Faculty of Mechanical Engineering

A SIMULATION OF SOLAR PHOTOVOLTAIC THERMAL SYSTEM WITH SPIRAL DESIGN ABSORBER USING MWCNT/WATER WORKING FLUID

Jayaprakash Ponnaiyan

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A SIMULATION OF SOLAR PHOTOVOLTAIC THERMAL SYSTEM WITH SPIRAL DESIGN ABSORBER USING MWCNT/WATER WORKING FLUID

JAYAPRAKASH PONNAIYAN

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DECLARATION

I declare that this thesis entitled "A SIMULATION OF SOLAR PHOTOVOLTAIC THERMAL SYSTEM WITH SPIRAL DESIGN ABSORBER USING MWCNT/WATER WORKING FLUID" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : P Jayaprakash

Name : Jayaprakash ponnaiyan

Date : 06-07-2023

APPROVAL

I hereby declare that I have this dissertation/report and in my opinion this dissertation/report is sufficient in term of scope and quality as a partial fulfillment of Master of Mechanical Engineering (Energy Engineering).

Signature :

Supervisor Name : Profesor Madya Ir. Dr. Mohd Afzanizam Bin Mohd Rosli

Date : 06-07-2023

DEDICATION

To my beloved family and friends, who have always supported and encouraged me in pursuing my educational goals. Your unwavering love and belief in me have been my greatest inspiration.

ABSTRACT

The photovoltaic (PV) module's temperature distribution is not even in most cases, which causes a region of hotspots to appear in some areas. Due to these hotspots, less effective cell performance causes declination in overall efficiency of PV systems. Due to this, temperature uniformity is distributed by adopting the appropriate absorber at the back of the PV panel and to increase the efficiency of the system by employing effective working fluid. In this study, considering a spiral design absorber attached with flow tube to provide temperature uniformity across the photovoltaic module. In addition to that, utilizing a multi-wall carbon nano-tube (MWCNT) with water as a base fluid provided improved performance for the system. The absorber model spiral absorber design is developed using computational fluid dynamics (CFD) simulation software, ANSYS Fluent 2022 R2. After applying necessary boundary conditions and solver settings the water based working fluids with the volume concentration of MWCNT (φ = 0.6 %), and (φ = 1 %) are tested to obtain the temperature uniformity along the PV top surface, and outlet temperature. The main findings of the study indicates that decrease in PV top surface temperature while varying the nanofluids, (φ = 0.6 %) as 30.43°C, and (φ = 1 %) as 30.41°C. This shows (φ = 1 %) temperature which is below than (φ = 0.6 %) which directly leads to reduction of the solar cell temperature, and hence increment in performance of the system. The temperature contour of PV top surface by utilizing these working fluids are compared and suggested that MWCNT (φ = 1 %) as a better working fluid to decrease the PV top surface temperature of the solar photovoltaic thermal system.

