A SIMULATION STUDY OF PHOTOVOLTAIC THERMAL NANOFLUID COOLANT BASED USING COMPUTATIONAL FLUID DYNAMICS

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "a simulation study of photovoltaic thermal nanofluid coolant based using computation fluid dynamics" 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 report 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 with Honours.

Signature	:	....
Supervisor's Name	:	....
Date	:	....

DEDICATION

Dedicated to Dr. Mohd Afzanizam bin Rosli for his advice, his faith, and his patience in me on my road toward project completion.

ABSTRACT

In the study, the photovoltaic thermal system using nanofluid as coolant is examined using numerical approach. Due to high cost and difficulty in preparing nanofluid, it is more practical to perform the study using numerical approach which is convenient and saves plenty of time. The photovoltaic thermal system is investigated numerically through Computational Fluid Dynamics Approach using Ansys 19.0 Fluent Software. The numerical study is based on different solar irradiation at different hours. The validation study between the experimental results and simulation results are achieved by examining the photovoltaic (PV) surface temperature and nanofluid outlet temperature. The MAPE results are within 10% of error which proved that there are good accuracy between the simulation and experimental results. Carbon-based nanoparticles appear to be the best choice among different type of nanoparticles based on the researcher experimental study. Graphene nanoplatelets (GNPs) nanofluid is selected for further study to examine the optimum operating parameters that provides higher conversion efficiency. The important operating parameters in photovoltaic thermal (PVT) system include solar irradiation, ambient temperature, wind velocity, nanoparticles mass fraction, coolant inlet temperature, and coolant mass flow rate. Parametric analysis is conducted to analyse the effect of different operating parameters on the thermal and electrical efficiencies. Taguchi analysis is conducted to analyse the optimum operating parameters that provides the higher conversion efficiency. The Taguchi analysis suggests that 900 W/m^2 solar irradiation, 41℃ ambient temperature, 7 m/s wind speed, 2 wt% nanofluid mass fractions, 35 ℃ coolant inlet temperature, and 30 kg/h mass flow rate leads to highest improvement in overall efficiency of the photovoltaic thermal (PVT) system. Finally, there is some discrepancy in the simulation results because it does not accurately predict the thermal efficiency of the system. However, the simulation results are still valid because the examination of the results based on the plotted graph of thermal efficiency show the same trend.

ABSTRAK

Dalam kajian ini, sistem termal fotovoltaik menggunakan nanofluid sebagai penyejuk diperiksa menggunakan kaedah berangka. Oleh kerana kos tinggi dan kesukaran menyediakan nanofluid, ia adalah lebih praktikal untuk menjalankan kajian menggunakan kaedah berangka kerana dapat menjimatkan masa. Sistem terma fotovoltaik diselidiki secara berangka melalui Pendekatan Dinamika Fluida Dinamik menggunakan Perisian Fluent Ansys 19.0. Kajian berangka ialah berdasarkan penyinaran suria yang berbeza pada waktu yang berlainan. Kajian pengesahan antara hasil eksperimen dan hasil simulasi dapat dicapai dengan memeriksa suhu permukaan fotovoltaik (PV) dan suhu keluar nanofluid. Hasil MAPE berada dalam lingkungan 10% ralat dan ini membuktikan bahawa terdapat ketepatan yang baik antara hasil simulasi dan eksperimen. Hasil kajian daripada penyelidik melalui eksperimen mendapati bahawa nanopartikel berasaskan karbon lebih baik berbanding dengan nanopartikel lain. Nanoplatelet Graphene (GNP) nanofluid dipilih untuk kajian lebih lanjut untuk memeriksa parameter operasi optimum yang memberikan kecekapan penukaran yang lebih tinggi. Parameter operasi penting dalam sistem termal fotovoltaik (PVT) merangkumi penyinaran suria, suhu persekitaran, halaju angin, pecahan jisim partikel nanopartikel, suhu masuk penyejuk, dan kadar aliran jisim penyejuk. Analisis parametrik dilakukan untuk menganalisis pengaruh parameter operasi yang berbeza terhadap kecekapan terma dan elektrik. Analisis Taguchi dilakukan untuk menganalisis parameter operasi optimum yang memberikan kecekapan penukaran yang lebih tinggi. Analisis Taguchi menunjukkan bahawa penyinaran suria 900 W/m^2*, suhu sekitar 41℃, kelajuan angin 7 m/s, pecahan jisim nanofluid 2% berat, suhu masuk penyejuk 35℃, dan kadar aliran jisim 30 kg/j membawa kepada peningkatan yang tertinggi dalam kecekapan keseluruhan sistem termal fotovoltaik (PVT). Akhirnya, terdapat ralat dalam hasil simulasi kerana tidak dapat meramalkan kecekapan terma sistem secara tepat. Walau bagaimanapun, hasil simulasi masih sah kerana pemeriksaan terhadap graf kecekapan terma menunjukkan trend serupa.*

