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DESIGN AND DEVELOPMENT OF SMALL SCALE WIND TURBINE FOR LOW POWER APPLICATION USING AUTOCAD

Norsuzilawati binti Hussin

Thesis submitted in fulfilment of the requirements for the award of the degree of
Bachelor of Engineering Technology in Electrical

Faculty of Engineering Technology (Electric & Electronic)
UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2021

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of degree of Bachelor of Engineering Technology in Electrical.

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Finally, my senior design project is done and thanks to my group member, Muhammad Sarif bin Azri and Arvin Kumar A/L Ravi. The contribution of each of them is very important in order to complete this project.

ABSTRACT

Awareness about the important of renewable energy such as solar, wind and geothermal as a primary alternative to non-renewable energy sources has been increase among the world society. Many country like United Kingdom, Spain, United State of America and Japan has started to develop a renewable technology especially wind energy in order to supply electricity to their citizen. In Malaysia the wind energy is not widely used for power generation as the average wind speed which is about 3-6 m/s (East Coast region) make it not very efficient for large scale of power production. However, a small scale of wind turbine can be used to generate an electricity from a low wind speed. This small capacity of electricity that generated by the wind turbine can be useful to many situation. For example, during an emergency or disaster where there is a shortage in electrical supply, the small scale wind turbine can be used to charge up a telecommunication device such as phone to make an emergency call at the disaster area. Other than that, the small scale wind turbine can also be utilize at rural area where there is no electrical supply to power up a small device.

On the surface of the Earth, wind consists of the bulk movement of air. The wind is also important for uses of transportation for seeds and small birds, with time things can travel thousands of miles in the wind. Wind is important to humans because wind energy is a source of renewable energy. It does not contaminate, it is inexhaustible and reduces the use of fossil fuels, which are the origin of greenhouse gasses that cause global warming. Wind energy does not generate waste or contaminate water which is extremely important factor given the scarcity of water.

In this project, our group want to build a small scale wind turbine. Below are the specifications of this small scale wind turbine.

Voltage produce	: 3-5 volts VAC
Type of current	: Direct current (DC)
Generator	: DC generator

Application	: Small appliances
Circuit	: Boost converter

The purpose of this project is to design and develop a small scale wind turbine for low power appliances using AutoCAD that is compatible with small dc generator for small appliances purpose. The combination of the wind turbine with the motor application is to make the function of the whole product and design become more efficient in term of their function as a small scale wind turbine. The design research begin with the study about the type of wind turbine, characteristic of wind turbine, review on wind speed in Malaysia and current trend of small scale wind turbine. Next, the methodology of designing was made by construct the morphology chart in to choose the design criteria for the wind turbine.

TABLE OF CONTENTS

LIST OF SYMBOLS

SBPWM	Simple Boost Pulse Width Modulation
ZSI	Z source inverter

LIST OF ABBREVIATIONS

SBPWM	Simple Boost Pulse Width Modulation
ZSI	Z source inverter

CHAPTER 1

INTRODUCTION

1.1 Project Background

The use of wind turbines for electrical power generation has been around for over one hundred years. Recent worries about the cost and environmental effects of fossil fuels have spurred the proliferation of wind turbines across a wide variety of industries. A large range of commercial wind power systems are commercially available today.

The work of a wind turbine is like a fan, except a fan uses electricity to create wind, but wind turbines turn the blade that spins a shaft, then connects to the generator and eventually produces electricity. This chapter is dedicated primarily to the design of turbine systems for low wind speeds. I concentrate on smaller turbines, as the available power in the wind is substantially lower at low wind speeds.

In order to develop this project, I need to make major improvements to the wind turbine to achieve the project goal.

There are two types of blades:

The horizontal axis design (HAWT) and the vertical axis design (VAWT). In our project we use HAWT type. It is because this type is more practical and it also easy to find at the store, the HAWT enjoys more attention than its sibling, the VAWT.

The HAWT has its main rotor shaft at the top of the column along with the electrical generator. The turbines must be pointed into the wind and is positioned favourably by either a small weathervane or a wind sensor. This makes it more accessible for maintenance and other necessary adjustments

As the wind turns the blades of the turbine they, in turn, turn the shafts running down the tower and are connected to a generator. The working of the shafts and the friction of the turning shafts link into the generator which then converts the energy created by the wind turbine into the useful electricity that is needed.

Windmills works in 3 parts :-

1) Blades (the parts that look like fan) - "catch" the wind. Sitting at a slight angle to the direction of the wind, the blades are pushed in a circle as the wind blows against them.

2) Hub of the windmill – like the hub of a wheel, with the fans sticking out likes spokes around it. Then the fans turn the hub as they move in a circle.

3) The part where hub is attached to the shaft, which spins as the hub spins. The shaft is connected to any mechanism the windmill is designed to turn such as generator part.

After finish the blade part, the next part is induction generators. Windmills that generate energy contain induction energy. It does not make energy, but rather converts kinetic (physical) energy into electrical by spinning a wire within a magnetic field, which causes an electrical current to flow through the wire.

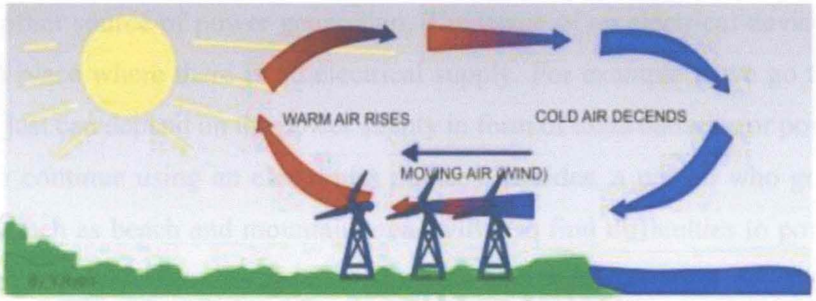


Figure 1.0: How wind turbine works

In Malaysia, especially at East Coast, have big potential to build wind power station. Since that there have enough wind moving for wind turbine. We can use the wind turbine at sea because we don't have enough space on land.

Nowadays, we try to find any alternative energy which is safe, friendly, renewal and useful in our life. Wind is one of the solutions which if we use it wisely wind will be our alternative energy support for our life.

1.2 Problem Statement

The application of wind turbine in Malaysia as the source of electrical generation is not widely use as it is not practical considering the low wind speed. However in the case where small capacity of electrical supply is needed, a small scale wind turbine could be a practical way to generate electricity. For example, a small scale wind turbine can be used to power up communication device for emergency purpose during a natural disaster event where there can be an electricity supply failure. Other than that, compared to solar energy where can only be extracted during day the wind energy can be harvest during day and night. Based on that judgment one of the objective for this project is to design a mini wind turbine that able to produce an electricity at low wind speed.

