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Investigation of Solar Panel Performance Based on Different Wind Velocity Using ANSYS

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Abstract

The low conversion energy efficiency of solar panel is affected by the several weather issues. Solar radiation, ambient temperature, dust accumulation and wind velocity are the weather problems. This main goal of this paper is to understanding the solar panel behavior under wind velocity effect. A three-dimension (3-D) model of solar panel is conducted in this investigation. The solar panel model is simulated under different wind velocity. Four different of wind velocity with 0 m/s, 0.43 m/s, 2.5 m/s and 6.95 m/s are selected to examine the solar panel performance. The simulation results are obtained with using ANSYS simulation software. The temperature distribution of the solar panel model will be discussed in this current paper. The simulation result is showed highest wind velocity can be provided good cooling effect for the solar panel model in order to enable the solar panel can be operated to perform well at lower temperature.

Keywords: *Solar panel, ANSYS simulation, Wind velocity, Temperature distribution*

1. Introduction

Solar energy is one of the most essential forms of renewable energy. Earth receives quantity of solar irradiation from sun is more than the consumption of humans need [1]. Solar panel is a solar device which absorbs solar radiation from the Sun directly converts into electrical energy. All the solar panels are manufactured according to Standard Test Condition (STC) which is rated is solar radiation of 1000 W/m^2, panel temperature of 25 °C and light spectrum with an air mass (AM) is 1.5 [2]. But, when the solar system is applied for domestic purposes in certain regions, the solar panel performance will be impacted by the weather problems for the area. Therefore, the solar panel cannot perform actual performance as the specification given by the manufacturer.

Solar panel work great in specific weather conditions, but, due to the weather is constantly changing; majority solar panel cannot function normally under normal operating conditions. Not only are the basic characteristics of solar panel will affect its performance, the weather problems also are one of the factors. Solar radiation, ambient temperature, dust accumulation and wind velocity are the weather problems that perform significant role in the conversion process of solar panel.

In this investigation, the effect of wind velocity is focus on the performance of solar panel. Several researchers were focused to investigate the solar panel performance that affected by wind velocity effect. Latifa Sabri and Mohammad Benzirar [3] carried out the different amount of wind velocity results in solar panel operating temperature. When increases in wind velocity, the solar panel temperature decreased and enhance in power generated. This is because the high wind velocity can be dissipated more heat from the solar panel surface. In the work of S Mekhilef et al [4], environmental issues were suggested taken into consideration when applied solar application system. Dust accumulated, humidity and wind velocity as environmental issues that can be impacted the solar panel performance. The experimental result is showed the better solar panel performance when the higher wind velocity can be removed the temperature of solar panel. Hassan BS et al [5] state that the excess photon energy is dissipated in the form of heat impacted the performance of solar panels.

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Jia Yang et al [6] constructed an experimental to investigate the impact of the wind velocity on the performance of solar array. The range of wind velocity is variable from 2 to 8 m/s. The result of the experimental is carried out the increasing wind velocity improved the power generated by solar panel. S Armstrong and WG Hurley [7] analyzed the heat transfer from the solar panel surface under varying wind velocity condition. The variable of wind velocity is 0.77 m/s, 2.14 m/s and 5.76 m/s for analysis the heat transfer rate. It can obvious that 5.76 m/s of wind velocity can be transferred more heat generated by the solar panel compared to other wind velocity value.

Being the solar energy has started to become more widely used; actually there is a need to speed up investigation to find out the effect of wind velocity towards them. A fast method when compared to conduct experimental is by the way of computational fluid dynamic (CFD). In the present study, ANSYS simulation software is used to analyze the performance of solar panel under varying of wind velocity from 0 m/s up to 6.95 m/s under Kangar, Perlis, Malaysia. ANSYS can be performed to simulate the test or even operating condition that enables for experimenting in a simulation environment before building a prototype product.