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Energy sources that are available today plays a key role to satisfy the need of world and living population. Growing of human population and industrial revolution across the globe in recent years has led to an increase in energy consumption. International Energy Agency has shown statistics that the world's energy needs would rise more than 50% by the year of 2030. Nevertheless, the major energy source that is available now is obtained from fossil fuel. Therefore, it has become a global concern that the available energy source may be depleted by this century (Shafiee, 2009). Hence, there is a need to seek for an alternative energy source to fulfill the demand.

Besides that, fossil fuel that is commonly used to produce energy to supply for human and is not environmentally friendly as burning of fossil fuels cause emission of harmful gases to the ecosystem. Furthermore, continuous use of non-renewable energy sources has significant effect to the global climate. It is therefore needed to seek for alternative energy which is eco-friendly to the environment. However, it is also important to note that the energy source should be reliable, cost effective and everlasting. Otherwise, it cannot cope with the energy demand by human and will cause energy crisis.

Renewable energy sources that are widely available now are solar energy, wind energy, hydropower energy and geothermal energy. Among the renewable energy sources available, solar energy is freely available to be used to satisfy the energy demand. It is a promising source of energy that is not exhaustible. Theoretically, solar energy is adequate to fulfill the demand of entire world if technology to harvest and supply are readily available. It is estimated that solar energy can provide nearly four million of exajoules to the earth. With this amount of energy, it is able to fulfill the global energy demand.

Solar energy technology has become well-established and popular energy now throughout the world. It exhibits potential to other renewable energy sources because solar energy is widely available across the globe. Unlike geothermal energy, it is only available in a few locations and the supply is not adequate. Solar energy is the primary source of energy that can be converted into useful energy such as electricity and heat. For electrical power generation, PV technology and Concentrated Solar Power system is used. For thermal energy, solar thermal collectors that heats flow of water or air is used.

In the research, it is focused to study about integration of photovoltaic panel with thermal collector system. Photovoltaic panel is used to convert the solar energy to electrical energy while the thermal collector system is used to absorb the heat away from the system. In thermal collector system, base fluid is needed to extract the excessive heat from it. The study focused on using nanofluid as base fluid in photovoltaic thermal (PVT) system to determine if there is any significant enhancement in the conversion efficiency using computational fluid dynamics (CFD) approach.

1.2 Problem Statement

The energy conversion of conventional photovoltaic panels is about 20% (Zhang, 2014). Only part of solar energy is converted into electrical energy while other part of energy is converted into heat energy. The heat energy that is accumulated on the surface of photovoltaic panel increases its operating temperature. As a result, the electrical efficiency of photovoltaic panel is reduced. Under standard test conditions (STC), photovoltaic panel generates maximum power when the temperature is at 25℃. For each degree rise in temperature, the maximum power of photovoltaic panel is reduced by 0.40 – 0.50% (Natarjam, 2011).

Therefore, combination of photovoltaic panel and thermal collector system are designed to extract excessive heat that is generated from photovoltaic panel. The combination of these systems is known as photovoltaic thermal (PVT) system. Apart from maintaining solar cell efficiency, photovoltaic thermal system produces electrical and heat energy simultaneously. Thus, the type of base fluid is important to enhance heat transfer from photovoltaic panel to thermal collector system. There are several types of base fluid that used in solar technology such as air, water, nanofluid and phase change material.

Many research have been focused on using air and water as base fluid in the photovoltaic thermal (PVT) system. The base fluids such as air and water have low thermal conductivity which limits the efficiency of photovoltaic thermal (PVT) system. To enhance the efficiency of the system, it is needed to increase the heat transfer characteristic of the base fluid. Studies have been performed using different types of nanofluids and the results show that the heat transfer coefficient is improved compared to other base fluids (Robert et.al, 2015). In addition, nanofluids have been widely used in other heat transfer application and show improved efficiency (Y.K.Lee, 2014).

