THE STUDY OF COOLING EFFECT ON PHOTOVOLTAIC USING COMPUTATIONAL FLUID DYNAMICS (CFD)

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This report is submitted
in fulfilment of the requirement for the degree of
Bachelor of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "The study of cooling effect on photovoltaic using Computational Fluid Dynamics(CFD)" is the result of my own work except as cited in the references

Signature : …………………….

Name : …………………..……

Date : ……………………..…

APPROVAL

I hereby declare that I have read this project and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	……………………
Name of Supervisor	:	……………………
Date	:	……………………

DEDICATION

الحمد لله ربّ العالمين

My family.

ABSTRACT

The temperature of photovoltaic (PV) panels is an important parameter in the conversion efficiency of solar radiation to electricity. PV cells generally can convert up to 20% of solar radiation to electricity and the rest is generated into heat which increases the panel temperature causing a drop in the performance. Various methods have been used by researches in order to reduce the panel temperature and still being cost effective. One of the cost-effective methods is by using natural convection. The purpose of this study is to study the cooling effect on solar PV by using ANSYS CFD simulation. The solar panel is simulated under two different condition where it is assumed there's no cooling with constant ambient temperature and the other one with air cooling with vary ambient temperature. The simulation is analyzed under transient state to simulate the PV performance during 10 a.m. to 4 p.m. in real time. The results show that the maximum efficiency of panel with air cooling is 15.90% while the panel with no cooling is 14.33% thus making the panel more efficient and productive when being cooled. It was shown that the presence of natural convection would reduce the temperature and increase the efficiency of PV. However, this would require a higher wind velocity for a better result as seen from the result obtained when the air velocity ranges between 2 m/s to 5 m/s.

ABSTRAK

Suhu panel fotovoltaik (PV) adalah parameter penting dalam kecekapan penukaran sinaran suria kepada elektrik. Sel-sel PV secara umumnya boleh menukar sehingga 20% radiasi solar ke elektrik dan selebihnya dijana menjadi haba yang meningkatkan suhu panel menyebabkan kejatuhan prestasi. Pelbagai kaedah telah digunakan oleh penyelidik untuk mengurangkan suhu panel dan masih kos efektif. Salah satu cara yang kos efektif adalah dengan menggunakan perolakan semula jadi. Tujuan kajian ini adalah untuk mengkaji kesan penyejukan pada PV solar dengan menggunakan simulasi ANSYS CFD. Panel solar disimulasikan di bawah dua keadaan yang berbeza di mana ia diandaikan tiada penyejukan dengan suhu ambien yang berterusan dan yang lain dengan penyejukan udara dengan suhu ambien yang berbeza. Simulasi dianalisis di bawah keadaan sementara untuk mensimulasikan prestasi PV pada 10 pagi hingga 4 petang. dalam masa nyata. Keputusan menunjukkan bahawa kecekapan maksimum panel dengan penyejukan udara adalah 15.90% manakala panel tanpa penyejukan adalah 14.33% dengan itu membuat panel lebih cekap dan produktif apabila didinginkan. Telah ditunjukkan bahawa kehadiran konveksi semulajadi akan mengurangkan suhu dan meningkatkan kecekapan PV. Walau bagaimanapun, ianya memerlukan halaju angin yang lebih tinggi untuk hasil yang lebih baik seperti yang dilihat dari hasil yang diperoleh apabila halaju angin berkisar antara 2 m/s hingga 5 m/ s.

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LIST OF ABBREVIATIONS

PV	Photovoltaics
CFD	Computational Fluid Dynamics
STC	Standard Test Conditions
ANSYS	Analysis System
TRNSYS	Transient System Simulation

LIST OF SYMBOLS

h	Convective heat transfer coefficient
η_{ref}	Maximum PV efficiency tested with reference temperature
η_{cell}	PV cell efficiency
β	Temperature coefficient of power
T_{cell}	Temperature of PV module cell
T_{ref}	Reference temperature of PV module
I_{STC}	Solar irradiance under STC

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In the last decades, the increasing global demand for electricity which resulting on the increase of political and environmental problems related to the fossil fuels are the main drawbacks of this energy source. A way to overcome this problem and minimizing the negative impacts of energy production and consumption on the environment is by switching to renewable energy sources; one of it is the sun. The conversion of sunlight into electricity called as solar power is done by using photovoltaic (PV) technology. This technology is one of the cleanest (does not produce pollutants) and the easiest sources to be obtained compare to fossil fuels.

In general, PV is a method which absorb the light transfer from the sun with the help of semiconductors material and convert it into electricity. Semiconductors are materials which become electrically conductive when supplied with light or heat but operate as insulators at low temperatures. Example of solar PV is shown in Figure 1.1.

