BLADE PARAMETERS ANALYSIS ON THE PERFORMANCE OF WIND TURBINE

MUHAMMAD FARHAN BIN ABDUL KAPOR

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BLADE PARAMETERS ANALYSIS ON THE PERFORMANCE OF WIND TURBINE

MUHAMMAD FARHAN BIN ABDUL KAPOR

This report is submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2016

DECLARATION

I declare that this project report entitled “Blade Parameters Analysis on the Performance of Wind Turbine” is the result of my own work except as cited in the references.

Signature : ....

Name : Muhammad Farhan Bin Abdul Kapor

Date : ....

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 and Innovation).

Signature	:.	....
Name of Supervisor	:	Masjuri Bin Musa
Date	:	....

DEDICATION

To my beloved parents.

ABSTRACT

Wind energy extraction has been vital focus since the oil crisis. This is because wind energy is clean and renewable energy. This project can help improvising the extraction of energy from the wind. The project was carried out to determine the effect of number of blade and blade length on the performance of wind turbine. The project also compares 3 different numbers of blade and blade length to determine which one should be used for optimum performance of a wind turbine. The project started with the design of the wind turbine blades. The blade was then assembled to be a complete rotor and further analyzing the stream velocity of wind. The torque of the blade was determined in order to find the power output and power coefficient of wind turbine. The results show that a wind turbine having 5 blades and 45 meters blade are the most efficient. The result also shows that increasing number of blades and blade length of wind turbine will improve its efficiency.

ABSTRAK

Penjanaan tenaga angin telah menjadi tumpuan sejak daripada krisis minyak. Ini kerana tenaga angin adalah tenaga bersih dan boleh diperbaharui. Projek ini dapat membantu memperbaiki penjanaan tenaga daripada angin. Projek ini telah dijalankan untuk menentukan kesan bilangan bilah dan panjang bilah turbin angin terhadap prestasi turbin angin. Projek ini telah membandingkan 3 bilangan bilah dan panjang bilah berbeza untuk menentukan yang mana satu harus digunakan untuk mendapat prestasi turbin angin yang terbaik. Projek ini bermula dengan mereka bentuk bilah turbin angin. Bilah itu kemudian dipasang menjadi sebuah pemutar lengkap dan halaju angina telah dianalisa. Tork pada bilah telah didapatkan bagi mendapatkan kuasa yang dijana dan pekali kuasa turbin angin. Keputusan telah menunjukkan bahawa turbin angin yang mempunayai 5 bilah sepanjang 45 meter adalah yang paling bagus. Hasil kajian juga telah menunjukkan bahawa peningkatan bilangan bilah dan panjang bilah akan meningkatkan prestasi turbin angin.

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to my supervisor Mr. Masjuri bin Musa for giving me this opportunity to complete my final year project under his supervision. I am extremely thankful for his patience and advice while leading me in this project. Furthermore, I would like to show appreciation to Mr. Masjuri for being extremely patient with me throughout the extent of this project.

Besides that, I would like to thank all my lecturers who have showered me with their knowledge and broadened my understanding in the field of engineering. I would like to especially thank my lecturers who taught me Computer Aided Drawing and Fluid Mechanics, Mr. Nazim and Dr. Cheng See Yuan respectively, which really helped me complete my final year project.

Last but not least, I would also like to take this opportunity to thank my course mates and family members for providing me with support and encouragement, love, care.

CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBEREVATIONS

CFD	Computational Fluid Dynamics
CATIA	Computer Aided Three-Dimensional Interactive Application
HAWT	Horizontal-Axis Wind Turbine
VAWT	Vertical-Axis Wind Turbine
TSR	Tip-Speed Ratio
NREL	National Renewable Energy Laboratory
SERI	Solar Energy Research Institute
NACA	National Advisory Committee for Aeronautics

LIST OF SYMBOL

E	=	Kinetic Energy
r	=	Radius of Wind Turbine
Cp	=	Power Coefficient
ρ	=	Density of Air
ω	=	Angular Velocity
τ	=	Torque
A	=	Swept Area of Wind Turbine
v	=	Velocity of wind

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Wind energy utilisation is not a new technology as it has been used for a long time. It is hard to tell the date of origin the first windmill was built to do works. Some claim that the Egyptian was the first to invent windmill but there is no evidence to proof that. The earliest known windmill was invented by the Persians around 500 to 900 A.D., and was used to grind grain and pump water. The windmill technology then spread to Europe in early 12th Century.

