THE EFFECT OF BLADE ANGLE AND ORIENTATION OF HORIZONTAL AXIS WIND TURBINE

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2022

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

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2022

DECLARATION

I thus declare that this thesis of the title "Effect of Blade Angle and Orientation of Horizontal Axis Wind Turbone", which was submitted to University Malaysia Sabah as part of the requirements for the Bachelor of Mechanical Engineering degree, has not been submitted for a degree to any other university. Except for quotations and summaries of sources that have been properly recognized, I further attest that the work described above is entirely my own.

JULY 2022

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CERTIFIED BY

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ACKNOWLEDGEMENT

First and foremost, I would like to extend my gratitude towards Dr. Mohd Kamel Wan Ibrahim for his patience and kind patronage, as well as the invaluable advice and suggestions as the supervisor throughout the commencement of this project. His kind guidance has been invaluable towards the completion of this thesis.

My sincere thanks to the examiners Dr. Mohd Suffian bin Misran @ Misaran and Dr. Wan Khairul Muzammil bin Abd Rahman for their critical inputs towards the betterment of this writing and taking the time to read this thesis.

I would also like to express my thanks to my colleagues who have been lent their helpful comments and suggestions into completing this project. A token of gratitude to the Engineering Faculty of Universiti Malaysia Sabah would be noted for the location of the experiment.

I would like to give a special thanks to my family and friends for the continual support and understanding of my undertaking in writing and completing this project. The moral support has been one of the backbones into finishing this thesis and kept me going throughout the project.

Lastly, I thank to God for allowing me into completing this project, as much as His grace has motivated me to finish the last leg into this journey.

ABSTRACT

Renewable energy is still an ever-expanding industry in power generation, especially in the tropical country Malaysia where solar power is prominent due to its geographical location. Wind power has been a challenge for power generation especially in a low wind speed area. Therefore, this study will try to generate power to at least power up a small device using wind power with a HAWT. The small scale HAWT would be tested with three blades and five blades at different blade lengths; 27cm, 32cm, 37cm, 42cm and 47cm, as well as different blade angle at angle 4.2˚,8.4˚,12.6˚ and 21˚. The wind speed of Kota Kinabalu area was also collected using the weather API with the month April recording the highest at 2.5m/s and lowest in February at 1.8m/s in the year 2022 across seven months December 2021-May 2022. The study recorded data of current, voltage, turbine rotation, and lastly wind speed in the controlled area for testing to determine the power output, coefficient of power and also tip to speed ratio from the blade length. The three blades HAWT recorded the highest power output at 1.42W from 42cm blade length (12.6˚ blade angle), at 0.3 efficiency where the five blades HAWT recorded its highest power output at only 1.07W using 27cm blade length (12.6˚ blade angle), at 0.5 efficiency.

Keywords: HAWT, blade number, blade lengths, blade angle, low wind speed, wind power, wind energy

ABSTRAK

Tenaga boleh diperbahurui adalah sebuah industry yang masih berkembang terutamanya di negara tropikal Malaysia di mana tenaga solar lebih kerap digunakan atas sebab lokasi geografi negara. Tenaga angin merupakan sebuah cabaran bagi pembuatan tenaga, terutama sekali di lokasi yang mempunyai kelajuan angin yang rendah. Oleh itu, projek ini akan fokus untuk menjana kuasa ke peranti yang kecil menggunakan HAWT. Projek skala kecil ini akan dipandu uji menggunakan tiga bilah dan lima bilah pada kepanjangan bilah yang berbeza; 27cm, 32cm, 37cm, 42cm, dan 47cm, tidak juga terkecuali pada sudut bilah yang berbeza iaitu 4.2°, 8.4°, 12.6°, dan 21°. Kelajuan angin Kota Kinabalu didapatkan darupada API cuaca tempatan yang merekodkan bulan April pada kelajuan angin 2.5m/s dan Februari pada kelajuan angin terendah 1.8m/s. Rekod ini diambil pada jangka masa tujuh bulan dari Disember 2021 sehingga Mei 2022. Keputusan nilau arus, voltan, rotasi turbin dan juga kelajuan angin juga diambil untuk mengenal pasti kuasa, pekali kuasa dan juga ratio kelajuan tip daripada panjang bilah turbin. HAWT tiga bilah merekodkan kuasa tertinggi dijana pada 1.42W menggunakan bilah 42cm pada sudut bilah 12.6° yang mempunyai kecekapan 0.3, berbanding daripada HAWT lima bilah yang merekodkan kuasa tertinggi dijana pada 1.07W menggunakan bilah 27cm pada sudut bilah 12.6° yang mempunyai kecekapan 0.5.

