ABSTRACT

Abstract of project report presented to the supervisor and examiners of Universiti Putra Malaysia in partial fulfilment of the requirement for the degree of Master of Innovation and Engineering Design

CONCEPTUAL DESIGN OF WIND ACCELERATING DEVICE FOR SMALL VAWT

By

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A conceptual design of wind accelerating device was developed for small VAWT wind turbine with the objective of improving incoming wind speed before reaching and subsequently hitting the turbine blades. Low wind speed particularly in Malaysia need to overcome in order to improve the wind turbine efficiency in harvesting potential wind energy into electricity. In this thesis, the Theory of Inventive Problem Solving (TRIZ) was used in order to produce an idea in generating solutions to the problem. TRIZ contradiction matrix and 40 inventive principle solution tools has been applied in the early stage of solution generation. Based on the general solutions, the most relevant principles with respect to the design intent are selected as a guideline to develop the device. Two different concepts with working condition similar to wind vane are designed using CAD software (CATIA), focussing particularly on the main part namely head of the wind accelerating device. In

addition, the device is also designed with the intention of sharing the same pole of the VAWT wind turbine. The performance of the device was further analysed using CFD method (ANSYS) with various wind speed with the aim of increasing incoming wind speed after passing through the wind accelerating device.

Abstrak laporan projek yang dikemukakan kepada penyelia dan para pemeriksa Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan untuk ijazah Master Inovasi dan Rekabentuk Kejuruteraan

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Satu reka bentuk konsep peranti mempercepatkan angin telah dibangunkan untuk turbin angin VAWT yang kecil dengan matlamat untuk meningkatkan kelajuan angin yang masuk sebelum menghampiri dan kemudiannya memukul bilah turbin. Kelajuan angin rendah terutamanya di Malaysia perlu diatasi untuk meningkatkan kecekapan turbin angin dalam penuaian tenaga angin yang berpotensi menjadi tenaga elektrik. Dalam tesis ini , Teori Penyelesaian Masalah Inventif (TRIZ) telah digunakan untuk menjana idea dalam menghasilkan penyelesaian kepada masalah. TRIZ matriks percanggahan dan 40 alat penyelesaian prinsip berdaya cipta telah digunakan dalam peringkat awal penyelesaian kepada masalah. Berdasarkan penyelesaian umum, prinsip-prinsip yang paling relevan dengan niat reka bentuk dipilih sebagai satu garis panduan untuk membangunkan peranti. Dua konsep yang berbeza dengan keadaan bekerja menyamai penunjuk angin ini direka menggunakan perisian CAD (CATIA), tumpuan khususnya kepada bahagian utama iaitu kepala kepada peranti mempercepatkan angin. Di samping itu, peranti ini juga direka

dengan niat untuk berkongsi tiang yang sama daripada turbin angin VAWT. Prestasi peranti ini seterusnya dianalisis menggunakan kaedah CFD (ANSYS) dengan kelajuan angin masuk yang pelbagai dengan tujuan untuk meningkatkan kelajuan angin masuk selepas melalui peranti mempercepatkan angin.

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Alhamdulillah, praise to Allah S.W.T. for giving the author the patience to be able to finally complete this project after going through all the challenging moments.

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This thesis is dedicated to the author's beloved parents, wife, sons and daughter for their moral support.

APPROVAL SHEET

I certify that an Examination Committee has met on Januart 23rd, 2014 to conduct the final project presentation of **AHMAD NIZAM BIN JAMALUDIN** on his **Master Degree of Innovation and Engineering Design** project entitled "**Conceptual Design of Wind Accelerating Device for small VAWT"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for my other degree at Universiti Putra Malaysia or other institutions.

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AHMAD NIZAM BIN JAMALUDIN

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NOMENCLATURE

LATIN SYMBOLS

A	Cross sectional area
v	velocity
ρ	Density of fluid
g	Acceleration constant
h	Height
P_a	Fluid pressure
P	Power
mm	Millimetre
m/s	meter per second
%	Percentage
W/m^2	Watt per meter square
GW	Gigawatt

LIST OF ABBREVIATONS

HAWT	Horizontal Axis Wind Turbine
VAWT	Vertical Axis Wind Turbine
3D	Three Dimensional
CAD	Computer Aided Design
CATIA	Computer Aided Three-dimensional Interactive Application
TRIZ	Theory of Inventive Problem Solving
CFD	Computational Fluid Dynamics
ANSYS	Analysis System
GWEC	Global Wind Energy Council
ARIZ	Algorithms of Inventive Problem Solving
FMEA	Failure Mode and Effect Analysis
QFD	Quality Function Deployment
AHP	Analytic Hierarchy Process

