DEVELOPMENT OF SAVONIUS AND DARRIEUS VERTICAL AXIS HYBRID WIND TURBINE TO INCREASE EFFECTIVENESS IN WIND ENERGY CONVERSION SYSTEM

by

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LIST OF ABBREVIATIONS

%	Percentage
¯	Negative
°C	Temperature (Degree Celsius)
A	Current (ampere)
T	Temperature
I	Constant current
m/s	Meter per second
m^2	Meter square
V	Voltage (volt)
K	Weilbull shape parameter
W	Power (watt)
α	Current change temperature coefficient (Amps/°C)
β	Voltage change temperature coefficient (Volts/°C)
e	Overlap
c	Scale parameter
Ω	Resistance (ohm)
ρ	Water density (1.2256 kg/m^3)

PEMBANGGUNAN SAVONIUS DAN DARRIEUS HIBRID PAKSI ANGIN MENEGAK UNTUK MENINGKATKAN KEBERKESANAN DALAM SISTEM PERTUKARAN TENAGA ANGIN

ABSTRAK

Tesis ini membentangkan penyiasatan terhadap potensi tenaga angin di Perlis dan pembangunan Savonius dan Darreius Paksi menegak Hibrid Turbin angin untuk kelajuan angin yang rendah (iatu di bawah 2 m/s). Objektif kajian ini adalah untuk menyelidik potensi tenaga angin berdasarkan data cuaca di Kangar, Perlis. Seterusnya, untuk mengkaji ciri-ciri Paksi Turbin Angin Mendatar (PTAD) dan Paksi Turbin Angin Menegak (PTAT) yang sesuai untuk keadaan kelajuan angin yang rendah. Akhir sekali , untuk membangunkan dan Savonius Darrieus Paksi menegak hibrid Turbin Angin dan menganalisis prestasi turbin hibrid ke arah kecekapan penukaran tenaga angin . Data kelajuan angin diukur di Pusat Kecemerlangan bagi Tenaga Boleh Diperbaharui (CERE) stesen , Universiti Malaysia Perlis di Kangar, Perlis. Bagi kelajuan angin dan angin data ketumpatan kuasa yang telah dianalisis secara harian, bulanan dan tahunan. Kelajuan angin di Malaysia dikawal oleh kedua-dua musim iatu monsun timur laut dan monsun tenggara. Semasa monsun tenggara kelajuan angin purata kurang daripada 2 m/s sementara di monsun timur laut kelajuan purata angin adalah sekitar 2-5 m/s. Dalam usaha untuk mengatasi cabaran-cabaran ini , model turbin angin yang sesuai direka dengan perhatian khusus diberikan kepada sensitiviti rendah kelajuan permohonan angin . Oleh itu merujuk perkara itu, Paksi menegak turbin angin Hibrid direka adalah memilih untuk menggabungkan bahawa Savonius dan Darrieus turbin. Eksperimen telah dilakukan dengan menggunakan blower sebagai sumber angin untuk tiga reka bentuk turbin yang Savonius turbin, turbin dan Darrieus Hibrid (Savonius dan Darrieus) turbin . Keputusan akhir adalah memuaskan dimana turbin hibrid menunjukkan untuk memiliki ciri-ciri permulaan yang baik dan meningkatkan kecekapan kepada 0.44 % jika dibandingkan dengan reka bentuk tunggal PTAT . Dari hasil data tenaga angin di Perlis Kangar dan prestasi turbin hibrid, ia dipercayai bahawa Kangar tidak sesuai untuk pemasangan turbin angin kerana ia terletak di kawasan berbukit (halangan angin). Pemasangan di kawasan pantai atau kawasan terbuka boleh meningkatkan keberkesanan turbin Hibrid untuk penukaran tenaga angin.