2. Experimental

2.1. Effect of Heat Transfer and Wind Velocity for Solar Panel Performance

During operation of solar panel, the excessive solar radiation and high temperature are the major factory cause the solar panel facing overheating. This result to solar panel produced less power output. It is also found that performance of solar panel is very sensitive to its operating temperature. The heat energy produced by solar panel and heat loss to the environment will be leading to equilibrium of solar panel operating temperature. This heat energy can be transferred away by conduction, convection and radiation as shown in Figure 1.

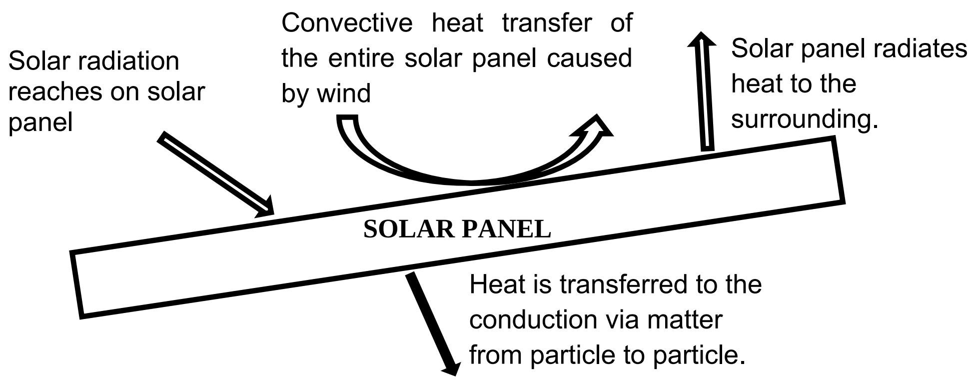


Figure 1. The heat transfer of a conventional solar panel

The concept of conduction is carried out in the case of the two objects in contact; it is passed from the higher temperature to another lower temperature. Conductive heat losses that occurred on the solar panel are due to the thermal gradients between the solar panel and ambient surrounding condition the solar panel connected. In the one-dimensional in a rectangular coordinate, the following equation can be calculated by [8]:

$$\mathrm{Q} = \mathrm{kA}\frac{T_H - T_C}{\Delta x} = -\mathrm{kA}\frac{T_C - T_H}{\Delta x} = -\mathrm{kA}\frac{\Delta T}{\Delta x} \quad (1)$$

Where, Q is represent heat transfer rate (W), K is the thermal conductivity [W/(m·K)], A is cross-sectional area (m^2), T_H is temperature of hot surface, T_C is the temperature of cold surface, ΔT is the difference between hot and cold temperature and Δx is thickness of the plane.

Convection heat transfer is transfer of heat by the movement of a fluid from higher temperature region to the lower temperature region. The lower temperature of fluid is move to the high temperature of fluid. Then, the lower temperature of fluid will take the place of the higher temperature. Generally, liquid and gas are the dominant form of this heat transfer. Convection heat transfer can be occurred either natural convection or forced convection. The natural convection is by density differences within fluid that happened due to temperature gradient and without any external source of support. Forced convection is movement of the fluid that is produced by an external source.By Newton's law of cooling, the rate of convective heat transfer can be calculated is given by [9]:-

$$Q = h \times A \times (T_S - T_f) \quad (2)$$

$$h = 5.7 + 3.8v \quad (3)$$

The quantity of Q (W) is known as the rate of convective heat transfer, h is represent the coefficient of convective heat transfer ($W/m^2{}^\circ C$), A is the area of contact between the two materials (m^2), T_s is temperature of surface, T_f is temperature of fluid and v is represent wind velocity. In the Equation1, it can be seen the variation of wind velocity will play an important role on the wind heat transfer coefficient.

Radiation heat transfer is not similar as the concept of conduction and convection. Both conduction and convection is the transfer of heat via matter. While, radiation is transfer the heat in form of electromagnetic waves. Radiation is the heat transfer from the body according to the temperature; it increases as the body temperature increases. When the heat reaches to another surface of the body, they may be absorbed, reflected or transmitted. The emitted energy by a blackbody is given by Stefan-Boltzmann law as [10]:

$$P = \sigma \times T^4 \quad (4)$$

Where P is the PV panel produced as heat, σ is the Stefan-Boltzmann constant as 5.67×10^{-8} $W/m^2\,{}^\circ C^4$ and T is represent the temperature of PV cell in ºC.

