SMALL SCALE WIND TURBINE (SYNCHRONOUS GENERATOR)

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A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Electrical Engineering (Power System)

Faculty of Electrical & Electronic
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NOVEMBER 2008

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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Date : 17 NOVEMBER 2008__________

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Special dedicated to my parent, siblings, lecturer, friends and anybody were involved in this project.

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May Allah reward His peace and blessings to all of you, and may this work brings benefit to the mankind.

ABSTRACT

Small wind-powered electricity generation system, providing regulated AC electric power from wind energy to a power system grid, has a wind turbine that produces less than 10kW of peak electric power in a permanent magnet generator that produces generator power with a frequency that varies with the wind speed. The wind turbine utilizes a cross-wind type rotor having a power coefficient that varies with the operating tip speed ratio and has an optimal tip speed ratio where the power coefficient is maximum. A power converter, for converting generator power to regulated electric power by applying a controlled load to the generator controls operation of the wind turbine rotor such that the operating tip speed ratio is greater than the optimal tip speed ratio in a low wind speed region, is approximately equal to the optimal tip speed ratio in a medium wind speed region, and is greater than the optimal tip speed ratio in a high wind speed region. Boost converter used to boost up the output from the generator. However, wind turbine modeling should be done with more accurate to get the best value and have good efficiency.

ABSTRAK

Turbin angin kecil menjana sistem kuasa elektrik yang melaraskan kuasa elektrik ulang-alik dari tenaga angin kepada sistem grid kuasa, mempunyai turbin angin yang menghasilkan kurang dari 10kW puncak kuasa electrik di dalam penjana magnet kekal yang menjana kuasa dengan frekuensi yang berubah-ubah mengikut kelajuan angin. Turbin angin menggunakan rotor dari jenis pemancung angin untuk mendapatkan pekali kuasa yang berubah-ubah dengan nisbah kelajuan operasi untuk memberikan nisbah kelajuan yang optima pada pekali kuasa di tahap maksimum.Pengubahsuai kuasa digunakan untuk mengubahsuai kuasa dari penjana kepada kuasa elektrik yang selaras dengan menggunakan beban boleh kawal di kawalan operasi penjana di turbin angin apabila nisbah kelajuan operasi lebih besar dari nisbah kelajuan optima dalam kawasan kelajuan angin yang rendah, iaitu hampir sama dengan nisbah kelajuan optima dalam kawasan kelajuan angin sederhana dan lebih besar dari nisbah kelajuan optima di dalam kawasan kelajuan angin yang tinggi. Pengubahsuai injak naik digunakan untuk menginjak naik keluaran dari penjana. Namun, pemodelan turbin angin perlu dilakukan dengan lebih terperinci untuk mendapatkan nilai keluaran yang terbaik dan mempunyai kecekapan yang tinggi.

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LIST OF SYMBOLS

s	-	Second
V	-	Voltage
I	-	Current
P	-	Power
kW	-	kilowatt
m	-	meter
ft	-	feet
kV	-	kilovolt
MW	-	megawatt
SO_2	-	sulfur dioxide
NOx	-	Nitrous Oxide
Hg	-	mercury
ρ	-	air dnsity
A	-	Area swept by rotor
V^3	-	wind speed
H	-	height
m.p.h	-	mile per hour
km/h	-	kilometer per hour
Ω	-	ohm
F	-	farad
Hz	-	hertz
GDN	-	ground

LIST OF ABBREVIATIONS

AC	-	Alternating current
DC	-	Direct current
PVC	-	Polyvinyl chloride
B.C	-	Before Century
PIC	-	Programmable Interface Controller
HAWT	-	Horizontal Axis Wind Turbine
VAWT	-	Vertical Axis Wind Turbine
CCM	-	Continuous Current Mode
MOSFET	-	metal–oxide–semiconductor field-effect transistor

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CHAPTER 1

INTRODUCTION

1.1 Background

Wind power is generated by moving air. As the sun heats the land, the air above also warms and rises. Cold air then replaces the rising air. This creates the winds that we feel most days of the year. The diagram below shows how this 'system' works. Air tends to warm at a faster rate over land because the land retains its heat. Over the sea the air warms more slowly as heat by the sun is slowly cooled by the cold water. If you visit the seaside or coastal area you will probably find that the weather is more breezy or windy than inland. This is because the warm air rises over the land and cold air over the sea replaces it.