The turning point of historical windmill which was used to do works to modern wind turbine which generates electricity marks by the name of Poul La Cour. Poul La Cour was an inventor and also an educator is Denmark. In 1891, La Cour built and wind turbine that drives a dynamo for experimental purpose. He also built the first wind tunnel for the purpose to identify the best shape of wind turbine. Larger wind turbine with higher efficiency was built during the first half of 20th Century in United States. However, the interest in wind turbine came to its dawn after World War II as the price of other energy resource such as fossil fuel cost cheaper and easier to get. The interest in development of wind turbine then renewed after the oil embargo of 1973. The concern about limited source of fossil fuel and also the negative effect of energy production using coal and oil makes the re-emergence of wind power, a renewable and clean energy, almost inevitable.

Wind turbine is a machine that converts kinetic energy from wind into electrical energy. Wind turbine basically is made up of four main components which is the rotor, the nacelle, the tower and base. The rotating part of a wind turbine, the rotor, is made up of a hub and a few blades. A wind turbine blade which has an aerofoil shape rotates the rotor creating mechanical energy as the wind passes over it. The aerofoil shape of wind turbine blades causes a difference of wind speed passing over the blades. This difference of speed produced high and low pressure system which creates lift force that rotates the blade about the rotor axis. The spinning of the rotor turn the generator inside the wind turbine thus converts the energy into electrical energy. Wind turbine has many different sizes with different capabilities to generate power. Small scale wind turbine with power output lower than 40kW is used to supply power to boat, caravan, and telecommunication tower. Large scale wind turbine can produce power output from 1MW up to 5MW. A wind turbine with power rating between 40kW and 999kW are considered as medium wind turbine.

Generally, wind turbine can be classified into two types which are horizontal-axis wind turbine and vertical-axis wind turbine. A horizontal-axis wind turbine (HAWT) is a common type of wind turbine which is adapted from the design of the windmill. Tall tower base is the main advantage of HAWT which allows the rotor to access stronger wind flow. Other than that, HAWT has high power generating capacity and higher efficiency compared to vertical-axis wind turbine (VAWT). The performance of wind turbine mostly depends on the blade parameters. To optimize the performance of wind turbine, blade parameters such as, blade shape, number of blades, hub to tip ratio, weight and materials must be taken into consideration when designing and developing a wind turbine.

1.2 PROBLEM STATEMENT

As mention earlier, number of blades and hub to tip ratio of the wind turbine are main characteristic to be considered for the wind turbine to have optimum performance. More number of blades means more lift force acting on the whole turbine system. However, adding number of blades will increase the resistance of wind flow which causes drag to increase. In this case, fewer numbers of blades are better. The hub to tip ratio of the wind turbine is determine by the length of its blades. Longer blade will increase the swept area of the wind turbine, thus catching more wind which means more power will be generated. But, increasing blade length will also increase the deflection of blade due to axial wind force. This might leads to a collision between blade and tower or blade failure. Furthermore, if the length of the blades was increased, the height of the tower needs to be increased as well to make sure the swept area is in strong wind region. To harness wind energy to its optimum point, the suitable parameters for the blades of wind turbine need to be determined.

1.3 OBJECTIVE

The objectives of this project are as follows:

i. To determine the influence of number of blades and length of the blades on the performance of wind turbine.
ii. To identify the suitable number of blades and length of wind turbine blades for the optimum performance.

1.4 SCOPE OF PROJECT

The scopes of this project are:

i. To design and develop a 3D solid modelling of wind turbine by using CAD software such as Solidworks, CATIA, Inventor.
ii. To optimize the blades of wind turbine system in order to gain most optimum performance.
iii. To analyse the stream velocity of the related blades parameters by using CFD software.
iv. To identify the values of the power output for each combination of the related parameters involved.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss about the general information of wind turbine and comes to detail information on horizontal-axis wind turbine. This chapter will also review several previous studies.

