STUDY ON THE EFFECT OF REFLECTOR AT TILT ANGLE 75° AND 65° ON SOLAR PV PANEL SYSTEM WITH FINS AND CHIMNEY COOLING

ALLYSSA MAREON MARAUN

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITI MALAYSIA SABAH

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DECLARATION

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

25th JULY 2022 ALLYSSA MAREON MARAUN

CERTIFIED BY

DR MOHD SUFFIAN MISARAN @ MISRAN

SUPERVISOR

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ABSTRACT

Various ambient environmental factors such as incident irradiance, the module temperature, and the spectral irradiance distribution can greatly influence the performance of PV modules that are installed outdoor. As the temperature of the solar PV panel may affect its efficiency, cooling system through the fins and absorber plate are implemented in the system. Moreover, the role of the reflector is to increase the amount of light that hits the surface of the solar PV panel which will then help improve its electrical power output. Other than that, the role of the reflector is also to concentrate solar radiation on the absorber, which will then facilitate convection through buoyancy effect as the air draft from the absorber towards the chimney is caused by the increasing air velocity. Therefore, reflectors that are angled at 75° and 65° were designed and constructed. The objective of this project is to investigate the effect of reflectors that are integrated in the solar PV panel system with fins and chimney cooling and measure the solar PV power output at different reflector angle and solar radiation. The experiment was conducted by placing a reflector at each side of the solar PV panel and readings of the ambient temperature, solar panel surface temperature, solar irradiance, current, voltage, power output, air velocity and temperature at four sections of the test rig were taken in a one-hour interval starting from 10 AM to 3 PM. From the results obtained, the highest average velocity, 0.6218 m/s, was discovered to be produced by solar panel systems with integrated reflectors at a 75° angle. Apart from that, the highest chimney temperature exit for 75° and 65° reflectors is 55.8° Celsius at 1204.2 W/m^2 and 49.2° Celsius at 1204.2 W/m^2 respectively. The best chimney thermal efficiency was created by 75° reflectors, which had a value of 24.42% at 1131.4 W/m^2. The highest power output was achieved by the solar panel system using the 75° reflectors, which was 80 W. The solar panel systems with 75° and 65° reflectors have the highest solar panel efficiencies, which are 7.24% and 6.68%, respectively. The system utilizing 65° reflectors has a maximum solar panel surface temperature of 77.4° Celsius, whereas the system using 75° reflectors has a maximum solar panel surface temperature of 73.2° Celsius. Since the reflector with the angle of 75° was able to focus more solar radiation on the solar panel than the reflector with the angle of 65°, it

can be concluded that it was more effective. In summary, 75° reflectors help the solar chimney cool down more effectively than 65° reflectors.

ABSTRAK

KAJIAN MENGENAI KESAN REFLEKTOR PADA SUDUT KECONDONGAN 75° DAN 65° PADA SISTEM PANEL PV SOLAR DENGAN PENYEJUKAN SIRIP DAN CEROBONG

Pelbagai faktor persekitaran ambien seperti sinaran kejadian, suhu modul, dan taburan sinaran spektrum boleh mempengaruhi prestasi modul PV yang dipasang di luar. Memandangkan suhu panel PV suria boleh menjejaskan kecekapannya, sistem penyejukan melalui sirip dan plat penyerap dilaksanakan dalam sistem. Selain itu, peranan reflektor adalah untuk meningkatkan jumlah cahaya yang mengenai permukaan panel PV solar yang kemudiannya akan membantu meningkatkan output kuasa elektriknya. Selain itu, peranan reflektor juga adalah untuk menumpukan sinaran suria pada penyerap, yang kemudiannya akan memudahkan perolakan melalui kesan keapungan kerana draf udara dari penyerap ke arah cerobong disebabkan oleh peningkatan halaju udara. Oleh itu, pemantul yang bersudut 75° dan 65° telah direka dan dibina. Objektif projek ini adalah untuk menyiasat kesan pemantul yang disepadukan dalam sistem panel PV solar dengan penyejukan sirip dan cerobong serta mengukur keluaran kuasa PV solar pada sudut pemantul dan sinaran suria yang berbeza. Eksperimen dijalankan dengan meletakkan reflektor pada setiap sisi panel PV suria dan bacaan suhu persekitaran, suhu permukaan panel suria, sinaran suria, arus, voltan, keluaran kuasa, halaju udara dan suhu pada empat bahagian pelantar ujian adalah diambil dalam selang satu jam bermula dari 10 pagi hingga 3 petang. Daripada keputusan yang diperolehi, halaju purata tertinggi, 0.6218 m/s, didapati dihasilkan oleh sistem panel solar dengan pemantul bersepadu pada sudut 75°. Selain itu, keluaran suhu cerobong tertinggi untuk pemantul 75° dan 65° ialah 55.8° Celsius pada 1204.2 W/m2 dan 49.2° Celsius pada 1204.2 W/m2 masing-masing. Kecekapan terma cerobong terbaik dicipta oleh pemantul 75°, yang mempunyai nilai 24.42% pada 1131.4 W/m2. Output kuasa tertinggi dicapai oleh sistem panel suria menggunakan pemantul 75°, iaitu 80 W. Sistem panel suria dengan pemantul 75° dan 65° mempunyai kecekapan panel suria tertinggi, iaitu masing-masing 7.24% dan 6.68%. Sistem yang menggunakan pemantul 65° mempunyai suhu permukaan panel suria maksimum 77.4° Celcius, manakala sistem

