MODELING AND SIMULATION OF RESPIRATORY EFFORT IN ENERGY HARVESTING USING MATLAB

by

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DECLARATION OF DISSERTATION

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LIST OF ABBREVIATIONS

AC	Alternating Current
BPM	Beats Per Minute
DC	Direct Current
MPPT	Maximum Power Point Tracker
MMV	Magnetically Induced Membrane Vibration
PV	Photovoltaic
TV	Television

Pemodelan dan Simulasi Usaha Pernafasan dalam Penuaian Tenaga

ABSTRAK

Penuaian tenaga daripada kuasa manusia dikaji untuk menjana tenaga kuasa rendah dan membolehkan peranti kuasa elektrik rendah beroperasi tanpa bergantung sepenuhnya kepada sumber DC. Usaha pernafasan dipilih sebagai penuaian tenaga bagi membuktikan keupayaan usaha pernafasan manusia dalam menghasilkan tenaga yang dapat digunakan untuk menggerakkan alat elektrik berkuasa rendah. Selain itu, tenaga daripada tubuh manusia boleh dijana selama 24 jam sehari tanpa had walaupun semasa tidur. Kuasa yang dijana dapat dihasilkan dengan adanya penjana elektromagnet yang dipakaikan di dada manusia. Hal ini kerana penjana yang digunakan akan beroperasi apabila terdapat gerakan dinding dada semasa proses penyedutan dan pembuangan. Sistem usaha pernafasan dimodelkan dan disimulasikan menggunakan perisian Matlab/Simulink. Beberapa situasi pernafasan diambilkira untuk mengkaji pengeluaran yang berbeza dari sistem ini. Daripada hasil yang diperolehi sepanjang simulasi, dengan ini dapat dibuktikan bahawa sistem usaha pernafasan manusia boleh menghasilkan tenaga melalui teknik penuaian. Sebagai contoh, sebanyak 6.17 mW kuasa pengeluaran telah dihasilkan daripada kaedah penuaian tenaga oleh individu dewasa. Berdasarkan keputusannya, daya pengeluaran akan meningkat apabila kadar pernafasan turut meningkat.

Modeling and Simulation of Respiratory Effort in Energy Harvesting

ABSTRACT

Energy harvesting from human power is investigated without being fully dependent to the DC sources. Respiratory effort is chosen as an energy harvester in order to prove the capability of human respiratory effort in producing the energy which can be used as the other alternative in powering low power electrical devices. Besides, the energy from human body can be generated 24 hours daily without having any limitation as the human is continually breathing even during sleep. The generated power carried out as the electromagnetic generator is worn on the human chest because the generator can be operated when there is a motion of the chest wall during the inhalation and exhalation processes. The respiratory effort is modeled and simulated using Matlab/Simulink software. A few conditions of breathing are being considered in order to examine different output power from the system. From the result obtained throughout the simulation, it can be proven that the human respiratory effort can produce energy through harvesting technique. The energy harvesting method produced 6.17 mW of the output power from an adult. Moreover, the output power increases as the breathing rate increases.

CHAPTER 1: INTRODUCTION

1.1 Overview of the Project

In line with the current development nowadays, the demand of energy from consumer is increasing in order to continue the daily life. This necessity has resulted in the evolution of energy harvesting from renewable sources, which is the most popular energy sources as it is generated from natural phenomenon considered as free energy. Many kinds of sources have been discovered before, but generating low power energy using human power is not too popular among renewable researchers. Renewable energy from human power can produce low electrical energy power throughout the body motion, such as walking, respiration, or any other physical motion related. Likewise, human energy harvesting is the best method of powering personal electronic devices as the source is continuously produced without any restriction (E. Shahhaidar, 2015).

A few harvesters have been investigated by taking advantages from various human body activities and transduction mechanism in generating electricity (U Goreke, 2015). Besides that, manipulating human motion as the energy sources in producing energy power perhaps can help the society from using battery to a better environmental friendly solution. Therefore, it can cut off the cost and provide the most effective way, especially in powering up low power devices.

Fundamentally, this project is a conversion of kinetic energy of the body motion of the electrical energy based on the movement of the chest wall through the breathing process

in producing low electrical power energy. Electromagnetic generator is being focused on this project because of its function as a respiratory effort energy harvester. Matlab/Simulink software is used in order to replicate the respiratory effort activity of constructing the schematic diagram using electrical and mechanical Simulink toolboxes.

