SOLAR-THERMOELECTRIC DEVICE OPTIMIZATION USING A SIMULTANEOUS TEG AND TEC CHARACTERIZATION

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

This thesis is dedicated to my friends, Tan Pei Yi, Cheok Yan Qi, Caroline Hon and Chua Song Guan who are always act as a constant source of support and encouragement during the challenges in my life. Also, to my friend Adern Chong and Tai Wai Yip, who are provide a lot of useful information so as the idea for me to complete the task. This work is also dedicated to my parents who have always loved me unselfishness, taught me to work and accompany me until today.

ABSTRACT

Thermoelectric is a bi-directional conversion between heat and electric. In other words, if there is a temperature difference, then there is a voltage created or vice versa. The objective of this project is to bring a two-design approaches (from temperature to electric and from electric to temperature) to develop two solar-thermoelectric devices. By doing so, the technique and importance of Solar-Thermoelectric Generator (STEG) and Thermoelectric Cooling (TEC) are better recognized by the world. There would be two final products at the end of the project, a solar-power source for STEG, and a portable refrigerator for TEC. Since the relationship between temperature gradient and voltage in thermoelectric is linear under condition that is not exceed the limitation of the TE module labelled, the way to improve the output power from STEG is studied and at the end of this project showed the mean improvement of 164.15%. On the other hand, the problem that TEC is failed operate for long period had been solved.

ABSTRAK

Thermoelectrik adalah penukaran bi-arah antara haba dan elektrik. Dalam erti kata lain, jika ada perbezaan suhu, maka voltan akan terhasil atau sebaliknya. Objektif projek ini adalah untuk membawa pendekatan dua reka-bentuk (dari suhu ke elektrik dan dari elektrik ke suhu) bagi membangunkan dua peranti solar-thermoelectrik. Dengan berbuat demikian, teknik dan kepentingan penjana Solar-Thermoelectrik Generator (STEG) dan penyejuk Thermoelectric Cooling (TEC) akan lebih diiktiraf oleh dunia. Dua produk akhir dihasilkan pada akhir projek, iaitu, sumber kuasa elektrik yang menukar tenaga haba dari solar kepada tenaga elektrik, dan satu peti sejuk mudah alih untuk TEC. Oleh kerana hubungan antara perbezaan suhu dan voltan dalam termoelektrik adalah linear dalam keadaan yang tidak melebihi had modul TE yang dilabelkan, cara meningkatkan kecekapan tenaga output dari STEG dikaji dan tesis ini menunjukan tenaga output meningkat sebanyak 164.15%. Masalah TEC yang tidak boleh beroperasi dalam tempoh yang panjang juga dapat diselesaikan.

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LIST OF SYMBOLS AND ABBREVIATIONS

For examples:

TE	:	Thermoelectric
STEG	:	Solar-Thermoelectric Generator
TEC	:	Thermoelectric Cooling
CSP	:	Concentrating Solar Power

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CHAPTER 1

INTRODUCTION

1.1 Background of the project

Thermoelectric is a bi-directional conversion between heat and electric. In other words, if there is a temperature difference, then there is a voltage created or vice versa. This phenomenon is discovered by Thomas Seebeck in 1800s [1] and this effect had been paid attention on it since most of the energy loss is in term of heat. In other words, thermoelectric can be used to convert the heat energy back to electric energy, which in term reduce the loss of energy. Basically, this phenomenon can be described in three effect. First, Seebeck effect states that the potential differences appear at the junction of dissimilar material when heated. [2] Second, The Peltier effect which is discovered by Jean Charles A. Peltier at 1834 and he found that the electrical current would produce heating or cooling at the junction of two dissimilar metals [3]. And finally, Thomson effect discovered by

William Thomson in 1851 states that the heat flow in a conductor with terminals held at different temperatures is depend on the current flow [4]. For this project, TEG is apply Seebeck effect to generate a voltage by applied a temperature difference on the both side of the TE module. Meanwhile, apply Peltier effect by supply a voltage to TE module in order to have temperature difference for cooling purpose. The voltage generated by STEG is known as a clean energy since the energy source is from solar heat, which result in conversion of solar heat energy to electric power source (or power supply). Besides, the TEC module allow human to have a portable refrigerator, air-coolent system, water cooling device easily since the power supply can be just batteries. However, there are some shortages for both TEG and TEC currently. For TEG, the efficiency to convert from temperature gradient to electric current is very low. Typically, 5% to 8% [5]. Besides, a relative constant heat source is needed for TEG leads to the slow technology progression, and this problem still can't be solved perfectly nowadays. On the other hand, TEC is facing some similar problem with TEG. That includes of the low efficiency of a TEC system, which is around only 6% [6]. Besides, the hot side of the TE module must be cool down to decrease the temperature at the cold side of the TE module and the TEC system can function properly. However, that means another power source is needed to cool the TE module and in turn of more energy consumption and loss.