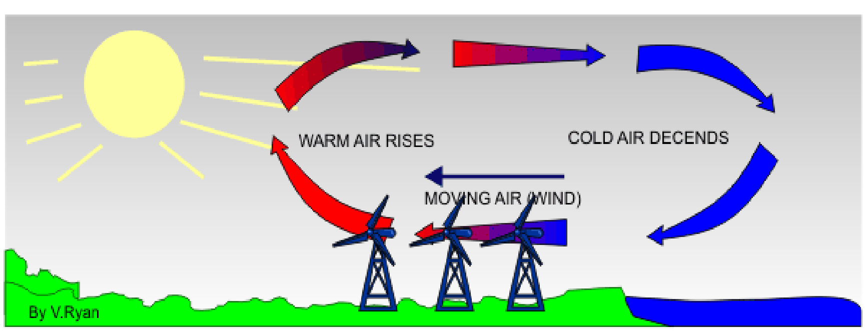

Figure 1.0: How wind turbine works

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.

Large wind turbine technology is already one of the larger future energy supplies and small wind turbines have a big potential. What is needed for a common use of wind are turbines that meet a specification that is flexible enough for general application and be possible to mount almost everywhere and plug-in to the grid. Wind turbines on the market are often larger, mounted on high towers and need plenty of space around them for safety and efficiency. The only way is therefore to specify flexible wind turbines which need a small space, cheap, low risk to install and high efficiency.

1.2 Objective of Project

The objective of this project is to;

i. To build a small scale wind turbine which produce 15Vac
ii. To understand the concept of designing a synchronous generator
iii. To built an additional boost converter circuit to amplified the result to 30Vdc

1.3 Scope of Project

In this project, I want to build a small scale wind turbine. There are the specifications of this wind turbine.

Voltage produce	: 15 volts VAC
Type of current	: Alternating Current (AC)
Generator	: Synchronous generator
Application	: Small appliances
Circuit	: Boost converter (double value from input about 30 Vdc)

1.4 Summary of Project

Implementation and works of the project are summarized into Figure 1.1 and Figure 1.2 below. Gantt charts as shown in Figure 1.3 and Figure 1.4 show the detail of works progress of the project that has been implemented in the first and second semester.