2.2 WIND TURBINE

A wind turbine is a machine that coverts kinetics energy contains in a moving air into electrical energy, Hau E. (2013). The wind flow passing through the rotor of a wind turbine causes the rotor to spin and rotates the shaft. The shaft is connected to the gearbox and generator which convert the mechanical energy into electricity. The electricity produced by wind turbine will ultimately be used to supply electricity for homes, communities and business. Wind turbines are becoming one of the most important sources of renewable energy and they are being used widely all around the world.

2.3 WIND FARM

Wind farm is a place where several numbers of wind turbine is installed to produce electricity. As of 2013, 83 countries are using wind power to supply electricity. The top leading countries that use wind power as source of energy are

China, Germany and United States of America. The largest wind farm in the world is Gansu Wind Farm located in China with a capacity over 7100 MW of power. Figure 2.1 below shows a part of biggest wind farm in China.

Figure 2.1: Gansu Wind Farm in China (www.skyscrapercity.com, 2009)

2.4 TYPES OF WIND TURBINES

Generally, there are two main types of wind turbine which are horizontal-axis wind turbine (HAWT) and vertical-axis wind turbine (VAWT). A review from www.eia.gov shows the differences of these two types of wind turbines.

Figure 2.2: Vertical-axis Wind Turbine (www.eia.gov, 2015)

Figure 2.3: Horizontal-axis Wind Turbine (en.wikipedia.org)

2.4.1 Vertical-Axis Wind Turbine (VAWT)

A VAWT has a vertical axis of rotation. Manwell et al (2009) mentioned that VAWT is a drag machine which work on drag principle. A VAWT needs to be located on the ground which means it cannot access high speed wind flow. This is the main reason why this type of wind turbine performance is much lower than HAWT. The common type of VAWT was patented by Georges Darrieus in 1931 and named after himself.

