DESIGN AND DEVELOPMENT OF MINIATURE ELECTROMAGNETIC MICRO-GENERATOR FOR HARVESTING ENERGY FROM VIBRATION

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To my dearest parents and my beloved friends

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ABSTRACT

Nowadays, green energy is widely use in our life and it becomes popular since it is pollution free, energy conserve and cost saving. There are various types of green energy which we can harvest from the environment such as the solar energy, hydro energy, wind energy and vibration energy. One of the common energy we found in our surrounding is vibration energy. Moving cars, refrigerator, washing machine and industrial machine are the sources of the vibration energy. The vibration energy can be harvested and converted into useful electrical energy which can use to power up small electrical devices such as wireless sensor node.

In this project, a miniature electromagnetic micro-generator has been designed and developed to harvest the free vibration energy from the vibration source. The generator works purely based on electromagnetic theory which use the magnetic induction to generate electricity.

The structure of the generator consists of a cantilever, Neodymium magnets, magnetic wire coil and a rectifier circuit. The size of the generator is small with a volume approximately 24cm^3 which made it capable to be deployed in some inaccessible place. Besides, the generator can be tuned to fit with the vibration source by adjusting the length of the cantilever. It is capable to produce a maximum power of 0.1Watt with a 2.1G vibration source at its resonant frequency of 49.1Hz.

ABSTRAK

Pada masa kini, tenaga hijau diguna secara meluas dalam kehidupan kita dan ia menjadi popular kerana ia tidak mencemarkan persekitaran, jimat cost dan dapat dipulihkan. Terdapat pelbagai jenis tenaga hijau yang kita boleh dapat daripada alam sekitar seperti tenaga suria, tenaga hidro, tenaga angin dan tenaga getaran. Salah satu tenaga yang biasa kita dapati di sekitar kita adalah tenaga getaran. Kereta yang berjalan, peti sejuk, mesin basuh dan mesin dalam industri merupakan sumber tenaga getaran. Tenaga getaran dapat dikumpul dan ditransformakan kepada tenaga elektrik yang berguna untuk meghidupkan alat-alat elektronik yang kecil seperti sensor tanpa wayar.

Dalam projek ini, sebuah mesin penjana kecil elektromagnet telah direka dan dicipta untuk menjana tenaga elektrik daripada sumber tenaga getaran dalam alam sekitar. Mesin penjana itu berfungsi berdasarkan teori elektromagnetik yang menggunakan induksi magnet untuk menjana tenaga elektrik.

Struktur mesin penjana terdiri daripada julur, magnet Neodymium, gegelung wayar magnet dan litar penerus. Mesin penjana itu bersaiz kecil dengan isi padu lebih kurang 24cm^3, oleh itu ia dapat dipasang dan diguna dalam tempat atau ruang yang kecil. Selain itu, ia dapat dilaraskan supaya muat dengan sumber getaran dengan mengubah panjang julur ia. Ia mampu menghasilkan kuasa maksimum

sebanyak 0.1Watt dengan sumber getaran 2.1G pada frekuensi salunan sebanyak 49.1Hz.

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Many research activities has been carried out in the area of micro-energy harvesting which aimed to find an alternative solutions to batteries, which required charging and replacement, as power supply of low power devices (Bouendeu et al. 2009). The main idea of micro-energy harvesting is to obtain free environment energy and transform the energy into useful electrical energy which can be used to power micro-electronic devices like wireless sensor nodes. Hence, energy harvesting system is invented to replace the conventional chemical batteries that lead to costly replacement fees in a huge wireless sensor network and cause chemical pollution problems to the environment. The demand for energy harvesting system has been growing rapidly due to the wide application of wireless sensor nodes and mobile electronic devices (Yang et al. 2012).

Free environment energy can be found in the form of solar, thermal, chemical or mechanical vibration. Inferior to solar energy, mechanical energy from the ambient vibration source or known as vibration energy has been one of the major power sources for energy harvesting system. Vibration energy is a green energy which can be harvested from any moving mechanism of our surrounding including biological and mechanical movement. There are various vibration sources in our surrounding such as common household goods (refrigerator, washing machines and

air conditioners), industrial plant equipment, machines, moving vehicles such as automobiles and structures such as buildings and bridges. The energy harvested can be transform into useful electrical energy to power up small electronic devices such as the sensor node. Wireless sensor node which is small in size, low power consumption and its deployment in some inaccessible location has made the vibration energy as an ideal and inexhaustible power source.