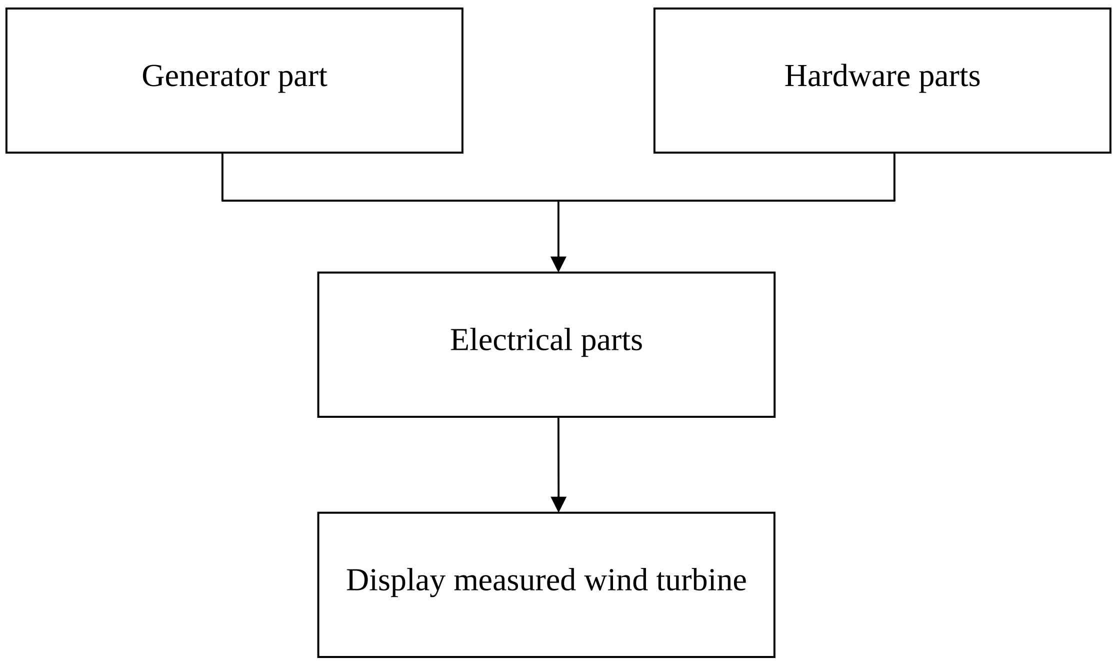

Figure 1.1: Block diagram

Description:

Generator part had been customize and modified from the car spare part components and bicycle's dynamo. By the first move on this project, the experiment about how to fabricate a synchronous generator had been done at Tasek Kasturi Company at Indera Mahkota Industrial Park. About 4 of bicycle's dynamo had been used to study the generator mechanism. During the experimental period, several sizes of magnetic coil are used to rewinding the stator to see the value changes when the size of coil is vary. Then the number of turns also had been manipulated.

However during that period, another customize generator by using car’s spare parts had been built. By using the alternator part, it had been modified into another generator. So in this project there have 2 prototypes that are built as comparison project. The first prototype is modified of dynamo and second prototype is modified of car alternator.

Description:

Hardware parts including the rotor blades, stand and tail. Rotor blades are made from PVC conduit pipe. There are 3 of blades is about 1 feet long each. The blades had been patterned with aerodynamic type that useful to cut off the wind and make them easy to rotate. The PVC type had been chosen because it was light weight and has strength.

The stand used to support the wind turbine while operate. It is portable stand that easy to move the prototype but in the real wind turbine, the stand must be fixing and has strong foundation to the ground to make sure it safe from strong wind. Then, the tail will direct according to the wind direction.

Description:

Electrical parts consist of power supply circuit, voltage regulator circuit, boost converter and all of this circuit only an additional circuit that only to double the wind turbine value about 30Vdc. This circuit also implements PIC circuit that used for control circuit. However this circuit can be upgraded directly to the appliances.

