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EFFECT OF WIRE MESH ON SOLAR CHIMNEY PERFORMANCE IN A SOLAR PV COOLING SETUP

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DECLARATION

I hereby declare that this thesis, submitted to Universiti Malaysia Sabah (UMS) as partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering, has not been submitted to any other university for any degree. I also certify that the work subscribed herein is entirely my own, except for quotation and summaries sources of which have been duly acknowledged.

15th July 2022

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CERTIFICATION

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ABSTRACT

The performance of the solar photovoltaic (PV) panel is greatly affected by the rise in operating temperature. Plus, due to the fact that solar panel can only harness a limited amount of energy from the irradiation of the sun, the excessive solar radiation will only contribute to heat up the solar panel which in turn causes the drop of efficiency of the solar panel. Besides, it was determined that cold inflow phenomenon occurred at the chimney's outlet which affect the natural convection of the chimney. Hence, this study aims to provide a passive cooling mechanism of solar PV that consist of three different types of setups. It can be classified as (i) control prototype, (ii) prototype mounted with a chimney, and (iii) prototype mounted with a chimney with a wire mesh attached inside of it. Specifically, it investigates the effect of chimney and wire mesh on the performance of solar PV in terms of temperature and electrical efficiency. Furthermore, temperature distribution on the wire mesh will also be investigated to see the existence of the cold inflow. Thus, the data between a prototype that mounted with and without a wire mesh will be compared. To test the hypothesis that chimney leads to an increased electrical performance of the solar PV and wire mesh can prevent the occurrence of cold inflow which will affect the solar PV performance, an experimental investigation was carried out in the Faculty of Engineering, Universiti Malaysia Sabah. The results showed a significant effect in increasing the efficiency of solar PV while decreasing the panel temperature with the prototypes that have a chimney and wire mesh on it. However, due to unforeseen circumstance, the solar panel used in Prototype (ii) is faulty and malfunction making the comparison for the solar panel efficiency cannot be done. Fortunately, the data for the existence of cold inflow at the chimney's outlet can still be compared between Prototype (ii) which has only a chimney with Prototype (iii), a chimney setup that equipped with a wire mesh. The results show that with the used of chimney the electrical efficiency of solar PV increased up to 15%, while the temperature was able to decrease to 15.23%. The used of wire mesh was also determined manage to minimize the effect of cold inflow or reverse flow at the exit of the the chimney by comparing the mass flow rate and air temperature between Prototype (ii) and Prototype (iii). It was found that cold inflow effect the solar chimney performance as the solar panel temperature in Prototype (ii) is higher than Prototype (iii). Hence, the best solar PV cooling setup is Prototype (iii) which has stainless-steel wire mesh installed inside of it.