CHAPTER I

INTRODUCTION

1.1 Introduction

Wind is a clean and renewable source of energy and has fewer impact on environmental as compared to other energy sources. Nowadays, green or sustainable energy becomes very popular topic due to earth's natural source of energy is getting expensive and the source are getting lower and lower due to high usage. The development of wind turbine grows rapidly and has been used in developed countries to produce an alternative energy. Wind turbine uses free wind captured from its surrounding and converted the kinetic into electrical energy. Wind turbine can be divided into two categories determined by the position of the rotating shaft of the wind turbines. Generally, there are two type of wind turbine called HAWT (Horizontal Axis Wind Turbine) and VAWT (Vertical Axis Wind Turbine).

Even though there is no doubt the sustainable energy is very important for developing country like Malaysia, the efficiency of the wind turbine generating electricity is depending on the location of the wind turbine itself. Generally wind turbine need a suitable place as the physical properties of the land differs from one place to another. Wind in urban areas is very low as compared to rural areas because of it surrounding. Buildings affect the wind due to their size, shape and spacing in between building. Tall buildings provide frictional drag on the air movement and will creates turbulence, which gives rapid changes in wind direction and speeds of the wind.

1.2 Problem Statement

Wind in Malaysian is generally light and unsteady, as most of the mainland experiences low wind speed which is less than 4 m/s for more than 90% of total wind hours (Chong, Fazlizan, Poh, Pan, & Ping, 2012a). Vertical Axis Wind Turbine is said to be one of the ways to overcome this problems due to its advantages of able to operate with low wind speed and able to rotate from any wind direction as compared to Horizontal Axis Wind Turbine. The cut-in speed or the speed at which the turbine first starts to rotate and generate power is typically between 3 and 4 metres per second. The current wind turbine in the market today is designed for high wind speed and this will complicates the application of wind turbine in Malaysia. Thus, wind energy generation using wind turbine need to overcome this disadvantage.

Power output generated by wind turbine is proportional to the wind speed cubed. The possibility to create a slight improvement of the approaching wind before it reach to a wind turbine could increase a significant output of wind velocity. The power output of the wind turbine can be increased substantially by utilizing the nature of fluid dynamic on the local wind velocity. Therefore, it is essential to integrate wind turbine systems with wind accelerating device for low windy areas. This, the focus of the study is to introduce a conceptual design of wind accelerating device that can improve the wind speed for Vertical Axis Wind Turbine.

1.3 Objectives of the project

The objectives of this project are:

i. to design a wind accelerating device for small VAWT

ii. to investigate the effect of the wind accelerating device towards local wind velocity before approaching the turbine blade

1.4 Scope of the project

The conceptual design of wind accelerating device will be developed in order to achieve the stated objectives; the scopes that need to be considered are as follows:

i. To determine the wind velocity value for Malaysia areas

ii. To generate a design in 3D CAD model of the wind accelerating device using CATIA software

iii. To apply TRIZ methodology towards problem solving in concept design development of wind accelerating device

iv. To observe the distribution of local wind velocity in between the wind accelerating device and wind turbine using flow analysis (CFD method)

1.5 Thesis Layout

This thesis consists of six chapters:

i. Chapter I: Introduction

   The chapter briefly describes about the introduction of wind energy and wind accelerating device for VAWT, the problem statement, the objectives and the scope of study for this project.

ii. Chapter II : Literature Review

   Chapter II consists of the numerous aspects about the project. It is discussing the classification, advantages and disadvantages of wind turbine, wind turbine in urban areas, wind energy resources in Malaysia, previous research to improve wind turbine efficiency and application of TRIZ in problem solving..

iii. Chapter III : Methodology

   In this chapter, the flow chart of the project is illustrated and described generally. The flow chart starts with literature review, application of TRIZ in problem solving, 3D modelling, CFD analysis and finally the final concept design.

iv. Chapter IV : Result and Discussion

   Chapter IV consists of the result carried out from application of TRIZ methodology towards the generation of conceptual design of wind accelerating device. The device was then developed using CATIA software.

CFD analysis to evaluate the velocity performance with the aim of increasing wind speed after passing through the proposed design will be obtained using ANSYS software. The result of the outlet velocity from the device and potential energy that could be harvested by VAWT wind turbine is discussed and the percentage of improvement is estimated.

v. Chapter V : Conclusion

Chapter V concludes the results and discussions of this project, towards achieving the objectives. Some recommendations are included for future study purposes.