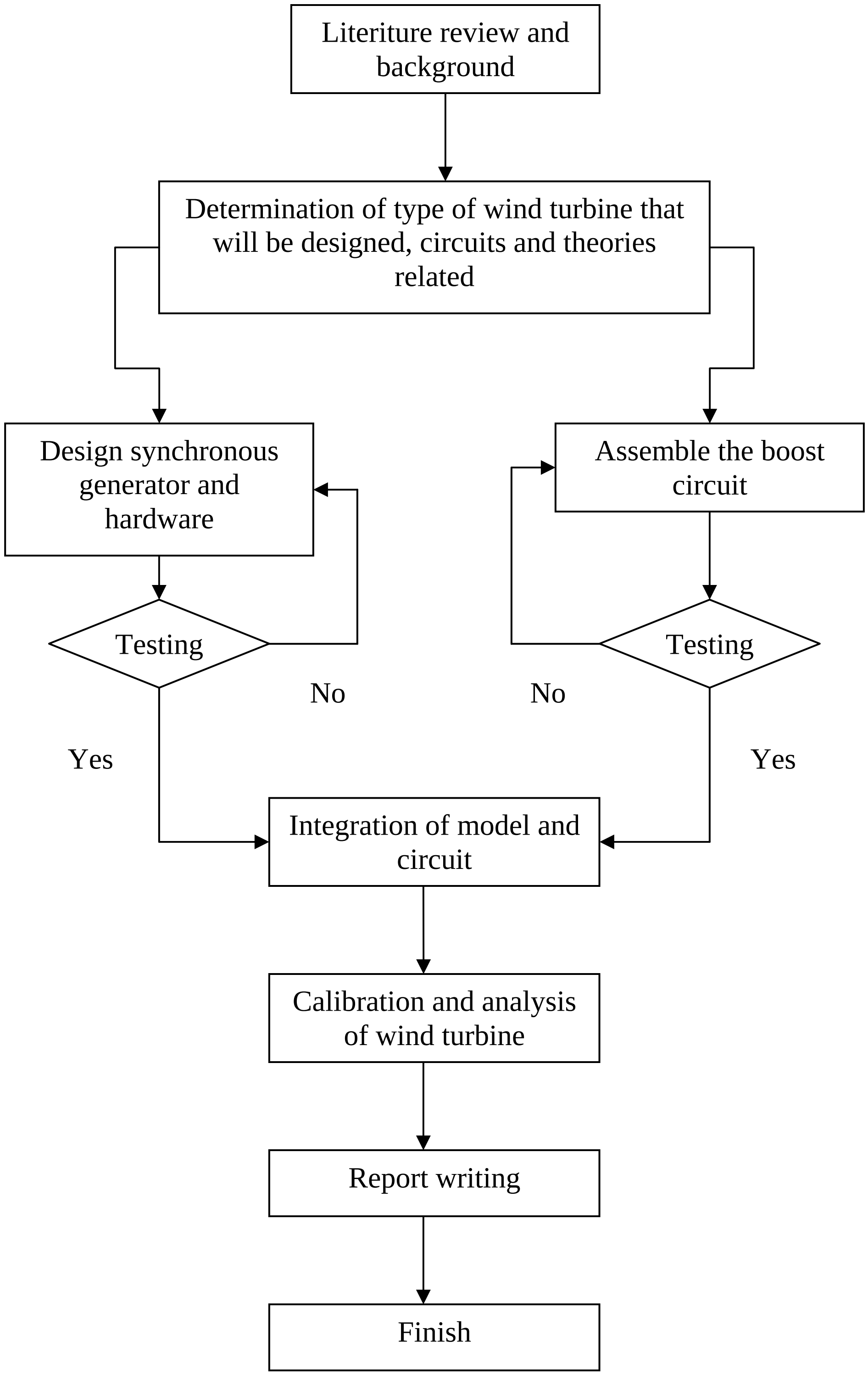

Figure 1.2: Flow of development

Description:

Literature review and research on theories related to the projects begin after the title of project was decided. These involve theories of numerous of wind turbine by obtaining most of the information from the internet and a few reference book. Small scale wind turbine was chosen to be developed in this project because it was relevant based on size and cost involved.

The project is divided into two parts; the modeling and circuit. The modeling part involves developing a synchronous generator, rotor blades, stand and tail. They had been testing to get the best model and it can be redoing if the model are not suitable for the project.

For the circuit part, boost converter had been fabricating based on calculation to get the output about double from the input voltage. It also includes power supply circuit and voltage regulator circuit since that output from wind turbine should be AC voltage. Then, this circuit had been tested to make sure that it will operate properly. All this circuit was doing by stage to avoid complicated during troubleshoot the error.

The integration of both the model and circuit will be done when both parts are ready.

Calibration process and analysis both are important to make sure the output are as expected. All the results and will be analyze for any changes that are needed. The value of output will be displayed on multimeter and oscilloscope.

After the entire task was done, report writing had been writing based on overall project related. Its was considered finish when the project had been succeed to achieved objective and all the information and data will be implement into a thesis.