In order to improve the function of power generation, the wind turbine can be integrated with other source of power generation. The usage of an electrical device is also limited at a place where there is no electrical supply. For example if we go to a remote area, we just can depend on the power supply in form of extra batteries or power bank in order to continue using an electronics devices. Besides, a person who go to recreation place such as beach and mountain areas will also find difficulties to power up their electronics devices. Thus the design of portable mini wind turbine is needed for a better transportation and storage purpose.

During the development of generator part for wind turbine, the analysis of each element need to be criticized so that the specific component used can be known. The details of type of material used also must consider in order determining the production of generator part of wind turbine experiment. Therefore, analysis must be done in order to know the strength and weakness of making the generator part in order to produce the output voltage.

1.3 Objective

The objectives of this study are:

- To construct a small scale wind turbine that produce 3V to 5V.
- To observe humidity and temperature of surrounding .
- To understand the concept of designing a synchronous generator.

1.4 Scope Of Study

- Analysis of literature and wind turbine generator studies.
- Research and analysis component that use in generator part.

1.5 Summary of Project

Implementation and works of the project are summarized into Figure 1.1 and Figure 1.2 below show the detail of works progress of the project that has been implemented in the first and second semester.

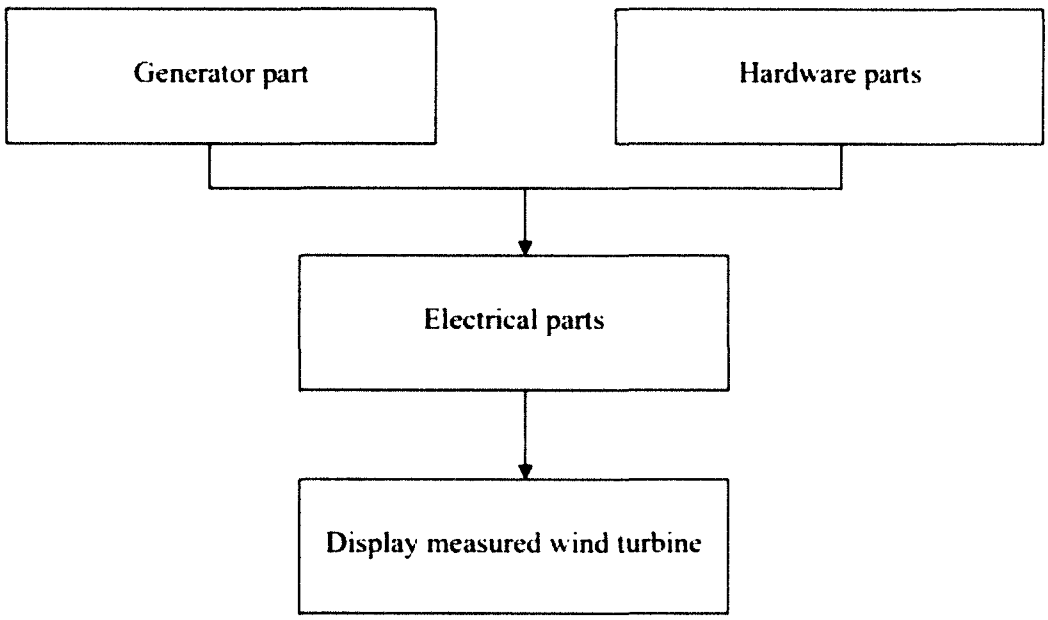


Figure 1.1: Block diagram

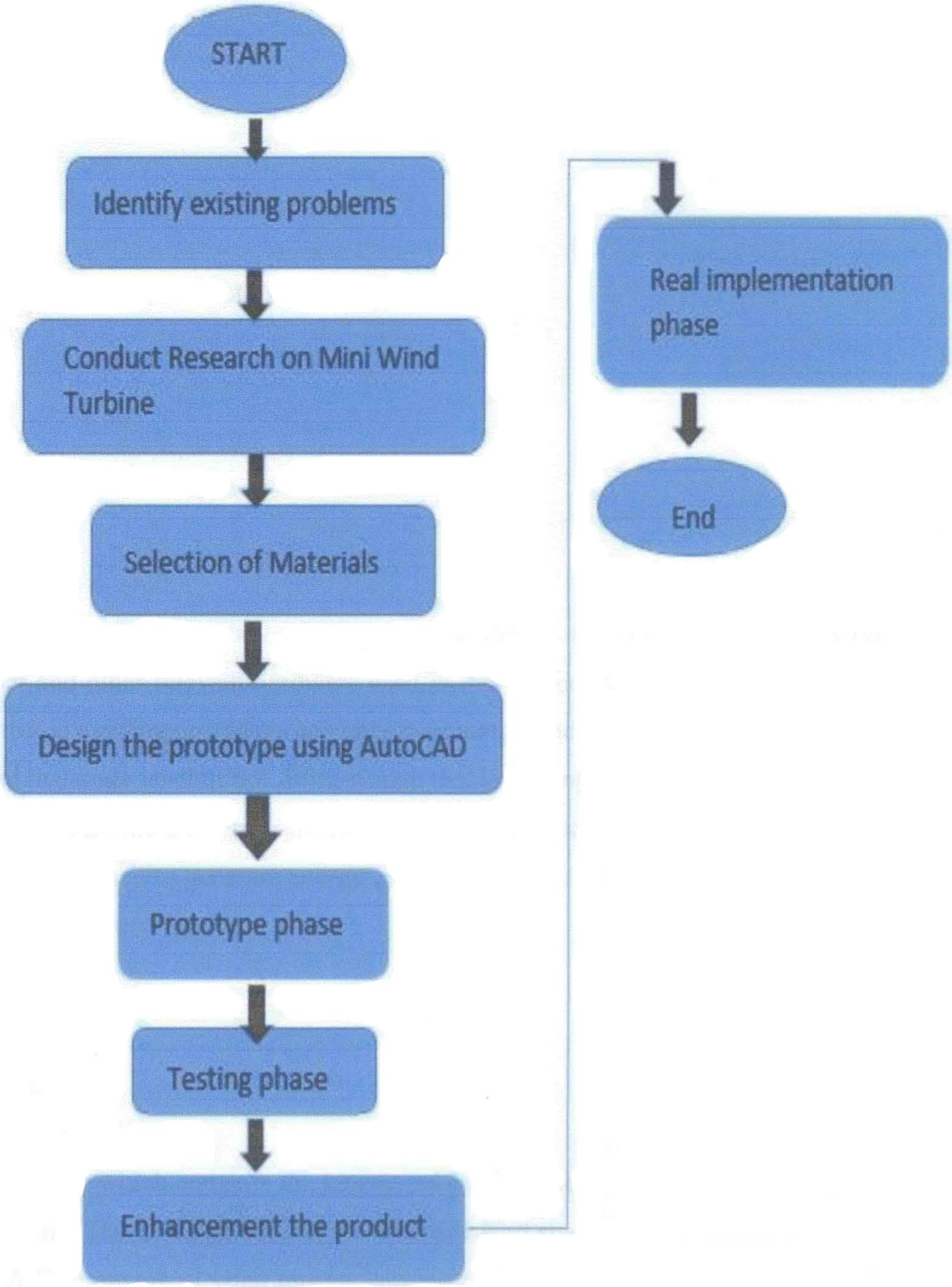


Figure 1.2: Flow of development

CHAPTER 2

LITERITURE REVIEW

2.1 Introduction

This chapter includes the study of wind turbine and its system. It also touches on microcontroller and other relevant hardware used in this project. Our project has features and function that is existing nowadays can only indicating wind direction and do not know the wind speed in danger level or not. With system that isexisting able endanger consumers when through in crosswind area on highways. Among our project improvement carried out, 12VDC motor to are used to generate energy from the wind. LCD also used to display the himidty and temperature value.