ABSTRAK

Pengagihan suhu modul fotovoltaik (PV) tidak sekata dalam kebanyakan kes, yang menyebabkan kawasan titik panas muncul di beberapa kawasan. Disebabkan titik panas ini, prestasi sel yang kurang berkesan menyebabkan kemerosotan dalam kecekapan keseluruhan sistem PV. Disebabkan ini, keseragaman suhu diagihkan dengan menggunakan penyerap yang sesuai di bahagian belakang panel PV dan untuk meningkatkan kecekapan sistem dengan menggunakan bendalir kerja yang berkesan. Dalam kajian ini, mempertimbangkan penyerap reka bentuk lingkaran yang dipasang dengan tiub aliran untuk memberikan keseragaman suhu merentasi modul fotovoltaik. Di samping itu, menggunakan tiub nano karbon berbilang dinding (MWCNT) dengan air sebagai cecair asas memberikan prestasi yang lebih baik untuk sistem. Penyerap reka bentuk lingkaran model penyerap dibangunkan menggunakan perisian simulasi dinamik bendalir pengiraan (CFD), ANSYS Fluent 2022 R2. Menggunakan syarat sempadan yang diperlukan dan tetapan penyelesai, cecair kerja berasaskan air dengan kepekatan isipadu MWCNT (φ = 0.6 %), dan (φ = 1 %) diuji untuk mendapatkan keseragaman suhu di sepanjang permukaan atas PV, dan suhu alur keluar. Penemuan utama kajian menunjukkan bahawa penurunan suhu permukaan atas PV sambil mengubah cecair nano, (φ = 0.6 %) sebagai 30.43 °C, dan (φ = 1 %) sebagai 30.41 °C. Ini menunjukkan (φ = 1 %) suhu atas PV yang lebih rendah daripada (φ = 0.6 %) yang secara langsung membawa kepada pengurangan suhu sel suria, dan seterusnya peningkatan dalam prestasi sistem. Kontur suhu permukaan atas PV dan tiub alir dengan menggunakan cecair kerja ini dibandingkan dan mencadangkan bahawa MWCNT (φ = 1 %) sebagai cecair kerja yang lebih baik untuk mengurangkan suhu permukaan atas PV sistem terma fotovoltaik suria.

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LIST OF SYMBOLS

V	-	Velocity
ρ	-	Density
C_p	-	Specific Heat Capacity
∇	-	Divergence
k	-	Thermal Conductivity
f	-	Fluid
s	-	Solid
P	-	Pressure
μ	-	Viscocity Coefficient
h_w	-	Heat Transfer Coefficient
σ	-	Stefan Boltzman Constant
ε	-	Emissivity
$\dot{q}_{loss}$	-	Convective Heat Transfer
V_w	-	Wind Velocity
T_{amb}	-	Ambient Temperature
T_w	-	Wind Temperature
T_{sky}	-	Sky Temperature

LIST OF ABBREVIATIONS

2-D	-	Two-Dimensional
3-D	-	Three- Dimensional
CFD	-	Computational fluid Dynamics
CNT	-	Carbon Nanotubes
DWCNT	-	Double Wall Carbon Nanotubes
EVA	-	Ethyl Vinyl Acetate
GIT	-	Grid Independence Test
MWCNT	-	Multi Wall Carbon Nanotubes
PV	-	Photovoltaic
PVT	-	Photovoltaic Thermal System
ST	-	Solar Thermal
SWCNT	-	Single Wall Carbon Nanotubes

CHAPTER 1

INTRODUCTION

1.1 Background of Study

As the world strikes with the depletion of fossil resources and the essential demand to prevent climate change, renewable energy gains the primary attention to overcome these problems. Among all renewable energy resources, Solar energy emerges as a potential and affordable energy source. Solar Photovoltaic Thermal (PVT) systems have evolved as an advanced technology that combines photovoltaic (PV) and solar thermal (ST) technologies to generate both electricity and heat from solar irradiance at the same time. So this Solar Photovoltaic Thermal System (PVT) not only increasing the productivity of the system but also helps in combating the climate change as well.

Researchers had been exploring various designs for solar absorbers and investigating alternative working fluids to optimize the performance of solar photovoltaic thermal systems (PVT), The design of the solar absorber is important in maximizing power conversion efficiency and overall thermal performance. The spiral absorber stands out among the other designs for the reason that it could enhance heat transfer by offering a larger area of contact for effective heat change. This has gathered considerable amount of attention.

After selecting the suitable absorber design, the selection of working fluids performs a major role in determining the overall performance of solar PVT systems but yet the conventional operating fluids like air and water have been significantly studied.

Their heat switch abilities and thermal efficiency have limitations. Consequently, researchers have turned to identify the better working running fluids to conquer these constraints. This study particularly focuses on performance comparison of water and MWCNT/water. Carbon nano-fluids as working fluid have demonstrated promising capacity in enhancing heat transfer properties and average system overall performance.