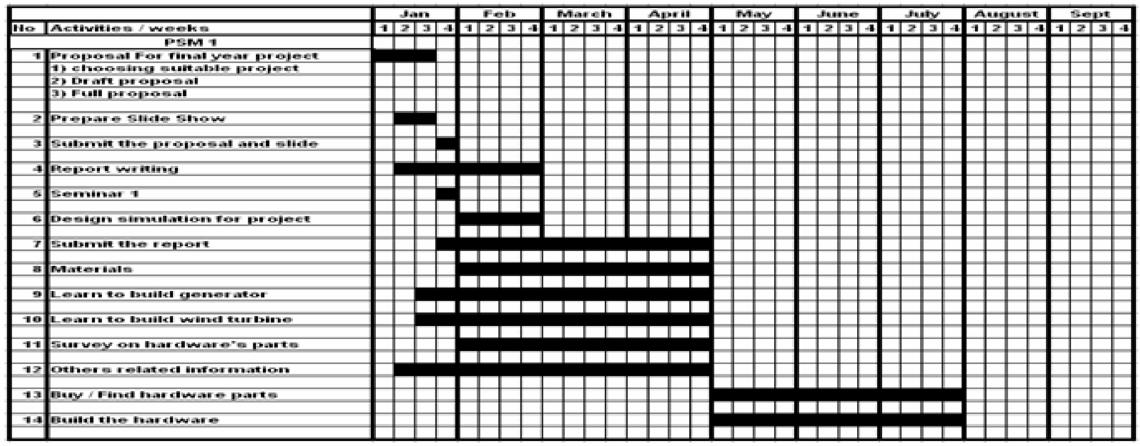

Figure 1.3: Gantt chart of the project schedule for semester 1

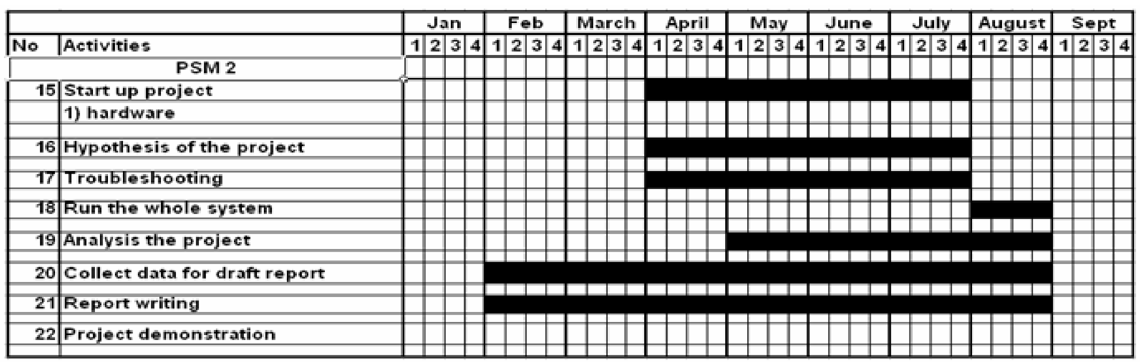

Figure 1.4: Gantt chart of the project schedule for semester 2

CHAPTER 2

THEORY AND 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.

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^{th} 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^{th} 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 wind-driven 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, high-tensile 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.

As we are know basically energy use in power plants accounts for 67% of air emissions of Sulfur Dioxide (SO_2), the primary cause of acid rain. SO_2 causes acidification of lakes and damages forests and other habitats. Then 25% of Nitrous Oxide (NOx), which causes smog and respiratory ailments. Also 33% of Hg (mercury), a persistent, bio-accumulative toxin which increases in concentration as it moves up the food chain which is example from fish to birds, causing serious deformities and nerve disorders.

Wind turbine one of the best choose that we have because it was no air emissions such as Sulfur Dioxide (SO_2), 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). However a good wind resources are (class 3 and above) which have an average annual wind speed of at least 13 miles per hour, that are found along the east coast, the Appalachian Mountain chain, the Great Plains, the Pacific Northwest, and some other locations. As we know wind speed is a critical feature of wind resources, because the energy in wind is proportional to the cube of the wind speed. Here is wind turbine population in United State Resources.

