DESIGN AND DEVELOPMENT OF WIND ENERGY CONVERSION SYSTEM AND POWER INTEGRATION FOR SMALL SOLAR VAWT

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2015

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

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2015

DECLARATION

I hereby declare that this thesis, submitted to University Malaysia Sabah as partial fulfilment of the requirements of the Degree of Bachelor of Mechanical Engineering. This work has not previously been submitted for any degree or diploma in any university. I also certify that the work described herein is entirely my own, except for quotations and summaries sources of which have been duty acknowledged.

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08 JUNE 2015 Robin Low Chong Eu

CERTIFIED BY

Mr. Chua Bih Lii

SUPERVISOR

ACKNOWLEDGEMENT

Foremost, I would like express my gratitude to my Final Year Project Supervisor, Mr. Chua Bih Lii for his continuous support, patience, guidance, enthusiasm and immense knowledge throughout the project. Problems and questions faced along the project that raise to him have been replied with patience and sighted direction. These continuous effort have enable me to complete the project that required various work, research and dedication.

Besides my supervisor, I would like to send my appreciation to my partner in this group project, who are Mr. Hong Yong Shen and Mr. Tan May Chan. This project required large amount of work and implementation. Without all the efforts from my group partner in handling various part of the project as well as completing the project as a team work, this project will not be able to even carry out. Thanks also to Mr. Hong Yong Shen for his immense support in providing transportation whenever needed.

My sincere appreciation also goes to Mr. Kit Guan for the effort in borrowing the necessary tools and application from Universiti Laboratory for the completion of my project. Much of the work and testing would not be able to done without the help from him.

It is also very important for me to have all the moral support, motivation, commitment and inspiration from my parents, friends, course mate and everyone that are related whenever I was in difficulty in the project.

At the end, would like to send my appreciation to all the lecturers for their eternity influence and knowledge that have been given all the time throughout my study in University Malaysia Sabah.

THANK YOU

ROBIN LOW CHONG EU

JUNE 2015

ABSTRACT

Solar energy is considered as one of the most consistent green energy in our country with the regular sunny days in Malaysia and the condition of weather here is good throughout the year. Besides, Malaysia does have winds of approximately 10 to 20 knots (approximately 5.14 to 10.29 m/s) of wind speed energy but it is dependent on the monsoon season and sea breeze. Thus both the solar and wind power will be integrate together in the project. In the project, it is important to know how system should works when lack of either source of energy so that losses in integration would be minimize. The problem in integrating is the suitability of connection and how to minimize the losses. Thus the objective of the project is to design and develop a wind energy conversion system for solar VAWT and to integrate wind and solar power as a hybrid system that can function concurrently. To start all the work, review have been made on various sources so that the direction of the project is specified. Then, the work that carried out are the conceptual design that includes the transmission for energy conversion, size and type of generator, solar panel specification in terms of suitability as well as the integration of power with consideration on the local weather condition. Then appropriate material and application are used to fabricate the project prototype so that testing are able to be done. The generator used is the normal dc motor generator, whereas chain drive is used as the energy extraction. Circuit design is done between solar and wind power system with addition of diode to further improve the performance of the system. With the prototype done, testing and analysis through site have been carried out with the result of parallel circuit with blocking diode as the better circuit for this prototype. Site test purpose is also to show that the system are able to work as according to design and targeted location. Through laboratory test, the parallel circuit is further analyse on its characteristic on various controlled environment. The results shows that the system are able to integrate both solar and wind power system at similar power output range and performance is lowered when the power output range varies in large amount. The results is plotted into graph where intersection shows the range at which the performance rate changes. However the power dissipation is still low for solar panel whenever the variation of power output is large. The generator itself also shows that the efficiency grows higher as the rpm. The generator performance have not reached its optimum as well. The testing for integration shows that efficiency of the generator reached maximum at 39.3% at wind speed 4m/s. Thus there's room of improvement that can be done on the future work.

