Faculty of Engineering

THERMOELECTRIC ENERGY HARVESTING FOR FOREST FIRE DETECTION USING GLOBAL POSITIONING SYSTEM (GPS)

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Bachelor of Engineering (Hons) in Electronics (Computer)

2016/2017

UNIVERSITI MALAYSIA SARAWAK

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Final Year Project Report ☑

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THERMOELECTRIC ENERGY HARVESTING FOR FOREST FIRE DETECTION USING GLOBAL POSITIONING SYSTEM (GPS)

PANG SZE KOI

A dissertation submitted in partial fulfilment

of the requirements for the degree of

Bachelor of Engineering (Hons) in Electronics (Computer)

Faculty of Engineering

Universiti Malaysia Sarawak

2016/2017

Dedicated to my beloved family and friends.

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest appreciation and gratitude to my supervisor, Dr. Lakshmanan A/L Gurusamy who had been providing me brilliant guidance and expressing generous attitude throughout the Final Year Project. I feel very thankful to my supervisor for patiently taking me through this very tough moment during my educational research. His tremendous support and dedication has eventually made me worked towards success of this study.

Meanwhile, I also owe a lot of thanks to some of my course mates as well as seniors whereby their names are listed in the following as promised, Goh Ju Han, Joselyn Jok, Tee Tian Yun and Lee Kin Choong. They had suggested me viable suggestions and somehow a light bulb went on my head. Besides, UNIMAS technical staffs who had been very cooperative in term of providing assistance on my research and their responsibilities of taking care of the laboratories are literally worth for my respect and more importantly, thousands of thanks.

Most of all, it should also not be forgotten to thank my parents and siblings. The countless time my parents spent in order to motivate and encourage me to keep my work going will always be remembered vividly in my mind. Their love and care can never be replaced and will always be in the first place of my entire life. Besides, the past experience shared by my brothers was extremely helpful which without I might not be able to complete my research on schedule.

ABSTRACT

Forest fire has always been a major concern which cannot be solved for centuries. It occurs very frequently and its disastrous impacts affect every living organism worldwide. Forest fire is prevalent or prone in continentals such as North America, South America and South East Asia where deep forests can be found; therefore, regular monitoring is deemed necessary. However, big forests often give big troubles to human when it comes to fire monitoring. Moreover, forests such as Indonesia peatland swamp forests limit our monitoring completely due to its gigantic size and density. This project proposes a novel idea of utilizing thermoelectric energy harvesting technique to assist an Arduino based Global Positioning System (GPS) module to monitor forest fire prone area. The combination of thermoelectric energy harvesting and GPS to monitor deep forest is a totally new approach and bold attempt. The main aim of the research is to test the efficiency as well as reliability of the GPS prototype that will be fabricated as well as minimize the effect of the ever existing forest fire issue by detecting the fire as early as possible and send feedback to the control center to take further initiatives. In the operation point of view, the amount of energy harvested through the thermoelectric energy harvesting technique depends on the temperature gradient created. Then, the energy generated from the system would be used to charge the built-in rechargeable battery which operates the Arduino based GPS module. In the end of the operation, the GPS prototype would transmit data through GPS to the control center or end user through messages as alert notifications. The final result in this research proved that the GPS prototype managed to identify the location of the monitoring area accurately although it was shaded with trees while recharging itself as an energy-sustainable complete system.