Kata Kunci: HAWT, jumlah bilah, panjang bilah, sudut bilah, kelajuan angin yang rendah, kekuatan angin, kuasa angin

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C_p - Coefficient of Power

ρ - Density of air = 1.2574kg/m^3

Re - Reynolds Number

LIST OF ABBREVIATIONS

AOA	-	Angle of Attack
DC	-	Direct Current
HAWT	-	Horizontal Axis Wind Turbine
LED	-	Light Emitting Diode
OPT	-	Optimum
PVC	-	Polyvinyl Chloride
RE	-	Renewable Energy
RPM	-	Rotations per Minute
UOT	-	Untapered and Optimum Twist'
UPVC	-	Unplasticised Polyvinyl Chloride
UUT	-	Untwisted and Untapered
VAWT	-	Vertical Axis Wind Turbine

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Civilization has been harnessing wind power for more than a millennia ago, from sea to land; of sailboats to windmills. Generally, wind power has been one of the more efficient alternatives for power generation especially in windy areas. A wind turbine converts the kinetic energy of the wind into electrical energy. The first known automatically operated wind turbine was dated as far as 1888, with a generation power of 12kW using 144 wooden blades made by Charles F. The development of the said source power was divided into at least three primary types; HAWT, VAWT Savonius and VAWT Darrieus. The installation location of the wind turbine will also affect the design of the device, where land-based wind turbines differ in sizes producing as low as 100kW as they are mostly gathered in a collective and most cost effective. Other than that, the offshore wind turbines are usually large in size to generate huge amount power from ocean winds while distributed wind turbines are smaller wind turbines generating power mainly below 100kW (Office of Energy Efficiency & Renewable Energy, n.d.).

A modern wind turbine uses odd numbered aerodynamically shaped blades to produce lift force on the blade, moving the rotation of the blades. Theoretically, using the concept of relative velocity on the wind turbine blade, the angle of attack increases when the rotational speed increase, and the angle of attack decreases when the wind speed against the blade increases. In short, the attack angle of the blade changes when the relative airflow to the turbine varies.

In Malaysia, the country plans to increase the RE capacity to 31% by 2025 (Malaysian Investment Development Authority, 2021), where most of the focus would be relying on solar power for its higher potential than wind power. There is slower development in wind power as there is no uniform wind blowing where the velocity of the wind is also affected by the monsoon season and its location, with an example of Kuala Terengganu averaging its wind speed from 1.7 m/s to 3 m/s (Saberi, Fudholi, & Sopian, 2018). On the other hand, such locations such as coastal areas in Sabah and the district of Kudat located on the northside of Sabah can be an strategic places for HAWT for small scaled plan (Ibrahim & Albani, 2014).

1.2 Problem Statement

Renewable energy in the country is still growing, where one of the largest potentials in energy generation is solar power. In Malaysia, the low wind speed on most areas and non-uniform wind velocity poses a challenge for the implementation of power generation when the mean wind speed is only at 4.5m/s max (Abdullah et al., 2019). Typically, a strategic location should be applied on the placement of wind turbines such as coastal areas to improve the wind speed, especially with the changing the monsoon season throughout the year (Albani et al., 2011) especially during the monsoon season. The lower pickup of a wind turbine will need to be sensitive enough to produce power output of a minimum of 4V to be able to charge a device. Hence, a sensitive HAWT to a lower wind speed at targeted above 1.5m/s would be needed to be fabricated.