ABSTRAK

Tenaga solar adalah dianggap sebagai salah satu tenaga hijau yang paling konsisten di negara kita kerana keadaan hari yang sentiasa cerah di Malaysia dan keadaan cuaca di sini adalah baik sepanjang tahun. Selain itu, Malaysia mempunyai kelajuan angin antara 10 hingga 20 knot (kira-kira 5.14-10.29 m/s) yang bergantung kepada musim tengkujuh dan angin laut. Oleh itu kedua-dua kuasa solar dan angin akan diintegrasikan dalam projek ini. Dalam projek ini, amatlah penting untuk mengetahui proses atau cara untuk sistem berfungsi secara sepatutnya, perkara ini amatlah penting disebabkan oleh kemungkinan berlakuya kekurangan salah satu sumber tenaga yang disebut dan keupayaan integrasi adalah untuk mengurangkan berlakunya pembaziran tenaga. Masalah dalam mengintegrasikan system ini adalah kesesuaian sambungan dan bagaimana untuk mengurangkan tahap pembaziran tenaga. Oleh itu, objektif projek ini adalah untuk merekabentuk dan membangunkan sistem penukaran tenaga angin serta solar VAWT dalam menyepadukan angin dan kuasa solar sebagai sistem hibrid yang boleh berfungsi serentak. Bagi memulakan kerja dalam projek ini, kajian yang mengenai serta menyeluruh telah dibuat supaya arah tuju projek dapat dinyatakan secara terperinci. Seterusnya, kerja-kerja yang dijalankan adalah rekabentuk konsep yang merangkumi penukaran tenaga dalam sistem penghantaran kuasa, saiz dan jenis generator, spesifikasi panel solar dari segi kesesuaian dan juga integrasi antara kuasa dengan pertimbangan keadaan cuaca tempatan. Selain itu, bahan dan aplikasi yang sesuai telah dipilih serta digunakan dalam pembuatan prototaip projek dan ujian yang diperlukan telah dijalankan. Penjana digunakan dalam projek ialah penjana motor dc, manakala pemacu rantaian telah digunakan sebagai system penghantaran tenaga. Reka bentuk litar juga dilakukan antara sistem integrasi antara solar dan angin dengan penambahan diod bagi meningkatkan lagi prestasi sistem. Dengan prototaip yang telah dihasilkan, ujian dan analisis melalui ujian di tapak telah dijalankan dan keputusan ujian menunjukkan bahawa litar selari dengan diod penyekat adalah litar yang lebih sesuai untuk prototaip ini. Ujian di tapak juga menunjukkan bahawa sistem ini dapat berfungsi di lokasi yang disasarkan. Melalui ujian di makmal, litar selari dapat dianalisis dari segi sifatnya dalam pelbagai persekitaran terkawal. Keputusan ujian di makmal menunjukkan bahawa sistem ini dapat mengintegrasikan kedua-dua sistem kuasa solar dan angin pada jarak pengeluaran kuasa yang agak sama manakal prestasi akan menurun apabila pengeluaran kuasa berbeza jauh antara satu sama lain. Keputusan ujian telah dihasilkan dalam graf dan persimpangan dalam graf menunjukkan julat perubahan bagi kadar prestasi. Walau bagaimanapun pelesapan kuasa masih rendah untuk panel solar yang menghasilkan pengeluaran kuasa yang tinggi. Penjana turbin juga menunjukkan sifat di mana kecekapan penjana akan meningkat bersama dengan rpm dan penjana tersebut belum lagi mencapai optimum. Ujian untuk integrasi juga menunjukkan bahawa kecekapan penjana dapat mencapai maksimum prestasi pada 39.3% dengan kelajuan angina pada 4m/s. Ini menunjukkan bahawa terdapat ruang penambahbaikan untuk projek ini.