1.2 Problem statement

Energy crisis, ozone depletion, and global warming have become a worse topic as the social development. And this energy crisis and environmental burden are becoming increasingly urgent and drawing enormous attention to solar-energy

utilization. Direct solar thermal power generation technologies become an attractive way to provide electric from solar heat. According to research, the amount of energy consumed by air conditioners, refrigerators, and water heaters is increasing rapidly, and occupies about 30% of the total power consumption. [7] Because of the global warming, the percentage of these power consuming will keep on increasing. On the other hand, Because of the rapid growth in world population and economy, the total world energy consumption is projected to increase by about 71% from 2003 to 2030 [8]. However, the realistic conversion efficiency of direct solar thermal power technology is still not very high, mainly due to material restriction and inconvenient design. And there is no conventional intermediate mechanical conversion process in direct thermal power conversion, which therefore guarantees the enormous potential of thermal power efficiency when compared with traditional indirect solar thermal power technology [8]. On the other hand, most of the energy wastages are in the form of heat. [9] This wasted heat is reducing the overall efficiency of the system and damage the component in the system at the same time. Therefore, thermoelectric is a good way to deal with this wasted energy. By converting the waste heat energy back to electric energy and stored the energy for future works or feedback to the input of the system, the efficiency of the system is then improved. Also, as global temperature keeps on arising, the requirement of the refrigerator and air-conditioner is increase rapidly. However, the above devices are releasing harmful gases to surrounding likes CFC, HFC, CO, CO2, Cl and some other greenhouse gases in order to have their function well. And those gases are the major reason of the global warming that deplete ozone layer. [10] Hence, TEC is a better and environment friendly option to human since this technology is not releasing any gases. So, a deeper study on solar TE

technology is needed to develop a steadier TE device and to deal with the energy wastage and global warming.

1.3 Objective

i. To design and develop a solar-thermoelectric generator and cooling device

ii. To verify the performance of a solar-thermoelectric generator and cooling device

1.4 Scope project

The project consists of two major part, a STEG application and a TEC application are designed and developed. For the STEG, it was using magnifying glass to focus the sunlight, and the sunlight heat is trapped by using an iron-plate to maintain high temperature of the hot side of the TE module, which is modeled TEC1-12706. The 4 modules were connected in series to produce a larger voltage and the output is regulated to have a stable output voltage and the modules are placed on a heat sink to lower the temperature at the other side. The final set-up will be placed in an external dimension of 21.5cm x 14.1cm x 15.5cm polystyrene. While the internal dimension is 15.5cm x 8.1cm x 12.5cm. On the other hand, the TEC application would be made by using 1 TE module with a heat sink and a brushless DC fan DC 12V stick together, with an extra 12V, 1A supply to the TE module. The module is then placed in a square box made by polystyrene with the cold side face inside the box and lower temperature inside the box so that it can be used as a freezer. The applications would have their own shortage for each. For example, solar heat is applied for STEG to produce the required voltage. Therefore, STEG couldn't function during rainy day or night. On the other hand, the rate of heat transfer at the hot side of TE module in TEC must be fast enough

so that the temperature at the cold side can be low enough to keep foods or drinks cold. In other words, there would be a large electric consumption for TEC in order to work in a higher efficiency. Also, the temperature inside is lower due to thermal equilibrium, which is a slow process. Therefore, it takes time to cool down the temperature inside the box.

1.5 Thesis Outline

This thesis is organized into 5 major chapters to cover the research work that is related to Solar-thermoelectric device optimization. The outline of thesis is described as below:

i. Chapter 1- Introduction

In this chapter is briefly explain what the project is, the objective and the scope of the project together with the problem statement.

ii. Chapter 2 -Literature review

This chapter present the literature review of TE module, TEG and TEC

iii. Chapter 3- methodology

This chapter is the research methodology of obtaining the required data and build up the final product. Also, the materials and the tools needed to complete the project and the flow chart of this project is shown.

iv. Chapter 4- Result and Discussion

Chapter 4 is mainly focus on the analysis result and discussion on the result obtained from chapter 3. The relationship between the weather (temperature form the sunlight) and the voltage generated by TE module was studied. Also, the relationship between the input voltage and the temperature gradient generated had been investigated.

v. Chapter 5- Conclusion

For chapter 5, an overall conclusion for the research done, the availability of the final product, and the future works for Thermoelectric will be stated. The improvement can be in tern of reducing the size or improve the efficiency and functionaity.