2.2 Wind Turbine

Rotating machine which converts the kinetic energy in wind into mechanical energy is called wind turbine. The developments of wind turbine start since 200 B.C which in Persia but until 250 A.D the usage of wind turbine had been introduced by Roman Empire. In 7 century, the first vertical axle windmills had been developing at Sistan, Afghanistan. These windmills had long vertical drive shafts with rectangle shaped blades. It was made of six to twelve sails covered in reed matting or cloth material. It was used to grind corn and draw up water and was used in the grist milling and sugarcane industries.

In 14 century, the same type of windmill had been developing that use to drain areas of the Rhine River delta at Dutch, Denmark. Then in 1887, the first known electricity generating windmill operated was a battery charging machine installed by James Blyth at Scotland, United Kingdom. These technologies still grown when Charles F Brush develop the first windmill for electricity production at United States Cleveland, Ohio in 1888. After that about 2500 windmills for mechanical loads such as pumps and mills, producing an estimated combined peak power of about 30 MW at Dutch, Denmark in 1900.

Wind turbine technologies still grown up until 1908 at United States. There have 72 winddriven electric generators from 5 kW to 25 kW. The largest machines were on 24 m (79 ft) towers with four-bladed 23 m (75 ft) diameter rotors. Around the time of World War I, American windmill makers were producing 100,000 farm windmills each year, most for water-pumping.

In 1930, the Windmills for electricity were common on farms, mostly in the United States where distribution systems had not yet been installed. In this period, hightensile steel was cheap, and windmills were placed a top prefabricated open steel lattice towers.

Yalta, USSR in 1931 had made a forerunner of modern horizontal-axis wind generators was in service. This was a 100 kW generator on a 30 m (100 ft) tower, connected to the local 6.3 kV distribution system. It was reported to have an annual capacity factor of 32 percent, not much different from current wind machines.

However in 1954, the first utility grid-connected wind turbine operated was built by the John Brown Company at Orkney Islands, United Kingdom. It had an 18 meters diameter, three-bladed rotor and a rated output of 100 kW.

From 1955 until nowadays, every country want to used these technologies as alternative and renewal energy. More developments and research have been done to use wind turbine as renewal energy that have more advantages for natural. There have 3 level of range for the wind turbine. They are large scale for 500 kW until 5 MW, medium scale between 10 kW until 500 kW and the small scale is below than 10 kW.

Figure 2.1: Wind turbines near Aalborg, Denmark. For scale, a normally-sized doorway can be seen at the base of the pylon.

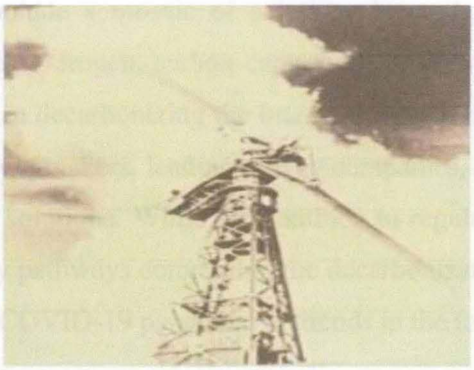


Figure 2.2: The world's first megawatt wind turbine at Castleton, Vermont.

2.3 Why we use wind turbine?

We use wind turbine energy because wind for now is the renewable energy resource and technology of choice. It was a "free" resource and naturally. Also its a "clean" resource due to replacement of a "dirty" energy source (coal) and no emissions associated with its use. Wind turbine can be utilized on underutilized land or on lands currently in commodity crop production which is can be "harvest" on the surface and "harvest" above the surface. Then it will primarily be used for electricity generation for immediate end-use or as a "driver" for hydrogen production. Also in nowdays the world become more challenging because of the COVID-19. The COVID-19 pandemic is one of the most severe economic and energy shocks in modern history. On top of the massive disruptions to business, mobility, and everyday life, there clearly will be longer-lasting implications for the energy transition away from fossil fuels. While the shocks from the pandemic are leading to reductions in fossil fuel consumption and emissions, they will not be enough to put the world on a path to meet 2 degree global warming target, nor bring forward peak oil demand, nor drive coal consumption to near zero.

To achieve the targets under the United States Agreement and limit global climate change, the energy transition will need to include a mosaic of solutions beyond just renewables and fossil fuel demand destruction: Hydrogen, carbon capture utilization and storage, and biofuels are all likely to play roles in decarbonizing the interconnected global energy system. Recent announcements from policymakers, leading energy companies, and end users illustrate the many kinds of climate solutions. While we continue to regularly publish our views and outlooks on all of the key pathways comprising the decarbonization mosaic, this report focuses on the impact of the COVID-19 pandemic on trends in the fossil fuels and renewables sectors.

Wind turbine one of the best choose that we have because it was no air emissions such as

Sulfur Dioxide (SOB 2B), Nitrous Oxide (NOx), or Mercury Emissions. Also don't have Greenhouse Gas Emissions. Then it no need for fuel to mine, transport, or store for the source. Its also don't need any equipment like cooling water that we always use at fuel engine and nuclear reactor. There are never making pollution for example water pollution that always produces by mine activity. After all there is no waste when used wind turbine.

