UNIVERSITI TEKNOLOGI MARA

PARAMETRIC INVESTIGATION OF A GREEN TOWER USING SOLAR OVENS AS A HEAT COLLECTOR

ZAINOOR HAILMEE BIN SOLIHIN

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Mechanical Engineering)

Faculty of Mechanical Engineering

May 2019

ABSTRACT

The importance of understanding sustainable energy, especially in solar, has led to many research interests in developing new technology of renewable energy. Solar chimneys generally have very large size of solar collectors and high chimney height. Aside from the size, Solar Chimney is also known to have low efficiency. In order to be more feasible, Solar Chimney needs an improvement effort towards smaller collector and better efficiency. This will greatly attract many small and developing countries to invest in renewable energy compared to the current fossil fuel. Small in size and better efficiency produces are two major tasks that drive researchers around the world to study Solar Chimney. In terms of efficiency, most large solar collectors are in cylindrical shape. Thus, this study proposes the role of solar oven to be used as solar collector which has a rectangular shape build in smaller size and known as Green Towers. Major study showed that collector's diameter and chimney's height had the ratio of nearly 1:1. Nonetheless, the minimum collector diameter suitable for the same chimney height has not yet been determined. Therefore, the main purpose of this study is to determine the performance of the solar oven as a solar collector for Green Tower development. Solar oven is used as the solar collector in order to reduce energy loss, better efficiency and smaller in size. This report presents the numerical simulation and validation of the field experiment of the Green Tower. Various analyses were carried out in investigating the Green Tower performances and the result shows simulation model number 7 (CFD7) recorded the highest efficiency at 2.02% and experiment model is the lowest at 0.57%. The minimum size of solar collector was determined and optimum size of Green Tower was also proposed at a chimney height to collector area ratio of 2:1. In summary, using the rectangular shaped solar collector significantly reduces the energy loss for the Green Tower; thus, improves its efficiency and overall performance.

ACKNOWLEDGEMENT

In the name of Allah SWT, Most Gracious and Most Merciful.

Alhamdulillah, in the name of Allah SWT, all praises to Him for the strengths and His blessing in completing this thesis. Special appreciation goes to my supervisor, Professor Dr. Wirachman Wisnoe and to my co-supervisor Professor Madya Dr. Ramlan Zailani, for their continuous support, assistance and encouragement throughout the course of my PhD degree.

Not to forget, to my dedicated family especially my parents, Hj. Solihin Osman and Hajah Wakinam Md Esman; my beloved wife, Engku Nuzulhana Raja Omar; and my children, Nik Eleeza Fatini, Nik Zachquan Rashidin and Nik Zacharia Borhanudin, for their understanding towards my study and continuous support from my family members.

Last but not least, gratitude also goes to all my friends and colleagues who provided knowledge and experience to solve my study's complication. Thank you all.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Background of the Research

Solar Chimney is also known as solar updraft tower, where the technologies are considered and acknowledged by several researchers to generate electrical energy from solar energy. Since it is being acknowledged for its clean energy, it offers highly interesting opportunities to use pollution free resources of energy [1]. It is Solar Chimney that has a combination of solar air collector and central updraft tube to generate solar induced corrective flows which drive the turbines to generate electricity [2]. The first researcher who investigated the concept of Solar Chimney plant in 1903 was Isidaro Cabanyes, and he has published the idea in the La Energia Electrica magazine [1]. The first description being acknowledged after the article by Isidoro Cabanyes was written by German author, Hanns Günther, who described the design of Solar Chimney power plant in 1931. The article gave the researchers a new era to develop an alternative solution regarding renewable energy. In 1975, Robert E. Lucier came out with his new design and applied for a patent of Solar Chimney electric power generator.

The idea from Isidaro has opened many researcher's interest and the first prototype of the design was proposed by two German engineers, Jorg Schlaich and Rudolf Bergerman in 1976 [3]. The first ever acknowledged prototype was built in 1982, with a much smaller experimental model of a solar updraft tower being built in Manzanares, Ciudad Real, which was 150 km south of Madrid, Spain. The solar updraft tower power plant had a life time of approximately eight years of operation until the draft tower wire ropes were badly corroded due to rust and failed during a storm. The plant was shut down and decommissioned in 1989 [2]. In the year 1993, Hanns Gunther conceived the concept of the pilot plant operation and it was constructed until it was proven successful in Manzanares, Spain [4].

The concepts and operating principles of solar updraft power plant are constituted by two major factors; 1) the collector area that creates buoyancy phenomena, and from that the larger collector area will affect in greater volume of air