1.2 Problem Statement

The development of electrical devices nowadays can lead to the increasing waste disposal from the batteries used in electrical devices. In order to overcome batteries disposal problem, energy harvesting is the best way to reduce chemical pollution towards environment as chemical substances need a longer time to fully dispose. Thus, energy harvesting can help society in generating electrical energy to the electrical devices without using any batteries and can immediately cut off expenses from replacing a new battery and also preventing the environment from the contamination.

1.3 Project Objectives

The objectives of this project are as follows:

1. To model and design the human respiratory effort in energy harvesting using an electromagnetic generator using Matlab Simulink software.

2. To verify the capability of respiratory effort in harvesting low power energy.

3. To compare and evaluate the produced output for different conditions of breathing.

The first objective of this project is to model and design the human respiratory effort in energy harvesting using an electromagnetic generator using Matlab Simulink software. The human respiratory effort using an electromagnetic generator will be designed using a Simulink package with Simscape toolbox and the simulation is run in order to get the result of low output power.

The second objective is to verify the capability of respiratory effort in harvesting low power energy. In energy harvesting, there are a lot of sources that can be used in harvesting, such as mechanical energy, thermal energy, light energy, and also electromagnetic energy. In this project, the human body is being used as the energy sources in producing output power. Theoretically, the human body is a combination of mechanical and thermal energies that are naturally generated by bio-organisms or through actions like walking or sitting ("Energy Harvesting Forum," 2012).

The third objective is to compare and evaluate the produced energy in different conditions of breathing and also different conditions of a person. The output power from the simulation obtained is compared and further discussed in the next chapter.

1.4 Scopes of the Project

The scopes of the project are limited to the following aspects: for example, the Matlab/Simulink software. The replication of human respiratory system is done using the Matlab/Simulink software. Basically, this project only focuses on software simulation. Therefore, in order to prove and verify the capability of respiratory effort in energy harvesting, the schematic diagram is designed and simulated using the Matlab/Simulink software. It is the best option when the system gets involved with electrical and mechanical processes in replicating the respiratory effort activity.

Simscape Toolbox is fully used in constructing the overall system starting from the detecting input part until the conversion part. All the related Simulink blocks along the parameter in this toolbox is used to generate the overall system in order to achieve the objectives. Finally, the results and analysis are carried out on the output power obtained from different breathing conditions.

1.5 Report Outline

The report consists of five main chapters altogether. Every chapter is discussed clearly in terms of the concept, mechanism, and the outcome of the project. Chapter 1 briefly discusses the overview of the project, problem statement, objectives of the project to be done, and scopes of the project where the overall idea of this project is explained while the literature review, which is focusing on energy harvesting especially in human motion or respiratory

activity related with the theories is briefly discussed in Chapter 2. In this chapter also, the observation based on past articles and journals that have been studied will be included. Chapter 3 is about the methodology of this project; thus, the flowchart and also the model of human respiratory activity along with the simulation are included. The results obtained from the simulation that have been done are discussed in detail in Chapter 4. Lastly, in Chapter 5, the overall project that has been made will be concluded and then briefly explained in detail throughout this chapter, including the suggestions in modification of this project for future works.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The aim of this project is to model and design the human respiratory effort in energy harvesting using an electromagnetic generator in Matlab/Simulink software. In this chapter, all the theories related to the project will be discussed in detail, including the concept of respiratory system, especially the respiratory effort activity. This system will be replicated in order to verify the effort of human motion as an energy harvester and also the function of electromagnetic generator in detecting the motion of the chest during the breathing process. Usually, research is made based on the problem that has occurred around the society. Hence, from the problem statement as listed in the previous chapter, all the theories along with the related concept need to be studied in detail in order to make sure that the problem is completely solved. The purpose of the theoretical studies is due to its importance during the analysis to make sure that the result obtained from the simulation is relevant to the theory given. As the production of the project is not new, the analytical data obtained needs be compared with the analysis of past research in order to make an enhancement in the next project.