According to the Wind Resources in the United States, wind resources are characterized by wind-power density classes, ranging from class 1 (the lowest) to class 7 (the highest). Below show the difference renewable energy supplyin 2018 and 2030. (Roman Kramarchuk, 24 Sep, 2020)

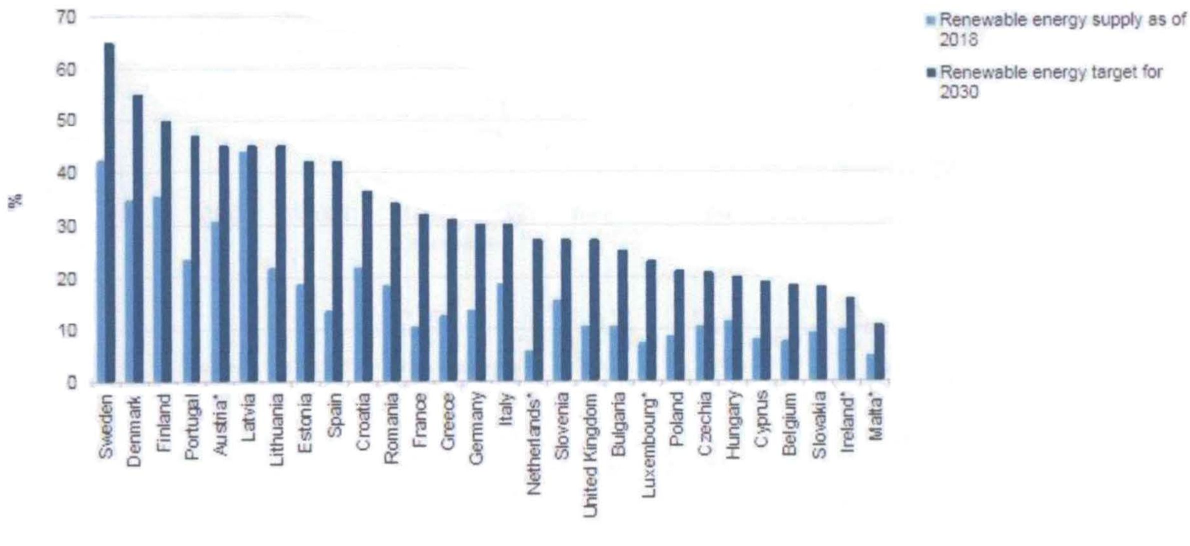


Figure : difference renewable energy supplyin 2018 and 2030.

2.4 Efficiency of wind turbine

The efficiency of wind turbine will reduce due to :

- Tip losses
- Wake effect
- Blade shape simplification losses

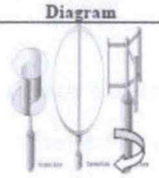
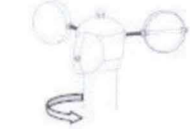
Ref No.	Design	Orientation	Use	Propulsion	* Peak Efficiency	Diagram
1	Savonius rotor	VAWT	Historic Persian windmill to modern day ventilation	Drag	16%	
2	Cup	VAWT	Modern day cup anemometer	Drag	8%	
3	American farm windmill	HAWT	18th century to present day, farm use for Pumping water, grinding wheat, generating electricity	Lift	31%	
4	Dutch Windmill	HAWT	16th Century, used for grinding wheat.	Lift	27%	
5	Darrieus Rotor (egg beater)	VAWT	20th century, electricity generation	Lift	40%	
6	Modern Wind Turbine	HAWT	20th century, electricity generation	Lift	Blade Qty / efficiency 1 / 43% 2 / 47% 3 / 50%	

Figure 2-2 Type of rotor design (Schubel & Crossley, 2012)

2.5 Characteristics analysis of wind turbine

The analysis for the performance of wind turbine is crucial in order to evaluate the result. The parameter for the analysis of a wind turbine include:

- Swept area
- Power extracted
- Tip speed ratio
- Number of blades
- Initial angle of attack

Swept area

The swept area is the cross-sectional part of the wind turbines that face the air movement. Therefore, for HAWT the swept area is the area that cover by the rotation of blade which the formula will be:

$$A = \pi r^2$$

Where A is the swept area, r is the blade radius

Where L is the length of the blade. The swept area cover the volume of air that pass through the turbine. Therefore, the swept area will affect the rotational movement of wind turbine.

Power extracted

The power that extracted from wind turbine can be calculated using the following formula:

$$P = \frac{1}{2}\eta\rho A v^3$$

Where ρ is the density of air, A is swept area, υ is the speed of wind and η is the theoretical limit efficiency of the wind turbine called the Betz's limit where for HAWT, the value is 19/27 and for VAWT the value is 16/25.

Tip speed ratio

The tip speed ratio is defined as a relationship between the tangential speed of rotor and the wind velocity where the equation is as the following:

$$\lambda = \frac{\omega R}{v}$$

Where λ is tip speed ratio, ω is a rotational velocity in rad/s, R is radius of blade and υ is the speed of wind. Each blade design has an optimal tip speed ratio at which the maximum power extraction is achieve.

Number of blades

Number of blade affect the performance of wind turbine. The increase number of blade will give more adjusting gap to the cut in wind speed without affect the power coefficient too much. Our propeller has 5 blade the size is 11.5cm

Size of the blade

Initial angle of attack

Angle of attack is an angle between the incoming wind flows with the trajectory of the blade airfoil. The effect of the angle of attack to the performance of wind turbine may vary according to the design of the wind turbine. However, it is proved that the use of single airfoil along the entire length of blade will cause inefficient design of blade.

2.6 Wind Speed in Malaysia

The wind sources of certain region need to be identify in order to develop a wind turbine that able to be operate and generate electricity. The average wind speed analysis at Mersing, Malaysia state that the annual average of wind speed in Malaysia is about 3 to 5 m/s.

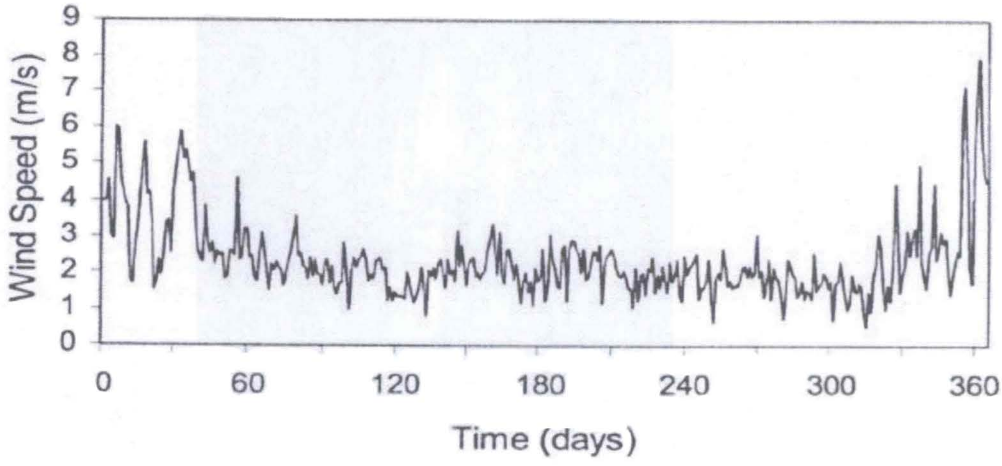


Figure 2-3 Mean daily wind speed in East Coast of Malaysia

2.7 Trend on mini wind turbine development

Currently there are several concept for mini wind turbine development. Most of the mini wind turbine concept use savonius type of wind turbine. The application of VAWT in the development of mini wind turbine give advantage to the wind harvesting process. The blade wind turbine that using VAWT type does not need to be orient to the direction of wind in order to extract the wind efficiently.