2.2. Method and Software

The main goal of this investigation is to investigate the temperature distribution of solar panel under different amount of wind velocity via CFD. The dimension of the investigated solar panel is 120 cm × 54 cm × 3 cm. This solar panel is consists of 36 solar cells which is made by monocrystalline silicone.

2.2.1. Geometry Model

CATIA V5 is Computer-aided design (CAD) software which is used to build the geometry model. The geometry model of solar panel is drawing according to the actual solar panel dimension. Solar panel model is consisted of six layers such as a top glass covering, Ethylene Vinyl Acetate (EVA) layer 1, solar cells, EVA 2, tedlar layer and metal back sheet (aluminum). And, each thickness layer of the solar panel model is listed in Table 1. After sketching all each of the layers, the layers will be assembled between each other to form a solar panel model as shown in Figure 2. Follow that, they will be save the solar panel model as "stp" format and import into the ANSYS Transient Thermal simulation software.

Table 1. Material Properties and Sizes of each layer in Solar Panel [11]

No.	Material (Layer)	Thickness (cm)	Thermal Conductivity (W/m°C)	Specific Heat Capacity (J/kg°C)	Density (kg/m^3)
1.	Glass Covering	0.3	1.8	500	3000
2.	EVA	0.05	0.35	2090	960
3.	Solar Cell	0.04	148	677	2330
4.	Tedlar	0.01	0.2	1250	1200
5.	Aluminum Frame	2	204	996	2707

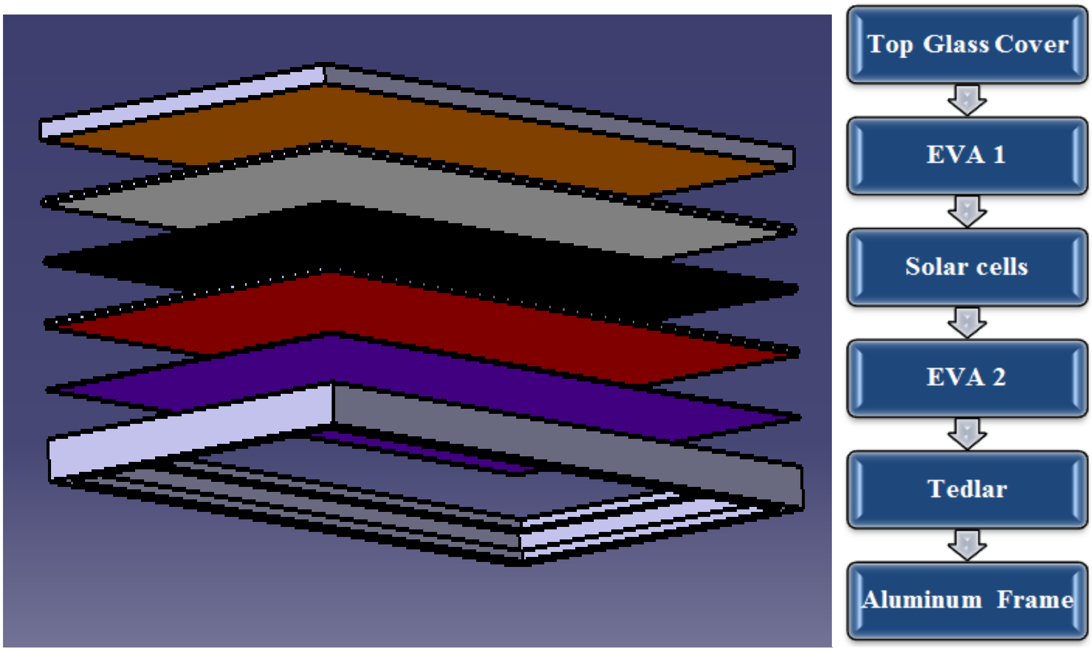


Figure 2. Solar panel model created in CATIA

2.2.2. Software

ANSYS version 14.5 was used to analyze the temperature distribution throughout the solar panel with reduction of lead times and costs of new product prototype. ANSYS is a CFD tools utilized by engineers or researchers for design and analysis the performance of model. ANSYS can work integrated together with another employed engineering software program on computer with the addition of CAD and FEA connection modules. ANSYS can import model designs from the CAD program and also can develop geometry in the pre-processing step.