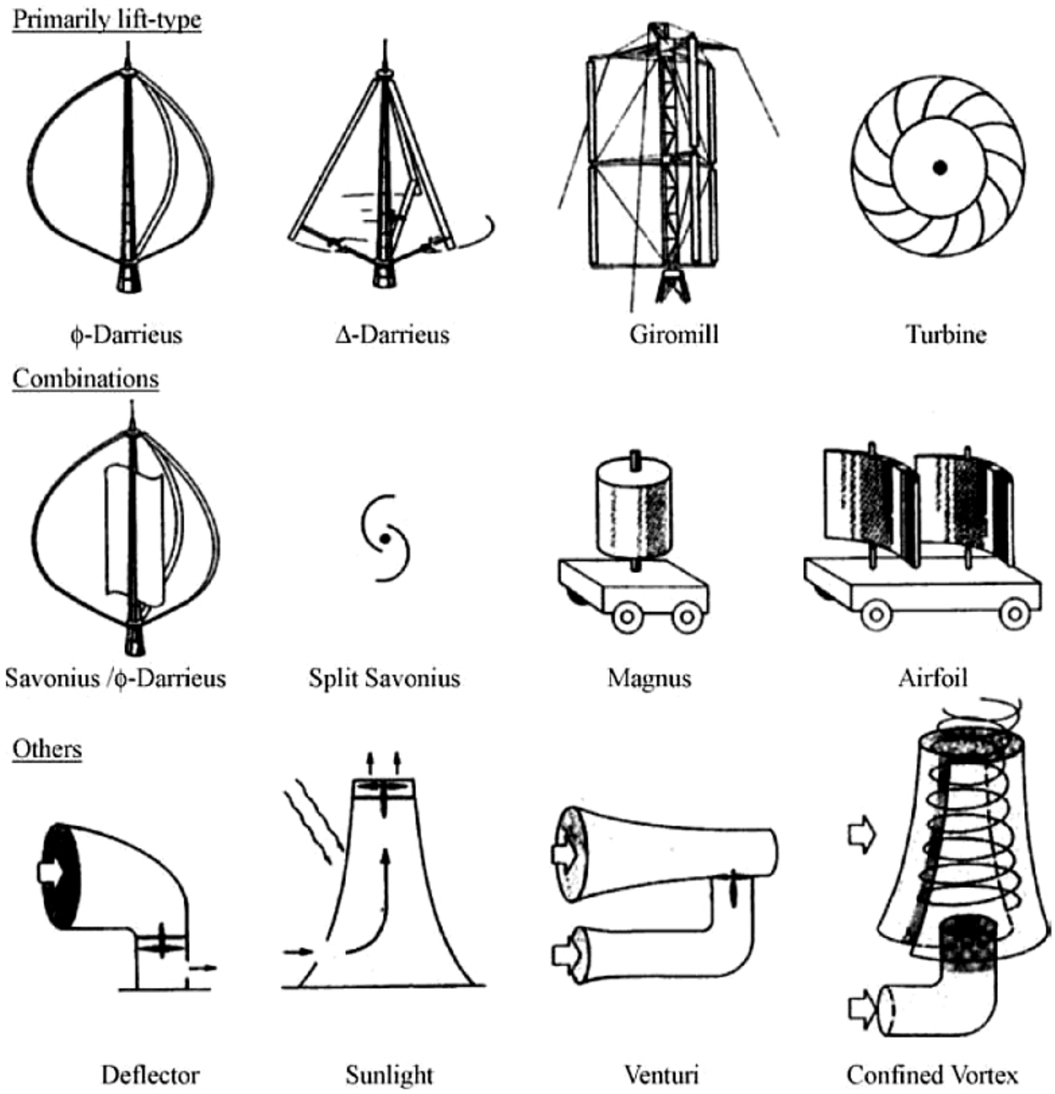

Figure 2.4: Various designs of Vertical-Axis Wind Turbines (Manwell et al, 2009)

2.4.2 Horizontal-Axis Wind Turbine (HAWT)

This type of wind turbine is the common type of wind turbine which is also the primary focus of this report. The horizontal-axis means the rotation axis of the wind turbine is parallel to the ground. HAWT works on the principle of lift just like the aeroplane wings. When the wind flows through the blades, the aerofoil shape of the blade creates pressure differences on the upper and lower side of the blade. This pressure difference creates lift force that rotates the blades.

