DEVELOPMENT OF AXIAL FAN WITH CONTRACTION NOZZLE FOR PERPETUAL MOTION ENERGY HARVESTING SYSTEM

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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August 2022

Chairman : Professor, Ir Faizal Mustapha, PhD
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Nowadays, renewable energies are highly demanded as they are sustainable and environmentally friendly. One of the renewable energy is wind, and it can be harvested by using a wind turbine. However the power generated in any system by natural phenomenon has lots of limitations because of the inconsistency in the supply of the energy by the source. Wind energy from nature environment has limitation and inconsistency. Sometimes there are wind energy and sometimes no wind energy. It is mandatory to design a system which produces continuous and repeated power for the effective use. Also, in some parts of the country the weather is unpredictable to apply wind turbine system because of the environment. Hence, the research aimed to design and develop axial fan with contraction nozzle for Perpetual Motion Energy Harvesting System. The study focused on the design of a new concept to improve the energy harvested of wind turbines to be appropriate for the unpredictable wind energy condition in Malaysia. The concept involves the implementation of axial turbine fan and concentrator nozzle for Perpetual Motion Energy Harvesting System, to increase the electricity generated. Although the system used electricity to start, the implementation of the fan and nozzle should contribute to improve the electricity harvested by wind turbine system so that the harvested electricity can cover the used electricity in the system. Before the configuration of fan and nozzle were fabricated, the concept of axial fan was studied to get the best performance and then the nozzle was simulated with the use of a program to obtain the high wind speed in the system. Next the axial fan and contraction nozzle were fabricated and tested. Results showed that axial fan can produced wind energy with average speed of 3.6 m/s while the contraction nozzle improved the wind speed at outlet which average is 4.7 m/s. Then the integrated axial fan and contraction nozzle were verified for perpetual motion energy harvesting system by analysed the rotation speed of wind turbine and the output voltage of the turbine generator. The maximum output voltage that can be generated by perpetual motion energy

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harvesting system was 3.7 V using integrated axial fan and contraction nozzle. The voltage was measured using digital multimeter.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN KIPAS PAKSI DENGAN MUNCUNG PENGUNCUTAN UNTUK SISTEM PERGERAKAN AKAL PENUAIAN TENAGA

Oleh

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Pada masa kini, tenaga boleh diperbaharui sangat dituntut kerana ia mampan dan mesra alam. Salah satu tenaga boleh diperbaharui ialah angin, dan ia boleh dituai dengan menggunakan turbin angin. Walau bagaimanapun, kuasa yang dijana dalam mana-mana sistem oleh fenomena semula jadi mempunyai banyak batasan kerana ketidakkonsistenan dalam bekalan tenaga oleh sumber. Tenaga angin dari persekitaran alam semula jadi mempunyai had dan tidak konsisten. Adakalanya ada tenaga angin dan adakalanya tiada tenaga angin. Ia adalah wajib untuk mereka bentuk sistem yang menghasilkan kuasa berterusan dan berulang untuk kegunaan yang berkesan. Selain itu, di beberapa bahagian negara cuaca tidak menentu untuk menggunakan sistem turbin angin kerana persekitaran. Oleh itu, penyelidikan bertujuan untuk mereka bentuk dan membangunkan kipas paksi dengan muncung pengecutan untuk Sistem Penuaian Tenaga Pergerakan Akal. Kajian itu tertumpu kepada reka bentuk konsep baharu untuk menambah baik tenaga yang dituai turbin angin agar bersesuaian dengan keadaan tenaga angin yang tidak dapat diramalkan di Malaysia. Konsep ini melibatkan pelaksanaan kipas turbin paksi dan muncung penumpu bagi Sistem Penuaian Tenaga Pergerakan Akal, untuk meningkatkan tenaga elektrik yang dijana. Walaupun sistem ini menggunakan tenaga elektrik untuk dimulakan, pelaksanaan kipas dan muncung harus menyumbang untuk menambah baik tenaga elektrik yang dituai oleh sistem turbin angin supaya tenaga elektrik yang dituai dapat menampung tenaga elektrik yang digunakan dalam sistem. Sebelum konfigurasi kipas dan muncung difabrikasi, konsep kipas paksi telah dikaji untuk mendapatkan prestasi terbaik dan seterusnya muncung disimulasikan dengan menggunakan program untuk mendapatkan kelajuan angin yang tinggi dalam sistem. Seterusnya kipas paksi dan muncung penguncupan telah direka dan diuji. Keputusan menunjukkan kipas paksi boleh menghasilkan tenaga angin dengan kelajuan purata 3.6 m/s manakala muncung penguncupan meningkatkan kelajuan angin di alur keluar yang purata ialah 4.7 m/s. Kemudian kipas paksi bersepadu dan muncung penguncupan telah disahkan untuk sistem penuaian tenaga gerakan berterusan dengan