Considering the developing interest in PVT systems, alternative operating fluids and spiral design absorber, there's still a need for complete numerical investigations to understand their combined outcomes on system performance. Numerical simulation techniques, along with computational fluid dynamics (CFD) and overall performance analysis, serve as beneficial tools for analyzing the thermal behavior, heat transfer characteristics. This research helps to provide valuable insights into the layout and optimization of solar photovoltaic thermal systems, with a specific focus on spiral absorber designs and the choice of suitable operating fluids. The findings will make contributions to the development of more efficient and sustainable solar energy systems, using development in renewable energy technologies, and facilitating the worldwide transition to a greener and greater sustainable future.

1.2 Problem Statement

Solar photovoltaic thermal (PVT) systems are becoming a more engaging field to explore in the solar energy industry for their capability to produce both electricity and thermal energy simultaneously. These systems can offer high efficiency by absorbing the waste heat from the photovoltaic (PV) cells for thermal energy production, also by reducing the PV cell temperature leads to increase in electrical efficiency. The design of the absorber in the PVT system is necessary to maximize its performance. One of the significant design which shown good progression is spiral absorber design which involves a spiral tube in the absorber layer for improved heat transfer. However, the optimal working fluid for this design has not been clearly identified.

Apart from the design, the next factor to consider is the selection of working fluid that plays a vital role in overall efficiency that can have a significant impact on the performance of the PVT system. Water is the most common working fluid, but its low thermal conductivity and specific heat had limit its effectiveness. On the other hand, metal-based nanofluids and carbon based nanofluids have demonstrated high potential as working fluids due to their high thermal conductivity and specific heat.

However, additional research is required to establish the best working fluid for spiral flow PVT systems. The purpose of this study is to evaluate the performance of a spiral flow design PVT system utilizing water, and MWCNT/water, in order to discover which fluid provides the best overall efficiency. The research includes the simulation of the CFD model with Ansys fluent software to determine the thermal and electrical performance of the PVT system with MWCNT/water as a working fluid. The model will be validated using data from earlier simulation and investigations.

1.3 Research Objective

The research objective of the Simulation of solar photovoltaic thermal system using spiral flow design absorber with MWCNT/Water working fluids to identify the optimal concentration of working fluid for the proposed system. Specifically, the objectives are:

1. To design the spiral design absorber of photovoltaic thermal system using Ansys design modeler.
2. To analyze the performance of spiral design absorber of photovoltaic thermal system by employing MWCNT/water as working fluid in term of PV top surface temperature, flow tube temperature and outlet temperature.

1.4 Research scope

The research scope for the simulation of solar photovoltaic thermal system consists of three main elements to be focused in this research the Enhancement of absorber design using the spiral tube and identifying the better working fluid from the metal-based and carbon based nanofluids to determine the best efficiency providing working fluid for the system. Performance analysis of the system with different working fluids using simulation software Ansys fluent to analyze the PV top surface temperature and outlet temperature of the system with water and MWCNT as working fluids. Optimizing the solar photovoltaic thermal system with suitable absorber design and optimal working fluid for achieving better heat transfer to improve the performance of the system. These parameters will help to identify the critical elements that significantly affect the performance of the PVT system.

1.5 Significance of study

The current study focus on the performance comparison of water and MWCNT/Water as working fluids in the spiral absorber design to identify the suitable working fluid which possess better thermal and electrical performance. As this absorber design has improved temperature uniformity than other designs while implying the suitable operating fluid will further enhance the heat transfer and helps to increase the efficiency of the system. The findings have a potential impact on the performance solar photovoltaic thermal system while also contributing the global change towards the sustainability and low carbon future.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

The rising demand in renewable energy sources initiated the essential advancement in the solar energy industry, particularly solar photovoltaic thermal systems. It has attracted significant attention for its capability to generate electricity and thermal energy simultaneously, resulting in better overall efficiency. The researchers continue to identify ways to improvise the performance of the solar photovoltaic thermal system by employing innovative absorber designs and incorporation of nanofluids in working fluids to deliver higher overall efficiency for the system.