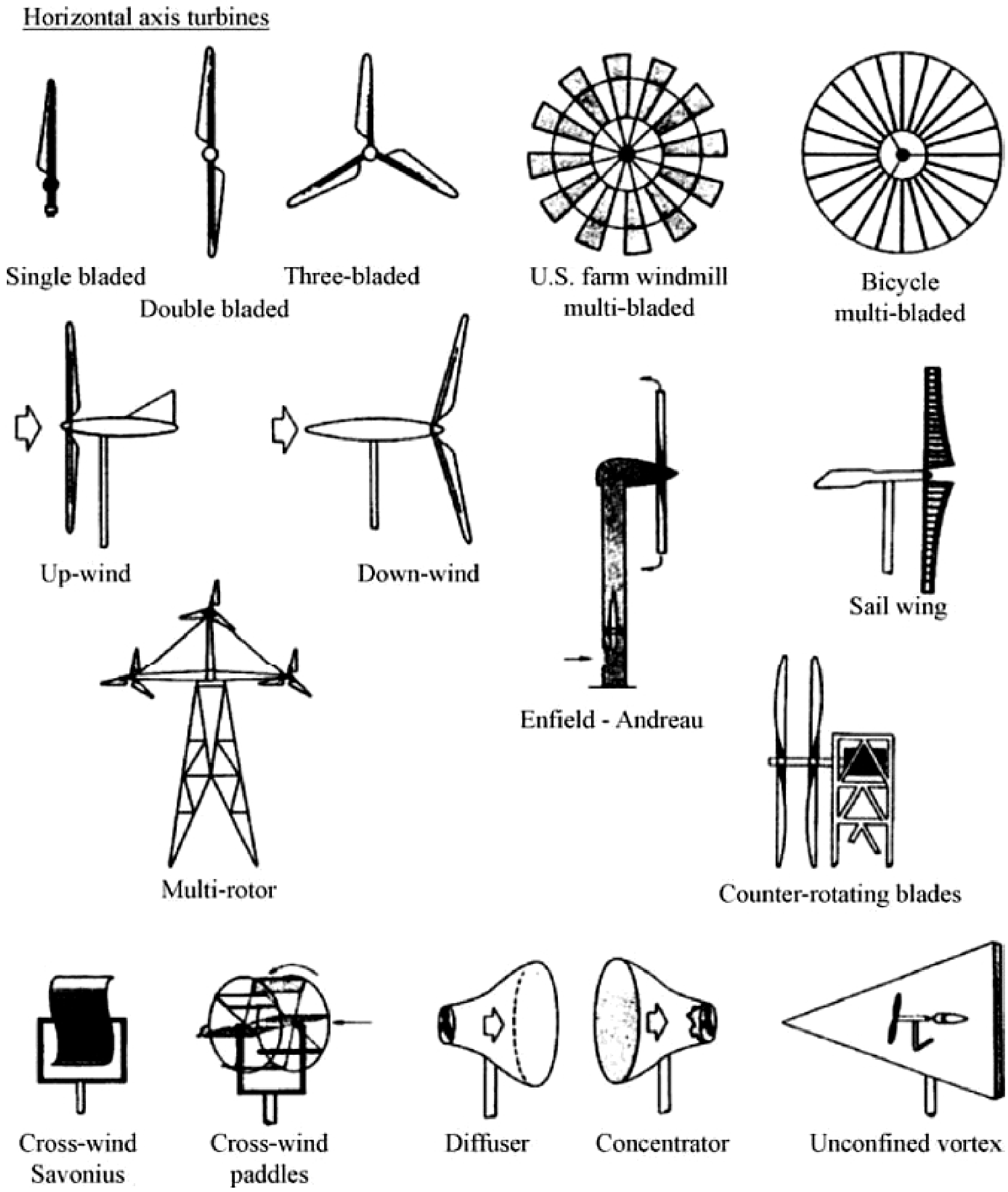

Figure 2.5: Various Designs of Horizontal-Axis Wind Turbines (Manwell et al, 2009)

Generally, a horizontal axis wind turbine consists of four main parts which is the base, tower, nacelle and blades. The parts of horizontal axis wind turbine are shown in Figure 2.6 below.

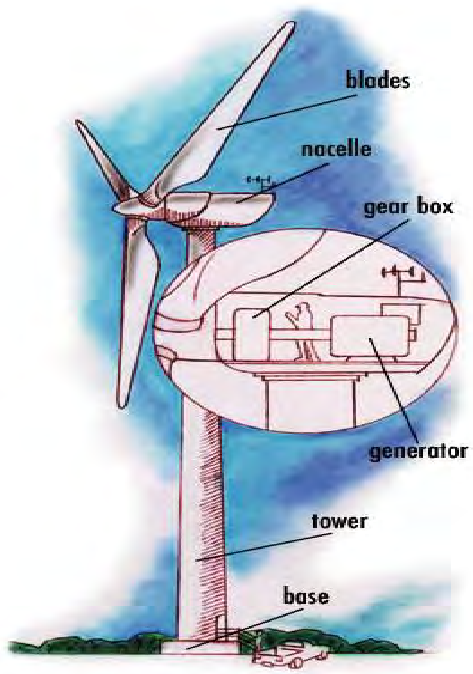

Figure 2.6: Main Parts of Horizontal-Axis Wind Turbine (www.ecw.org)

2.4.2.1 The Base

The base of the wind turbine is made of concrete strengthen by steel bars. The base is located on the ground to support the tower.

2.4.2.2 The Tower.

Referring to the wind gradient, the speed of wind increase with height which means the wind at higher altitude contains more energy. The horizontal-axis wind turbine is located on top of the tower to capture more energy from high velocity