menganalisis kelajuan putaran turbin angin dan voltan keluaran penjana turbin. Voltan keluaran maksimum yang boleh dijana oleh sistem penuaian tenaga gerakan kekal ialah 3.7 V menggunakan kipas paksi bersepadu dan muncung penguncupan. Voltan diukur menggunakan multimeter digital.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

DAWT	Diffuser Augmented Wind Turbine
DWT	Ducted Wind Turbine
HAWT	Horizontal Axis Wind Turbine
PMM	Perpetual Motion Machine
RPM	Revolution Per Minutes
VAWT	Vertical Axis Wind Turbine

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CHAPTER 1

INTRODUCTION

This chapter describes the research background, problem statement, objectives, scope of the research work and the importance of the study to the engineering community in general and to researchers in particular.

1.1 Research Background

The worldwide increase in demand for energy and the obligation to protect the environment further necessitates the use of renewable energy. One such renewable energy resource that can be used is wind energy. The use of wind mills to produce energy from wind power dates back as far as 3000 years. From the late nineteenth century wind mills with generators or wind turbines have been used to generate electricity (Burton et al. 2001).

As the demand for energy increased, it became clear that it will be necessary to locate wind turbines at certain terrains and regions which previously have not been considered suitable. These terrains and regions may have gust, turbulence and low wind speeds or other physical constraints. Progressively more wind turbines tend to be installed at such complex terrains (Palma and Castro, 2008). Also, recently more efficient designs have been introduced for low wind speeds as well as for urban use where turbulence, noise levels and appearance needed to be considered and addressed (Wright and Wood, 2004). Some new designs propose that the turbine forms part of a building and structures. Other designs apply turbines in conjunction with solar panels or other types of renewable energy systems (Grant et al. 2008).

The need for energy in societies increases as technology advances in certain areas, so the capability to produce energy must keep pace with increasing demands. Due to the rapid depletion of fossil energy sources which is high price and high maintenance, there is a necessary need to seek alternative and sustainable sources of energy. As such, wind energy as a renewable and inexhaustible source of energy is now the fastest growing energy technology worldwide. Compared to conventional energy sources, wind power has many advantages and benefits. Unlike fossil fuels that emit harmful gases and nuclear power that generates radioactive wastes, wind power is a clean and environmentally friendly energy source. As an inexhaustible and free energy source, it is available and plentiful in most regions of the earth. In addition, more extensive use of wind power would help reduce the demands for fossil fuels, which may run out sometime in this century, according to present levels of consumption. As providing of electrical power from renewable sources such as wind is one of the factors of economic growth and industrialization for any nation (Tsaousis, 2008).Wind power systems, represented by wind turbines have been

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the focus of interest of scientists and researchers in the past decades. Flowing of wind through the turbine rotor leads to produce mechanical energy which can be used in many applications specially to produce electricity. However, power produced by wind turbine is dependent on the incoming speed of wind energy.

There are different ways in which the energy can be generated in a natural way. It can be by solar, wind, hydraulic, pneumatic principle etc. Turbine generator principle is effectively used throughout the years to generate power efficiently. In this study, the turbine fan will be used to create the wind power in an attempt to keep the system run and continuously operated. The techniques of augmenting wind by the concept of Diffuser Augmented Wind Turbine (DAWT) have been used to improve the efficiency of the wind turbines by increasing the wind speed upstream of the turbine. A nozzle system which will be known as contraction con system, will be installed in the system to control the effective and increase the wind speed between the wind turbine and generator to improve power captured. It is anticipated that this configuration will also improve overall turbine system performance.

To effectively determine the overall effectiveness of the dynamic system, the wind energy produced, speed of wind and power used will all be evaluated experimentally.

1.2 Problem Statement

Although generating electricity from the sun, wind or from both sources on a large scale will dramatically reduce carbon emissions, the amount of land required to set up large scale solar farms, wind farms or a hybrid solar-wind farm is tremendous. Voltage and frequency fluctuation, as well as harmonics, are significant power quality issues for grid-connected RE systems. Solar and wind power are inherently intermittent, which can pose technical challenges to grid power supply, particularly when the amount of solar and wind power integration increase or the grid is not robust enough to handle rapid changes in generation levels (Metayer 2015).

