/m2 of dust reduces solar conversion efficiency by approximately 40% [15]. The effect of Iraq's dusty climate on the operation of traditional solar heaters was examined. The solar heater's efficiency decreases from 49.74% in bright weather to 48.94% in dusty weather. Additionally, during hot weather, the temperature of the heater's hot water output was dropped from 43.85°C to 33.7°C. When the weather is dusty, the researcher suggests regularly cleaning the solar collector used to heat water to guarantee that it is heated to the right temperature [16].

METHODOLOGY

Ansys is a robust general-purpose CFD programmer that combines an intuitive graphical user interface with the OpenFOAM® libraries' features. With SimFlow software, we can generate and import the mesh, establish boundary conditions, parameterize the case, run the simulation, calculate in parallel with a single click, and use ParaView to post-process the results. SimFlow is a comprehensive numerical tool that can simulate compressible and incompressible fluid flows, turbulent flows, conjugate heat transfer, multiphase flows, cavitation, and chemical reactions, among other things. Ansys also known as Computational Fluid Dynamics (CFD). CFD is the process of mathematically describing a physical event involving fluid flow and solving it numerically using computer power. Ansys is utilized in this study to calculate the temperature reduction that effected on PV panel that expose to the high temperature of sunlight by applying the cooling technique parameters on PV modules which are water flow rate, airflow rate and inclination angle.

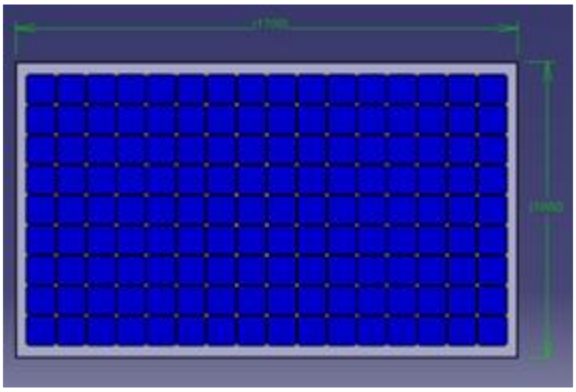

Figure 1. Design of photovoltaic panel.

Table 1. Parameter and conditions

Parameter and Condition	Range
Water flow rate (kg/s)	0.01, 0.02, 0.05
Airflow rate (kg/s)	0.01977, 0.02704, 0.05402
Inclination angle (°)	35, 45, 50
Initial temperature (°C)	43
Ambient temperature (°C)	36
Time of PV panel setup (PM)	12
Dimension of PV panel (CM)	1700 length × 1000 width × 5 thickness

Figure 1 shows design of the PV panel that had been design by using Catia V5 software. The dimension of the PV panel is 1700 length × 1000 width × 5 thickness. The dimension of the PV panel is the actual dimension from the original PV panel that already in the marketplace. Table 1 shown the parameter that will be setup in the simulation by using Ansys software. There is fixed parameter which is initial temperature, ambient temperature, time of panel setup and dimension of the PV panel. The variable parameter are mass flow rate of water and air, and inclination angle of the PV panel. Figure 3 shows the flow chart of simulation by Ansys software