menggunakan pemantul 75° mempunyai suhu permukaan panel suria maksimum 73.2° Celcius. Memandangkan reflektor bersudut 75° dapat memfokuskan lebih banyak sinaran suria pada panel suria berbanding reflektor bersudut 65°, bolehlah disimpulkan bahawa ia lebih berkesan. Ringkasnya, pemantul 75° membantu cerobong suria menyejuk dengan lebih berkesan daripada pemantul 65°.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIXES

CHAPTER 1

INTRODUCTION

1.1 Introduction

There is a continuous increase in the global demand of energy, but primary sources like fossil fuels experience a gradual depletion through the time. Thus, new renewable and sustainable technologies are explored to generate environment friendly energy sources. The most promising source of renewable energy is solar energy since it it is the safest, clean, and abundant (Ajayan et al., 2020). Solar energy has various usage as it is able to produce both heat and electricity. In industrial sectors, for instance, solar thermal sources produce heat which is then used in the application for space heating, chemical processing, food processing, and textile industry. Moreover, telecommunication, transportation, water heating, water treatment, agriculture, and the construction industry also make use of solar energy (Hayat et al., 2018).

Depending on the type of semi-conductor material used in the PV panel, solar energy is converted to electrical energy on the PV panel with an efficiency range of 6% to 20%. However, low panel efficiency has been caused by a variety of factors, including panel tilt angle, shade, dust, solar radiation intensity, temperature, and other losses. Solar radiation level and temperature have taken centre stage among these variables (Karafil et al., 2016).

The PV module reflects some of the radiation incidents on the PV solar cells. On the other hand, it stores some percentage of the incident radiation in the PV module as heat which causes the surface temperature of the PV module to rise. Thus, the operating temperature is increased and negatively affect the performance of the PV panel. Cooling techniques can be employed to lower the surface temperature so that the electrical performance of the PV module remains at an acceptable level. Other than that, this will also prolong the lifetime of the PV module (Shastry & Aruchanala, 2020).

One of the cooling methods is the integration of the solar chimney. Solar chimney is able to create a natural air draft below any heat absorber. As the solar panel absorbs heat and has its temperature increased due to receiving increasing solar radiation, its efficiency will decrease. Thus, the solar chimney may provide air flow below the panel to cool it and increase its efficiency (Yelpale et al., 2014).

1.2 Problem Statement

Although there is an abundance of solar energy, the solar cells face an obstacle as the power output is very low in comparison to other types of power plants. Moreover, various ambient environmental factors such as incident irradiance, the module temperature, and the spectral irradiance distribution can greatly influence the performance of PV modules that are installed outdoor (Eke et al., 2017). Research by Senthil Kumar et al. (2019) has shown that at temperature 38.55 °C at the solar PV panel temperature, the solar PV's efficiency was at 12.51%. However, when the panel's temperature increased to 44.15 °C, the efficiency dropped to 11.09%. Past research has revealed that an increase in solar cell temperature of around 1 °C leads to a decrease in efficiency of about 0.45% (Peng et al., 2017).

