DESIGN AND DEVELOPMENT WIND TURBINE SYSTEM FOR HARVETING WIND ENERGY ON HIGHWAYS

GAVIN GOH HENG YAU

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A report submitted
in fulfilment of the requirements for the Degree of
Bachelor of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Design and Development Wind Turbine System for Harvesting Wind Energy on Highways" is the result of my own work except as cited in the references.

Signature	:	………………………………..
Name	:	GAVIN GOH HENG YAU
Date	:	18 JUNE 2021

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design & Innovation).

Signature	:	………………..
Name of Supervisor	:	PROF. MADYA DR. NOR AZMMI BIN MASRIPAN
Date	:	18 JUNE 2021

DEDICATION

I would like to dedicate this project to my family and supervisor, PROF. MADYA DR. NOR AZMMI BIN MASRIPAN. The encouragements and mental supports from them help me to overcome the hard time during this project. God bless you.

ABSTRACT

In this era of globalization, the renewable energy is developing. The wind energy is clean and safe energy to generate power. In Malaysia, the wind energy is rich on North-South Expressway (NSE). The wind energy can be utilized to generate power for streetlights. In this project, the objective is to design a micro wind turbine and simulate the performance of micro wind turbine. The designs of micro wind turbine are drawn by using Solidwork. The Computational Fluid Dynamics (CFD) simulation is used in the simulation of performance. The discussion and analysis will be completed on the results of CFD simulations. The optimum design of a micro wind turbine is chosen by comparing the results of CFD simulations. At the end of this project, the recommendations for future works are suggested.

ABSTRAK

Pada era globalisasi ini, tenaga yang boleh diperbaharui sedang berkembang. Tenaga angin adalah tenaga yang bersih dan selamat untuk menghasilkan elektirk. Di Malaysia, tenaga angin kaya di Lebuhraya Utara-Selatan (NSE). Tenaga angin dapat digunakan untuk menghasilkan tenaga untuk lampu jalan. Dalam projek ini, objektif adalah untuk merancang turbin angin mikro dan mensimulasikan prestasi turbin angin mikro. Reka bentuk turbin angin mikro dilukis dengan menggunakan Solidwork. Simulasi Computational Fluid Dynamics (CFD) digunakan dalam simulasi prestasi. Perbincangan dan analisis akan diselesaikan mengenai keputusan simulasi CFD. Reka bentuk turbin angin mikro yang paling sesuai dipilih dengan membandingkan keputusan simulasi CFD. Pada akhir projek ini, cadangan untuk masa depan telah dibuatkan.

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Moreover, I would like to express my gratitude and appreciation to my parents and sibling. Their encouragements and supports helped me to overcome the hard times during this project.

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LIST OF ABBREVIATIONS

3D	Three dimensions
AC	Alternating current
AVR	Automatic voltage regulator
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
DC	Direct current
EMF	Electromagnetic force
HAWTs	Horizontal axis wind turbines
LED	Light Emitting Diode
NSE	North-South Expressway
VAWTs	Vertical axis wind turbine

CHAPTER 1

INTRODUCTION

1.1 Background

Electricity is the most usage rate of energy in this world. In Malaysia, the power plants are divided into 2 parts, there are thermal power plants and hydro power plant. These power plants will destroy the environment and there are many renewable energies can be used to generate the electricity such as wind energy. The wind energy is the good available energy source after the solar energy. We know that the Jiu Quan Wind Power Base, China is the world's biggest wind farm, and it will feature 7 thousand wind turbines. So, this project is to design a wind turbine to generate the electricity. If we want to design a system for the wind generation, we need a large place and there are always passed by strong wind.

In addition, Malaysia experiences 2 main weather seasons in one year and the coast will experience the stronger wind. As we know that our longest expressway, North-South Expressway (NSE) is located at the west coast of Malaysia. Then, we also know that there will produce a strong wind while a vehicle passing, if the vehicle is heavier, the stronger wind will be produced. There are more than 100 thousand drivers using highways every day in Malaysia especially the lorry and bus drivers. These vehicles will produce wind energy while moving with the high velocity which is more than 100 km/h. So, if we put the wind generation system on the roadside of the highway, we can get the more efficient wind generation system. This generated power can be used by the streetlights, tolls, households, or others.