The vibration energy harvested is transform into electrical energy using electromagnetic, electrostatic and piezoelectric transduction mechanisms. The amount of energy generated by these approaches fundamentally depends upon the quantity and form of the kinetic energy available in the application environment and the efficiency of the generator as well as the power conversion electronics (Beeby et al. 2007).

This project aimed to design and develop a miniature electromagnetic micro-generator for harvesting energy from ambient vibration source. The micro-generator designed is small in size and works based on electromagnetic induction to transform kinetic energy harvested from ambient vibration source into useful electrical energy. Its basic structure consists of a cantilever, magnets, magnetic coils and an electrical circuit. The power generated was measured tested to power up small electronics.

1.2 Motivation

Battery is a convenient power source for small electronic devices in our daily life. However, the conventional use of chemical batteries in electronics such as wireless sensor nodes in a large wireless network could be a problem for its user. The batteries apply in the wireless sensor nodes network need to be replaced or recharged from time to time to ensure a constant power supply. Hence, the user needs to spend a costly replacement fees when the batteries of the sensors nodes are drained. Besides, the replaced batteries will eventually become a chemical waste that causes environment pollution.

The application of vibration energy harvester will serve as an alternative power source which can eliminates the costly replacement fees of batteries in large wireless sensor network and reduces the waste of chemical batteries.

1.3 Problem Statement

Conventional electromagnetic generator structure is big in size because it consists of large magnets and large number of wire coils in order to produce sufficient energy for the electrical device. Hence, it is inconvenient for the electromagnetic generator to integrate with wireless sensor nodes which designed to be deployed in a large scale of area and some inaccessible place for monitoring purpose.

Besides, conventional electromagnetic generator produces a low output voltage which is impossible to be rectified by the diodes. The output current must be rectified into DC as electrical supply for electronic device. Hence, the output voltage of the electromagnetic generator must be higher than 0.7V, which is the operating voltage of a diode.

1.4 Objectives

The objective of this project is to design and develop a miniature electromagnetic micro-generator which operates at its resonant frequency to function with maximum efficiency. The size of the electromagnetic generator is aimed to design in a 30- 130cm^3 range to be integrated with the small electronic devices such as wireless sensor node. Besides, the project aimed to determine the maximum power generated by the micro-generator when it is tuned to work at its resonant frequency resonant frequency. Lastly, a rectifier circuit is developed to rectify the output voltage for the power of wireless sensor node.

1.5 Significant of project

The electromagnetic generator proposed in this project has a high sustainability as it does not need to be replaced like conventional batteries. After the electromagnetic generator is deployed, it can be left to work on its own as long as there is any moving mechanism which served as the power source.

Besides, the miniature size of the electromagnetic generator made it possible to be deployed in some inaccessible place for a long term application. This feature makes the electromagnetic generator suitable to integrate with wireless sensor nodes in a large wireless sensor network for surrounding condition monitoring purposes.

Last but not least, the electromagnetic generator may gain a high marketability since it is a green technology which saves cost and energy. Free vibrational kinetic energy can be harvested from the surrounding to be used for powering small electronic devices instead of using chemical batteries which may cause pollution and require scheduled replacement.

1.6 Scope

The electromagnetic micro-generator is work based on the oscillation of a cantilever equipped with four Neodymium magnets from Bunting Magnetics Europe Ltd work and a magnetic coil winded using magnetic wires from Magnetic Sensor Systems Ltd. The working principle of the micro-generator is solely depended on electromagnetic theory.

The physical volume of the micro-generator is approximately $24cm^3$. The micro-generator has a vibrating frequencies range of 5Hz- 150Hz and a vibrating level less than $50ms^{-2}$. It can only work efficiently with a limited bandwidth near the resonant frequency of the vibration source apply and capable of generate an output power of 0.1 to 5 milliWatts.