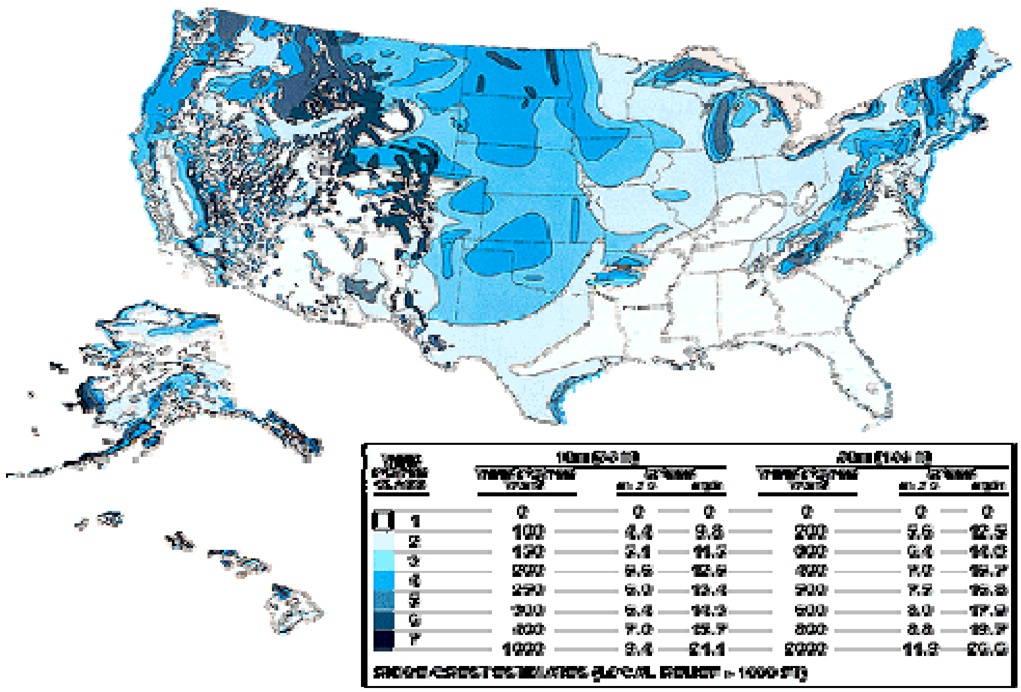

Figure 2.3: Wind turbine population in United State Resources

2.4 Wind energy basic

2.4.1 Physical & Engineering Aspects

2.4.1.1 Wind Power Equation

P = ½ * air density * Area Swept by Rotor * Wind Speed3

$P = ½ * \rho * A * V^3$

Power in the wind is correlated 1:1 with area and is extremely sensitive to wind speed (the cubic amplifies the power significantly). If the wind speed is twice as high, it contains 23 = 2 x 2 x 2 = 8 times as much energy. A site with 16 mph average wind speed will generate nearly 50% more electricity and be more cost effective than one with 14 mph average wind speed (16*16*16) / (14*14*14) = 1.4927. Therefore, it hunt for a good wind sites with better wind speeds.

2.4.1.2 Energy from the Wind

Turbine output drives wind economics and output is a strong function of wind speed. Wind speed increases with height above the ground and equation is shown below:

$$\text{Power} = 1/2 \times (\text{air density}) \times (\text{area}) \times (\text{wind speed})^3$$

Energy in the wind increases as height increases (theoretically) but in practical there must be some losses.