1.2 Problem Statement

In Malaysia, the number of streetlights on highways is not enough to cover along the NSE. The establishment of power plant for streetlights is wasted and there have other energy can be used such as wind energy which is produced by moving vehicles. Moreover, there are many situations of vehicles will affect the efficiency such as low traffic and traffic jam. So, the generated power by the wind turbine must be able to store while these matters are happening. Since the wind generation system will be affected by the fluctuation of wind, we need to design the wind turbine to achieve the best performance on highways.

1.3 Objectives

The objectives of this project are as follow:

1. To design a micro wind turbine for harvesting wind energy produced by moving vehicles.
2. To stimulate the performance of micro wind turbine by using Ansys Workbench.

1.4 Scope of Project

The scopes of this project are:

1. The design of micro wind turbine must be done and can be pushed by wind easily.
2. The stimulation of micro wind turbine will be determined by using computational fluid dynamics (CFD) in Ansys Workbench.

CHAPTER 2

LITERATURE REVIEW

2.1 Working Principles of Wind Turbine System

This is an article states that, wind turbine utilizes wind to generate electricity. The windblown turns the blade of rotor which is connected with the generator. We know that wind is a natural phenomenon by the rotation of earth and other environment impacts. The higher speed of windblown, the higher power generated. The power of wind is directly proportional to the area of windmill, the cube of wind speed and the air density. There are some factors will affect the actual power of wind. The factors are the types of machines and rotors, the sophistication of blade's design, the friction losses, and others. (Agrar Energy, 2015)

Next, another research supports the idea above. The simple working principle of wind turbine is using the wind to generate electricity. The wind strikes the blades of the propeller which is around the rotor of the turbine and connected with a generator to generate electricity. The wind is caused by the natural phenomenon such as uneven heating by sun and other environment impacts. The wind turbine utilizes the mechanical energy from the windblown by using the aerodynamic principle to produce electrical energy. The different air pressure across the two sides of blades will create the drag and lift force, this will cause the rotation. The rotor can directly connect to the generator or connect to a gearbox to increase the speed of rotation. (Energy.gov, n.d.)

This article states that, there are some blades attach on the air turbine. The turbine will be rotated while the wind strikes on the blades of turbine. An electrical generator is linked with the spin shaft of the turbine. This generated will come out the electric and the electric can be stored. The turbine is connected to a gearbox. This gearbox will increase the speed of rotation. The high-speed rotation will run in the electrical generator. In the generator, an exciter is required in the magnetic coil to generate the electricity. Then, this generated voltage depends on the speed and field flux of the alternator. The higher speed of the rotation will produce the larger voltage. Hence, the availability of wind is important. There are two control mechanisms of modern wind turbine, there are controlling the design shaped of turbine blade and face. The design shaped of turbine blade states that the blades will help to rotate the gear and motor. The rotation of blades depends on the speed of wind. A technique is called pitch control provides the best orientation of turbine blade to obtain wind power. The orientation of turbine face will allow the turbine to follow the direction of windblown to improve the performance of the mechanical energy from the windblown. An automatic speed measuring device is called anemometer will sense the direction of windblown and send a signal to an electronic microprocessor-based controlling system to rotate the turbine to face the direction of windblown. (Electrical4U, 2020)

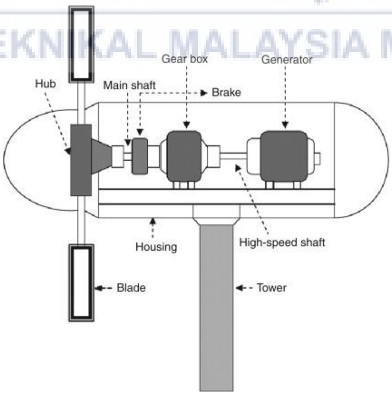

Figure 2.1: Section View of Wind Turbine.