ABSTRACT

Prestasi panel solar fotovoltaik (PV) sangat dipengaruhi oleh kenaikan suhu operasi. Selain itu, kerana panel suria hanya dapat memanfaatkan sejumlah tenaga dari penyinaran matahari, sinaran suria yang berlebihan hanya akan menyumbang kepada pemanasan panel suria yang seterusnya menyebabkan penurunan kecekapan panel solar. Selain itu, ditentukan bahawa fenomena aliran sejuk masuk berlaku di saluran keluar cerobong yang mempengaruhi perolakan semula jadi cerobong. Oleh itu, kajian ini bertujuan untuk menyediakan mekanisme penyejukan pasif PV solar yang terdiri daripada tiga jenis persediaan yang berbeza. Ia dapat diklasifikasikan sebagai prototaip kawalan (i), prototaip (ii) yang dipasang dengan cerobong, dan prototaip (iii) yang dipasang dengan cerobong dengan jaring dawai yang terpasang di dalamnya. Secara khusus, ia menyelidiki kesan cerobong dan jaring dawai terhadap prestasi PV solar dari segi suhu dan kecekapan elektrik. Selanjutnya, pengedaran suhu pada jarring dawai juga akan disiasat untuk melihat adanya aliran sejuk masuk. Oleh itu, data antara prototaip yang dipasang dengan dan tanpa jarring dawai akan dibandingkan. Untuk menguji hipotesis bahawa cerobong membawa kepada peningkatan prestasi elektrik PV solar dan jarring dawai dapat mencegah berlakunya aliran sejuk masuk yang akan mempengaruhi prestasi PV solar, penyelidikan eksperimental dilakukan di Fakulti Kejuruteraan, Universiti Malaysia Sabah. Hasilnya menunjukkan kesan yang signifikan dalam meningkatkan kecekapan PV solar sambil menurunkan suhu panel dengan prototaip yang mempunyai cerobong dan jarring dawai di atasnya. Namun, atas factor yang tidak dapat dielakkan, panel suria yang digunakan dalam Prototaip (ii) rosak dan tidak dapat berfungsi dengan baik. Ini menyebabkan perbandingan untuk kecekapan panel solar tidak dapat dilakukan. Namun, data untuk kewujudan aliran sejuk masuk di saluran cerobong masih dapat dibandingkan antara Prototaip (ii) yang hanya mempunyai cerobong dengan Prototaip (iii), cerobong yang dilengkapi dengan jarring dawai. Hasilnya menunjukkan bahawa dengan penggunaan cerobong, kecekapan elektrik PV suria meningkat hingga 15%, sementara suhu dapat menurun menjadi 15.23%. Penggunaan jarring dawai juga ditentukan dapat meminimumkan kesan aliran masuk sejuk atau aliran balik di pintu keluar cerobong dengan membandingkan kadar aliran jisim dan suhu udara antara Prototaip (ii) dan Prototaip (iii). Didapati bahawa aliran sejuk masuk mempengaruhi prestasi cerobong suria kerana suhu panel solar dalam Prototaip (ii) lebih tinggi daripada Prototaip (iii). Oleh itu, sistem penyejukan PV solar terbaik adalah Prototaip (iii) yang mempunyai wire mesh keluli tahan karat yang dipasang dalam cerobong.

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LIST OF SYMBOLS

Re	–	Reynold Number
u	–	Kinematic Viscosity
b	–	Width of Solar Panel
L	–	Length
K_{air}	–	Thermal Conductivity of Forced Air Flow
h	–	Convective Heat transfer Coefficient
V_{fin}	–	Volume of Aluminium Fin
ρ	–	Density
m	–	Mass
t_{fin}	–	Thickness of Aluminium Fin
H_{fin}	–	Height of Aluminium Fin
$Sopt$	–	Spacing Between Fins
I_m	–	Maximum Current
V_m	–	Maximum Voltage
P_{output}	–	Power Output
η_{pv}	–	Efficiency of Solar Panel

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CHAPTER 1

INTRODUCTION

1.0 Overview

Solar chimney is one of the most widely used renewable energy sources in the world. Every year, the earth's temperature rises dramatically, and the Arctic Sea ice melts as a result of climate change. Using renewable energy is one of the viable strategies for reducing global warming. Solar energy is one of the most promising renewable energy sources (Zhou, Xiao, et al., 2010). Solar chimney which utilizing the solar radiation from the Sun can be made as an excellent device for enhancing natural ventilation in the building. As a matter of fact, solar chimney has been regularly employed to improve natural ventilation for decades (Guzma et al., 2009).

Solar chimney can also be integrated with solar photovoltaic (PV) cooling setup. The solar chimney can be fitted into any heat-absorbing material to generate a natural flow. The installation of a solar chimney in a solar PV system can enable air to flow beneath the panels, cooling them and perhaps increasing their efficiency and output (Yelpale et al., 2014). However, solar chimneys, like other technologies, have their own set of restrictions and flaws that limit their effectiveness such as external winds and diameter outlet of the chimney which eventually lead to cold inflow inside of the chimney (Shi et al., 2018).

The structure of a solar chimney is an open cavity that, with the help of sun irradiation, produces air flow. Although it can be used to improve daytime ventilation, the solar chimney is mostly used to consolidate night ventilation (Monghasemi & Vadiee, 2018). Solar collectors, chimneys, and turbines are all combined into the solar chimney. The sun's rays reach and pass through the cover, heating the soil beneath it, which heats the air. The most important things for a solar chimney to be used as a ventilation system is to make sure all of the hot air went out of the exit chamber. However, it was

found that there is cold inflow occurred at the exit outlet which eventually effect the solar chimney performance (Zhou, Wang, et al., 2010a).