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LIST OF SYMBOLS

A	Area
C	Center distance between sprockets
C_p	Power coefficient
D	Diameter
D_1	Diameter of Driver Sheave
D_2	Diameter of Driven Sheave
L	Chain Length
p	Chain Pitch
P	Power
n_1	Driver Sprocket Speed
n_2	Driven Sprocket Speed
N_1	Number of Teeth for Driver Sprocket
N_2	Number of Teeth for Driven Sprocket
V_w	Wind velocity
Θ_t	Tilt Angle
Θ_a	Azimuth Angle
ρ	Density
τ	Torque
ω	Angular Velocity

CHAPTER 1

INTRODUCTION

1.1 Overview

The usage of green energy has been getting more popular and turning into trend lately. Research and development on green energy have been ongoing for a while and the awareness on its advantages towards the environment is well known. The examples of green energy which are able to utilize for extraction of energy are the wind, tide, solar, hydro and so on. In Malaysia, research and development on this alternative energy are well encouraged. However due to various constraint of geographical issue such as low wind speed, weak water tide speed and others, development on the green energy have to be narrow down to limited selection of field.

Much of the available energy sources are believed to have the potential for development but not widely used yet in Malaysia. There are several factors that might contribute to this phenomenon, for example the climate and geographical suitability. In some research and development, to overcome the constraint on relying to only single energy source, obtaining two energy sources from a single system is presume to have more reliability with greater or even more consistent input of energy.

Solar energy is considered as one of the most consistent green energy in our country with the regular sunny days in Malaysia and the condition of weather here is good throughout the year. Even if its rain, it doesn't last for very long period where it would be totally non-productive for solar energy. According to the Mekhilef *et al.* (2012),

solar energy in Malaysia does have approximate monthly output of around 400-600MJ/m^2. These values can reach even higher during Northeast monsoon and it would fell during Southwest monsoon. According to Malaysian Meteorological Department (2013), solar energy in Malaysia has average of 6 hours sun shine per day and is seasonal dependent. This would be the constraint for continuous and supply of energy during the night time.

Besides, Malaysia does have winds of approximately 10 to 20 knots (approximately 5.14 to 10.29 m/s) of wind speed energy but it is dependent on the monsoon season and sea breeze. The wind energy varies according to places such as seaside, hills and mountain area, land and even varies according to height. Wind power production is dependent on the type of wind turbine. Vertical axis wind turbine (VAWT) is selected as the design rather than the conventional horizontal axis wind turbine (HAWT), mainly is due to wind direction flexibility in capturing wind energy. VAWT have two common types, which is the Savonius type wind turbine and Darrieus type wind turbine. According to Clean Technica (2014), "Savonius style turbines are basic drag machines. They typically have rounded paddles which catch wind in the cup and shed in on the rounded front, allowing the difference in drag to rotate the turbine.", "Darrieus style vertical axis wind turbines have aerodynamic blades which fly through the wind on their power strokes as they rotate around a shaft." Basically, what it means is that Savonius style turbine utilize wind drag to rotate its blade and Darrieus style turbine utilize Bernoulli's principle and aerodynamic to rotate its blade.

The two energy sources mentioned above do have respective constraints but on the other hands, these two energy sources seems to be able to fills the gap of each other. The two energy source of wind and solar seems to provide solution in both of the green energy power production system where theoretically combination of solar and wind energy into a single generator would be able to produce more energy or in

a more consistent production during the day time and night time. The system would be able to works whenever either one is lack of energy source through increasing the input of the system where more energy can be obtained. This project therefore, is to investigate the viability of such hybrid systems in Malaysia, particularly in Kota Kinabalu town and followed with localization of the prototype to meet the geometrical condition in Kota Kinabalu. Basically the idea is to design the hybrid system of vertical axis solar wind turbine which able to work concurrently whenever solar or wind power sources are available.

1.2 Problem Statement

In this project, the main focus of the design is a system that can be used in Kota Kinabalu. Thus, it is important to first investigate the wind condition as well as solar radiation condition as well. These are the surrounding condition that will affects the input and output of the system. The consideration on the condition of weather particularly in Kota Kinabalu, Malaysia in terms of sunlight and wind condition must be used for designation reference so that the design of the system is able to work best under the local weather condition.