2.2 Respiratory Effort

The respiratory system is a series of organs that is responsible to supply oxygen towards the body and also works in expelling the carbon dioxide from the human body or in a simpler meaning, the respiratory system is a system that allows the human breathing. There are two processes in breathing, which are inspiration and expiration while three important parts in respiratory system are known as airway, the muscles of respiration, and the lungs. A breath comprises one inhalation and one exhalation and usually occurs about several times per day. Inhalation and exhalation processes are conducted by the lung as it is the main functional organ in the human respiration process by passing oxygen inside the body and move the carbon dioxide out from the body. In order to maintain the level of oxygen and carbon dioxide in the human body and also remove the waste substances, breathing process is very essential to human ("Respiratory System," 2017).

Inhalation is the process related to the flow of air into the lungs by the expansion of chest volume. As a person breathes in, the air is inhaled by the nostrils and then directly passed through the nasal cavity. During the inhalation process, the expanded chest volume results in contracting of muscles between the ribs along with the diaphragm and the expanding of chest cavity. This process goes on due to the low pressure of air deep down the lungs compared to the area outside the lung as the air pressure will flow from a higher pressure to a low pressure area.

Meanwhile, an exhalation is the process that is related to expelling the air from the lungs by contraction of chest volume. As a person breathes out, the lung will deflate in order to force the air exhaled from the body. Oppositely, in the inhalation process, when the exhalation process occurs, the deflation of chest volume results in relaxing of muscle and diaphragm and makes the chest cavity to become smaller. This phenomenon takes place due to the high pressure of air inside the lungs tends to push the air to run out from a higher region to a region with low pressure. Figure 2.1 briefly explains the inhalation and exhalation processes.

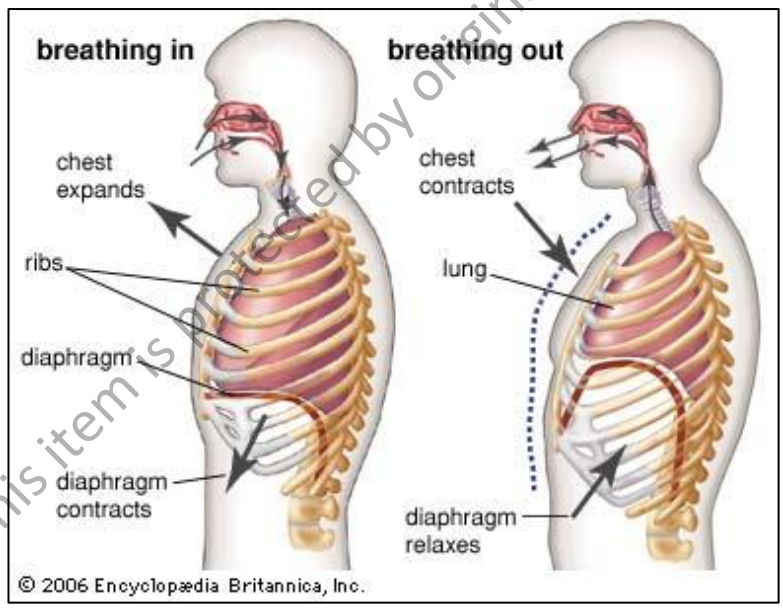

Figure 2.1: Human Respiratory Mechanism

2.2.1 Respiration Rate

Average rate of breathing is dissimilar in different ages of people. The breathing rate for an adult is normally around 12 to 16 breaths per minute at rest as according to the University of Rochester Health Encyclopedia. However, according to 'WebMD', the

breathing rate for children and infants is slightly different from an adult by which normally, infants of new-borns until 6 months have their breathing rate at an average of 30 to 60 times per minute, while the normal breathing rate for infants above 6 months and up to 1 year is from 24 to 30 breaths in a minute. For children with age 1 to 5 years, the normal respiratory rate is from 20 to 30 breaths and kids with age from 5 to 12 years is from 12 to 20 breaths, which is slightly faster compared to an adult. The average respiration rate of a person can be different due to fever, illness, or any other medical conditions which can make an effect towards the respiratory rate (Blahd, 2015). Based on the respiration rate in a certain condition, the velocity of the output shaft can be calculated as in equations (1.1), (1.2), and (1.3).

