INVESTIGATION ON THE PERFORMANCE OF A SMALL-SCALE SOLAR CHIMNEY POWER PLANT FOR DIFFERENT GEOMETRICAL PARAMETERS USING EXPERIMENTAL

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in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Investigation on The Performance of a Small-Scale Solar Chimney Power Plant for Different Geometrical Parameters Using Experimental" 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.

Signature	:	....
Name of supervisor	:	....
Date	:	....

DEDICATION

To my beloved mother and father.

Thanks to the non-stop encouragement and guide given by my honourable supervisor, Mr. Mohd Noor Asril Bin Saadun, I can complete the task successfully.

ABSTRACT

In recent years, there has been a lot of interest in developing solar updraft tower (SUT) technology because of the increased use of solar energy. Many experimental and theoretical studies have been conducted in this area, with experimental studies focusing primarily on small-scale systems. The result predictions ware validated through comparison of five previous studies with the experimental data of indoor scale solar updraft tower. The results show that, collector height of 0.1 m, chimney height of 1 m, area of collector of 4.67 m^2 and solar radiation intensity of 300 W/m^2 are the best alternatives for construction of small-scale solar updraft tower. It is found that the velocity magnitude obtained is 0.4375 m/s with 307.51 K of temperature inside the solar collector. The height of chimney, area of collector and solar radiation intensity are also the most important physical variables for solar updraft tower design, according to the comparison.

ABSTRAK

Dalam beberapa tahun terakhir ini, terdapat banyak minat dalam mengembangkan teknologi ‘Solar Updraft Tower’ (SUT) kerana peningkatan penggunaan tenaga suria. Terdapat banyak kajian eksperimental dan teori telah dijalankan dalam teknologi ini, dengan kajian eksperimental yang memfokuskan keutamaan pada sistem yang berskala kecil. Projek ini dilakukan melalui kaedah perbandingan oleh lima kertas kajian yang dijalankan terhadap ‘Solar Updraft Tower’ yang berskala kecil dan dilakukan secara ‘indoor’. Hasil kajian menunjukkan bahawa, ketinggian pengumpulan solar 0.1 m, ketinggian menara 1 m, luas pengumpul solar 4.67 m^2 dan solar radiasi 300 W / m^2 adalah alternatif yang terbaik untuk pembinaan “Solar Updraft Tower’ berskala kecil. Melalui parameter ini, magnitud halaju yang diperoleh adalah 0.4375 m/s dengan suhu 307.51 K di dalam pengumpulan solar ini. Ketinggian menara, luas pengumpul solar dan solar radiasi merupakan pemboleh ubah fizikal yang terpenting untuk reka bentuk ‘Solar Updraft Tower’ menurut hasil perbandingan.

ACKNOWLEDGEMENT

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I would like to thank Mr. Mohd Noor Asril Bin Saadun that act as my Project Sarjana Muda supervisor. Without his guidance and assistance, I would not have a clear path on how to engage this project successfully.

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LIST OF ABBEREVATIONS

SUT	-	Solar Updraft Tower
PV	-	Photovoltaic
CSP	-	Concentrated solar power
m	-	Meters
mm	-	Millimeters
h	-	Hours
s	-	Seconds
MW	-	Megawatt
K	-	Kelvin (Temperature)
AM	-	Air Mass
ASTM	-	American Society for Testing and Materials
IEC	-	International Electrotechnical Commission
PC	-	Polycarbonate
PE	-	Polyethylene
PVC	-	Polyvinyl Chloride
UV	-	Ultraviolet
m/s	-	Velocity
nm	-	Wavelength
LTI	-	Long Term Instability
STI	-	Short Term Instability
LED	-	Light-Emitting Diode
CSI	-	Compact source iodide
HID	-	High intensity discharge
L	-	Length
W	-	Width
H	-	Height
PCM	-	Phase change material
AESL	-	Artificial environment simulation laboratory
mW/cm^2	-	Solar Radiation Intensity

LIST OF SYMBOLS

$^{\circ}$	-	Degree
λ	-	Wavelength
ϖ	-	Ratio of circle’s circumference to diameter (pi)
η	-	Efficiency
ρ	-	Density
$\dot{m}$	-	Mass flow rate

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is among the countries that rely on green energy sources to meet its current energy demands. Coal is the main energy source used to generate electricity in this country follow by natural gas, hydropower, and oil. This non-renewable resources except hydropower are limited in supply to fulfill future requirements and cannot be used sustainably. Therefore, we need a technology which is easy, reliable, and easy to access by even less development countries that are always clear and have limited raw material resources. Solar energy is a renewable resource that is fully unpolluting, economical, and abundant which can be used to fulfill the needs of the world [1]. Solar Updraft Tower (SUT) is the most effective technology for many solar energy technologies that meets these requirements.