ANSYS Transient Thermal was applied to this simulation process. Commonly, the transient behavior is generally started at the system beginning or shut-down. During this simulation, heat flux change as from time to time, lead to difference in temperature, which is able to impact the overall performance of the model. For that reason, there is certainly a need to analyze the transient thermal behavior of the system to find out the scope of deviation from the normal condition [12].

The procedure utilized to simulate the solar panel by ANSYS Transient Thermal simulation software is presented below:

1. Imported the geometry that built by CATIA V5 into Design Workbench of ANSYS Transient Thermal.
2. Defined material properties for each layer of the solar panel model in the Engineering Data such as, thermal conductivity, specific heat and density.
3. In the Geometry part, named each layer of the solar panel model.
4. Generate an automatic mesh in the Model part (Make sure choice “CFD” in the Physics Preference and “Fluent” in the Solver Preference as shown in Figure 3.

5. Set a fixed 35 °C in the initial temperature with uniform applied to the model in Setup part.
6. Applied the fixed of solar radiation with 1000 W/m^2 on the solar panel model.
7. Applied different wind velocity to the Equation 3 to obtain the convection coefficient.
8. Applied the amount of convection coefficient from the Equation 3 on the solar panel model.
9. Set the step end time as 3600 seconds in the Analysis Setting part, which the simulation of the solar panel model was conducted from one hour with all initial conditions.
10. After finish set the environment condition, the simulation results of solar panel model can be obtained in a form of contour plot.

The initial temperature of the model is fixed in the 35 °C where it is the average daily ambient temperature captured in Malaysia in the work of M. Z. Hussin et al. [13]. Based on Newton's Law of Cooling, the value of the convective heat transfer coefficients can be obtained from the Equation 3.

In this simulation, it is assumed the environmental conditions under climatic condition of Kangar, Perlis, Malaysia. The simulation of solar panel model is analysis under fixed solar radiation with 1000 W/m^2 and 35 °C of ambient temperature. Additionally, the range of wind velocity is variable from 0 m/s up to 6.95 m/s. In the study of M. Irwanto et al. [14] state that the average wind velocity of Kangar, Perlis is 2.5 m/s. While, the lowest wind speed is 0.43 m/s and the highest wind velocity is 6.95 m/s.