On the other hand, the article says that, the wind turbine system is the common types for electricity generation. The purpose of wind turbine is to utilize the wind energy at a large area. We use the aerodynamic modelling to determine the optimum tower height, control systems, number of blades and blade shape. The wind turbine system is optimized to minimize the cost for producing the energy from the wind turbine. The wind turbines will produce the electrical energy by harvesting the mechanical energy from wind. The system generally consists of the three main components. There is rotor component, generator component and structural support component. (S.C. Bhatia, 2014)

2.2 Horizontal Axis Wind Turbine

This article says that horizontal axis wind turbines (HAWTs) are the most common wind turbine design nowadays. HAWTs use aerodynamic blades which connect to rotor for rotating the alternator inside the generator. The blades can be positioned in upwind and downwind. Then, HAWTs with upwind rotors require the yaws, or tail vane to help orient in the wind. HAWTs with downwind rotors require the coned blades to orient on its own. The lift force of aerodynamic is used to turn the rotor blade. The large HAWTs use electronic controls and anemometers to detect windblown and orient themselves, but the small HAWTs use the yaw system to orient themselves. These will cause the difficulty to align properly and quickly. This is a disadvantage of HAWTs. These will also cause the reduction of efficiency of HAWTs. HAWTs only can be placed in urban areas to reduce turbulence from surrounding objects. (M.A. Hyams, 2012)

Furthermore, this article is related to the idea, HAWTs allow their rotation direction horizontal to the ground and nearly parallel to the windblown. HAWTs use the lift force to rotate the rotor while the wind interacting with the rotor blades. Some of the spin shafts will connect with a gearbox to increase the rotational speed for achieving the requirement of generator. Then, the generator will convert the mechanical energy to electrical energy. These require the control system to ensure the yaw alignment, power regulation and safety. By the way, there are some disadvantages of HAWTs. HAWTs require the yaw drives to orient themselves toward windblown in case of small turbine. HAWTs need expensive cost and complex design to support the heavy units of turbines for placing over the tall tower. The installation and maintenance of HAWTs are also expensive and difficult. Then, the height of HAWTs make them can be seen from longer distance and will cause the visual impact of windmill. (S. Mathew, 2012)

Figure 2.2: Example of Horizontal Axis Wind Turbine.

2.3 Vertical Axis Wind Turbine

The article states that, vertical axis wind turbines (VAWTs) are the small wind turbine which rotation is perpendicular to the ground. VAWTs can operate independently of windblown. This also is one of the advantages of VAWTs, can orient themselves rapidly toward windblown. There are two primary design of VAWTs, Darrieus rotors and Savonius rotors. Darrieus rotors use the lift force to rotate the blades and the Savonius use the drag force. Then, Darrieus rotors are the most common design of VAWTs. The designs are looked like a eggbeater, this help them to extract the mechanical energy while the wind strikes perpendicularly. If under a low turbulence of wind, HAWTs will provide the higher performance than VAWTs. But if under a high turbulence, Darrieus rotors will run smoothly and provide the higher performance. Savonius rotors will be turned slowly but with the high torque. Sovonius rotors have the lower efficiency because they use drag force. These will not be good for generating electricity. VAWTs have the advantages. They can provide a better performance than HAWTs in turbulent condition. VAWTs produce less noise because of the lower rotating speed. The components of VAWTs are less so these will cause the less maintenance and installation cost. (M.A. Hyams, 2012)

Figure 2.3: Example of Darrieus rotors.

In addition, this article also supports the idea, VAWTs have some advantages. VAWTs allow turbine to get struck by windblown from any direction. The yaws or tail vane to orient themselves toward the wind. The simple structural requirements do not require the high working situation and they can be done at the ground. Then, VAWTs also have some disadvantages. The turbines will provide a worse performance at the higher-level elevation. VAWTs are not self-starting in general, but it is not a serious issue because the generator can be utilized as a motor for starting the system. (G.S. Philip, 2012)

Moreover, this article has said that, HAWTs do not provide a efficient power generation under a windblown of low place condition. VAWTs have the advantages. There is lower tip speed ratio, lower cost, insensitive to the wind direction, less noise and less moving parts. VAWTs have two types of design, Darrieus design and Savonius design. Savonius design utilizes the drag force of the wind to operate the wind turbine system. In the real world, the wind condition is complex and turbulent especially close to the ground. Therefore, the Savonius design VAWTs will bring the efficiency under the lower part wind condition. Then, this Savonius design VAWTs are also suitable used in the micro wind turbine system to operate at the low wind speed. (B. Loganathan, 2019)

Figure 2.4: Savonius design shaped VAWT.