A solar updraft tower plant is made up of updraft tower or chimney, collector, and turbine. During the day, solar radiation passes through the collector's transparent roof and receives more energy as the absorber from the ground, so that the air can be heated within the collector area. During nighttime or cloudy days, the solar radiation is weakening hence heat that had been stored inside the absorber will be release. Air buoyancy was created when there is the difference in density between the warm air inside the Solar Updraft Tower (SUT) and the ambient air entering from outside therefore acts as a driving force. The collector center produces a strong air flow through the tower as higher pressure drops and is used to power the turbine to turn out electricity in the solar tower. The following Figure 1.1 shows the air circulation going through the turbine power generator inside the collector.

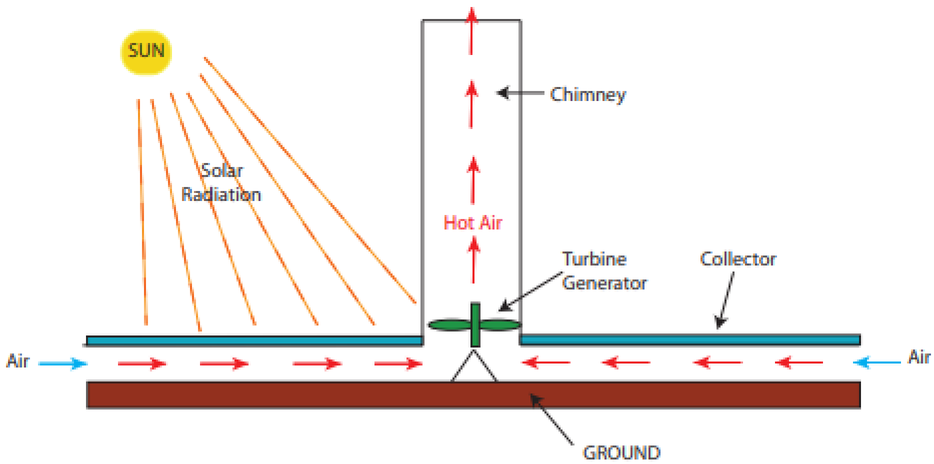

Figure 1.1: Solar updraft tower schematic diagram [2].

Solar updraft tower has a great opportunity to make them worth in terms of comparing and considering other ideas on renewable energy at present. There is no advanced technology used and it is free from failure to develop because it has low operating and maintenance costs, and this system can run even over decades. However, for the collection field, a wide land area is needed for a fully sized commercial power plant, and development of tall chimney will lead to civil engineering challenges and thus needs high prices to construct. It is possible to solve the associated issues to a realistic level. Even so, technology competes directly with high-tech solar photovoltaic and other solar thermal methods. Beside advantages that already mentioned by now, the solar updraft tower has ability to maintain absorbed energy up to one day by implementing heat storage under roof of the collector. This can be done by implementing heat storage beneath roof of the collector. Heat energy will be absorbing during the warm day and release to keep it continuous throughout the night electricity supply [3].

1.2 Problem statement

The easiest setup for Renewable Energy Power Plant is solar updraft tower compare with other plants such as Hydropower, Solar PV etc. The main reason is the maintenance for this plant is not too complex where they only need to maintain the turbine generator while the cleanliness of transparent solar collector may be a little problem for tropical countries such as Thailand, Malaysia Singapore and etc as frequent rain can cause greater maintenance in solar collector only. In general, the initial cost for setup the solar updraft tower is less expensive compare with other power plants. Even though building the solar updraft tower is inexpensive and easy to maintain, but the solar updraft tower geometry and the coverage of the collector still need to examine.

From the literature review that had been carried out, to obtain enough radiation from the sun to allow minimum power generation velocity, there is a few amount requirements for the collector radius and height. Therefore, the position to setup the solar updraft tower needs to study and identify first because the size of collector may take up space more than meter square (m^2) of land surface to produce more power.

Besides that, location to install the solar updraft tower must be receives abundant sunlight throughout the year. As Malaysia have already implemented solar PV plants, this should not have been an issue. However, for the places with the fewest daylight hours, it will be a problem to setup this plant.

Secondly, the total efficiency of the solar updraft tower is low due many factors. Hence, the study will be conduct by adjusting the geometry of the solar updraft tower, so its performance with efficiency of overall system will be further increase.

1.3 Project objective

This study is focusing on the potential for the development of small-scale solar updraft towers in remote areas in Malaysia for the next generation of electricity. The project objective is stated as follows. Hence, from the explanation given in the problem statement to promote the new technologies of solar energy plant for reducing the conventional type of power generation, it has inspired us to search out for alternative innovations to improve the existing solar updraft tower system. The project target is described as follows:

1. To design and develop a small-scale solar updraft tower by using a solar simulator with different geometry by comparing several model from previous studies.
2. To analyse the performance of solar updraft tower with different solar radiation by comparing previous studies and to identify the optimum and suitable solar radiation.