Generally, to ensure the most power efficiency out of a wind turbine, an optimal blade angle will result in a higher rotational rotor speed. Relevant other factors affect the performance of a HAWT such as the speed-tip ratio where a higher force lift with a reduced drag force will maximise the performance of the HAWT, thus the longer blade may help with the power output. At certain angle of the blade will occur a phenomenon as stalling, as this happens when the AOA of the blade reaches critical angle, where this will affect the power output of the wind turbine to decrease. Therefore, experimentation of the HAWT to test the blade angle as well as the power output would be needed to be studied with different wind speed acting on the HAWT blades at different blade length.

Aside from that, this project would be focusing on the buildability of HAWT for other people for easy access of power generation, especially for those in limited access of power. The simple build of this HAWT design should also be applicable for simple power generation in small devices.

1.3 Objectives

This project has a few objectives to be achieved for optimal power generation output of the horizontal axis wind turbine. These are the following objectives of this research:

1. To measure the rotational speed of different angles of blade of a three-bladed design turbine to be compared with a five-bladed wind turbine, at different blade length.

2. To determine the effect of angle of blade and power output generated of the wind turbine.

1.4 Scope of Work

The project will be based on the past studies conducted for the different angle of attack on the horizontal axis wind turbine blade as well as the type of motor used for the rotor on the power output of the project. Introductory basics will be reviewed on the topic of renewable wind energy as well as references to the other small scale horizontal wind axis turbine in the literature review.

This project will be focusing on the experimental data obtained from the different blade lengths of the wind turbine, as well as the different orientation of the blade in three blade number and five blade number. The iterations of the experimental values were repeated to compensate for the volatility of wind in a closed room. The blades of the wind turbine would be using the same material with the same thickness but with different blade length. Each experimental trials would be recorded its no load voltage before the load (LED or battery) is connected to the circuit. The current and voltage after the load was connected would also be recorded, while the wind speed recorded would be using anemometer. Rotations of the wind turbine would also be assessed at the end of the blade length, and from the current and voltage output obtained the power output can be recorded.

From the different blade angle of attack recorded from the trials, the power output will be then compared to when the voltage reached the minimum 4V to power up the load (LED).

1.5 Research Methodology

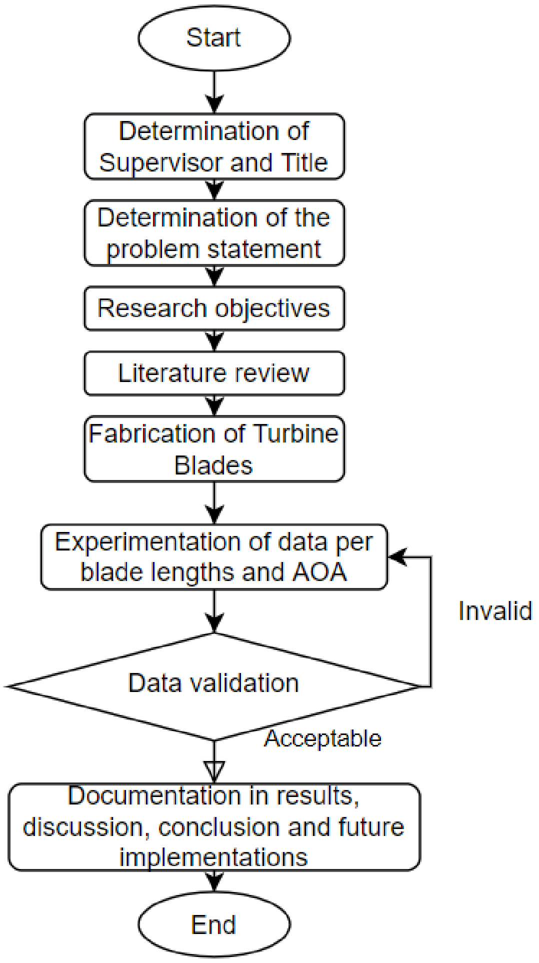

Figure 1.1 : The project flowchart.