COMBINATION OF VERTICAL AXIS WIND TURBINE AND SOLAR PHOTOVOLTAIC FOR HYBRID ENERGY

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By

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One of the most inexpensive and cleanest sources of renewable energy or technology is wind energy. The emergence of a new market i.e. wind technology, has the means of efficiently converting wind energy into a usable form of energy, which is electricity. The foundation of this new technology is the wind turbine, a machine that transfers fluid energy that passes through the blades and shafts, to mechanical energy, and later transforming mechanical energy to electricity via the use of a generator. The Vertical Axis Wind Turbine (VAWT) has been a popular choice as it is quiet, small and has a simple design. Some examples of VAWT are Darrieus, Savonius, and Vane. In developing countries, VAWT is used as a suitable alternative to wind power extraction, mainly due to its advantages over the horizontal axis type, such as ease of construction, cost efficient, and capable to accept wind flows from any direction without requiring orientation. Notwithstanding these advantages, today VAWT is not gaining popularity because of the low efficiency of the Savonius type rotor and low starting torque of the Darrieus type wind machines. There is also a lack of energy harvesting for the VAWT system. The problem arises because the average wind speed is very slow. Therefore, low wind speed causes the energy harvesting to not operate efficiently. Hence, the first objective of this research is to design a VAWT by combining both the Savonius and Darrieus types so that the combination of these designs meets the expectation of having a wind turbine that performs well. Besides that, to overcome the problem of efficiency of the wind turbine, a solar photovoltaic system with solar tracking will be designed and embedded into the turbine to function as another harvesting tool in the system. Lastly, the main objective of this research is to design a solar tracking combined with photovoltaic and integrating it into the VAWT system, to maximise energy harvesting. A few concepts were generated in the conceptual design stage. The Darrieus-Savonius VAWT design can be suitably placed in a built environment where it can harness more power from wind and at the same time, is also able to self-

start in low wind conditions prevalent in such environment. The study shows improvements in the power coefficient and efficiency for the Savonius-Darrieus wind turbine in comparison with the use of the Savonius wind turbine and Darrieus wind turbine only. The results showed the start-up speed and rotation of the Savonius-Darrieus wind turbines is the best design of VAWT, as it has a good start-up speed and rotation which enables it to generate electricity more efficiently. The weighted objective method is then used to finalise the most suitable design and the dual axis solar tracking system is defined, before proceeding with the next step. When the dual axis solar tracking system is built up, it is able to track with the light source and make adjustments on the tilt base for the PV to harvest solar energy. This dual axis tests are to prove the functionality and response towards the DC and servo motors. Finally, this research will emphasise the integrated design of solar photovoltaic embedded in a solar tracking system to ensure maximum energy harvest.