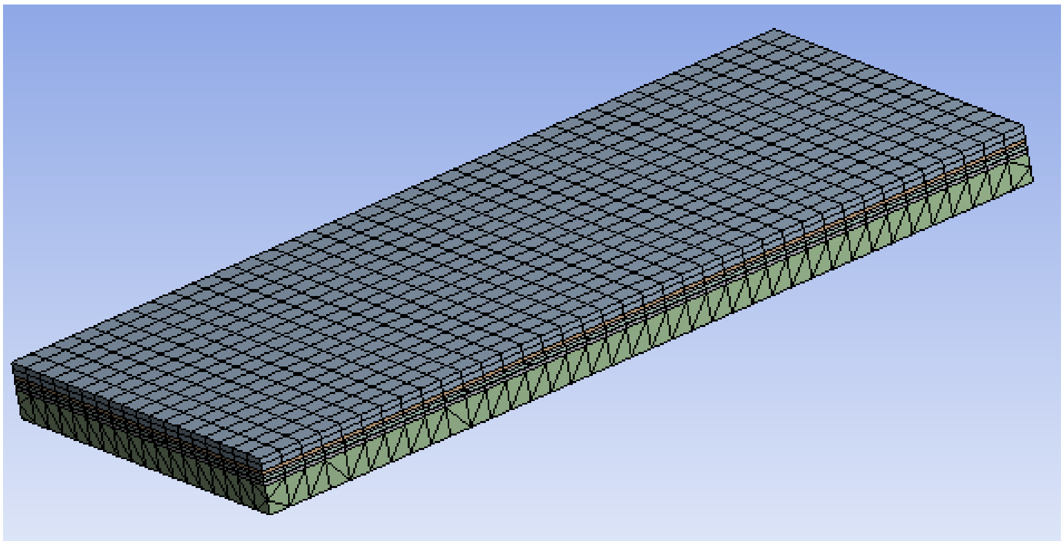
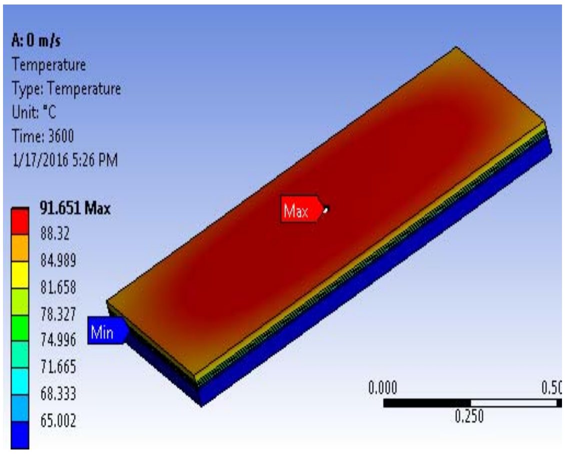


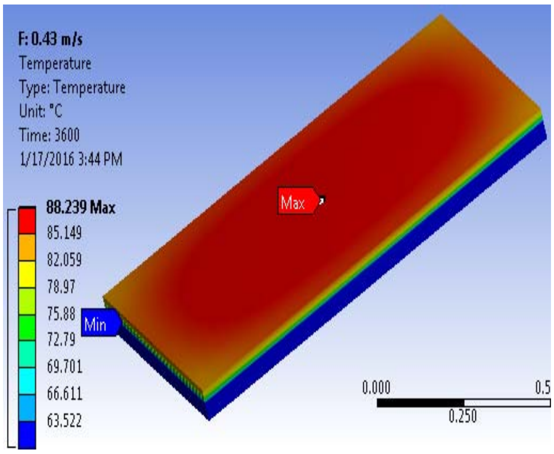
Figure 3. Solar panel model was meshing using ANSYS simulation software

3. Results and Analysis

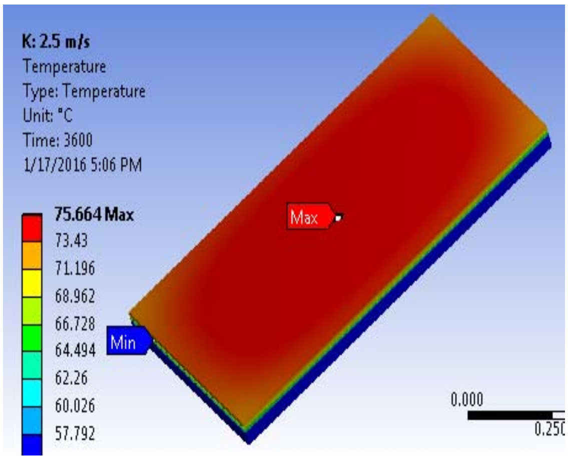
In this section, the CFD simulation results of the solar panel model are analyzed. With a purpose to study the influences of wind velocity effect used for solar panel; a model was created by using ANSYS simulation software. The range of simulated wind velocity is 0 m/s, 0.43 m/s, 2.5 m/s, and 6.95 m/s. The simulation of the model has been run from an hour together with all the initial conditions.