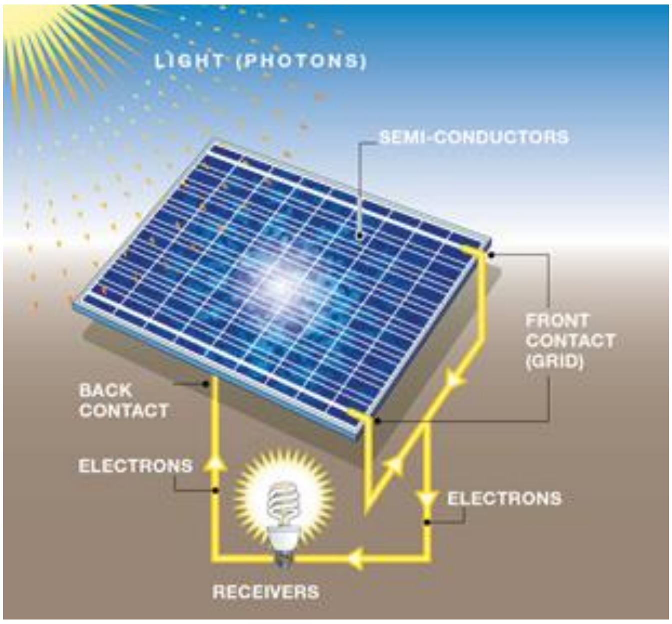

Figure 1.1: Schematic showing PV power source [1]

Even though this clean technology has free energy source and has made tremendous improvement in the past years, but it also can be expensive in many ways. Solar researchers are still trying to come out with the way to increase the performance of the PV panel while minimizing the modifications cost.

It is known that the performance of PV panel is affected by numerous factors and one of it is the temperature. The relation between these two are inversely proportional, as the temperature increases the efficiency of the solar panel decrease and vice versa. With the exposure of high temperature to the PV panel in a long period of time can cause degradation on its electrical power output. The incident solar radiation absorbed by the PV can be up to 80% but only a small amount of it is converted into electricity as the remainder energy increase the cells temperature [2]. Each solar cell is tested under the Standard Test Condition (STC) which the temperature is at 25 ºC with the irradiance of 1000 W/m^2. PV cell generates the maximum power in these conditions [3,4]. Some researches claim that maximum power generated varies almost linearly with the operating temperature of PV cells [5,6]. But in real operating conditions, it is hard to obtain these conditions with the ambient temperature and the irradiance always changes throughout the day [7,8]. In Figure 1.2, it shows that when temperature rises the current produced become slightly increase but the voltage is also reduced causing a drop on the power generated by the PV.

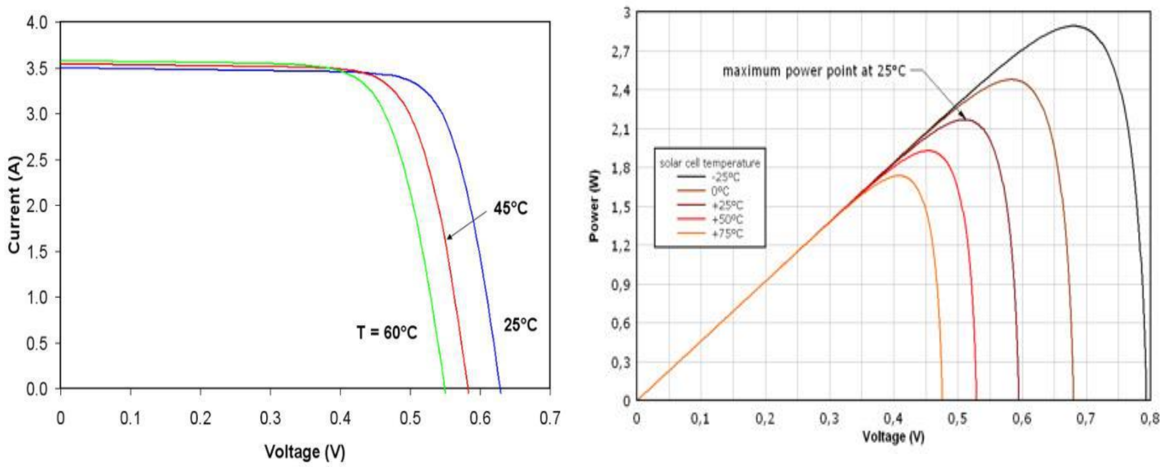

Figure 1.2: I-V and P-V curves of a typical PV module [2]

1.2 PROBLEM STATEMENT

The operating temperature of PV cells has a big impact on its performance. The maximum output power production is reduced when the temperature of PV cells elevated. An increase in efficiency is important to the development of solar PV, as it would save money while providing greater amounts of energy and increase the lifespan of it. Finding the best method to cool down the solar panel in Malaysia weather and climate which is usually hot while saving the cost of improvement is crucial in this country economic state.

1.3 OBJECTIVES

The objective of this project are as follows:

1. To study the effect of air cooling on the temperature and efficiency of solar PV using ANSYS.
2. To study the performance of solar PV under different wind velocity by using ANSYS.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. The analysis is studied only on polycrystalline solar panel.
2. The results of this analysis are only focusing towards the temperature and efficiency of solar PV.
3. The simulations of this study using 3D analysis on ANSYS in transient state.
4. Cooling effect from air ranging from 2 m/s to 5 m/s.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will describe briefly on the heat transfer of solar PV and the cooling system of solar PV. Solar PV can be cooled by using passive and active cooling methods which uses air or water as the coolant. These cooling methods have been carried out by many researches and it produces good results on optimising the PV performance. This chapter further presents some of the existing work regarding the implementation of these methods of cooling the PV cells carried out by other researches.