$$\omega = \frac{(\pi G\theta)}{(180°ts)} \tag{1.1}$$

$$\omega = Rotational\ velocity\ output\ shaft$$

$$G = Gear\ ratio$$

$$\theta = Desired\ angle\ of\ rotational$$

$$ts = Streching\ time$$

$$Vr = \left(\frac{2.5cm}{beat}\right)\left(\frac{20\ beat}{min}\right)\left(\frac{1min}{60sec}\right) \tag{1.2}$$

$$= \frac{0.8333cm}{s}$$

$$= \frac{0.008m}{s}$$

$$Strecthing\ time, ts = \frac{Ls}{Vr} \tag{1.3}$$

$$= \frac{0.01m}{0.008m/s}$$

$$= 1.25s$$

Where,

$$Desired\ strecthing\ distance, Ls = 1\ cm = 0.01\ m$$

2.2.1.1 At Rest

Referring to the medical studies, the normal breathing rate for an adult during rest is mostly between 16 to 20 breaths per minute. At resting condition, the muscles between the ribs and diaphragm will contract and expand in every breath. An adult with breathing rate below 12 or above 25 breaths per minute is considered abnormal. A person who has a breathing rate more than 25 breaths per minute during resting condition usually has

Tachypnea, a medical term that describes a rapid breathing due to excessive carbon dioxide inside the lung (Haak).

2.2.1.2 After Intense Exercise

However, the breathing rate of a person will be slightly different after exercise. The normal breathing rate for an adult who undergoes an intense exercise usually will increase up to 40 or 50 breaths per minute. Even 40 minutes after the intense exercise, the respiration rate still remains the same as the breathing is faster and deeper compared to before starting the exercise, but for a typical aerobic fitness workout, the respiration rate will drop to normal after 10 minutes. Normally, after finishing the exercise, the ventilation rate will slowly cut down to the normal state when at rest.

2.3 Energy Harvesting

In general, generating electrical energy from unused energy resources that is easily available in the environment is called as an energy harvesting. In terms of the process, energy harvesting is the method of capturing the amount of energy from one or more natural sources and then accumulating and storing the energy for later use ("Energy Harvesting Forum," 2012). Electrical energy generated from the harvesting technique is only suitable to the devices with low power energy such as the Walkman, TV remote, cell phone, or other devices that consume low power.

2.3.1 Solar Energy Harvesting

Solar energy is the largest renewable sources available on Earth. Besides, it is also a non-polluting and silent device that can convert about 10 to 15 percent of energy capture to the energy that can be used. There are many ways that can be done in order to harvest sunlight, which is involving capturing and converting the energy, for instance by using photovoltaic (PV) modules or solar thermal. During daylight, when the sun shines, the energy generated is stored by the solar cell or steam-driven turbine. At night or during a cloudy day, the energy stored will be released as an electricity (Panzer, 2013).

2.3.1.1 Photovoltaic (PV) Modules

The modules that are made from semiconductor material will capture and convert sunlight into electrical energy. Semiconductor inside the PV modules has the ability to create electricity from the absorbed sunlight. Figure 2.2 shows an example of solar harvesting system using PV modules.

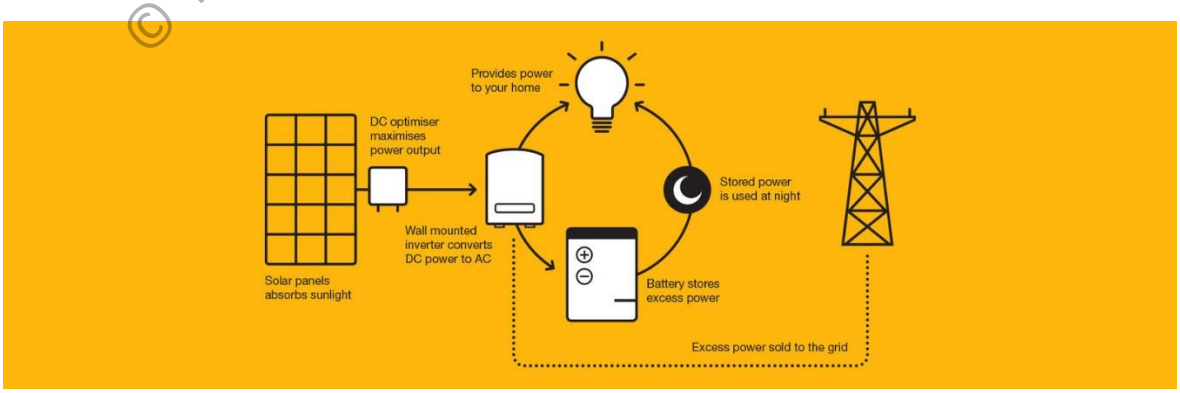

Figure 2.2: Solar Harvesting System using PV Modules ("How Solar works,")