For the above reason, nanofluid is selected as the base fluid to be applied in photovoltaic thermal (PVT) system. There are various types of nanoparticles available to be suspended in water to produce nanofluids. In previous studies, most of the researchers used single type of nanofluid to study the effect of nanofluid on performance of photovoltaic thermal (PVT) system. There is no clear indication on the types of nanofluid to be used in the photovoltaic thermal (PVT) system. Therefore, it is important to address this issue and fill the knowledge gap through literature study to determine the type of nanofluid that gives higher conversion efficiency in photovoltaic thermal (PVT) system.

Moreover, nanofluid is high in cost of production and preparation due to difficulty to achieve desired stability. Also, the experimental study of photovoltaic thermal (PVT) system requires consistent weather condition to obtain reliable results. The development of a numerical model using Computational Fluid Dynamics (CFD) approach is necessary to study the performance of photovoltaic thermal (PVT) system. The numerical model has low computational cost and can replicate the weather condition. Therefore, the numerical model that is developed can be used to study the effect of using nanofluid as coolant in the photovoltaic thermal (PVT) system.

1.3 Objectives

The objectives of this project are as follows:

1. To develop a model of photovoltaic thermal (PVT) system and simulate using computational fluid dynamics (CFD) approach.
2. To study the overall efficiency improvement of photovoltaic thermal (PVT) system using nanofluid based coolant through parametric and Taguchi analysis.
3. To determine the qualitative and quantitative results of photovoltaic thermal (PVT) system using the selected nanofluid.

1.4 Scope

Numerical simulation to predict the performance of PVT system using nanofluid is less covered. Therefore, the project aims to use computational fluid dynamics approach to study the efficiency of photovoltaic thermal (PVT) system. 3D-steady state simulation is performed to examine the heat transfer in the PVT system. Photovoltaic thermal (PVT) system with serpentine tube configuration is selected to be studied. The 3D model of photovoltaic thermal (PVT) system does not consider all layers of a photovoltaic (PV) module. Only glass, photovoltaic (PV), absorber plate, adhesive, and absorber tube are considered in the study. Finally, literature study is conducted to study different types of nanofluid and select the nanofluid that offer better thermophysical properties.

1.5 General Methodology

The general methodology describes about the task that will be carried out stage by stage throughout the research. First, the problem statement of the research is defined carefully. After that, the research objectives describe about the results to be achieved in the study. Next, journal papers and books are studied to write the literature review section. After literature review, trial run in Ansys Fluent software is performed. The data obtained from trial run is verified and validated with journal paper. Only then the simulation of the study will be performed using the type of nanofluid that is selected. When the final results are obtained, analysis and discussion of the results are written. Finally, the conclusion will summarise the study and give recommendation for future study.