Absorber flow design of the solar photovoltaic thermal system is a significant element, which can enhance heat transfer and improve the efficiency of the system. Among other flow designs, spiral flow design emerged as a preferable design to consider as it can produce uniform temperature distribution while reduce thermal stresses on PV cells (Kabeel et al., 2019). The integration of nanofluids along with unique flow designs, such as the spiral flow design, has the capacity to substantially enhance the performance of solar photovoltaic thermal system.

Nano-fluids are composed of colloidal suspensions of nanoparticles in a base fluid, which can enhance the thermal properties of the base fluid to provide the better heat transfer and performance of the overall system (Sarafraz et al., 2019). Investigation done on the metal-based nano-fluids and carbon nano-fluids to be specific copper oxide and multi-walled carbon nano-tube (MWCNT) showed an encouraging results in various applications, including solar photovoltaic thermal systems (Ahmed et al., 2019; Hissouf et al., 2020). Figure 2.1 shows the general model of PVT system by indicating each layer of the system (Salari et al., 2020).

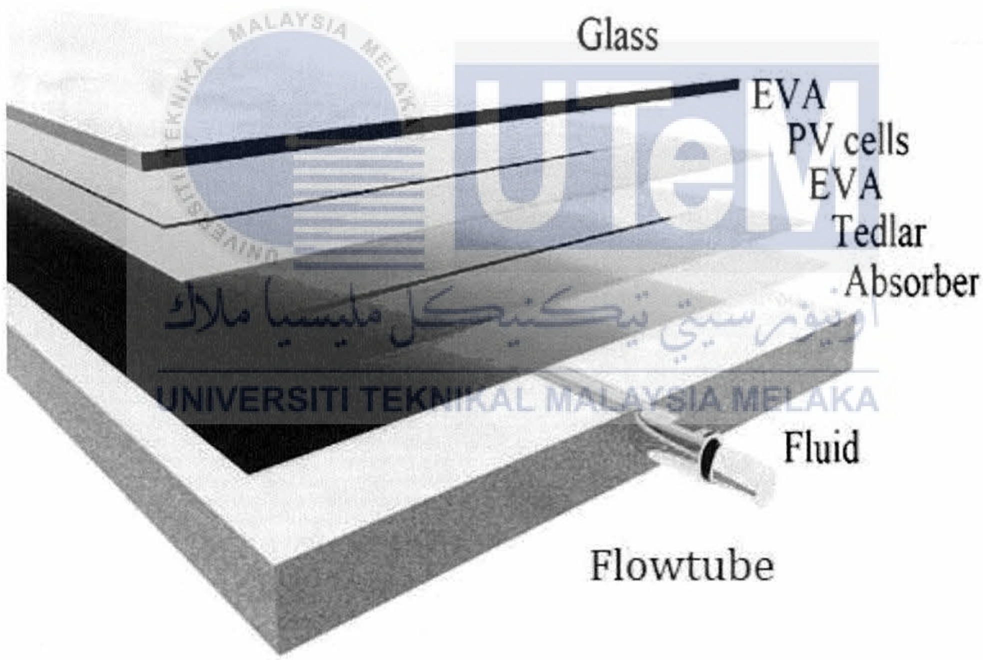
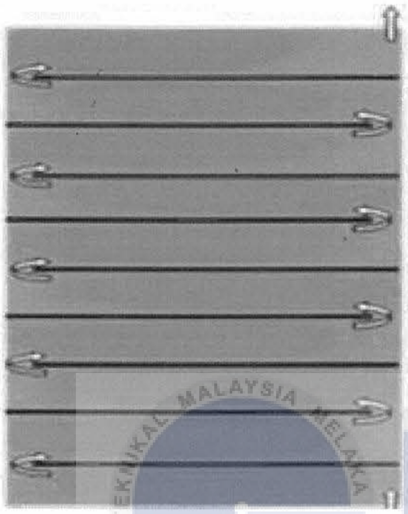