DEVELOPMENT OF SAVONIUS AND DARRIEUS VERTICAL AXIS HYBRID WIND TURBINE TO INCREASE EFFECTIVENESS IN WIND ENERGY CONVERSION SYSTEM

ABSTRACT

This thesis presents the investigation of the potential of wind energy in Perlis and the development of Savonius and Darreius Vertical Axis Hybrid Wind Turbine for the low wind speed application (below 2 m/s). The objectives of this research are to investigate the potential of wind energy based on the weather data in Kangar, Perlis. Next, to study the characteristic of Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT) suitable for low wind speed condition. Lastly, to develop Savonius and Darrieus Vertical Axis hybrid Wind Turbine and analyze the performance of Hybrid turbine towards the efficiency wind energy conversion. Wind speed data were measured at Centre of Excellence for Renewable Energy (CERE) station, University Malaysia Perlis located in Kangar, Perlis. The for wind speed and wind power density data was analyzed on a daily for 1 and half year, monthly and yearly basis. Wind speed in Malaysia is governed by the two monsoons that are north-east monsoon and south-east monsoon. During the south-east monsoon the average wind speed is less than 2 m/s while in north-east monsoon the average speed of the wind is around 2-5 m/s. In order to overcome these challenges, an appropriate wind turbine model is designed with specific attention given to its sensitivity to low wind speed application. As such as the matter, the Vertical Axis Hybrid Wind Turbine designed is opted to combine that of Savonius and Darrieus turbines. The test had been done by using a blower as the source of the wind for three designs of the turbine that are Savonius turbine, Darrieus turbine and Hybrid (Savonius and Darrieus) Turbine. The end results are encouraging as the Hybrid turbine shows to posses a good starting characteristic and its increase efficiency to 0.44% compared with a single design of VAWT. From the result of wind energy data in kangar Perlis and performance of the Hybrid turbine, it is believed that Kangar is not suitable for installation of wind turbine since it is located in a hilly area (wind obstruction). Installation in the coastal area or an open area may increase effectiveness of the Hybrid turbine for wind energy conversion.

CHAPTER 1

INTRODUCTION

1.1 Overview

Energy is thus one of the indispensable factors for continuous development and economic growth. However at the same time, energy production can contribute to local environmental degradation, such as air pollution and global environmental problems, principally climate change. According to the estimation of international Energy Agency, 53% global energy consumption will be increased by 2030, with 70% of the growth in demand coming from developing countries (Phang&Chua, 2010). Malaysia is one of the most developing countries among ASEAN countries next to Singapore, with gross domestic product (GDP) of US$15,400 per capita (PPP basis), and steady GDP growth of 4.6% in 2009 (International Monetary Fund, 2010). In parallel with Malaysia's rapid economic development, final energy consumption grew at a fast rate of 5.6 percent between 2000 and 2005 to reach 38.9 Milion tonnes in 2005. Fig. 1.1 shows global energy consumption by source.

Malaysia's energy sources primarily comprise oil, natural gas, hydro power and coal, although renewable energy (RE) sources such as solar, hydro, wind, and biomass. In the 9th Malaysia plan (2006-2010), the emphasis on energy efficiency is intensified to address the nation's energy challenge in line with the sustainable development agenda. The establishment of the Ministry of Energy, Green Technology and Water to replace the Ministry of Energy, Communications and Multimedia earlier in 2009 reflects Malaysia's seriousness in driving the message that ‘clean and green’ is the way forward towards creating an economy that is based on sustainable solutions (Islam, 2009).

Now, renewable energy has been put in the serious consideration in upgrading the efficiency of alternative power sources thus limiting the dependency on fossil fuel. Renewable energy refers to energy resources that occur naturally and repeatedly in the environment and can be harnessed for human benefit. Among the most popular renewable energy are wind, solar biomass, geothermal, and ocean energy