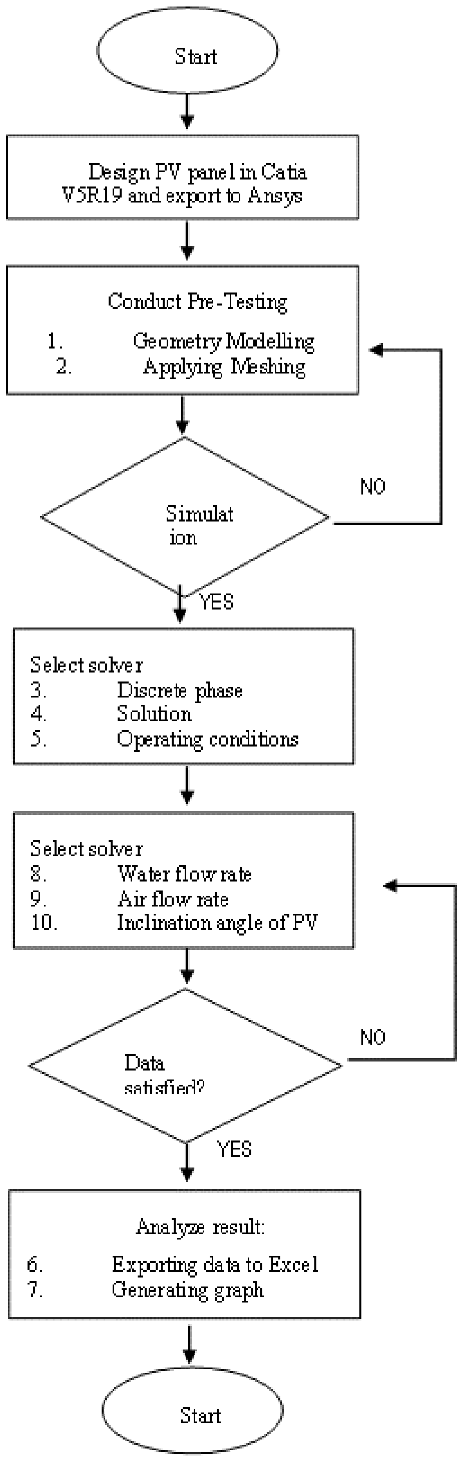

Figure 3. Flow chart of simulation by Ansys software.

RESULTS AND DISCUSSION

Figure 4 shows the effects of mass flow rate of air on average temperature of PV panel by using 35° degree of inclination angle. The mass flow rate that used was three different value which is 0.01 kg/s, 0.02 kg/s and 0.05 kg/s. The experiment was set up at the same time to all PV panel which is at 12 at noon which is the hottest time at our country. In the Figure 5 shows that the decreases of the temperature when the mass flow rate of water is increase. Its same goes to other PV panel that using inclination angle of 45° and 50° as shown in the Figure 5 and Figure 6.

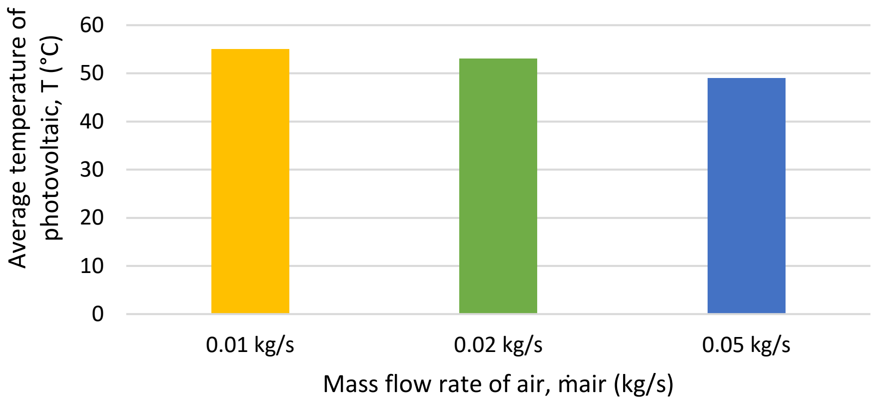

Figure 4. Effects of mass flow rate of air on average temperature of PV at inclination angle 35 deg.