ABSTRAK

Kebakaran hutan sering menjadi kebimbangan utama dan ia tidak dapat diselesaikan selama berabad-abad. Ia berlaku sangat kerap dan kesan buruk yang memberi kesan kepada setiap organisma hidup di seluruh dunia. kebakaran hutan adalah lazim atau terdedah di Continentals seperti Amerika Utara, Amerika Selatan dan Asia Tenggara di mana hutan yang mendalam boleh didapati; Oleh itu, pemantauan berkala difikirkan perlu. Walaubagaimanapun, hutan besar sering memberi masalah besar kepada manusia apabila ia datang kepada api pemantauan. Selain itu, hutan seperti Indonesia hutan tanah gambut paya menghadkan pemantauan kami sepenuhnya kerana saiz gergasi dan ketumpatan. Projek ini mencadangkan idea novel menggunakan teknik termoelektrik penuaian tenaga untuk membantu modul Sistem Kedudukan Global Arduino berdasarkan (GPS) untuk memantau kebakaran hutan kawasan terdedah. Gabungan penuaian tenaga termoelektrik dan GPS untuk memantau hutan yang mendalam adalah satu pendekatan yang sama sekali baru dan percubaan yang berani. Tujuan utama kajian ini adalah untuk menguji kecekapan serta kebolehpercayaan prototaip GPS yang akan dibina serta meminimumkan kesan isu kebakaran hutan yang sentiasa sedia ada dengan mengesan api seawal mungkin dan menghantar maklum balas kepada kawalan pusat untuk mengambil inisiatif seterusnya. Dari segi operasi, jumlah tenaga dituai melalui teknik penuaian tenaga termoelektrik bergantung kepada kecerunan suhu yang dicipta. Kemudian, tenaga yang dijana daripada sistem itu akan digunakan untuk mengecas bateri terbina dalam boleh dicas semula yang beroperasi modul GPS Arduino berasaskan. Di akhir operasi, prototaip GPS akan menghantar data melalui GPS ke pusat kawalan atau pengguna akhir melalui mesej sebagai pemberitahuan makluman. Keputusan akhir dalam kajian ini membuktikan bahawa prototaip GPS berjaya mengenal pasti lokasi kawasan pemantauan dengan tepat walaupun ia teduh dengan pokok manakala ia mengecas dirinya sebagai satu sistem yang lengkap dan berdikari.

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LIST OF ABBREVIATIONS

A

AC	Alternating Current
AC-DC	Alternating Current to Direct Current

B

BPSK	Binary Phase Shift Keying
BSS	Base Station System

C

C/A	Coarse/Acquisition
CDMA	Code Division Multiple Access
CTS	Charge Transfer Switch
CW	Cockcroft-Walton

D

3-D	3-Dimensional
DC	Direct Current
DC-DC	Direct Current to Direct Current

E

ETDYN	European Thermodynamics
EH1D	LTC3108 Energy Harvesting Breakout Board

G

GA	Ground Antenna
GLONASS	Globaluaya Navigatsionnaya Sputnikovaya Sistema or Global Navigation Satellite System
GMSC	Gateway Mobile Switching Center

GPS	Global Positioning System
GSM	Global System for Mobile Communication

H

H_2SO_4	Sulphuric Acid

I

IC	Integrated Circuit
IoT	Internet of Things

L

L	Legacy
Li-ion	Lithium ion

M

MCS	Master Control Stations
MS	Monitor Stations
MSC	Mobile Switching Center (MSC)

N

NAVSTAR	Navigation System with Time and Ranging
Ni-Cad	Nickel-Cadmium
Ni-Cd	Nickel-Cadmium
Ni-Fe	Nickel-Iron
Ni-H_2	Nickel-Hydrogen
Ni-MH	Nickel-Metal Hydride
Ni-Zn	Nickel-Zinc

P

Pb	Lead
PRN	Pseudorandom Noise
PM	Particulate Matter

PV	Photovoltaic

R

RMS	Root Mean Square

S

SV	Space Vehicle
SME	Short Message Entity
SMS	Short Message Service
SMSC	Short Message Service Center

T

TE	Thermoelectric
TEH	Thermoelectric Energy Harvester
TEG	Thermoelectric Generator

U

URA	User Range Accuracy
URE	User Range Error

W

WSNs	Wireless Sensor Networks

CHAPTER 1

INTRODUCTION

1.1 Background Study

Natural disasters such as forest fires are often hardly predictable and uncontrollable although several approaches have been tried such as Authorities Fire Suppression and Detection Techniques, Satellite-Based Systems, Optical Sensor and Digital Camera, and Wireless Sensor Network (WSN) by the top researchers around the world [1]. Unfortunately, the final outcome of the approaches did not prove to be effective; yet, sometimes in vain.

Forest fire has become more active in the recent decades due to the impacts of the El-Nino phenomenon. According to World Bank, El-Nino has turned the world's weather conditions to become extreme in most of the affected regions and Indonesia is one of the well-known examples [2]. It has increased the ocean temperatures in the Southern Ocean, delayed monsoon rain which then led to a drought that affected the whole country and caused the harvesting of crops to drop significantly. Under these extreme conditions, it eases the outbreak of wildfire and forest fire.