The article also supports the idea, the characteristics for manufacturing the wind turbine are cheap, simple manufacturing standard, maintenance easily and feasible. The VAWTs have some advantages. The main advantage is VAWTs can be operated in low wind velocity and do not need orientation system on wind direction. VAWTs are more suitable in a small-scale wind turbine. The VAWTs have two types of design, Darrieus design and Savonius design. Darrieus design use the lift force of the windblown to rotate the rotor. H-Darrieus design performs well in this regard. The pitch control is not required in this design. (T. Parra, 2015)

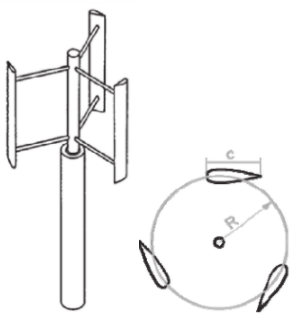

Figure 2.3.3: H-Darrieus design shaped VAWT.

In addition, the article states that, the VAWTs have a design that name helical shaped. VAWTs can be placed at various location without worrying the wind condition. The operation of helical shaped VAWT can be shut down for the safety reasons. This VAWT is safer because the birds will not be killed especially in migratory routes. The helical shaped VAWT do not require the tail-vane to orient it to follow the wind direction. The efficiency of this VAWT will not be affected easily by the influence of the windblown. The lift force of wind is utilized by this VAWT to operate the wind turbine system. (K. Vijayan, 2016)

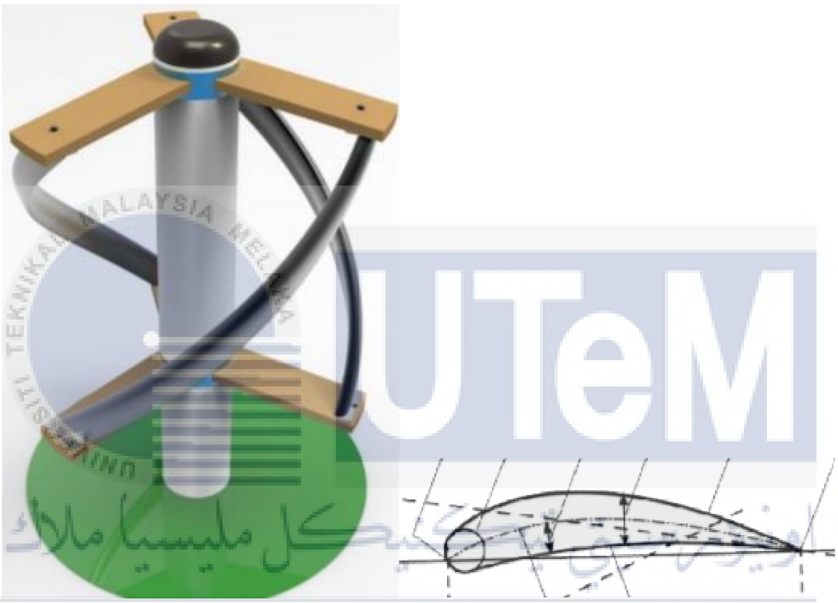

Figure 2.5: Helical shaped VAWT.

2.4 Micro Wind Turbine

The article states that, the small-scale wind turbines are commonly used in remote area and also suitable for businesses, individual uses, and electric government utilities such as streetlights. The large-scale wind turbines will create the noise. The noise and size of the turbine bring the impacts to the environment. The birds will be damaged by the blades of the turbine. The large amount of transportation and construction are required in using the large-scale wind turbine. The expensive maintenance and monitoring are required in large-scale wind turbines. The small-scale wind turbines produce less noise and minimize the impacts