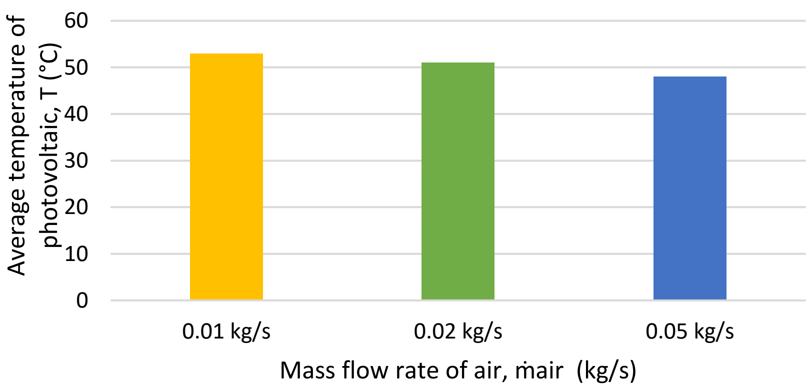

Figure 5. Effects of mass flow rate of air on average temperature of PV at inclination angle 45 deg.

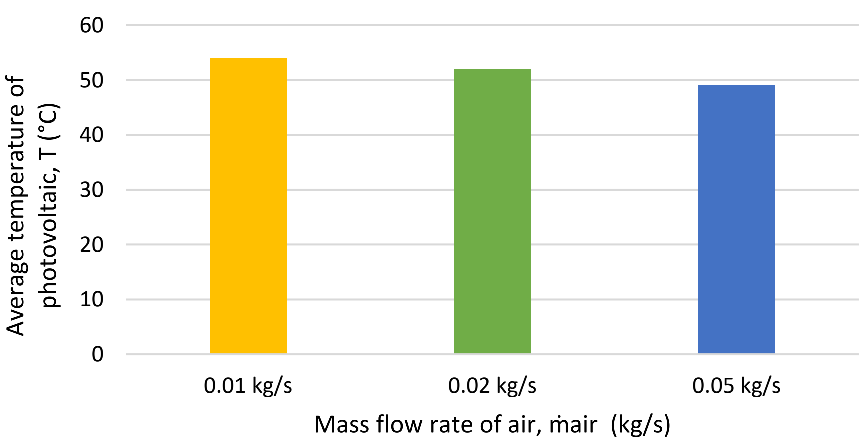

Figure 6. Effects of mass flow rate of air on average temperature of PV at inclination angle 50 deg.

By comparing the three result that shows in the Figure 4, Figure 5 and Figure 6 the effect of mass flow of air on average temperature of PV panel, at inclination angle of 35° recorded the highest temperature which is 55°C at beginning of the simulation by using 0.01 kg/s of air flow rate. When the mass flow rate increases to 0.02 kg/s, the temperature decreases to 54°C and decrease to 51°C when the mass flow rate of air is 0.05 kg/s. This is because at 35° of inclination angle of PV panel was exposed more to sunlight compared to another angle which are 45° and 50°. Morgan said in its previous study that the temperature of PV panel can be increase if the PV exposed more to the sunlight [3]. At inclination angle of PV panel of 45°, the first simulation using air flow rate of 0.01 kg/s the temperature recorded 53°C and reduce to 52°C when the mass flow rate of air increase to 0.02 kg/s. While using highest mass flow rate of air, the temperature is 49°C. Then, PV panel recorded 54°C at the first air flow rate when the inclination angle is 50°. The temperature reduce 1°C when the value of the mass flow rate is 0.02 kg/s. The highest the value mass flow rate of air reduce the temperature to 50°C.

The highest temperature recorded was 55°C by using 0.01 kg/s of air flow rate. The lowest temperature recorded by this simulation was 49°C at inclination angle of 45° by using 0.05 kg/s of air flow rate. When the mass flow rate is low, the temperature of PV panel is higher. By using the inclination angle of 50°, the temperature also decreases when the air flow rate was increase but is not so suitable to install it at houses or factory because the angle was too upright to the surfaces. The inclination angle of the PV panel plays a role to maintain its efficiency in absorption of sunlight energy [7]. This simulation shown that the best inclination angle of using air flow rate was 45° as shown in the Figure 4.2 and the decreases of the temperature of the PV panel by using different air flow rate.