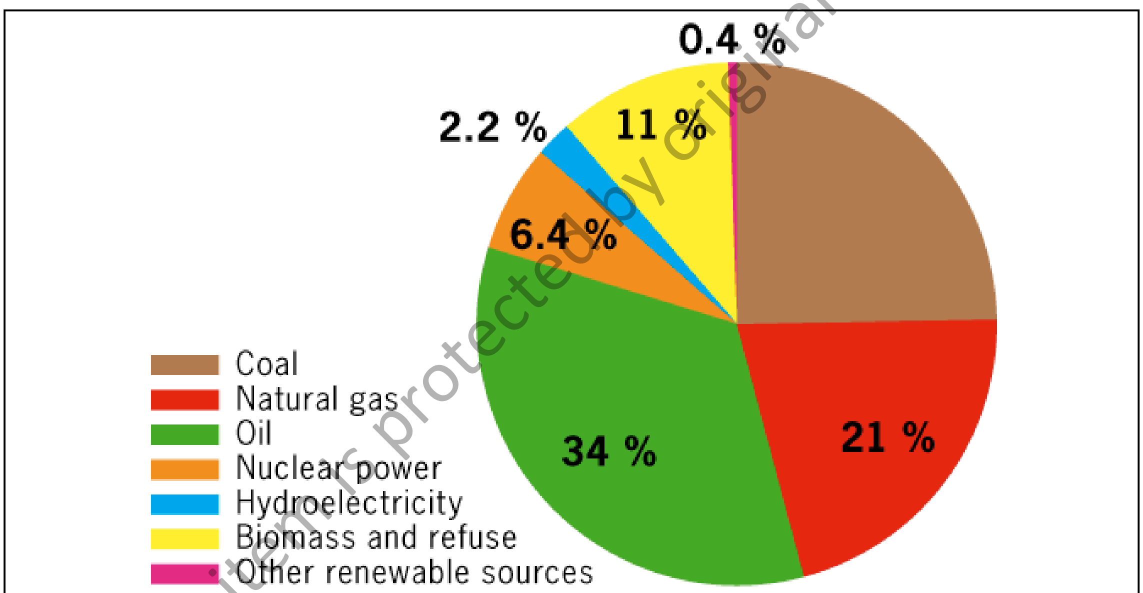

Figure 1.1: Global energy consumption by source (Energybc, 2011).

1.2 Problem Statement

Malaysia which consists of peninsular Malaysia, Sabah and Sarawak is situated in the equatorial doldrums area. The tropical Malaysian environment is under the influence of the North-east monsoon, South-west monsoon and two shotter period of the Intermonsoon.

Generally, these monsoon has been characterized by heavy rainfall, constantly high temperature and relative humidity. Since Malaysia lies near the equator, south of the latitudes where the monsoons are well developed winds over the area are generally light. The diurnal variation of wind speeds is important everwhere at all times of the year (Farriz, 2010).

According to the Malaysia Meteorology Department, the maximum average wind speed occurs during North-east monsoon with daily average 2-5 m/s while the minimum average wind speed is during South-west monsoon that are around 0-2 m/s. Normally in north-east monsoon which is starting from September until March, Where else the South-west monsoon start from end of March until early September.

Fluctuating of the wind speeds in Malaysia raise the problems to harvest energy of the wind. A suitable wind turbine is needed to capture wind efficiently. Vertical Axis Wind Turbine (VAWT) seems to be the best option to capture wind energy in Malaysia rather than using Horizontal Axis Wind Turbine (HAWT).

According to the previous research, there had a few designs of the VAWT that already been proven suitable using in a low wind speed and uncertainty winds condition. Normally, there are two common designs of VAWT mostly used in comerlized wind turbines that is Savonius turbine and Darrieus turbine. However, each type of the designs had their own excees and weakness. To improve the weakness of each design and at the same time increase the efficiency of each designs, the combination of the Savonius turbine and Darrieus turbine seems being a best options. Therefore, an efficient performance of the VAWT to capture wind demand an effective combination between Savonius turbine with Darrieus turbine (Hybrid turbine).

1.3 Aims and Objectives

The aim of this research is to design a low wind speed of wind turbine type to be implemented for low wind speed location.

The specific objectives of this research can be summarized as follows:

1. To investigate the potential of wind speed based on the weather data for wind potential power generating systems at Kangar, Perlis.
2. To study the characteristic of Horizontal Axis Wind Turbine and Vertical Axis Wind Turbine that is suitable for low wind speed application.
3. To develop Vertical Axis hybrid Wind Turbine which are a combination of Darrieus and Savonius turbine.
4. To analyze the performance of Vertical Axis hybrid Wind Turbine in low wind speed condition.