The most prevalent concern with the solid wall chimney exit is cold inflow. This is due to the instabilities in the wind flow and the resulting downdraft (Zhai & Fu, 2006). Cold inflow affects the heat transfer inside of the solar chimney by 4 % which indirectly decreasing the solar chimney performance and indirectly affecting the ventilation for the PV cooling setup. It was important for the solar chimney to be performing in its best state as a ventilation to make sure the temperature of the PV panel can be decrease due to the high temperature. The temperature of a polycrystalline solar cell affects its efficiency, and we can't avoid an increase in cell temperature. Even though cold inflow has been deemed as one of the problem that a solar chimney faced, not many research were conducted due its hard and complexity nature (Frutos Dordelly et al., 2019). However, it was suggested that this phenomenon can be avoided by using a wire mesh as a screen at the solar chimney outlet (Md. Mizanur Rahman et al., 2018). The effect of the wire mesh to the performance of the solar chimney in solar PV cooling setup need to be studied thoroughly so that a high-performance solar chimney can be achieve.

1.2 Problem Statement

Solar chimney faced cold inflow at the exit chamber thus affecting their overall performance as a ventilation system. In terms of energy conservation, natural ventilation performs well. However, there is a lack of study regarding the effect of using wire mesh in preventing cold inflow to occurred and improving the efficiency of the overall performance to the solar chimney. Solar chimney that used in the solar photovoltaic (PV) cooling system face a huge reduction of efficiency as the PV module's efficiency drops by 0.5 percent for every 1°C increase in surface temperature (Kumar K et al., 2006). As a result of the increased temperature, not all of the solar energy absorbed by photovoltaic cells is converted to electrical energy. Solar chimney which was integrated with the solar PV cooling setup cannot perform its job perfectly due to the cold inflow that happened at the exit chamber. The high temperature of the solar PV panel due to poor air circulation will reduce the system efficiency (Meneghel et al., 2018).

Thus, it is imperative to conduct an investigation on how does wire mesh will affect the solar chimney performance, thus increasing the efficiency of the solar PV

cooling setup. This research will allow the researcher to identify on how to prevent cold inflow to occur on the solar chimney exit chamber and effect on wire mesh pore size on the solar chimney performance.

1.3 Objective

The objective of this project are:

i. To observe the effect of wire mesh on cold inflow inside of the solar chimney.
ii. To increase the efficiency and performance of the solar PV with the use of solar chimney and wire mesh.

1.4 Scope of Works

The scope of work of this research was only limited to the effect of wire mesh on solar chimney performance. This is including the external winds and diameter outlet of the diameter which was deemed to be the reason that cause the cold inflow phenomenon. The other factors that affecting the solar chimney performance such as chimney height, air gap, climatic conditions and etc. are neglected.

This project's design and analysis were based on earlier research and data collection. However, because this effort aims to improve on prior research, several changes were made. Both with and without wire mesh, the performance of the solar chimney was measured. They were then compared based on the temperature of the PV panels over time and their efficiency. The general scope of work for completing this project is listed below.

I. Literature review on existing and past research regarding solar chimney and PV system to strengthen the fundamental of this research.
II. Designing a lab-scale solar chimney which is a suitable design.
III. Fabrication of prototype. This includes the assembly of parts, prototype testing and prototype optimization.
IV. Analysing the effect of wire mesh on the performance of solar chimney.
V. Collecting data and document it in the thesis form of figures, tables and graph together with results, discussion and conclusion.

1.5 RESEACRH OF METHODOLOGY

Methodology is an important component of a project since it guides students in their research and leads them so that they can complete duties according to the schedule plans and within the time limits. Two solar chimney systems were designed for this project, with the first serving as the control variable and the second acting as the manipulated variable. Many aspects are considered during the design process in order to meet the project's objectives and criteria. This Project I is typically completed in 14 weeks and covers a variety of mechanical design and heat transfer aspects. The methods and procedures in this project can be presented in the form of a flow chart.