Studies show that up to 45% of terrestrial carbon is stored in the forest around the world [3, 4, 5]. However, there are up to hectares of forests are on fire and destroyed every year [1]. The issue can never be solved and is sometimes even becoming more serious due to the inefficient solutions and approaches implemented [1]. The continuous burning of forest fire which is totally out of control already caused great alarm and proven to bring adverse effect to everybody [6]. Undeniably, forest fire afflicts tropical countries or regions such as Malaysia, Indonesia (refer to Figure 1.1), Africa, Mexico and Canada [69, 70, 71]. These countries are forced to spend extra money to take precautions and put off the forest fire endlessly every year. In short, it is totally a huge loss to the countries in term of revenue.

Figure 1.1: Indonesia forest fire at Ogan Komering Ilir in South Sumatra, Indonesia [4]

Therefore, regular monitoring is required and crucial in order to combat the issue. However, the human is not reliable when it comes to regular monitoring. This is because a human cannot monitor the forest fire prone area persistently for whole day long without having any rest. Furthermore, it is barely possible to send people to monitor the deep forest areas such as Sumatra forest and Kalimantan peatland swamp rainforest due to its enormously large of size, risk and also the complex forest landscape. It turns out that a regular monitoring can only be done by using robots or autonomous wireless monitoring system. Nevertheless, the idea of sending robots into the forest was eventually excluded as robots are costly and the current technology of robot does not perform stably in term of autonomous monitoring [7, 24].

Therefore, autonomous wireless monitoring system has been a subject of intensive research to address the forest fire problem. The autonomous system is expected to perform regular monitoring with high consistency in order to detect forest fire when it is still under control. A regular monitoring system requires a constant power supply and therefore a built-in battery is installed. However, battery issue arises soon after the system was proposed. A built-in battery cannot provide long-lasting power supply to the system as it has a limited amount of energy stored. Thus, thermoelectric energy harvesting has been proposed, which is an innovative approach to provide sufficient power to the system for long term operation.

Thermoelectric energy harvesting technique becomes more popular in powering remote applications, wearable devices and wireless sensor network (WSN) [9, 10 11]. For example, scientific researchers integrated the thermoelectric energy harvesting technique into a wearable device that provides parts of the electrical energy [11]. This technique helps to extend the battery life by a constant charging through the integrated thermoelectric energy harvester (TEH). Hence, this would significantly reduce the concerns of the low battery life and allow a

much longer lasting performance of the system while bringing the devices along for outdoor activities.

On the other hand, when technology gets more advanced, some of the electronic devices such as wireless monitoring system have already been made portable and small [12]. These portable devices are widely seen in the facets of medical care, wireless communication and Internet of Things (IoT). The prompt technology development allows thermoelectric energy harvesting to be applied widely in small electronic devices gradually. For an instance, researchers in the United States has successfully developed a system which includes a thermoelectric energy generator (TEG) and a wireless communication microcontroller to detect a nuclear power plant [13]. With this system, the occurrence of big explosions and unpredictable fires in big factories can be reduced to a minimum.

Besides the size of the device or system, the overall efficiency of the thermoelectric energy harvesting also gradually improves as scientists struggle to increase the Seebeck coefficient and overall conversion efficiency from the first generation until the third generation [14]. The type of thermoelectric material used always changes according to the development of the thermoelectric energy harvesting performance which cause the overall efficiency to keep increasing even until 2014 [14]. Therefore, the future potential of thermoelectric harvesting should not be neglected.

It is also observed that researchers successfully integrated the thermoelectric energy harvesting techniques into the wireless sensor networks (WSNs) [13]. It is a very similar application to the idea of this dissertation; however, its ending communication system is entirely different. There are also many similar applications and publications being published and exhibited in international conferences, but the combination of thermoelectric harvesting and Global Positioning System (GPS) is considered pioneering. This dissertation presents a novel idea and workable solution to combat the ever existing forest fire problems, particularly in the semi-cultivated forest regions.

1.2 Types of Energy Harvesting Techniques

Energy harvesting is a process of scavenging energy from external sources and converts the energy to electricity which is capable of driving numerous electronic devices. The external sources could be a temperature difference, a vibration, a pressure, a solar energy, a thermal radiation or a temperature gradient. Different sources of energy require unique technique to convert the energy for better usage. Some of the techniques include thermoelectric energy harvesting, piezoelectric energy harvesting, photovoltaic energy harvesting, magnetic