1.4 Scope of Project

The thesis focused on the development of Vertical axis hybrid wind turbine for low cut in wind speed in Perlis which is it can operate below 2 m/s and the feasibility of wind energy power generation. The duration of the data taken for wind energy feasibility study is from March 2011 to May 2012. The Vertical axis hybrid wind turbine is to meet the suitability to apply at a low wind speed locations that is around 0.50 m/s to 2.00 m/s in a normal day. This research project was conducted within one and half years period which is from January 2011 until June 2012. The Hybrid turbine dimension is calculated as a laboratory scale experiment. The proposed complete Hybrid turbine is designed to consist the aluminum film as a blade and acrylic board as a base in Savonius turbine designed. There are many factors that could influence the experimental duration and result such as weather costing of slab for wind turbine installation. Due to this challenge, the test of the hybrid turbine done by using a blower as the source of the wind. The data is applied to obtain the available wind speed and solar radiation for hybrid wind solar power generation.

1.5 Project Overview

This thesis begins with the study about the type of wind turbine and energy conversion system through the previous work, papers, journal and article based on the current situation of wind energy in Malaysia. The designs of the best type of wind turbine have been developed to suit the light speed of the wind. The data of the wind are collected from the Davis Vantage Pro 2 weather station that has been installed at Center of Excellent in Kangar, Perlis. The main purpose of the installation of weather station installation is to collect solar radiation, wind speed, rain, and temperature. Measured at 10 meters height above the ground level, the speed of the wind covered one and half years data.

The data of the wind speed variation over one and half year period has been described using Weilbull distribution function. Weilbull distribution is one of the most commonly used accepted, recommended distributions to determine potential of wind energy. The annual Weilbull distribution function and its two parameters are derived from the available data.

The Hybrid turbine which is the combination between Savonius turbine with Darrieus turbine was designed and test by using a blower as winds sources. The experiement was repeating a few times until the collected data enough in achieving objective of the research. Next, the result is analyzed and discussed properly including the constrain along the experiments was carried out.

1.6 Thesis Synopsis

Chapter one introduces the global energy demand issues, aims and objectives, problem statements, scope of the project and project overview.

Chapter two and three discuss about the literature review of the wind energy. The literature review of the wind energy focused on the studies on the characteristic of the winds and designed of the Vertical axis hybrid wind turbine for low wind speed application.

Chapter three explains the detail description of the methodologies used in the research. The parameters used to design the hybrid turbine also included.

Chapter four and five include all the experimental results and discussion of the research project. This chapter also presents the obstruction and errors arises during the experiments was conducted. In addition the energy policies in Malaysia and environmental impact of the renewable energy are also included.

Chapter six presents the conclusion and the future scopes with the most relevant findings after successfully finish the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Wind Energy Sources

Wind is the movement of air masses concerning an earth surface. This movement or circulation arises and is formed in the atmosphere under the influence of a difference of pressure in its various areas (or a pressure gradient), generated by heterogeneity of their heating and cooling under the influence of radiating, phase, turbulent and convective inflow and heat transformations (Nikolaev et al, 2008).

Wind can be considered as one form of a solar energy because the sun is that primary source which influences the weather phenomena on the earth. The wind arises because of non-uniform heating of a surface of the earth by the sun. Differential heating of water and land causes more minor changes in the flow of the air. Generally, during the daytime he water and territory surface, closed by clouds, heat up much more slowly accordingly the surface of the earth accessible to sunlight, heats up faster. Air from high pressure areas moves in the direction of low pressure areas, thereby creating a wind. Moving air masses are affected by Coriolis forces caused by rotation of the earth, the forces of inertia, force of gravity or weight in a ground layer of atmosphere forces of a friction of low air flow about the earth's surface (Kargiev, 2001). During at night time, the process is reversed with the day time because the air cools down more rapidly over the land and the breeze therefore the wind blows into the water. Fig. 2.1 and Fig. 2.2 shown the wind sources during day and night time.