Figure 2-4 Ventus Concept mini wind turbine (Xu, 2013)

Other that conceptual design, there are also product that currently exist in market. WinPax is a one of a company that produce portable mini wind turbine for public usage. The design of wind turbine by WinPax use the VAWT savonius type of wind turbine.

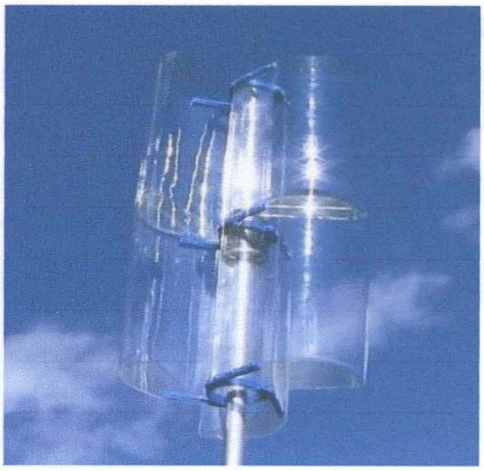


Figure 2.0-5 WinPax blade design

CHAPTER 3

METHODOLOGY

3.1 Chapter Overview

This chapter will explain about the methods that will be done to complete the project. Basically, the project will be divided into few parts and the project will be executed stage by stage. After the title has been decided, the first thing to do is to have a clear understanding about the whole idea of the project. Besides, literature review was done on various topics like the basic knowledge about a part of wind generator and the system will using for this project. In this chapter we will discuss more about the AutoCAD part.

3.2 Project management

This project was divided in two sections to complete the system of wind turbine. The flow chart is the first step to get the system follow by our design. The second step is by sketch the block diagram of the wind turbine system in the AutoCAD. These two steps have made before design the electronic and mechanical part. Also this project management has to define the basic component that use for wind turbine system.

3.3 Flow chart

The flow chart shown below is the method and approaches that need to be taken have been determined to make this project successful. The flow chart show the beginning of the project and the target and aim to make the wind turbine system is functioning.

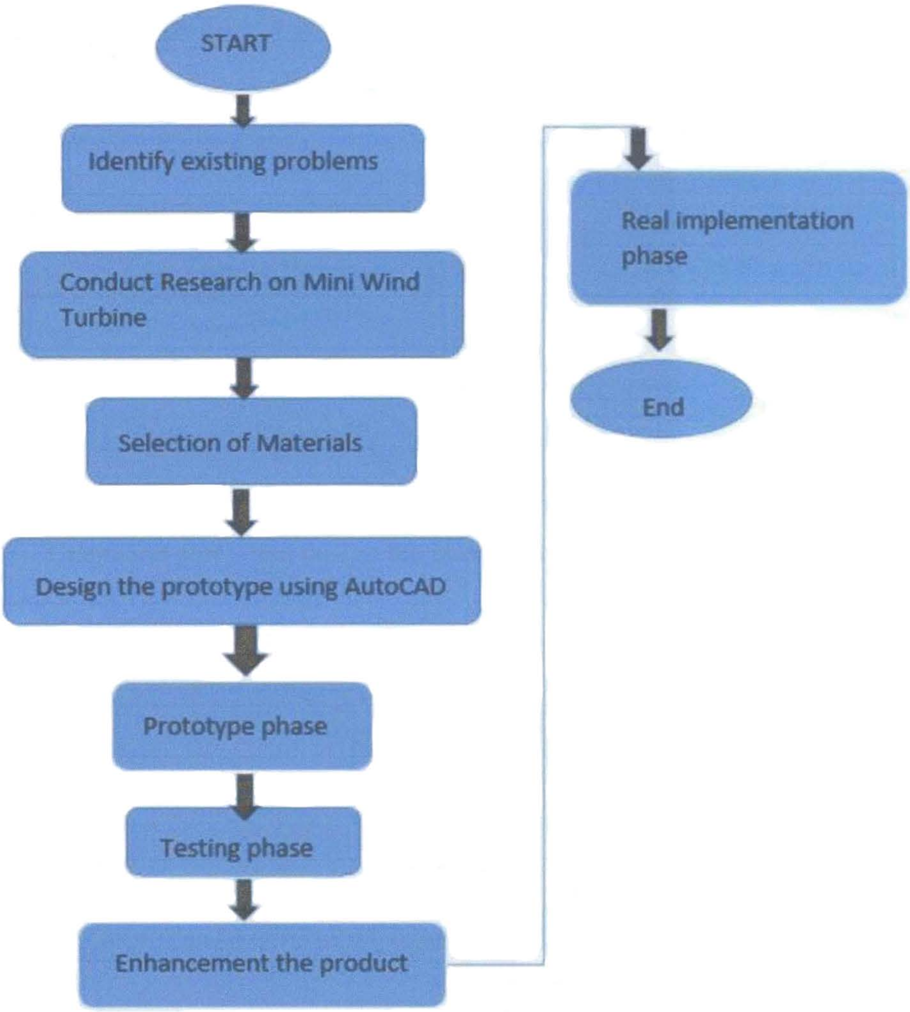
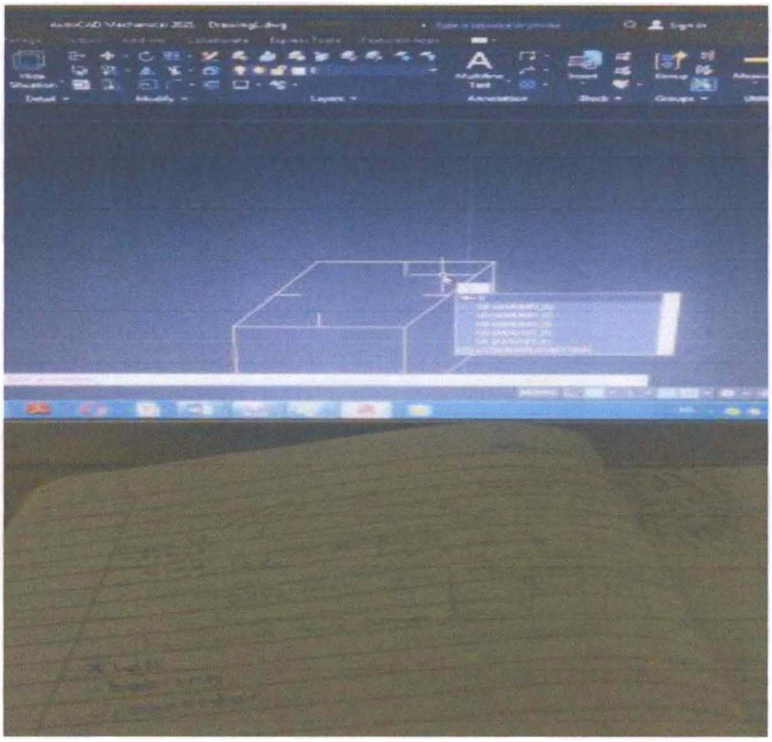
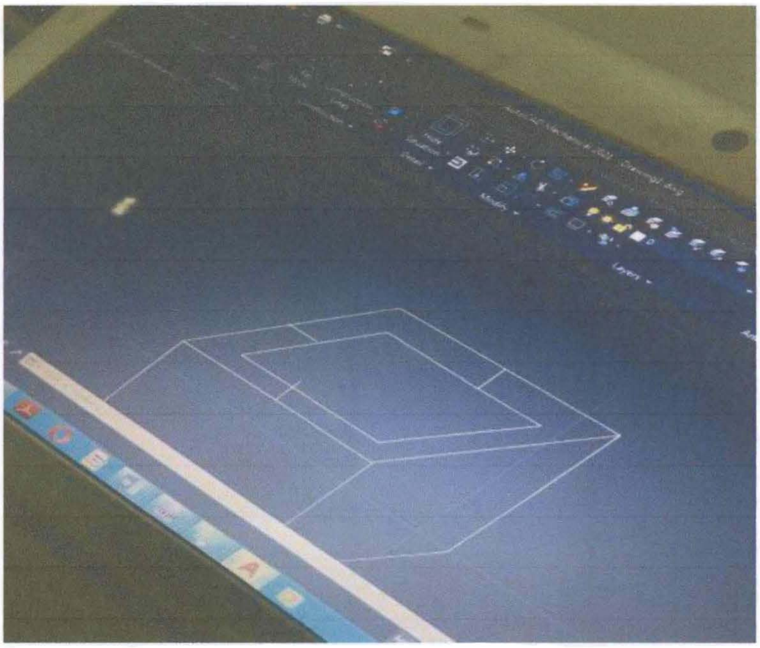