Figure 7 shows the effects of mass flow rate of water on average temperature of PV panel at inclination angle of 35°. The water flow rate had used in the simulation were 0.01 kg/s, 0.02 kg/s, and 0.05 kg/s. The value of the mass flow rate of water was fixed for every simulation but only the inclination angle of PV panel was different. The time was set up in the simulation was on 12 P.M which is same with the simulation by using mass flow rate of air. Figure 8 and Figure 9 shows the result of the effects of mass flow rate of water on average temperature of PV panel at inclination angle of 45° and 50°.

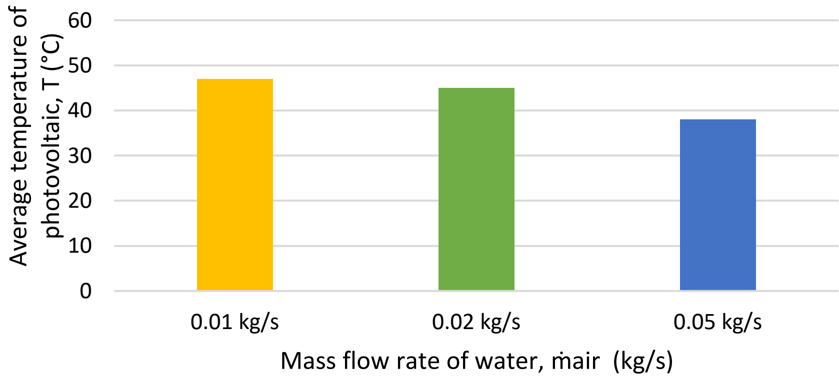

Figure 7. Effects of mass flow rate of water on average temperature of PV at inclination angle 35 deg.

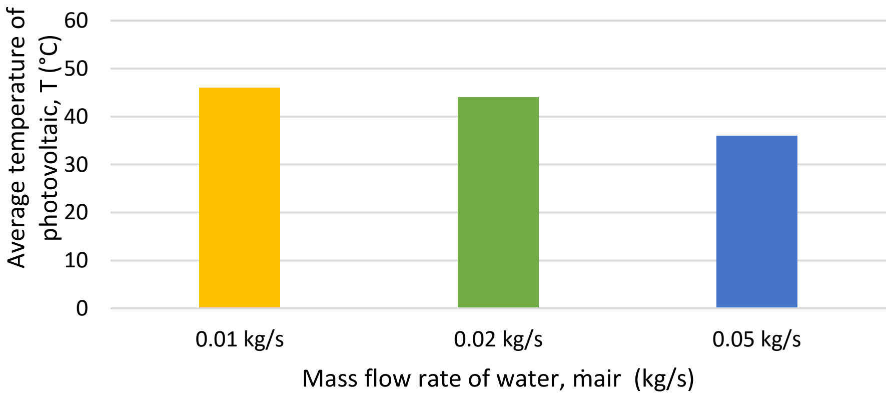

Figure 8. Effects of mass flow rate of water on average temperature of PV at inclination angle 45 deg.

Furthermore, by comparing the result of effect that happen to the temperature of PV panel that had been simulation by using mass flow rate of water shows that 45° inclination angle has the lowest temperature of PV panel which is 36°C by using 0.05 kg/s of water flow rate that shown in Figure 8. Shchekleina said in its paper about cooling PV panel that using water as cooling decreases 15% of the PV panel temperature [17]. By using the inclination angle of 50° of PV panel the lowest temperature recorded was 40°C that shows in Figure 9. It is because of the inclination of angle to upright and the water flow rate that had been absorb completely. The lower the angle of inclination, the more chances the PV panel can be cool. Optimum angle of inclination of PV panel can be reason of the temperature reduction [17]. Moreover, the simulation of PV panel that using inclination angle of 35° recorded the lowest temperature was 38°C. The angle that was using was good, but it exposed too much to the sunlight and that was why the PV panel cannot get the lowest temperature from all the simulation by using mass flow rate of water.