In the design of integration of solar VAWT, there's several aspect which must be considered. The method of extracting power from available sources in terms of conversion of power as well as to integrate the available power. In solar aspect, the consideration that can be taken is the angle of solar absorption and its efficiency varies according to angle. Wind turbine would need to consider on the method to convert the wind power into electrical power which is at same form as the solar power output. Selection of available item and specification will then need to suit the design. Besides, it is important to know how system should works when lack of either source of energy

so that losses in integration would be minimize. At the end of the design, the system with higher output on the power output of integration can be determine.

1.3 Objectives

The main objective of this project is to design and develop a hybrid system of solar and VAWT.

i. To design and develop a wind energy conversion system for solar VAWT.

ii. To integrate wind and solar power as a hybrid system that can function concurrently.

1.4 Scope of Work

Scope of work which is systematic, clear and well planned is critical and must be well considered in order to achieve all the objectives stated and well on time. The following are the planned scope of work:

i. Research and studies on the working principle of vertical axis wind turbine, working principle of solar panel and solar integration knowledge.

ii. Collections of data which includes the weather condition in Malaysia throughout the year through reliable source such as Weather Department Malaysia.

iii. Design on the wind energy conversion method as well as solar integration on the system.

iv. Calculation and analysis to be included on the wind energy conversion and solar panel application onto the integration design.

v. Selections of material where this is the simultaneous process between calculation and selections of material and application.

vi. Acceptance evaluation on the design and calculation with satisfaction on the targeted design.

vii. Fabrication such as machining on the materials and assembly on parts.

viii. Testing to obtain results and analysis of the prototype is to obtained once it is fabricated.

ix. Documentation of the results and analysis through discussion.

x. Conclude the project throughout the work done and suggest on future works for improvement.

1.5 Methodology

The important criteria before accomplishing this project of design and development of solar vertical axis wind turbine, is to have a systematic methodology which able to describe clearly the steps which are to be taken.

i. Research and Studies

Identification of the problem through research and studies are the vital steps to begin this project. The major studies on the project such as the types of vertical axis wind turbine, it's background, major component in the design, working principle of the solar vertical axis wind turbine as well as various forms of integration design and following design knowledge must first be identified and work it out in steps. These studies and researches must be done thoroughly in order to managed the design well and have good handling in the design concept. It affects the idea and plans ahead of the projects

in terms of the calculation aspect especially on the suitability of methods for energy conversion and integration. With a proper and thoroughly review, it could give various kind of ideas and saves a lot of time in producing a suitable design.

ii. Collections of Data

Then this project will need to have collection of data required such as weather condition in Malaysia throughout the year. Estimation can be done better with longer period of data as it covers better pattern and characteristics of data. It is important to understand the behavior of the wind as well as sunlight condition in Kota Kinabalu throughout the year so that the system designed are able to perform at the optimize condition and shows greater flexibility and covers more consideration.

iii. Calculation, Design and Selection of Material

These calculation, design and selection of material are a series of simultaneous work where this project is a calculation based system. Proper usage of method for energy conversion in selecting the application through calculation is needed. Calculation that are involved are the transmission for energy conversion, size and type of generator, solar panel specification in terms of suitability as well as the integration of power with consideration on the local weather condition.

iv. Acceptance

Analysis are to be done onto the calculated design so that to evaluate the acceptability of prototype according to require design before fabricating it, as well as making further modification on the prototype which to removes possible occurring error and issues. This step is to further improve the existing calculation and design as well as anticipate

problem that will surface. With the possible estimation on the outcome of the system, only further process will be move on.

v. Fabrication

Fabrication is the part where buying of parts, works of machining, material handling and assembly to be done. Designs and modification must have been done several times where sufficient of data and calculation has been made, then only the fabrication, with material selected is made. Assembly of all the parts from fabrication is done at the last stage of this step.

vi. Results and Analysis

Results and analysis are then to be done once the prototype is fabricated. A collection of data on the performance on the system and testing are carried out. Observation on the performance varies according to various environment condition so that a complete and variety data can be obtained as well as to analyze the workability of the project.

vii. Documentation

This step is to have the arrangement of the result and analysis done into a proper document. Thesis writing would be the documentation needed in the project where it includes all the parts done in the previous step. It would acts as the conclusion and future development of documentation as well.

viii. Group Work

One of the most important work is to collaborate with partners in order to design and fabricate this system. Works are to be distributed and collaborate in individual parts to design and develop a complete solar VAWT system. Time and scheduling between partners are the vital part as the development of project is works as stages by stages and works must be done simultaneously.