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

GABUNGAN TURBIN ANGIN PAKSI MENEGAK DAN SOLAR FOTOVOLTAIK UNTUK TENAGA HIBRID

Oleh

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Tenaga angin adalah salah satu sumber tenaga atau teknologi yang boleh diperbaharui yang paling murah dan paling bersih berbanding dengan jenis tenaga lain. Sebuah pasaran baru dalam teknologi angin telah muncul yang mempunyai cara untuk mengukuhkan tenaga angin secara efisien kepada bentuk tenaga yang boleh digunakan iaitu elektrik. Asas teknologi baru ini adalah turbin angin. Turbin angin adalah mesin yang memindahkan tenaga bendalir yang melepasi bilah dan aci kepada tenaga mekanikal dan mengubah tenaga mekanikal ke elektrik melalui penggunaan penjana. Turbin Angin Menegak Vertikal (VAWT) telah popular kerana reka bentuk yang kecil, tenang dan sederhana. Darrieus, Savonius, dan Vane adalah contoh VAWT. Turbin angin paksi menegak ini merupakan alternatif yang sesuai untuk pengekstrakan kuasa angin di banyak negara membangun. Alasan untuk ini adalah kerana kelebihan ke atas jenis paksi mendatar seperti pembinaan mudah, sangat kos efektif dan penerimaan aliran angin dari mana-mana arah tanpa orientasi. Walaupun mempunyai kelebihan ini, turbin angin paksi menegak tidak mendapat popularity kerana kecekapan rendah rotor jenis Savonius dan tork permulaan rendah mesin angin jenis Darrieus. Kemudian, kekurangan penuaian tenaga untuk sistem turbin angin paksi menegak (VAWT). Masalah yang dihadapi ialah kelajuan angin purata yang sangat perlahan. Oleh itu, kelajuan angin yang rendah menyebabkan penuaian tenaga tidak dapat beroperasi dengan cekap. Oleh itu, objektif pertama penyelidikan ini adalah untuk merekabentuk VAWT dengan menggabungkan jenis Savonius dan jenis Darrieus supaya gabungan kedua-dua reka bentuk ini memenuhi jangkaan untuk mempunyai prestasi turbin angin yang baik. Selain itu, untuk mengatasi masalah ini, fotovoltaik solar dengan penjejakan solar akan direka dan ditanam ke turbin untuk berfungsi sebagai alat menuai lain dalam sistem. Pertama, objektif utama ini adalah untuk merekabentuk pelacakan solar menggabungkan dengan fotovoltaik dan mengintegrasikannya ke dalam sistem VAWT, untuk memaksimumkan penuaian tenaga. Terdapat beberapa konsep

yang dihasilkan dalam peringkat reka bentuk konseptual. Rekaan VAWT Darrieus-Savonius boleh ditempatkan sesuai dengan persekitaran yang dibina di mana ia dapat memanfaatkan lebih banyak kuasa dari angin dan pada masa yang sama, juga dapat memulakan diri dalam keadaan angin yang rendah yang lazim dalam persekitaran sedemikian. Kajian ini menunjukkan peningkatan dalam pekali dan kecekapan kuasa untuk turbin angin Savonius-Darrieus berbanding dengan penggunaan turbin angin Savonius dan turbin angin Darrieus sahaja. Keputusan menunjukkan kelajuan permulaan dan putaran turbin angin Savonius-Darrieus adalah reka bentuk terbaik VAWT, kerana ia mempunyai kelajuan permulaan dan putaran yang baik yang membolehkannya menghasilkan tenaga elektrik dengan lebih cekap. Seterusnya, kaedah objektif berwajaran digunakan untuk memuktamadkan reka bentuk yang paling sesuai dan sistem penjejakan solar paksi ganda ditakrifkan untuk meneruskan dengan langkah seterusnya. Kemudian, sistem pengesanan solar paksi dwi dibina, ia boleh mengesan dengan sumber cahaya dan membuat pelarasan pada pangkalan kecondongan untuk PV untuk menuai tenaga solar. Ujian paksi ganda ini adalah untuk membuktikan fungsi dan tindak balas terhadap motor DC dan servo. Akhir sekali, dalam kajian ini akan menekankan reka bentuk bersepadu photovoltaic solar yang tertanam dalam sistem pengesanan solar untuk memastikan penuaian tenaga maksimum.

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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

HAWT	Horizontal Axis Wind Turbine
LDR	Light Dependent Resistor
LHS	Left Hand Side
PV	Photovoltaic
RHS	Right Hand Side
RPM	Revolution Per Minutes
VAWT	Vertical Axis Wind Turbine

CHAPTER 1

INTRODUCTION

This first chapter of this thesis presents the research background and the current challenges faced by various industries, particularly the oil and gas industry. The objectives, scopes of research as well as the problem statement are included in this chapter.

1.1 Research Background

Renewable energy, otherwise known as environmentally friendly power, turns out to be extremely prevalent and critical these days. An advantage of renewable energy is to overcome the issue of energy transformation from fuel, which is diminishing. Assets such as geothermal, wind, rain and daylight are used productively in the administration of energy for example, in control, warming and transport fuel. The advancement drive for renewable energy has become faster and more crucial ever since the development of the world's energy emergency amongst the general population back in the 1970s.