2.2 HEAT TRANSFER

Generally, the process of solar PV is the conversion of solar radiation into electricity. Because of the panels are not totally efficient, most of the energy absorbed are wasted as heat. By adapting convection, conduction and radiation, the heat can be dissipated as shown in figure below.

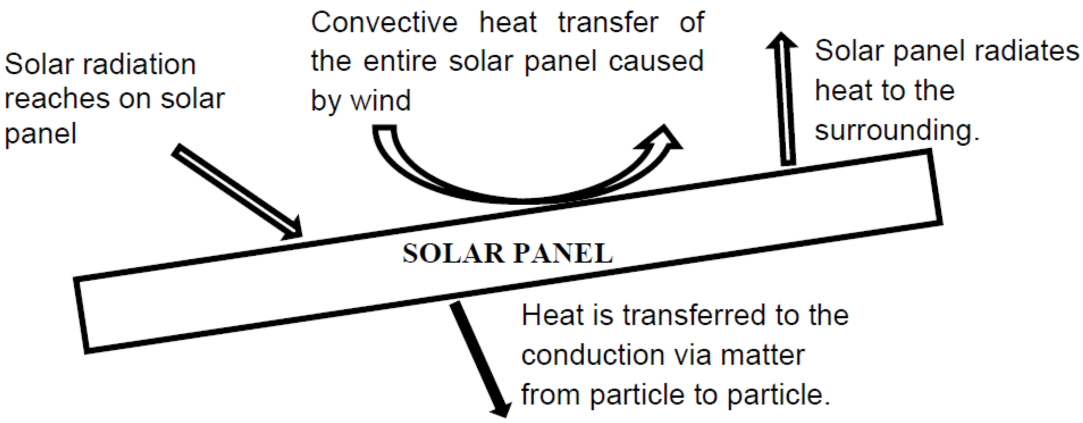

Figure 2.1: The heat transfer of a conventional solar panel.

2.2.1 Convection

Heat transfer within mixed portion of fluid is by convection. The fluid's movement can be caused by density differences resulting from temperature differences such as natural convection (or free convection) or by mechanical means such as forced convection. The fluid movement increases the heat transfer, as it brings hotter and cooler fluid into contact and initiates higher conduction rates at a greater number of sites in a fluid. Therefore, the heat transfer rate through a fluid by convection is higher than conduction [9].

Convective heat transfer is described by correlations between parameters without dimensions such as the Nusselt, Reynolds and Prandtl numbers in order to determine value of heat transfer coefficient, h in Newton’s law of cooling:

$$Q = hA_s(T_s - T_f) \tag{2.1}$$

where

h = convective heat transfer coefficient, $W/m^2.\ °C$

A_s = heat transfer surface area, m^2

T_s = surface temperature, °C

T_f = fluid temperature sufficiently far from surface, °C

2.2.2 Conduction

Conduction is the transfer of heat from one part of the substance to another part of the same substance or in physical contact with it from one substance to another. For the PV panel, energy is absorbed by the cell and heat is carried to the back and front of the panel [9]. Fourier's law of heat conduction state that:

$$Q = -kA\frac{dt}{dx} \tag{2.2}$$

where

Q = heat flow, kJ/kg

k = thermal conductivity of material, W/m^2. °C

A = area of the section at right angles

dt/dx = temperature gradient

2.2.3 Radiation

Radiation is the energy emitted by matter in the form of electromagnetic waves (or photons) as a result of the electronic configuration changes in the atoms or molecules. In contrast to conduction and convection, the radiation transfer of energy does not require the presence of an intermediate medium [9]. Stefan-Boltzmann law state that:

$$Q = \frac{\sigma A(T_1^4 + T_2^4)}{(\varepsilon_1)^{-1} + (\varepsilon_2)^{-1} - 1} \quad (2.3)$$

where

σ = Stefan-Boltzmann constant

A = surface area, m^2

$T_{1,2}$ = surface temperature, K

$\varepsilon_{1,2}$ = surface emissivity

2.3 SYSTEM OVERVIEW

This system consists of a set of photoelectric cells, also called photocells or solar cells. These are electronic devices made of silicon, the second most abundant substance in the Earth, which size ranges between 1 and 10 cm of diameter, and that can transform light energy (photons) into electrical energy (electrons) by the photovoltaic effect. It is important to notice, that it accepts both direct and diffuse radiation and can generate electricity even on cloudy days. These cells are manufactured of a material which benefits from the photoelectric effect: they absorb photons of the sunlight and emit electrons. When the sunlight strikes the surface of the photovoltaic cell, electrons are released from an atom. Electrons, excited by the light, move through the silicon as shown in figure below. When these free electrons are captured, the result is an electric direct current that can be use as electricity from a power between 1W and 2W.