Therefore, the role of the chimney is to create a natural air draft below the solar panel. The role of the reflector is to concentrate the solar radiation on the surface of the solar panel and absorber. As the intensity of the solar radiation on the absorber is increased, it will facilitate the buoyancy effect that will help to cool the solar panel (Yelpale et al., 2014).

A reflector is significant to increase the amount of light that hits the surface of the solar module which will then help improve the electrical power output of the solar panels. Naik & Palatel (2014) observed that with the integration of reflector into the system, the solar PV panel saw a significant increase in its thermal and electrical output.

1.3 Research Objectives

The objective of this project is to investigate the effect of solar photovoltaic cooling by using fins with solar collector and reflector into its system on the power output of the solar photovoltaic panel. The followings are the sub-objectives that complement the main objective:

i. To design a solar reflector at angle of 75° and 65° with consideration for the amount of sunlight concentrated on the solar PV panel
ii. To measure the air velocity and solar panel system temperature at different solar irradiance and sun position

1.4 Scope of Work

Researches will be conducted through literature review to obtain the necessary information to design and fabricate the solar reflector so that the objectives of this project can be achieved.

The main scope of this project is to investigate the effect of reflector at angle of 75° and 65° in a solar PV system with cooling and compare the performance between the solar PV system with reflectors of different angles. The parameters that were compared were the average air velocity flowing through the solar panel system, chimney outlet temperature, the temperature on the surface of the solar panel, and the power generated by the solar panel system.

1.5 General Methodology

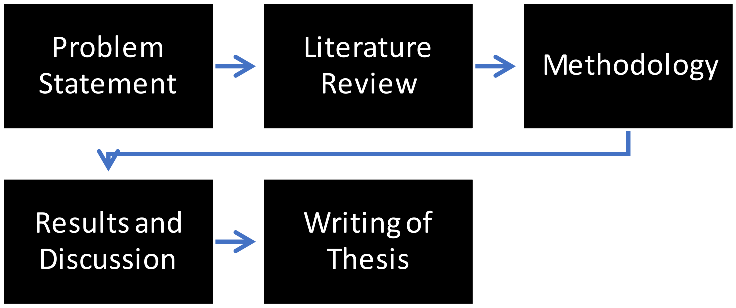

Figure 1.1: General Methodology of the Project

Figure 1.1 shows the general methodology of the project. First, a problem and its solution were recognized. Then, research was done on relevant topics through reading journals, articles, books, websites, and watching videos. After relevant information were gathered, the fabrication of the test rig was done. Following the completion of the test rig, the experiment was conducted. The data from the experiment were recorded in the form of tables, graphs, and bar charts where the observation made on them would be used to write the results and discussion.

1.6 Research Contribution

Although almost all Asian countries are working towards utilizing and enhancing the solar energy technology, only India makes use of the solar reflectors technology. This then has generated approximately 1100 MW of renewable energy to India's electricity grid. With the usage of solar reflectors being more widely used, for the sorts of applications such as concentrating solar radiation on the solar panel and for facilitating cooling method, by all of the Asian countries, it may open opportunities of collaborations between countries and enlarge the reflectors industry. Thus, as the integration of reflectors into the solar PV system become more common, cost-effective power generation and reduced carbon emissions can be achieved (Akhtar et al., 2018).

Apart from benefiting the industry, collaborative efforts between countries, and reducing environmental issues, the introduction of solar PV panel system with reflectors and passive cooling integrated into the system will also be helpful to rural or remote areas. Passive cooling is especially important because it does not use additional power. Thus, the residents do not need to distribute some of the power generated on the cooling system. In the research conducted by Abd Hamid et al. (2021) at Mantanani Island, it was mentioned that there is a limited supply of electricity on the island as the two sets of generators supplied by Sabah Electricity Sendirian Berhad (SESB) had to fulfill the energy supply of 157 houses with ongoing supply only from 6 PM to 6 AM.

Access to energy sources are hindered due to the island's geographical location. However, the study evaluated that as the location of the island is close to the earth's equator, it has an advantage in terms of sun path and azimuth. Therefore, the utilization of solar energy has been proposed. As solar reflectors facilitate the solar panels to get more intense solar radiation, more energy can be harnessed in a shorter time. Thus, this can ensure that the energy supply needs of the population in those particular areas can be fulfilled (Akhtar et al., 2018).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is critical to the project's completion since it provides all of the relevant information, notably for the study of the role of cooling techniques and reflector on the efficiency of the solar PV panel. This chapter's material and themes were gleaned from articles, journals, websites, books, and other sources.