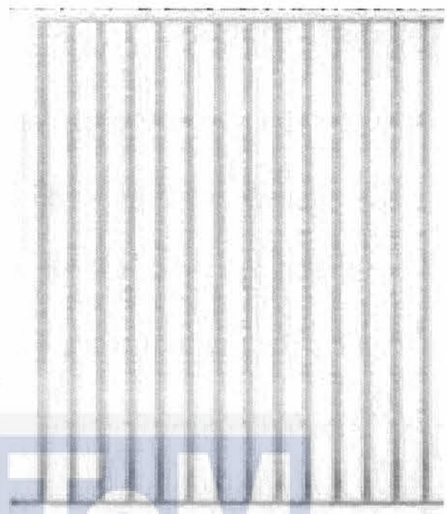
Figure 2.1: The General model of PVT System (Salari et al., 2020)

2.2 Types of Absorber Design

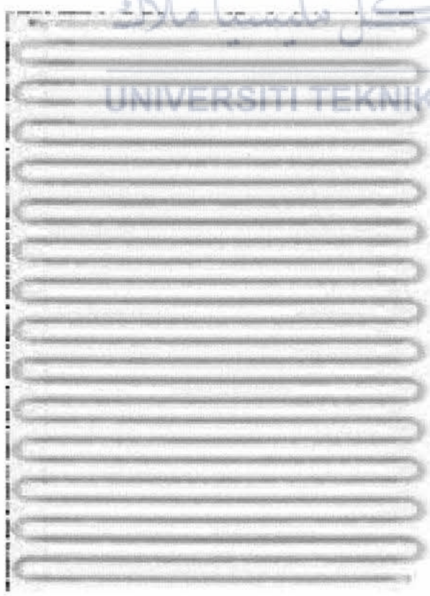
In this section described about the types of absorber design adopted in the solar PVT system. Figure 2.2 shows different types of absorber used by the previous researchers in the application of solar photovoltaic thermal system.



(a) Cross finned absorber



(b) Parallel absorber



(c) Serpentine absorber

(d) Spiral absorber

Figure 2.2: Types of Absorber design used by Previous Researchers (Rosli et al., 2021)

According to a research conducted by (Kazem et al., 2020), under the ideal conditions, parallel absorber designs can reach a thermal efficiency of up to 70%. But the investigation also denoted that this parallel absorber design frequently experienced uneven temperature distribution, which directly resulted in a chance to reduce overall efficiency. Serpentine absorber identified design is to produce enhanced heat transfer as compared to the parallel absorber. Serpentine design is superior due to the increased surface area to heat to be transferred and achieve 50% thermal efficiency according to a study by (Rosli et al., 2014).However, the study also pointed out that fabricating these designs might be more difficult because the shape, gap and diameter of the tube are deciding factor of performance of the system. In PVT systems, spiral absorber designs are a relatively recent idea. Spiral absorber designs emerged as simple design then allocated specific area for junction box also offered large areas of surface for heat transfer while preserving an easy and affordable production process, these designs seek to combine the advantages of both parallel and serpentine designs by (Rosli et al., 2021).

2.3 Spiral Design Absorber

A numerical investigation is performed by (Kuharat & Anwar Bég, 2019) using computational fluid dynamics simulation of absorber designs including flat plate, spiral, and serpentine also the nanofluid-based annular solar collector with various metallic nanoparticles. They reported that the spiral absorber design showcased superior thermal performance compared to the other designs, with an increase in thermal efficiency of up to 20%.

An experimental investigation and CFD simulation numerical analysis performed by (Misha et al., 2020) in a solar PVT system under weather conditions in Malaysia. In the investigation, they concluded that with an improvement of 12% thermal efficiency in the spiral absorber design compared to the flat plate design. (Abed Saheb et al., 2021) analyzed a review on solar photovoltaic thermal system with advanced design and working fluids. In comparison with the other absorber designs like a flat plate and serpentine design, they found that the spiral absorber design resulted in better thermal efficiency and heat transfer. This experiment concluded with an increase in thermal efficiency of up to 15% when compared with flat plate design.