DESIGN AND DEVELOPMENT OF NOVEL LOW SPEED WIND TURBINE GENERATOR SYSTEM

By

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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. There are two types of wind turbines: Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). 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 development of novel low speed wind turbine generator system. The study focused on the design of a new concept to improve the energy harvested by wind turbines to be appropriate for the unpredictable wind energy condition in Malaysia. The concept involves the implementation of wind turbines and output booster circuit for wind turbine generator system, to increase the electricity generated. Although the system used electricity to start, the implementation of the wind turbine system with booster circuit should contribute to improve the electricity harvested so that the harvested electricity can cover the used electricity in the system. Before the configuration of wind turbine and booster circuit were manufactured, the concept of wind turbine was studied to get the best performance of energy harvesting system while booster circuit was simulated with the use of a program to obtain the power booster in the system. Savonius type of Vertical Axis Wind Turbine was used in this research. Then the wind turbine system and booster circuit were fabricated and tested. Results showed that double wind turbine system can generated 0.5 V of voltage and 0.41 W of power at 1 m/s of wind speed while the booster circuit improved the result of voltage and power. Then the integrated wind turbine system with booster circuit was verified for perpetual motion energy harvesting system by analysed the output of the turbine generator and the output from

booster circuit. The voltage that can be generated by turbine generator was 6.7 V by using double wind turbine system and the voltage was increased to 13.4 V by booster circuit.

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

REKABENTUK DAN PEMBANGUNAN SISTEM PENJANA TURBIN ANGIN NOVEL KELAJUAN RENDAH

Oleh

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Penggunaan tenaga boleh diperbaharui digalakkan di seluruh dunia supaya kurang bergantung kepada bahan api fosil dan tenaga nuklear. Oleh itu penyelidikan di lapangan didorong untuk meningkatkan kecekapan sistem tenaga boleh diperbaharui. Walau bagaimanapun, kuasa yang dijana dalam mana-mana sistem oleh fenomena semula jadi mempunyai banyak batasan kerana ketidakkonsistenan dalam bekalan tenaga oleh sumber. 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 solar atau angin. Oleh itu, penyelidikan bertujuan untuk membangunkan Sistem Penuaian Tenaga Gerakan Kekal. Kajian itu tertumpu kepada reka bentuk konsep baharu untuk menambah baik tenaga yang dituai oleh turbin angin agar bersesuaian dengan keadaan tenaga angin yang tidak dapat diramalkan di Malaysia. Konsep ini melibatkan pelaksanaan turbin angin dan litar penggalak keluaran bagi Sistem Penuaian Tenaga Perpetual Motion, untuk meningkatkan tenaga elektrik yang dijana. Walaupun sistem ini menggunakan tenaga elektrik untuk dimulakan, namun pelaksanaan sistem turbin angin dengan litar penggalak harus menyumbang kepada peningkatan tenaga elektrik yang dituai supaya tenaga elektrik yang dituai dapat menampung tenaga elektrik yang digunakan dalam sistem. Sebelum konfigurasi turbin angin dan litar penggalak dihasilkan, konsep turbin angin telah dikaji untuk mendapatkan prestasi terbaik sistem penuaian tenaga manakala litar penggalak disimulasikan dengan penggunaan program untuk mendapatkan penggalak kuasa dalam sistem. Turbin Angin Paksi Menegak jenis Savonius telah digunakan dalam penyelidikan ini. Kemudian sistem turbin angin dan litar penggalak telah direka dan diuji. Keputusan menunjukkan bahawa sistem turbin angin berkembar boleh menjana voltan 0.5 V dan kuasa 0.41 W pada kelajuan angin 1 m/s manakala litar penggalak menambah baik hasil voltan dan kuasa. Kemudian sistem turbin angin bersepadu dengan litar penggalak telah disahkan untuk sistem penuaian tenaga gerakan berterusan dengan menganalisis keluaran penjana turbin dan keluaran

daripada litar penggalak. Voltan yang boleh dijana oleh penjana turbin ialah 6.7 V dengan menggunakan sistem turbin angin berganda dan voltan dinaikkan kepada 13.4 V dengan litar penggalak.

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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

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

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

Green energy or renewable energy becomes important nowadays. The application of renewable energy help people overcome the problem in traditional energy conversion from fuel which the stock gradually decreased. Natural resource such as wind, sunlight, rain and geothermal heat are utilized efficiently in energy services such as power generation, heating and transport fuel. The development and research drive for renewable energy become crucial and run rapidly since the emergence of the world energy crisis into the public in the 1970s.