Figure 3.1: Flow chart

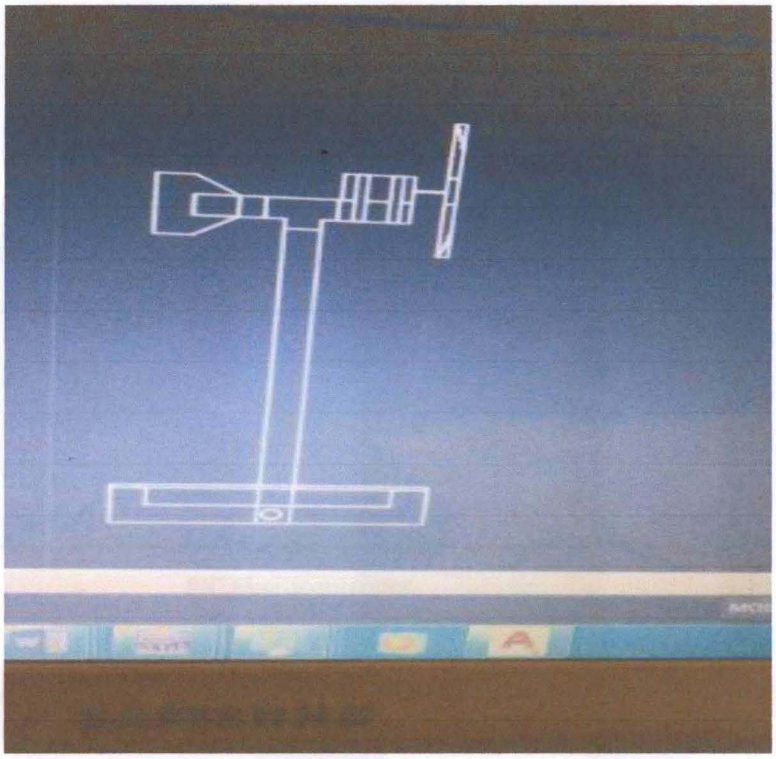
The second step is by sketch the block diagram of the wind turbine system in the AutoCAD. Below are the steps when design doing the AutoCAD software.



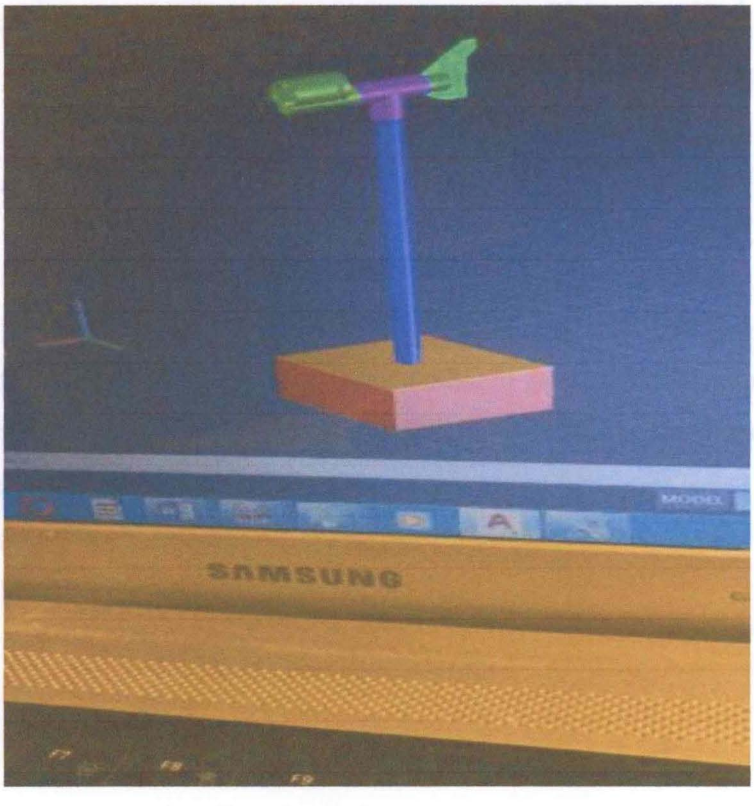
This is the part when design the basement



Basement



This is the mini wind turbine from side view in AutoCAD



Small scale wind turbine dimension

3.4 Block diagram

Block diagram is a diagram of a system, in which the principal parts or functions are represented by blocks connected by lines. For the block diagram of wind turbine system is connection by all main part of the system.

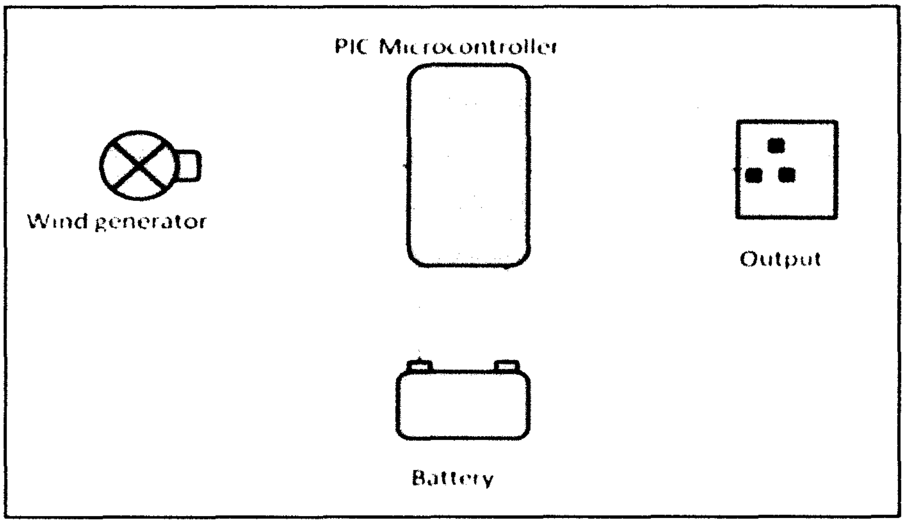


Figure 3.2: Block diagram of wind turbine.