1.4 Scope of project

This study is focusing on two scope which are:

1. The data is collected at indoor experiment by assuming the environment factor as control variable.

2. Two parameters including height of chimney and diameter of collector will be analysed as geometric parameter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Over the last few decades, many experiment models were successively design, setup and tested by different size of structure. The first construction was located at Manzanares, Spain as shown in Figure 2.1. The construction was built with 0.00125m thickness of wall, 194.6m high of chimney, and 122m radius of collector in 1982 [4] . Follow by the next pilot plant that was built in Wuhai, China as shown in Figure 2.2 and other small-scale experimental setups have been tested and developed in many countries. Solar updraft tower power generation has been shown as successful technique for the future electricity generation applications by using only solar radiation [5]. This plant system has potential to develop in desert region as it is not depending on cooling system. Hence, these are advantages for any country that lacks water resources but has enough solar energy [6]. A single solar updraft tower with and a high updraft tower and a large glazed roof area can be constructed to produce 100–200 MW continuously 24 hours for 1 day, and the large nuclear power station can even be replaced by a small number of solar updraft towers [7]. To estimate the cost-effectiveness of the plant's power output, four good conditions such as cheap local construction materials, sufficient size of area, good climate conditions and labour force should be fulfilled [5]. Several research works have been done on the improvement of various parameters of solar updraft towers [8]. This literature review examines the geometry parameter on experimental and numerical studies that will give some optimization on the efficiency and performance of the system.

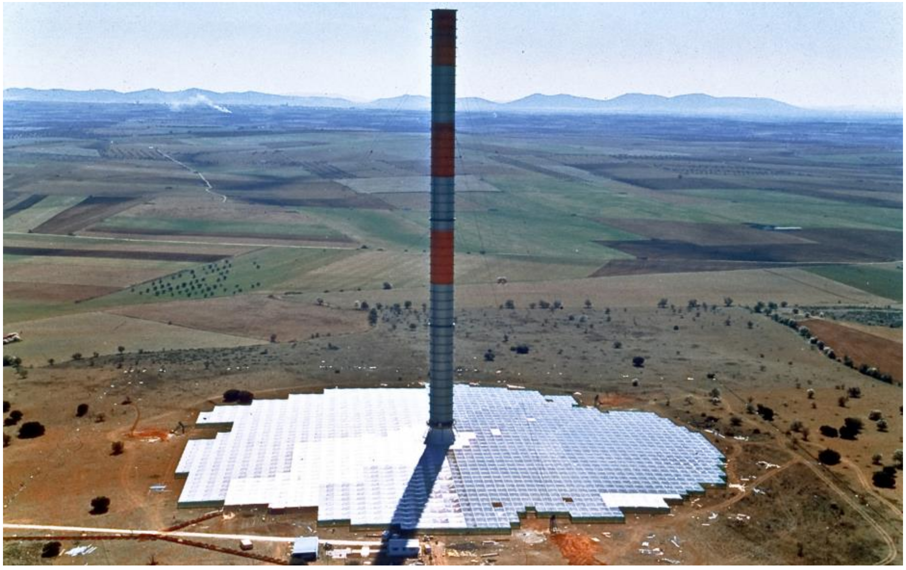

Figure 2.1: First pilot SUT prototype at Manzanares, Spain [4].

Figure 2.2: Wuhai pilot plant, China [5].

2.2 Solar energy

In the space, solar spectrum is more a black body's radiation and covers a wavelength range. However, the Earth's surface penetrates the chosen sunlight, which controlled by the atmosphere at a certain wavelength [9]. The surface of sun which has temperature of nearly 5800 K, generates a solar spectrum. [10]. As seen from space, the emitted spectrum of the sun is equivalent to the radiation emitted by a blackbody at that temperature. An idealized entity which is a perfect emitter and absorber of radiation is called as a blackbody. The dispersion and absorption of gaseous molecules such as oxygen, water vapor, nitrogen and aerosols as it passing through the earth's atmosphere attenuates by direct solar radiation. [11]. As a result, the solar spectrum after solar radiation has been transmitted to atmosphere was described as air-mass coefficient (AM). The AM coefficient is classified as the ratio of incident at a zenith angle (z), the solar radiation path length through the atmosphere (L) and the atmosphere thickness in the zenith direction (L_0) [12]:

$$\mathrm{AM} = \frac{L}{L0} = \frac{1}{cosz} \qquad (1)$$

There was no change in the spectrum as it passed through the vacuum of space, and this is called Air Mass 0 (AM0), this means the sunlight did not interact with any of the Earth's atmospheres. The direct radiation of the sun passes through the atmosphere vertically in the shortest possible path, known as Air Mass 1 (AM1). The spectrum produced by the sun at Air Mass 1 is often referred to as the radiation spectrum "Global Air Mass 1" (AM1G), which means "A single atmosphere". As the world's major solar installations and industrial centres that are located at mid-latitudes, such as Japan, Europe, China, United States, Northern India, Australia, and Southern Africa. A specified AM number was categorized at a zenith angle of z = 48.19°. which is called as Air Mass 1.5 (AM1.5). The AM number for mid-latitudes during the summer months is less than 1.5 while for higher figures it will occur during the morning and evening periods. Hence, AM1.5 can be useful description of the atmospheric thickness as an annual average for mid-latitudes. AM1.5 has been used for standardization purposes since the 1970s, as provided by ASTM G173-033 (Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and