The following figure 1.1 is the flow chart of methodology. It shows the flow of how does the project should go according to steps.

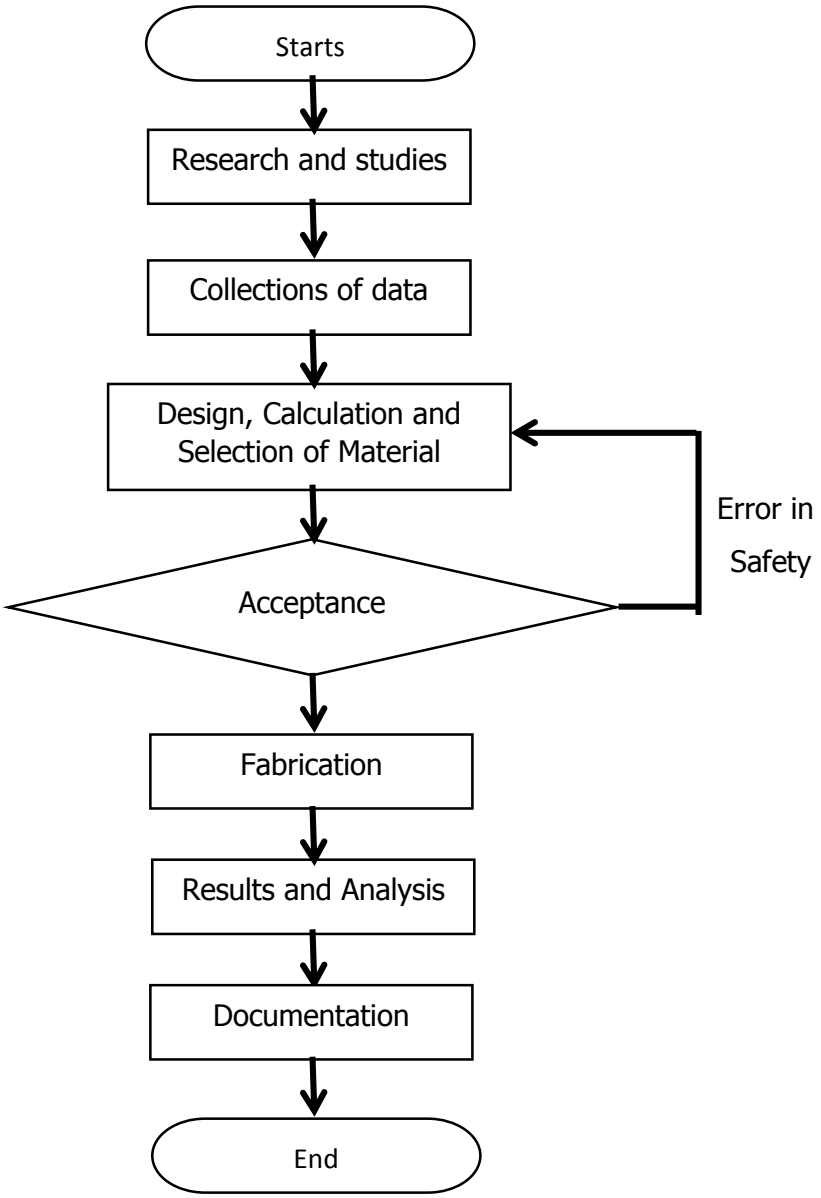

Figure 1.1 Flow Chart of Methodology