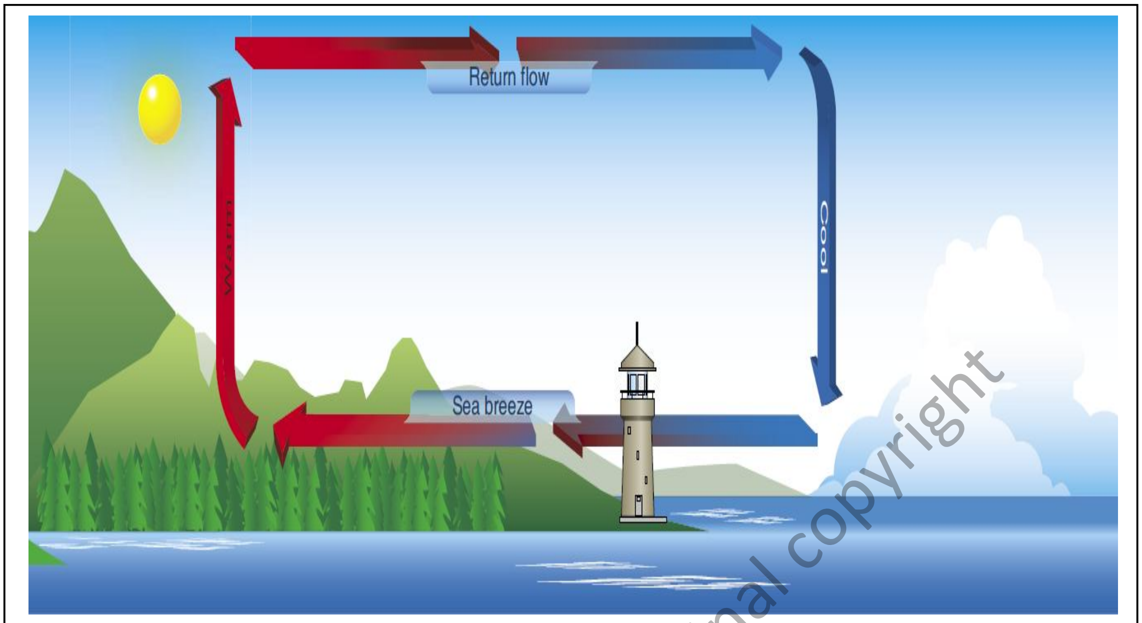

Figure 2.1: Wind sources during day time (climatessnack, 2010).