I. Study of an existing system and literature review.

Study of an existing system and literature review is needed in this project to strengthen the fundamental of this research. By examining the strengths, a weakness of an existing system, appropriate methods, data sources and analytical techniques can be adopted in this project.

II. Designing and modelling.

A few designs for the solar chimney will be reviewed to select the best one by considering the cost, availability of materials and preferable design.

III. Material selection and preparation.

Material selection and preparation is crucial for this project because wire mesh come with different type of size and materials. The material used to make the solar chimney must also be the suitable one that can allow a smooth ventilation.

IV. Experiment analysis and data collection.

The experiment which will be conducted to see the effect of wire mesh on the natural ventilation will be analyse. Collection of data will be recorded throughout the experiment analysis process to determine the performance of the solar chimney.

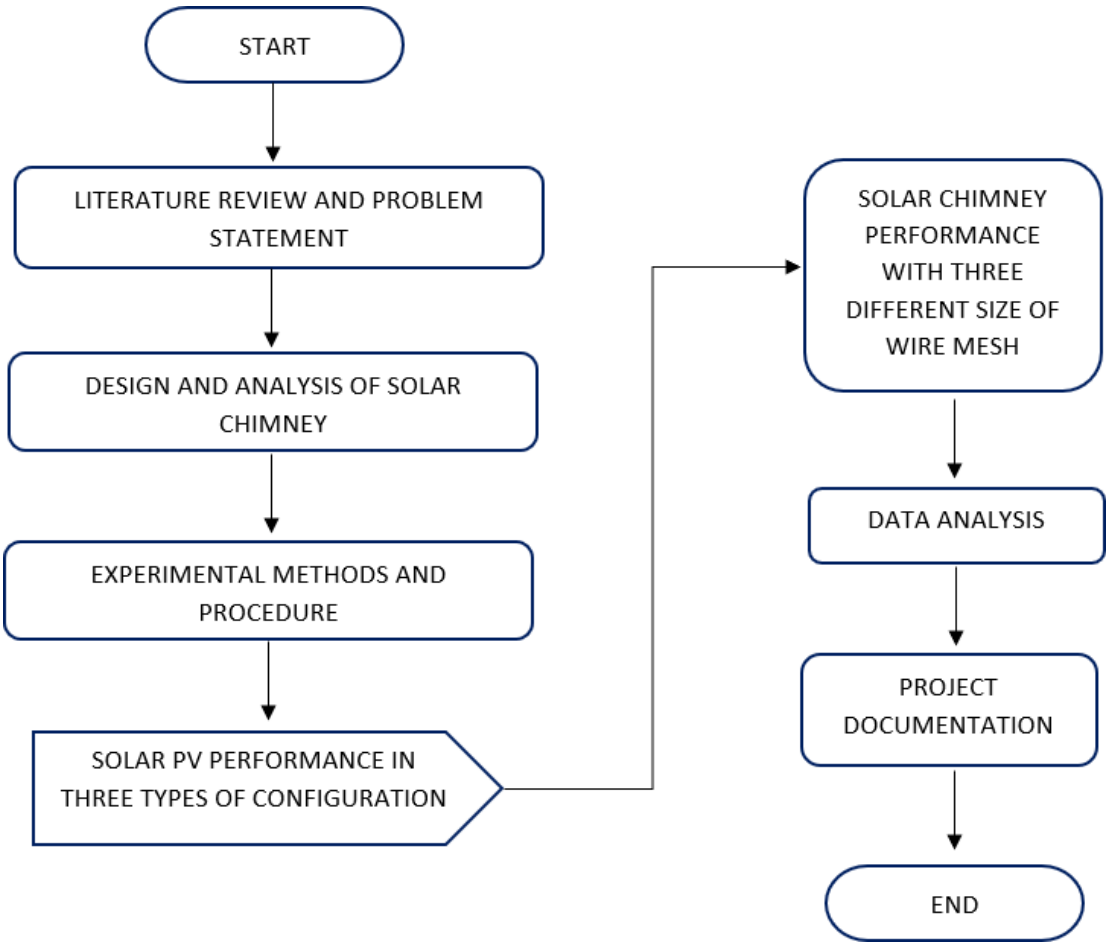

Figure 1.1: Methodology Flowchart

1.6 Research Contribution

One of the objectives of this project is to increase the efficiency and performance of solar PV. As the resources of the non-renewable energy is in the critical state, the improvement that was made in this research may encourage people to start using renewable energy in their household. The project which was done in local environment may convince the people about the relevance of using solar PV, which is a renewable energy not only in their household but also at schools, factories and even offices. This is because the data and information regarding the use of renewable energy mostly come from Europe, not from Malaysia, thus making people sceptical whether renewable energy can be done in our country or not. However, with this research, it will eventually become evidence that renewable energy can be use anywhere as long as that place can be reach by the sunlight. The contains of this research also focusing on solving one of the common problems of a solar chimney which is cold inflow. Even though cold inflow has been determined one of the problems that affecting the solar chimney performance, only a few researches were made to solve this problem because of its complexity (Khanal & Lei, 2012). Fortunately, the other objective of this project is to tackle this problem by using wire mesh and thus will increase the solar chimney performance. This will eventually contribute in creating a high-performance solar chimney equipped with a more environmentally friendly feature and low-cost maintenance. As solar chimney is widely use not even is household, but even in the industries, this will give them a huge benefit as a high-performance solar chimney with a high efficiency can provide the best result in a low-cost manner.

1.7 Research Commercialization