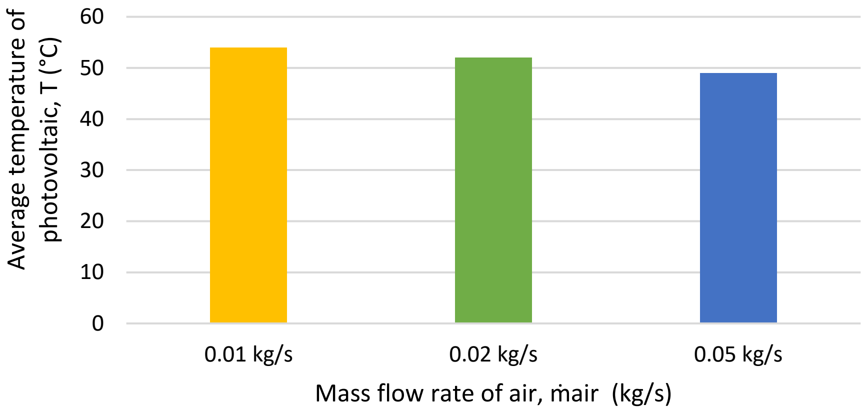

Figure 9. Effects of mass flow rate of water on average temperature of PV at inclination angle 50 deg.

The result had shown that every parameter that used in the simulation by Ansys software which are the mass flow rate of air and water had reduced the temperature of PV panel. The best result by using mass flow rate of air is shown in the Figure 5 and the best result using mass flow rate of water are shown in Figure 8. Each simulation was using the inclination angle of 45°. By comparing both of parameter, which is air flow and water flow rate, using mass flow rate of water drop the temperature of PV panel more than mass flow rate of air. Using air as a coolant reduced the temperature of the solar cells by 4.7°C and increased the solar panel efficiency by 2.6 percent, while using water as a coolant reduced the temperature of the solar cells by 8°C and increased the panel efficiency by 3% [18]. Water cooling offers more thermal conductivity of heat than air cooling [18]. As recorded in the Figure 4.5, the temperature drops to 46°C by using 0.01 kg/s while Figure 4.2 recorded 53°C. When the value increase to 0.02 kg/s of the parameter, the temperature reduction shows the drop of 2°C that using mass flow rate of water while using mass flow rate of air recorded 1°C was drop. While using highest value of parameter which was 0.05 kg/s the temperature PV panel drop drastically. Using mass flow rate of water reduce the temperature to 36°C while using mass flow rate of air the temperature drops to 49°C which is small reduction of temperature only. This quite a massive, good impact from using mass flow rate of water than mass flow rate of air.

CONCLUSION

In the conclusion, by creating the or designing the cooling system for PV panel under water and air flow cooling method has made this research more relatable in measuring the temperature reduction of PV panel. The design of cooling system also helps in investigate the effects of mass flow rate of air and water and inclination angle of PV panel.

The different value of parameter which is mass flow rate of air and water and inclination angle that has been use in the simulation by Ansys software gives the expected outcome which is the reduction of temperature of PV panels. When the value of mass flow rate increase, the temperature of PV panel is decrease. When the temperature of PV panel decreases, the maximum potential of efficiency of PV panel can be achieved.

By using the parameters that have been discussed in the simulation, it shows an interesting difference where we can compare and found the best result of using these parameters. Both mass flow rate which is mass flow rate of water and air showing the temperature reduction of PV panel in this simulation. In this simulation research, the lowest temperature of PV panel that has been recorded is 36°C and it's using mass flow rate of water and 45° of inclination angle of PV panel. By using the mass flow rate of air, the lowest temperature is 49°C and using 45° of inclination angle of PV panel. The 45° of inclination angle of PV panel is the best among other inclination angles. Lastly, in this research also show that using mass flow rate of water is better than mass flow rate of air in cooling the PV panel

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