There has been a delay in the interest for sun-based and wind energy applications as the process of extracting fossil fuel is costly whilst the source continues diminishing. The planetary system and wind energy framework are established innovations for power supply in confined areas which are a distance away from the distribution area. They offer a dependable administration free from the requirements of fuel supply, and can even work unattended for longer timeframes. Unlike ordinary generators, these frameworks utilise fluctuating and limited energy assets, and this element must be reflected in the framework outline. Limited experience exists with the PV operations and twist generators combined as a part of a half breed framework. From one perspective, there are clear advantages of consolidating the two generators.

For wind energy, wind turbine applications need to be appropriately selected. This innovation has broadened to a few areas of the world and created a great foundation, with comparative costs (Chiang et al., 2008). In this field, wind turbines can be classified into two primary types which rely on the hub course of the rotor shaft: the first is the Horizontal Axis Wind Turbine (HAWT) and the second is the Vertical Axis Wind Turbine (VAWT). The HAWT has a few sharp edges, and is mounted radially from the rotor. It is largely utilised for large scale, network associated electrical power era. The VAWT is not as regular and has just as of late been utilised for huge scale power era. A few studies have shown that the purpose of the VAWT offers more favourable circumstances in contrast to 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 for ease of 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 hybrid system which consists of a combination of solar and wind energy is suggested to reduce and prevent the issue.

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 transmission between the rotor and the generator, 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 combined plans of both the Savonius and Darrieus types of wind turbine models to produce better results and outcome from the experiment.

A sun-based energy framework is not able to provide a constant source of energy because of low accessibility during winter and no-sun periods. The wind energy framework is not able to do the same because of the different wind speeds. Therefore, there are enormous issues when these energy sources are independently utilised. Keeping in mind the end goal to attain high energy accessibility which is required in several applications, it is important to utilise a combination of at least two renewable energy sources.

The sources of renewable energy available today include solar, wind, biomass, ocean tides, geothermal, hydro power and etc (Antonia et al, 2001). Although all of these sources are able to produce electricity with zero or negligible CO2 emission, solar and wind generation methods are the most popular. For example, unlike ocean tide electric generators that must be built near the ocean, solar and wind farms can be implemented almost anywhere. Similarly,

this is why solar and wind is preferred to when compared to geothermal and hydro power generation. However, the area required to produce solar or wind energy is extremely large. This will bring forth socio-economic issues such as lack of land for agriculture and housing.

1.3 Research Objectives

The three main objectives in this study are as follows:

1. To design and evaluate the aerodynamic analysis on the vertical axis wind turbine for hybrid system.
2. To develop and determine solar photovoltaic with tracker system as an additional harvesting power device in a hybrid system.
3. To design a hybrid energy system with the combination of vertical axis wind turbine and solar photovoltaic with tracker system.

1.4 Research Scope and Limitation

The scope of this research concerns the application of the Vertical Axis Wind Turbines (VAWTs) and Solar Photovoltaic (PV). The design of VAWT is represented by combining the Darrieus and Savonius types. Then, the model of the designed VAWT is tested in the wind tunnel.

After that, solar harvesting is designed and fabricated as an additional harvesting power system to VAWT. Lastly, the designs of VAWT and the solar system are combined to produce a hybrid energy harvesting system.

1.5 Organisation of the Thesis

The overall thesis covers the development of the hybrid energy harvesting system in order to harvest wind energy and solar energy. This is due to the design of the wind turbine and solar system. The thesis is organised in the following manner:

Chapter 2: Literature Review
This chapter represents the background of the research which is divided into three main sections. The first section depicts the VAWT design, which consists of the Darrieus type and the Savonius type. The second section denotes the design of the solar energy harvesting system. The final section describes the hybrid energy harvesting system.

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

Chapter 4: Results and Discussions
This chapter examines the results obtained from the testing of the wind turbine, the solar system and the hybrid system design.

Chapter 5: Conclusion and Recommendations
An overview of the final thesis findings provide a comprehensive conclusion in which all steps have been taken, in order to prepare this thesis in alignment with its 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 hybrid solar wind turbine 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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