CHAPTER II

LITERATURE REVIEW

2.1 Wind Turbine

2.1.1 Introduction

Renewable energy resources has been around for decades and now becoming the popular source of energy due to recent world energy crisis and global emission of gases emitted by human activities. There are different renewable energy resources including biomass, solar, geothermal, and hydroelectric and wind. The kinetic energy from the wind can be converted into electrical energy by using a device called wind turbine. Apart from sustainable supply of energy, wind power is clean and cheap, thus causes the rapid growth of the use of wind power as an alternative source of energy to countries like Europe, Asia and North America (Alnasir & Kazerani, 2013).

Extensive research by universities, companies and research institution has led the development of numerous innovative designs of wind turbine for generating electrical energy. According to Global Wind Energy Council (GWEC), 44GW capacity of wind turbine has been installed all over the world in 2012 (Anonymous, 2013a). Asia has a lot of potential to grow and China are targeting to installed 150 GW of wind power by 2020 (Anonymous, 2013b). Table 1 shows the recent deployment growth compared with clean energy targets (Roy & Saha, 2013).

Technology	Current rate (%)	Required annual growth to 2020 (%)	Current status (GW)	Blue map target 2020 (GW)
Biofuel	18	7	2.54 (EJ)	5.04 (EJ)
Biomass	7	4	54	82
Hydropower	5	2	980	1219
Solar PV	60	19	21	126
Wind power	27	12	195	575
Energy intensity of manufacturing	−1.30	−0.60	3.73 (MJ)	3.81 (MJ)
Geothermal power	4	7	11	21
Nuclear power	3	4	430	512
CSP	8	50	0.6	42
Electricity generation with CCS	Zero projects	3 (GW per year)	Zero projects	28

Table 1 : Recent deployment growth compared with clean energy targets (Roy & Saha, 2013)

2.1.2 Classification, Advantages and Disadvantages of Wind Turbine

Wind turbine can be classified according to horizontal or vertical of shaft or rotor orientation. At present there are two primary types of wind turbines namely Horizontal Axis Wind Turbine (HAWTs) and Vertical Axis Wind Turbine (VAWTs). Historically, VAWTs itself has two different type of turbine with different operating principle. Darrieus turbine uses a lift forces, whereas the drag force acting on the blade of Savonius causing the rotor to rotate, hence generate electricity (M. Islam, Ting, & Fartaj, 2008). Figure 1, 2 and 3 illustrates the types of VAWTs.

Among the differences between these two types of turbine, VAWTs are design for low wind speed without yaw mechanism (Ross & Altman, 2011), operating with wind from any direction and mounted with the rotating shaft in vertical direction. Although HAWTs is well known as a common type of wind turbine, another merits factor of VAWTs is due to the economical factor such as low cost, easy installation and maintenance (Feng, Li, Li, & Xu, 2012). Table 2 summarizes the comparison of VAWTs and HAWTs of their advantages and disadvantages (Aslam Bhutta et al., 2012).

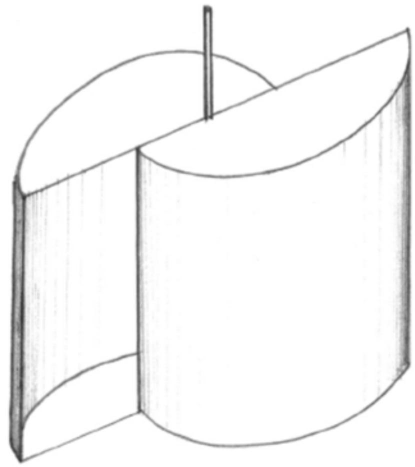

Figure 1 : Savonius VAWTs (M. Islam et al., 2008)

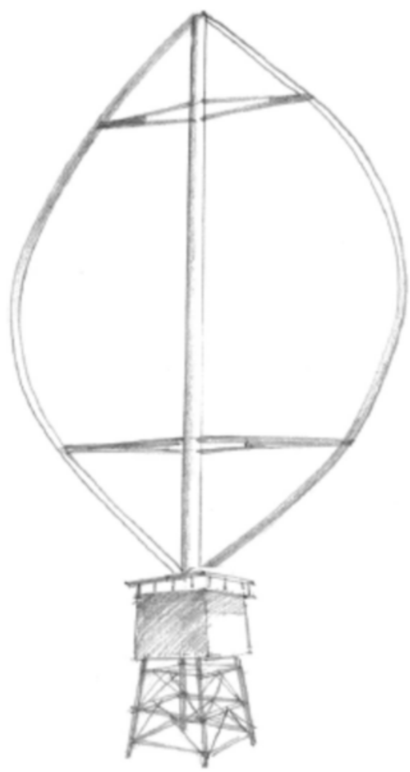

Figure 2 : Curved-bladed Darrieus VAWTs (M. Islam et al., 2008)