2.2 Solar Energy

The three global energy resources can be classified into three main groups which are fossil energy, nuclear energy, and renewable energy. Fossil energy includes oil, gas, coal, etc. In the document Directive 2009/28/EC attachment 1, renewable energy sources is defined as the energy obtained from non-fossil and renewable sources. This includes wind, solar, geothermal, ocean, hydropower, biomass, biogas etc. In the effort to overcome the dependence on non-renewable sources, renewable energy is the best option available in the role of generating electrical energy. Due to the advantageous features of availability, intermittent, replenishable, reliability, and environmental-friendliness, renewable energy resources are becoming more and more widely used in both domestic and industrial applications (Choifin et al., 2021).

Sun is the main source of renewable energy on earth. The photoelectric mechanism, which is incorporated in solar PV systems, extracts and converts the visible light to direct current (Varghese & Jacob, 2018). Other than the sun, other main sources of renewable energy-based systems are wind power generation systems, fuel cells, and micro-turbines (Choifin et al., 2021).

The benefits of solar energy are it is low maintenance, has long life, and is free of pollution. Therefore, it is considered to be a reliable, promising, and profitable energy source. Other than that, due to its abundance, it is able to meet community needs that come from sustainable economic development (Choifin et al., 2021). However, Hayat et al. (2018) stated that currently, the overall usage of solar energy to generate electricity is as small as 0.015%. Meanwhile, 0.3% is used for heating and 11% is used for photosynthesis. Fossil fuels still fulfil 80% to 85% of the global energy needs.

2.2.1 Solar Photovoltaic

The electric power is generated by using solar panels in which the solar radiations are converted into flowing electrons to generate electric current. Specialized cells, which are called photovoltaic cell and are made of semiconductor material, that can convert solar radiation into direct current are designed to harvest solar radiations at their maximum limits (Sainthiya & Beniwal, 2017).

The semiconductor material helps convert the radiations into direct current. The process happens when the intense sun rays are incident on the solar cells. Thus, it dislodges and releases electrons within the material which then mobilizes to produce a direct electric. When intense radiations are incident over solar panel, this leads to the dislodgement and release of electrons within the material which then leads to the mobilization of electrons. This generates a potential difference and thus produce a direct electric (Sainthiya & Beniwal, 2017).

The material decides the cost-effectiveness and efficiency of a solar PV cell. Based on Hayat et al. (2018), some of the requirements for the ideal solar cell material are the following:

i. The band gap of the solar cell material should be between 1.1 and 1.7 eV
ii. It must have a direct band structure
iii. It must be easily accessible

iv. It must be nontoxic
v. It should be able to be largely reproduced
vi. Possesses good PV conversion efficiency
vii. It must have a long-term stability factor

According to Varghese & Jacob (2018), in common households, electrical energy can be produced by a flat solar panel. However, due to its low power conversion efficiency which is only about 15%, the modules have low energy output. Other than that, the sun intensity and the panels' angle of incidence also affect the generation of electricity. Therefore, the power output is enhanced by trackers where the panels are physically tracked towards the sun position. Radiation is also obtained through tracked concentrators. Though, these methods are expensive and complex.

Hayat et al. (2018) states that the current-voltage or spectral responsivity-wavelength curves can be used to determine the performance of solar cells. The most common performance indicator for PV cells is as shown on the equation below:

$$\eta = \frac{P_{max}}{(E_{tot})(A)} \times 100$$

The power conversion efficiency equation is defined as the ratio of maximum electric output to the total irradiance.

2.3 Factors Affecting Solar PV Performance

The performance of the solar panel is influenced by various environmental factors such as sunlight, ambient and module surface temperatures, wind speed, humidity, shade, dust, and installation among many things. However, solar irradiation and temperature are two of the most significant factors. This is because the output of the PV module will be hindered with the increase of the surface temperature (Dwivedi et al., 2020).

Of all the sun's rays that hit the solar panel, only 5 to 20% of them are converted to electricity while the remainder is either reflected backwards or