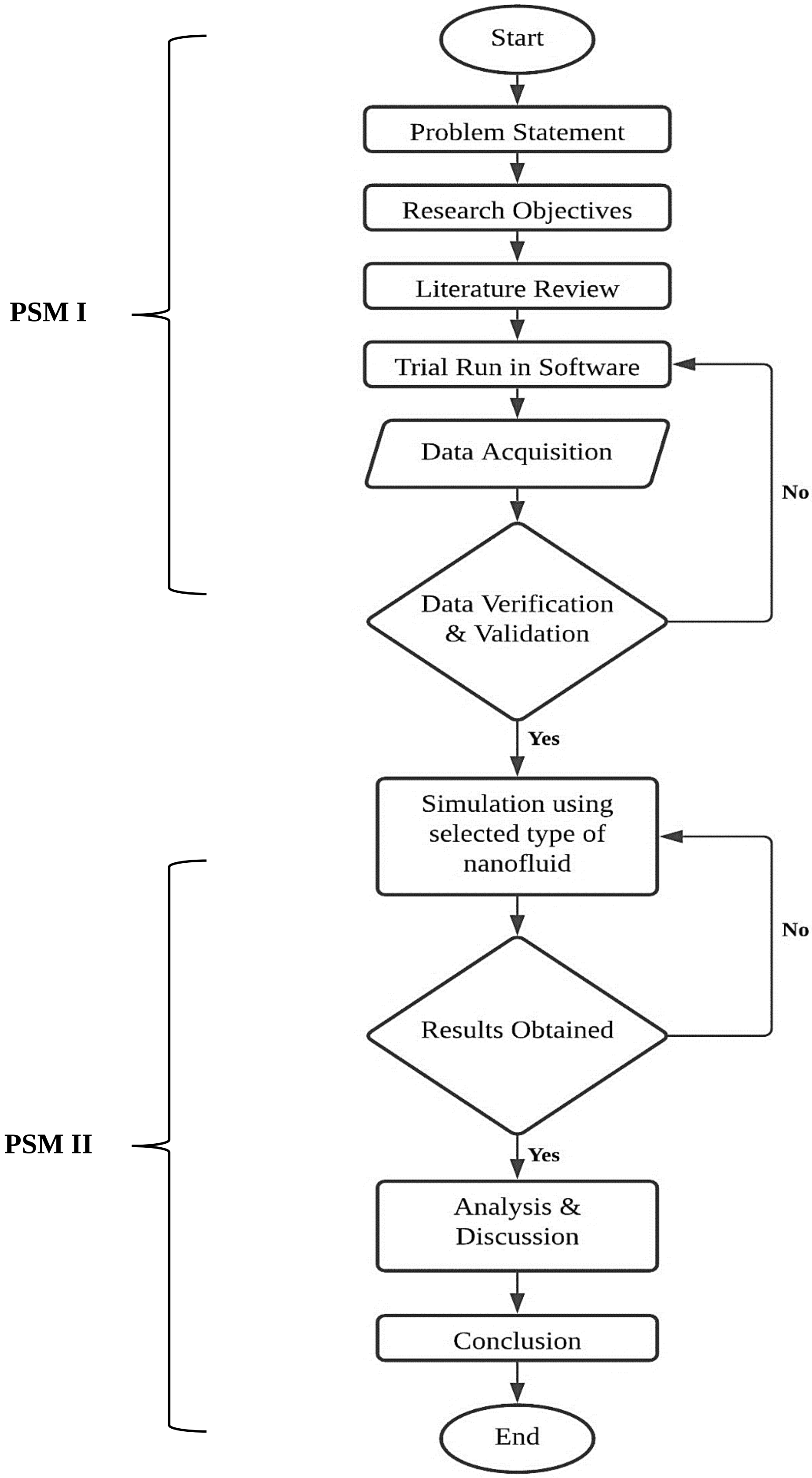

Figure 1.1: Flowchart of general methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review section will provide findings in relation to the research problem to be investigated. The section will help the reader to improve their knowledge and establish theory related to the research problem. The section will also help to provide an overview of the sources (books, scholarity articles, and other sources) that have been explored while researching for the problem. Finally, the section will help to trace the progress of knowledge between various researchers to help reader to familiarise the knowledge in the field.

2.2 Limitation of Photovoltaic Panel

Solar cells in PV system responds selectively to light wavelength where incident photon with wavelength longer than “cut-off” wavelength will not be absorbed (N.D.Kaushika, 2018). The photons with longer wavelength do not generate electron-hole pairs to produce electric current. However, they dissipate their energy as heat and is accumulated on solar cells. Most of the incident solar radiation that reaches on solar cells does not convert into electricity. The conversion efficiency from solar energy to electrical energy is relatively low and most of the energy is converted to heat energy. Consequently, the photovoltaic panel temperature is increased.

Generally, the photovoltaic panel power output is influenced by I-V characteristic of solar cells (Roland and Aurel, 2018). When the cell temperature is increased, the open-circuit voltage decreases linearly while short-circuit current increases slightly. This has led to lower conversion efficiency which in turn affect the power output. To encounter this issue, it is needed to reduce the photovoltaic panel temperature to achieve maximum electrical efficiency. The solar cells surface temperature is cooled by using thermal collector system. The heat is transferred away from the solar cells surface using fluid. Thus, the electrical output is remained at maximum performance.

2.3 Photovoltaic Thermal Collector

A solar photovoltaic thermal (PVT) collector system absorbs solar radiation and converts it into electricity and heat (Himangshu Bhowik, 2017). A PVT system mainly consists of two components: a PV module and solar thermal (air or water) collector. The thermal collector has flow channel that allows fluid to be circulated around to absorb the excess heat. Heat that is extracted can be served for other purposes. Moreover, the integrated PVT system offers benefits over separated PV and solar thermal systems. The combination of PVT system allows heat and electricity generated simultaneously and higher conversion efficiency compared to separated PV and solar thermal systems.

There are several types of PVT collectors, but the most popular are flat plate and concentrating PVT collector (Souroush Dabiri, 2016). Flat plat PVT collector is a thermal collector with PV above it. Concentrating PVT collector utilize concentrators to increase solar irradiance on PV surface to improve the electrical output. In these PVT collectors, air and water is preferred coolants to be used absorb the heat from the collectors. This is because the system cost is preferably low and ease of maintenance. However, nanofluid based coolant is apply in the study to investigate the effects of the coolant compared to conventional cooling method.