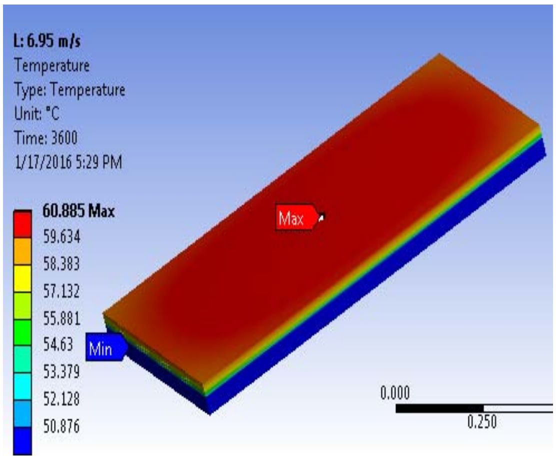
(a) 0 m/s of wind velocity



(b) 0.43 m/s of wind velocity



(c) 2.5 m/s of wind velocity



(d) 6.95 m/s of wind velocity

Figure 4. Temperature distribution of the solar panel model when wind velocity as 0 m/s, 0.43 m/s, 2.5 m/s and 6.95 m/s applied to the model

Figure 4 presents the temperature distribution of the solar panel model under varying wind velocity amounts. The 0 m/s, 0.43 m/s, 2.5 m/s and 6.95 m/s of wind velocity are flowed over the solar panel model. It can be obvious that the shape of contour plot for temperature distribution of each solar panel model is almost similar just different values under different wind velocity. From the color plot of the temperature distribution, the highest temperature generated by the solar panel model is bright-red color. It is a sign of the hottest area in the solar panel model. Meanwhile, the coldest area is represented by a dark-blue color and also marks the lowest temperature in the entire solar panel model. From the figure above, it could be discovered that the top glass covering consist of the highest temperature among entire solar panel model. In contrast, the lowest temperature of the solar panel model is occurred at the aluminum frame. The reason for this is aluminum consists of highest thermal conductivity as compared to the other material layers. And, also the combination of the effects of heat transfer conductive and convective removed the heat generated by the solar panel model away to the surrounding at a faster speed.

Figure 4(a) illustrates zero (0 m/s) of wind velocity applied to the solar panel model. The range of temperature distribution for solar panel model is between 65 °C until to 91.65 °C. When the 0.43 m/s of wind velocity flow over surface of the solar panel model, the model is obtained 63.52 °C as lowest temperature and 88.24 °C as highest temperature as displayed in Figure 4(b). In addition, Figure 4(c) presents the range of temperature distribution for the solar panel model is from 57.79 °C until to 75.66 °C when the 2.5 m/s applied to the solar panel model. Moreover, the highest temperature of solar panel model is 60.89 °C and the lowest temperature is50.88 °C when 6.95 m/s of wind velocity flow over the solar panel model as shown in Figure 4(d). All the temperature distribution of the solar panel model are presented in Table 2. It can be analytical that when zero wind velocity flow over the solar panel model, it is generated the highest temperature compared with the others wind velocity. This is due to the natural wind cannot provide cooling effect to the solar panel model. However, the 6.95 m/s of wind velocity flow over the solar panel model; it can provide good cooling effect to cool off the solar panel model. This result in this solar panel model obtained lowest temperature in comparison with others wind velocity. It can be concluded that highest wind velocity can be provided better the cooling effect for the solar panel in order to enhance its performance.