The wind turbine system has using the generator to generate direct current to PIC microcontroller system to switching on or off to charge the battery. The output voltage can be use to consumer in the low ratting watt usage.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Design Analysis

I use AutoCAD to design and drafting. It allows me to draw and edit digital the small scale wind turbine in 2D and 3D designs more quickly and easily than I could by hand. The files can also be easily saved and stored in the cloud, so they be accessed anywhere at anytime. First I Draft, annotate, and design 2D geometry and 3D small scale models with solids, surfaces, and mesh objects. Next I comparing drawings, adding blocks, creating schedules, and customize it.

4.2 Overall view on conceptual design

From the sketch and dimension, the first version of the wind turbine model is created using the AutoCAD software.

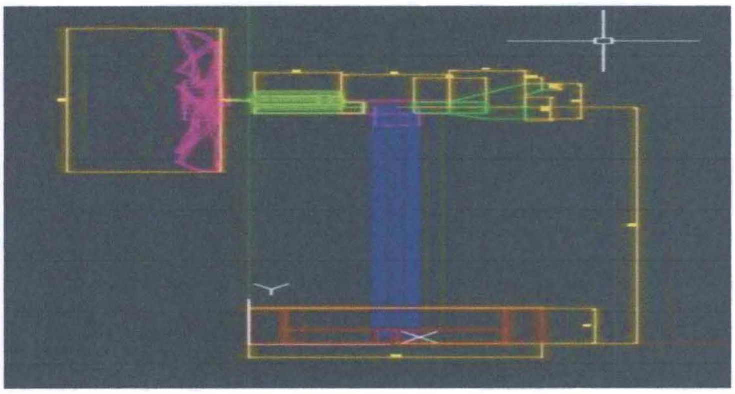


Figure 4-1 First Conceptual Drawing Model

The design consist of two blade which are savonius blade and darrieus blade. The combination of these two type of blade would increase the performance of the wind turbine as they neglecting each weakness and provide support to each other by their strength. In term of manufacturing, the blades and the darrieus branch and holder design are able to be manufactured by using PVC pipe as a material. Plastic blade is selected as a material for the drive shaft. Special standard part which is one way bearing used in the connection between the savonius rotor and the drive shaft. Other standard part includes bolt and locking screw without head.

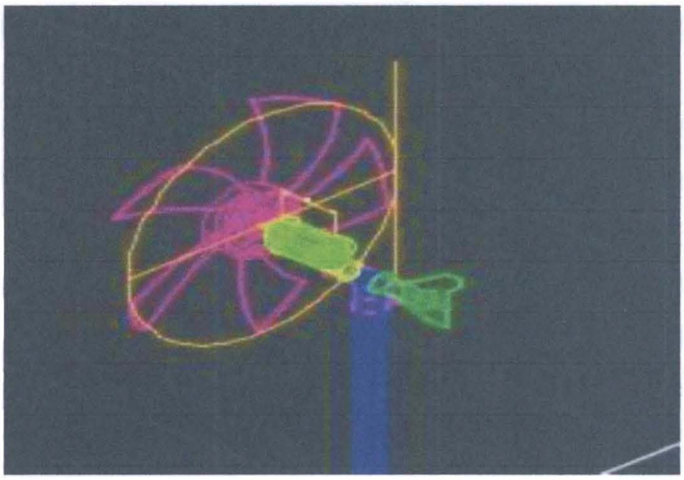


Figure 4-2 Zoom-in drawing of the Blades

4.3 Wind Turbine Design Advantage

I. Combination of two types of wind turbine

The unique value for the wind generator design is on the design of the blade itself. The design uses two types of Vertical Axis Wind Turbine (VAWT) namely Darrieus and Savonius Blades. This combination aims to improve the performance of wind energy extraction. Darrieus wind turbine has higher efficiency of power extraction from wind energy than that of Savonius. However, it needs high torque to start rotating. Savonius wind turbine, which requires low torque for rotation, is attached together to the overall wind turbine design to provide sufficient torque to start Darrieus rotation.

II. One way bearing

The starting step for the wind generator requires the Savonius blade to drive the wing turbine and generator. As the rotation of wind turbine rotor reaches higher speed, the Darrieus wind turbine will start to move faster than the Savonius wind turbine due to its higher efficiency. At this point, the rotation of Darrieus wind turbine will be cut off from the rotation of Savonius wind turbine and left only the Darrieus wind turbine to drive the generator. This mechanism requires one way bearing in the design as the function of one way bearing is to allow only one way of rotation and hold back the opposite direction of rotation. The advantages of using one way bearing are that it is easy to do maintenance and does not produce noisy sound during its working operation.

4.4 Design Advantage as a portable small scale wind turbine

- Pability

The design for small wind turbine make it easy to be installed for operation and to be stored in anywhere when not being used. The maximum size of the casing is about 50 m x 50 m x 70 m of dimension. All the components of this product can be easily stored when not in use and suitable to be carried to any places. This feature make it very suitable to be used in emergency situation also (Figure 4.3).

Figure 4.3

- Dual Modes of Operation

The small scale wind turbine can be powered by two sources of power generation namely human energy and wind energy. The human energy is gained when the generator of this product is driven by DC motor rotation and the wind energy is harvested by the wind turbine.

- Low cost power source solution during emergency

This product provides a cheap alternative solution for supplying power source to electronics devices in the situation where normal power source is inaccessible or down. During a disaster time, such as the big flood that occurred in East coast of Malaysia in December 2014, the reinforcement team and affected people faced a great deal of difficulty to power up their phones and make an important call to update situations in disaster areas and relief center. The solution back then was by asking for fully charged power bank to be distributed to the disaster relief center. This can involve high amount of money as one unit of power bank can cost about RM 60 to RM 80. Furthermore, the power bank needs to be recharged when the capacity is fully discharge. It is also time consumption to send power bank back and forth for charging and distribution. With this product which is cost below than RM 600, the problem of power demand for electronic devices can be solved effectively and efficiently.

- Power source during travelling to remote area

Other than its usage for low power appliancess, this product can also be used by travelers who travel to remote areas where there is a limited or no access to electricity supply. The crank generator would provide an easy solution to obtain emergency power supply. In areas with good wind speed, such as mountain and beaches, the wind generator would be useful to provide needed spare power. It can also be used by fisherman during emergency case.