The demand wind energy applications will continue to increase as fossil fuel prices continue to increase and the reservoir keeps decreasing. Wind energy systems are now proven technologies for electricity supply in isolated locations far from the distribution network. If designed well, they provide a reliable service and, free from the need for fuel supply, can even operate unattended for extended periods of time. Unlike conventional generators, however, these systems use fluctuating and finite energy resources, and this feature must be reflected in the system design. Only limited experience exists with the operation of more than one wind generators in combination as a part of an energy harvesting system. On the one hand, there are clear benefits of combining the two wind turbine generators to exploit the complementarity of the wind energy resources.

For wind energy, wind turbine applications need to be appropriately selected. This innovation has broadened to a few world areas and created a great foundation with comparative costs (Chiang et al., 2008). There are three types of wind turbines classified based on the shaft orientation and axis of rotation: horizontal axis wind turbines, vertical axis wind turbines, and ducted wind turbines. The first type of wind turbine, the Horizontal axis wind turbine (HAWT), is a turbine with a shaft-mounted horizontally parallel to the ground. This type of wind turbine is more commonly used. The second type of wind turbine is the vertical axis wind turbine (VAWT), which its shaft is normal to the ground. This type of wind turbine is less frequently used which Savonius and Darrieus are the most common in the group. The Savonius turbine consists of two or three scoop rotors which look like an “S” configuration in cross-section. The curved “S” shape allows the scoops to experience less drag force when going against the wind than when the scoops are moving along with the stream of the current of air. This discrepancy in drag causes the Savonius turbine to spin. While the design of Darrieus arranges the air foils in symmetrical ways so that the turbine has zero rigging angles. This arrangement is equally effective no matter which direction the wind blows. The third wind turbine can be either horizontal or vertical axis, but the turbine blades are encased in a shroud or hollow-shaped duct and known as a Ducted Wind Turbine (DWT). These wind turbines are mainly used for electricity generation (Paul, 2016).

The VAWT is not as regular and has just as of late been utilized for a huge-scale power era. A few studies have shown that the purpose of the VAWT offers more favorable circumstances than the HAWT. The VAWT does not require to be orientated to the course of the wind. Other than that, it does not need to be bothered with a tower, thus decreasing capital costs. The generator is mounted at ground level to ease access (Kanellos and Hatziargyriou, 2008, Yeh and Wang, 2008, Ibrahim, 2009).

1.2 Problem Statement

A stand-alone diesel generator power plant is the most applied system by remote industries. The disadvantage of this system is the maintenance of a regular supply of fuel and continuous electricity during breakdowns and scheduled shutdowns of the diesel units. It also causes pollutant gas emissions to the environment. Hence, a renewable energy harvesting system which consists of a combination of a few systems are suggested to reduce and prevent the issue.

However, 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.

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

The efficiency of the wind turbine is the existence of friction when wind energy is converted into electricity. This means that high efficiency will lead to higher electricity production. However, in order to obtain this, it depends on the turbine's blade design, the wind turbine, and also the generator used. The optimum design of wind turbine may extract 2/3 energy available in the wind, but practical wind turbines do not achieve high efficiencies as some energy will be lost due to friction.

The normal outline of a Savonius wind turbine type is not immaculate and the wind drive does not use the full scale because of many reasons pertaining to design. The Savonius wind turbine is outlined with a high drag variable to expand its productivity. Nevertheless, the edge components of the Savonius type need to be efficiently planned to lessen the drive on the twist activity of the non-working components of the turbine. Regardless of the low effectiveness of the Darrieus wind turbine and the fact that it is not able to self-begin, the Darrieus wind turbine utilises air foil as an edge which increases its efficiency. Hence, this research is focused on the best types of wind turbine models to produce better results and outcome from the experiment.

1.3 Research Objectives

The four main objectives in this study are as follows:

1. To develop novel low speed wind turbine generator system.
2. To design and fabricate the wind turbine to generate power for low speed wind turbine generator system.
3. To develop voltage booster circuit for low speed wind turbine generator system.
4. To validate on wind turbine system for low speed wind turbine generator system.

1.4 Research Scope and Limitation

The scope of this research concerns the application Vertical Axis Wind Turbines (VAWTs). The design of Vertical Axis Wind Turbine is represented by the Savonius types. Then, the model of designed VAWT is testing in the wind tunnel.

After that, the voltage booster circuit is designed and fabricated to increase the efficiency of perpetual motion energy harvesting system.
Lastly, the design of VAWT and p booster circuit is combined to produce high efficiency perpetual motion energy harvesting system.

1.5 Organisation of the Thesis

The overall thesis covers the development of wind turbine system in order to harvest the wind energy. This is due to the design of wind turbine and also power booster system. 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 Vertical Axis Wind Turbine design consist Darrieus type and Savonius type. The second section represents design of the voltage booster circuit.

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 wind turbine, and power booster system design.

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.

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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