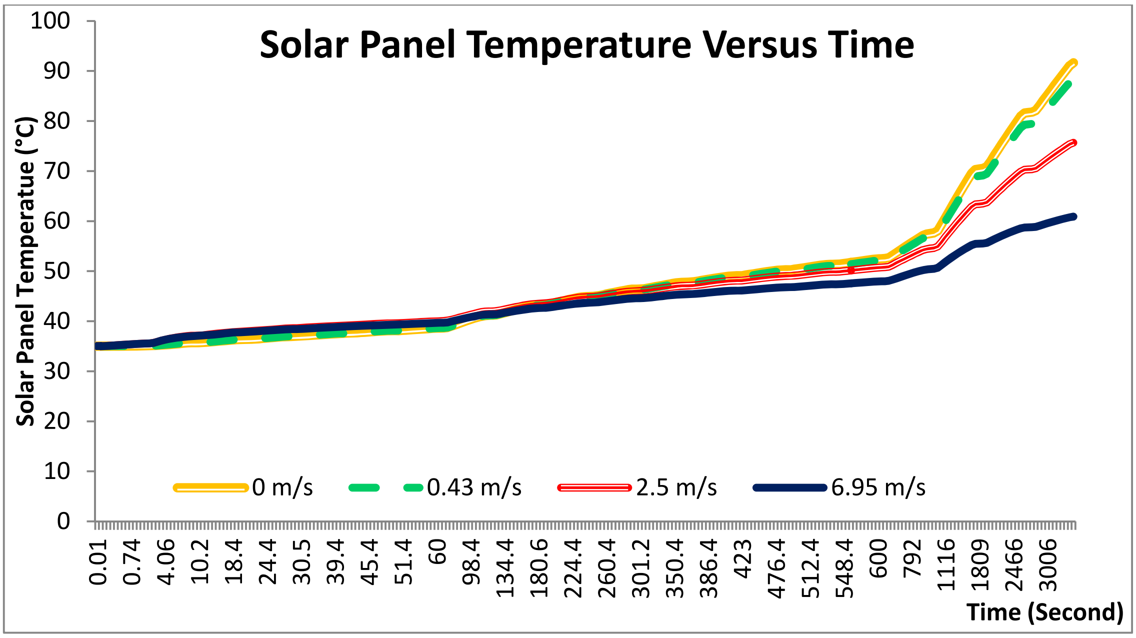


Figure 5. Highest temperature of solar panel model versus time under different wind velocity

Figure 5 shows the highest temperature that generated by the solar panel models under varying of wind velocity. All the simulation of solar panel model was carried out in an hour with all initial condition. It can be found out that the solar panel model generates lowest temperature at wind velocity value of 6.95 m/s and obtained highest temperature at 0 m/s of wind velocity. All the solar panel temperature is gradually increased over time. From these simulation results, 0.43 m/s of wind velocity applied to the solar panel model can be minimized 3.72 % of the solar panel model temperature rather than zero wind velocity. When the 2.5 m/s flow over to the solar panel model, it can be dropped 17.45 % in terms of solar panel model temperature against zero wind velocity. In addition, solar panel with 6.95 m/s of wind velocity can be reduced temperature of solar panel model around 33.65 % compared to zero wind velocity.

As the wind velocity is constantly changing, the cooling system is suggested to apply to the solar panel. The cooling system can provide cooling effect to cool off the temperature of solar panel. Air cooling system is good choice among all solar cooling systems. This is due to the air cooling system is low price and blowing air flow within air channel in order to reduce the solar panel temperature [15].

Table 2. Highest and lowest temperature of solar panel model on different wind velocity

Wind Velocity \ Temperature	Lowest Temperature (° C)	Highest Temperature (° C)
0 m/s	65	91.65
0.43 m/s	63.52	88.24
2.5 m/s	57.79	75.66
6.95 m/s	50.88	60.89

4. Conclusion

The performance of solar panel is a very important issue in the solar application system. This simulation works out to make a contribution to a better knowledge of the solar panel application behavior affected by the different amounts of wind velocity. The temperature distribution of solar panel model is obtained with the ANSYS Transient Thermal simulation software is reported. The benefits of the ANSYS simulation as compared to experimental-based is reduction time and cost consuming. The solar panel model is simulated under fixed in 35 °C of ambient temperature and solar radiation value of 1000 W/m^2. The range of simulated wind velocity is from 0 m/s, 0.43 m/s, 2.5 m/s and 6.95 m/s. It can be observed that the solar panel temperature is signifcantly impact by the wind velocity. The is due to wind velocity flow can be provided the cooling effect for the solar panel model surface. The highest wind velocity can be disipated more heat generated by the solar panel to the environment. Therefore, the solar panel can generate a good performance with the lowest temperature.

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