4.5 Fabrication of Components

Most part of the wind turbine for this project which is the blades and its auxiliary's part was fabricated. Other part which is the shaft was fabricated using cutting and lathe machine. The material for part that fabricated and the basement was made by an aluminum.

- Rapid Prototyping Method

The design used for this project is AutoCAD. The maximum dimension that use in AutoCAD is 180 mm x 180 mm x 180 mm. In order to do the design process the drawing file must be converted 3D format before the design can be seen clearly. After the drawing has finished, then the design that willused to fabricated will be seen.

- Assemble Process

Assemble process considered the last step in fabrication process. This process can be completed after all part of component of the small scale wind turbine were fabricated. During this step, many process such as abrasion, tapping and fitting include during the assemble process. Painting process need to be done as the parts that has been fabricated has not have a good surface finish. For the part that have a screw that need to be fitted in it, tapping process was done to make the groove at that part. Figure below show the full spraying part of the small scale wind turbine.

Figure: Spraying part of the small scale wind turbine.

4.6 Marketing/Business Plan

As the product mainly aims for the low power appliances. So we specified it to be used in a small area location which regularly being hit by natural disasters, the product can be promoted globally, not only restricted to Malaysia region.

The global map for natural disaster-prone places is shown in the figure below

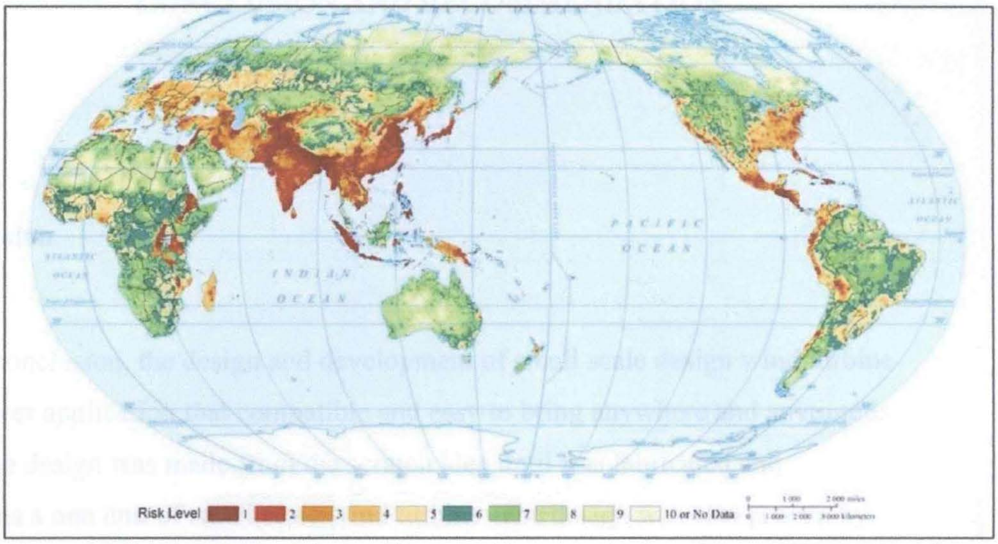


Figure Global mapping of annually multi-hazard risk level at small area location

From this map at Figure 4.9, it can be seen that the most highly risked level areas are in Asian, Europe and Central America regions. Types of natural disasters include earthquakes, floods, wildfire, landslides and volcanoes. Taking into account that the targeted user for this product is roughly 1% from the total affected population with high risk level, it is estimated that the potential users for this product is about 10 million.

4.7 Production

For the prototype cost, the product can be produced below RM600 as a single device. It will be much cheaper when it goes into the mass production later. To estimated costs of product which components consist of molded plastics, DC motor,

CHAPTER 5:

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the design and development of small scale design wind turbine for low power application that compatible and easy to bring anywhere and anytime is success. The design was made from the scratch idea until it is fabricated and assembled as a one unit of small scale wind turbine. The design was also proven by the fabrication. Finally the small scale wind turbine was assemble to according to the design target.

5.2 Recommendation

As a recommendation, further analysis on the performance of the small scale wind turbine can be performed. Result from the analysis can be used to improve the efficiency of the small scale wind turbine for power appliances. The improvement could be changed in term of material, dimension, and technique of fabrication. For the change in material, size are recommend to replace current material of wind blade which is bigger size for turning purpose. Other than that, the change in dimension can be revised based on an analysis of current dimension. Finally, the technique of fabrication can be improve. For example the surface of the pvc stand can be smoothed using a sand paper.

gearbox, simple electronic circuit board (arduino UNO), wires, Li-Po battery and PVC pipe, is roughly around RM530, including the wind blade.

The product is mainly in the polymer based material (plastic), thus we use PVC pipe as the stand for easy to setting. Also, we make a hole for the basement so that we can put the stand inside it to make it more good looking and easy to bring.

In a small scale, to reduce the production cost of the product, we only use PVC pipe as a stand and connector to the blake.

Table 4.3 below shows the rough estimation on the production cost of the product:

Components	**Cost (MYR)**
Generator Box (Circuit Board, DC motor, Li-Po Battery, Wires, Gearbox, Crank, PVC pipe, Rubber Holder,aluminium basement, arduino UNO, humidity and temperature sensor)	430
Wind Turbine (Shafts, Blades, Foils,)	100
TOTAL	**530**

Table 4.3

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Books:

Advances in Wind Turbine Blade Design and Materials (Wood head Publishing Series in Energy) by: Povl Brøndsted

The Optimum Design of a Wind Turbine Blade: In-depth View by: Stephen Anim - Mensah

Introduction to Wind Turbine Aerodynamics (Green Energy and Technology) 2014th Edition by : A. P.Schaffarczyk

APPENDIX A

Set Up an LCD Display on an Arduino, then upload this code to the Arduino :

```
#include <dht.h>
#include <LiquidCrystal.h>

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

dht DHT;

#define DHT11_PIN 7
 void setup(){
lcd.begin(16, 2);
}
void loop(){
  int chk =
DHT.read11(DHT11_PIN);
lcd.setCursor(0,0);
lcd.print("Temp: ");
lcd.print(DHT.temperature);
lcd.print((char)223);
lcd.print("C");
lcd.setCursor(0,1);
lcd.print("Humidity: ");
lcd.print(DHT.humidity);
lcd.print("%");   delay(1000);
}
```

Program to the Arduino and open the serial monitor :

```
#include <dht.h>

dht DHT;

#define DHT11_PIN 7

void setup(){
  Serial.begin(9600);
}
void loop(){
  int chk = DHT.read11(DHT11_PIN);
Serial.print("Temperature = ");
  Serial.println(DHT.temperature);
  Serial.print("Humidity = ");
Serial.println(DHT.humidity);
delay(1000);
}
```