Then, the power generated in any system by natural phenomenon has lots of limitations because of the inconsistency in the supply of the energy by the source. Therefore it is mandatory to design a system which produces continuous and repeated power for the effective use. A wind turbine is one of the system, which transforms the kinetic energy of the wind into mechanical energy. Then, this mechanical energy is converted into electrical energy in the generator. The system that can produce wind energy is needed to operate the wind turbine so that the electricity can be generated.

However, one of the main problems of this conversion is the character of the wind speed. The generators have some constant range of rotational speed,

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which is a fact that brings some limitations to the rotational speed of the wind turbine rotor due to the stationary relationship between the speed of the wind turbine rotor and the generator input shaft. The changes in the rotational speed of the wind turbine rotor results with changes in the rotational speed of the generator input shaft which cause fluctuations at the frequency of the generated electricity by the wind turbine, and this is a fact that decreases the electricity quality.

Most of the wind turbines that are on the market have been developed in countries that have higher mean wind speeds. These wind turbines do not work effectively in certain conditions. The imported wind turbines are designed to have high power coefficient values at higher wind speeds. These wind turbines will not generate much energy except for the period of time that the wind velocity is high. Also, a wind turbine that is optimised for high wind speeds usually have reduced efficiency at low wind speeds. These wind turbines will fail to start rotating at low wind speeds (Wood, 2011).

Locally designed wind turbines also face a similar problem. The design for low wind speeds also reflect on the performance at the occasion the wind speed is high. Small wind turbines do not have pitch adjustment and the blade will have non optimum angles of attack at wind speed that was not the design wind speed (Wood, 2011). The available energy at low wind speed condition is a minimum; therefore the wind turbine will resulted low efficiencies.

From this one can see the necessity for some new designs to enhance the power coefficient values of a wind turbine's rotor for low wind speeds condition. One way to increase the power coefficient value of the wind turbine is to use structures like concentrators and diffusers. Both of these configurations are impractical to use in high wind speed regions because of structural constraints (Wood, 2011). In low wind speed condition it could be feasible to use them to increase the power coefficient values of a wind turbine.

1.3 Research Objectives

There are four main objectives in this study, namely:

1. To design and develop perpetual motion energy harvesting system.
2. To fabricate the turbine axial fan to produce wind energy for perpetual motion energy harvesting system.
3. To design and evaluate the aerodynamic analysis on the nozzle system to increase the wind speed for turbine generator system.
4. To validate the axial fan and nozzle system for perpetual motion energy harvesting system.

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1.4 Research Scope and Limitation

The scope of this research concerns the application axial fan and contraction nozzle for perpetual motion energy harvesting system. The design of axial fan is represented by using tube axial fan type. Then, the model of designed axial fan is testing the generated wind speed.

After that, the contraction nozzle is designed and fabricated as increasing wind speed to wind turbine generator. The model is testing in the wind tunnel.
Lastly, the design of axial fan and nozzle is combined to produce wind speed for perpetual motion energy harvesting system.

1.5 Organisation of the Thesis

The overall thesis covers the development of electrical energy harvesting system in order to harvest the wind energy. This is due to the design of axial fan and also nozzle for increasing wind speed. The thesis is organized in the following way.

Chapter 2: Literature Review
This chapter represents the background of the research which is divided into two main sections. The first section depicts the axial fan design consist tube type and vane type. The second section represents design of the contraction nozzle.

Chapter 3: Methodology
This chapter highlights the methodology used in implementing the experiment. More detailed information on the materials used, the apparatus, the software and the programming is given in this section.

Chapter 4: Result and Discussion
This chapter examines the results obtained from the testing of axial fan, and contraction nozzle.

Chapter 5: Conclusions and Recommendations
The final overview of the thesis findings provides a comprehensive conclusion in which all the steps taken in preparing this thesis are aligned with the problem statement and objectives.

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1.6 Summary

It is concluded that these available electricity generator system are highly maintenance, causes pollutant gas emissions to the environment and less efficiency. Moreover its capacity or footprint is too small, thus, a large area is required to arrange a large number of these devices to generate energy at a massive scale. In this research, proposed that perpetual motion energy harvesting system is to be used for the next generation of electricity generators. This will allow a much more compact device with high capacity.

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