1.7 Thesis outline

Project Introduction provides a brief overview of this project that helps reader to visualize and understand the aim of the project. Motivation and significant of this project is discussed to explain the reason of why this project is proposed and its advantages. Scope is then outlined to set the specifications and limitation of the project proposed.

The Literature Review section presents some model of energy harvesters and tuning methods used in previous researches. It shows the relation between this project and those tasks done by other researchers.

Research Methodology part presents the overall process flow of this project includes the design of the micro-generator proposed, construction of experimental model, experiment test and optimising, as well as method of data collecting and analysing.

Results and Discussion provides the reader with all the data obtained and achievement of the research. The findings of this project are presented with the help of tables, figures and graphs. This section also used to define the achievement of the objectives set in the beginning of this research.

Lastly, the Conclusion and Recommendation section summarises the results obtained after this research and recommends some direction for the future research of energy harvesting system. Finally, it will discuss the knowledge obtained from this research and contribution of this project to the university.

CHAPTER 2

LITERATURE REVIEW

This chapter presents some projects related to energy harvesting system done by other researchers. It consists of various type of energy harvesting systems and tuning techniques developed to harvest vibration energy from the surrounding. Furthermore, literature review on rectifier circuit is also included in this section.

2.1 Types of vibration energy harvester

There are several types of energy harvester which harvest kinetic energy from surrounding vibration mechanism to generate useful electrical energy for small electronics use. The vibrational energy harvester can be differentiated into 3 main categories which are electromagnetic, piezoelectric, the fusion of both categories (hybrid) and magneto electric.

2.1.1 Electromagnetic based vibration energy harvester

Gherca and Olaru designed a vibration energy harvester that worked on ambient vibration by the mean of electromagnetic induction (Ă & Olaru 2011). The harvesting generator works at low frequencies which close to ambient vibration to

generate electrical energy. However, it can also be adapted to work at high values of frequency.

Figure 2.1 shows the cross sectional area view of vibration energy harvester designed based on the electromagnetic induction theory. The basic operating principle of the system is a moving magnetic component inside a coil which capable to generate electricity when the magnetic component sliding across the coil. The mobile magnetic component is a rare earth permanent magnet, NdFeB, which is high in energy density and good in sustainability. The housing that held the magnet in place is winded with 2 windings of coil connected in phase opposition which use to deliver the electricity generated when magnetic induction occurred. The magnetic component is held "floating" by 2 fixed magnets with same pole oriented to the mobile magnetic component, located at the top and lower covers respectively.

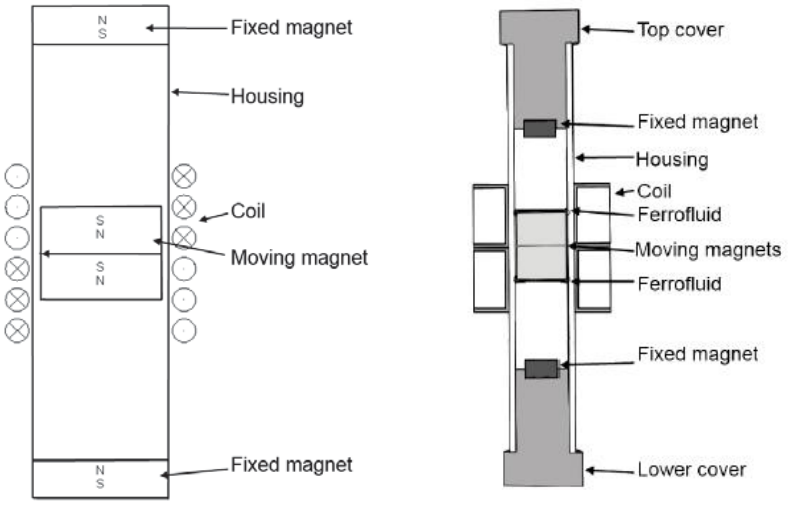

Figure 2.1: Vibration energy harvester designed by Gherca and Olaru. (Ă & Olaru 2011)

Ferro fluids are used as a lubricating agent attached to the permanent magnet. The Ferro fluids are a dispersion of magnetic particles (~10nm) in liquid base with approximately of 1023 particles per cubic meter. The Ferro fluid possesses the common properties of liquids as well as magnetic material.