The goal of commercialization is to make a profit from this research effort. Many modern industries will benefit from the outcome of this initiative as the focus of the world is shifted to a nature friendly and renewable energy. With this research, which will increase the performance and efficiency of the solar chimney and solar PV, people will become even more interested as an application or a system with a high efficiency is cost efficient. As we all know, economically, many people were affected by the Covid-19 pandemic. Thus, it is an even more reason for people to use a solar chimney and solar PV which a renewable energy.

1.8 Research Gantt Chart

Table 1.1: Semester 1 Research Gantt Chart

No	Item	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Topic selection														
2.	Project Proposal Preparation														
3.	Proposal Moderation														
4.	Literature Review														
5.	Material Selection and Preparation														
6.	Progress report preparation														
7.	Submission of progress report														
8.	Viva 1														

Table 1.2: Semester 2 Research Gantt Chart

No	Item	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Project Fabrication														
2.	Experimental Validation														
3.	Data Analysis														
4.	Draft Submission														
5.	Draft Correction														
6.	Technical Report Writing														
7.	Submission of progress report														
8.	Viva 2														

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In order to effectively attain the stated objectives, all theories, information, and current knowledges will be discussed in this chapter by selecting relevant research papers. In addition, all connected findings from earlier research or projects were reported, and only journal articles were evaluated for a better quality of literature review. This chapter consists of the background of solar chimney and it's working process. Followed by factors affecting the performance of the solar chimney and the effect of wire mesh in solar chimney. The PV cooling system which was used as a cooling system in the solar chimney will also be discussed in this chapter, including factor that affecting it's performance.

2.2 Solar Energy System

Continuous global population and economic growth, combined with fast urbanization, has resulted in a massive increase in energy demand, resulting in increased pollution and greenhouse gas emissions (Mukhtar et al., 2021). Due to a lack of energy generation, inefficient use of energy resources, and environmental degradation, energy efficiency and environmental security have garnered a lot of attention (Pei et al., 2019). Eliminating these kinds of toxins from the environment again necessitates huge costs. As a result, utilising these sources has become a major concern. The most critical component that can only transform the current scenario is sustainable energy generation (Saidur et al., 2012). Nowadays, the world focus has been shifted to the renewable energy which is known to be more environmentally friendly and cost-effective such as the solar energy.

Solar energy is the radiant light and heat from the Sun that is captured and used in a variety of methods, including solar power to create electricity, solar thermal energy, including solar water heating, solar architecture and even natural ventilation in buildings. In the previous decade, it has been demonstrated that solar energy is a