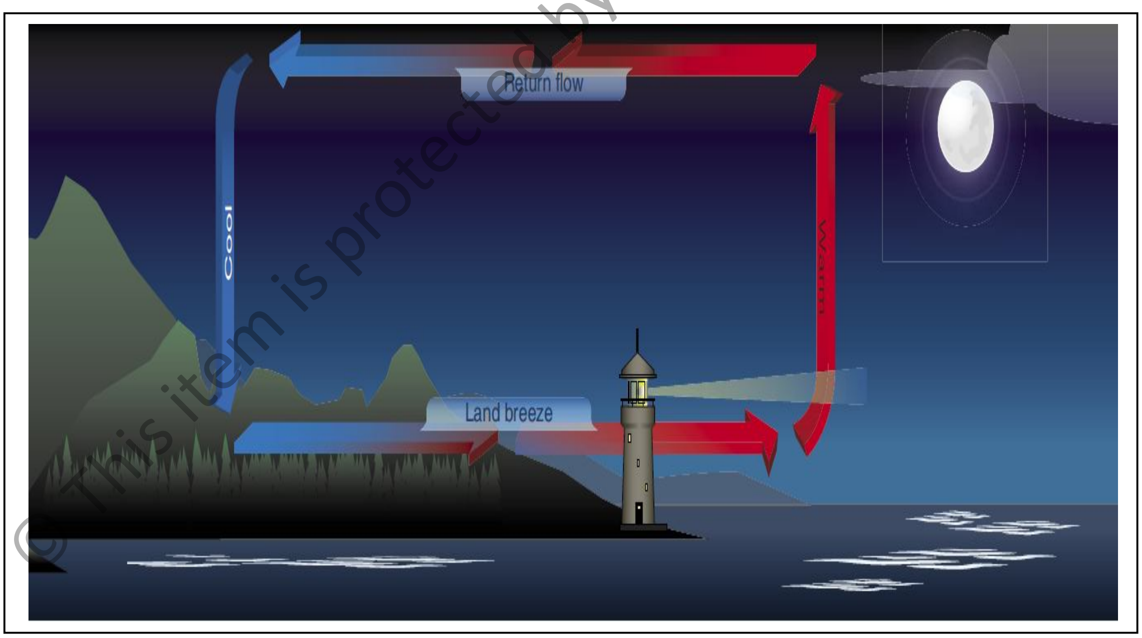

Figure 2.2: Wind sources during night time (climatessnack, 2010).

There are some advantages and disadvantages of wind energy on the surrounding environment and general reliability of wind turbine.

The advantages of wind energy:

1. Wind energy is extremely friendly to the surrounding environment; no fossil fuels are burnt to generate electricity from wind power.
2. Wind turbines take up less space than the average power station. Windmills only have to occupy a few square meters for the base. This allows the land around the turbine to be used for many purposes.
3. Newer technologies are making the extraction of wind energy much more efficient. The wind is free, and we are able to cash in on more of this free wind power.
4. Wind turbines are a great resource to generate energy in remote locations, such as mountain communities and countryside. The turbines can be a range of different size in order to support varying population levels.

The disadvantages of wind energy:

1. The main disadvantage regarding wind power is down to the wind unreliability factor. In many areas, the wind strength is too low to support a wind turbine or wind farm, and this is where the use of solar power or geothermal power are great alternatives.
2. A wind turbine can only support a specific population. Wind turbines aren’t like power stations, where it can just burn a bit more fuel to generate more energy when needed.
3. Wind turbine construction can last over a year, be very expensive and costly to the surrounding nature environment during the build process.
4. The noise pollution from commercial wind turbines is on a par with a small jet engine.
5. Vast protest and petitions usually confront any proposed wind farm site. People feel the countryside should be left in fact for everyone to enjoy its beauty.

2.2 Wind Measurements

An instrument called anemometer is used to measure wind speed. It comes in several types but the most common has three or four cups attached to a rotating shaft. Installation of the anemometer must be at least 10 meter height from the ground to ensure no obstacle for wind to hit the anemometer. The In this country, wind speed is reported in kilometers per hours or meters per second. Make the note that the energy that can be extracted from the wind is proportional to its velocity, meaning bad speed measurements will cause an even worse estimate of power available.

2.2.1 Power in the Wind

For the operation of wind turbine, it is important to take into account the equation of power density. It is used to find which wind site is potentially available to install the wind turbines

$$P = \frac{1}{2}\rho V^3 \tag{2.1}$$

P = power density (W)

ρ = density of air (which sea level is 1.2256 kg/m^3)

V = Wind velocity (m/s)

2.3 Tower Height

The economic impact of even modest increases in wind speed can be significant since the wind power density is proportional to the wind speed. To generate a higher output production from the wind turbines, a wind tower must be taller to get a higher wind speed. In the first few hundred meters above the ground, wind speed is greatly affected by the friction that air experiences as it move across the earth's surfaces. The only modest variation is smooth surfaces such as a calm sea, offer very little resistance, and the variation of speed with elevation. Wind speed is slowed at other extreme surfaces likes forests and buildings. Table 2.1 representative values for rather loosely defined terrain types.

Table 2.1: Friction coefficient for various Terrain

Terrain Characteristic		Friction Coefficient, α
1.	Smooth, hard ground, calm water	0.10
2.	Tall grass on level ground	0.15
3.	High crops, hedges and shrubs	0.20
4.	Wooded countryside, many trees	0.25
5.	Small town with trees and shrubs	0.30
6.	Largest city with tall buildings	0.40

The expression that is generally used to characterize the impact of the roughness of the earth's surface on the wind speed is the following:

$$\frac{v}{v_0} = \frac{\ln(H/z)}{\ln(H_0/z)} \tag{2.2}$$