$$V_2/V_1 = (H_2/H_1)^{1/7}$$

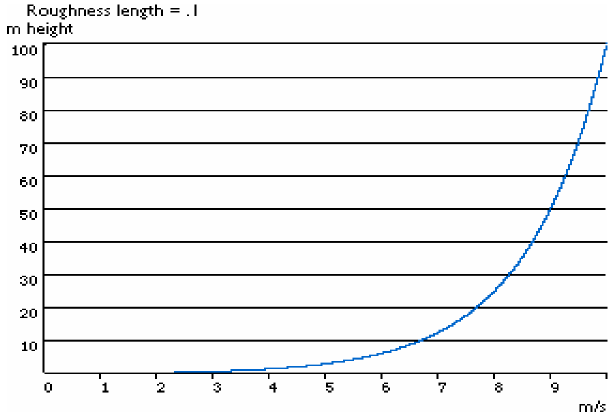

Figure 2.4: Energy from the wind

2.4.1.3 Turbines: Different Sizes and Applications

Figure 2.5: Small scale wind turbine

This is a small scale wind turnine which produce below than 10 kW power that used for homes (Grid-connected), farms and remote applications such as battery changing, water pumping and telecom sites.

Figure 2.6: Medium scale of wind turbine

This is an intermediate scale wind turbine which produces between 10 until 500 kW power that used for village power, hybrid systems and distributed power.

Figure 2.7: Large scale of wind turbine

This is a large scale wind turbine that can produces between 500 kW until 5 MW that used for Central Station Wind Farms, distributed power and offshore wind.

2.4.1.4 “Value” of Wind Energy

The value of a wind turbine or wind farm depends upon many factors which are where the location it is is. The wind speed is important because how many energy can be produced just depend on this factor then the value is there. Then the value of wind turbine can be determined by cost of the competing energy source. Also based on rate structure of competing energy source.

2.4.1.5 Wind - Natural Gas Comparison

These are the comparison between wind energy and natural gas energy. Wind energy had low operating cost but natural gas need high operating cost. Although wind energy use high capital cost, it was non-dispatch able but natural gas energy just need low capital cost and dispatch able. The most beneficial of wind energy are it doesn’t need fuel supply or even cost of risk with no emission or pollution. Compare to natural gas energy that it must use fuel supply and cost of risk of smog also can cause of greenhouse gas emission and make pollution.

2.4.1.6 Wind Energy Economic Effects

Wind energy is free. It does not have to be imported or mined or harvested in any way, other than through a wind energy system. Once the initial financial outlay has been made, there is some regular maintenance, but the resource is by and large zero cost. Surprisingly, though, wind accounts for far less than half a percentage point of the US electricity generation, as of 2003. Although wind energy remains capital intensive, the cost is coming down annually. In fact, (according to the US Department of Energy), in the 1980's, wind energy cost 40 cents per kWh, and the cost today is less than 5 cents per kWh. And in the meantime, the cost of non-renewable energy has continued to climb.

The day is not far off when wind and other renewable energies will be demonstrably cheaper than non-renewable such as fossil fuel. There are other benefits to wind, too. Wind power already employs thousands of people all over the American North and Midwest, and the numbers will continue to rise. The USDE estimates that wind will create as much as 80,000 jobs by the year 2020.

2.4.1.7 Wind Energy Effects on Society

The human race is proud of the many advances it has made over the past few centuries. However, much of that progress has been speeded by use of energies that burn quickly. For human development to continue as it has, we would benefit greatly from the use of energy sources that are renewable, infinite and cheap (or better yet, free). Wind meets all these criteria, as do very few energy forms we now use. Some even argue that our current energy (fast burning and very finite) symbolizes the nature of our culture.

For humans to survive long term we need to start thinking long term. In order for wind and solar energy to reach their potential, people need to concentrate on developing these energy forms. The growing amount of energy devoted to these forms of energy seems to symbolize a hope for our world that people are beginning to think in the longer term. In spite of the lack of societal support for wind energy, this form of energy has grown. This is for a few reasons.

One reason is that a small but growing number of people want to gain power over their own power. In the same way, alternative medicine is growing because people want to have control over their own physical well being and have a growing distrust of medical and pharmaceutical industries. The renewable energy industry benefits from people's desire to fully understand and have more control over their own lives.

Furthermore wind energy is really one of the simplest forms of energy to understand-wind turns a turbine that generates electricity. The story of wind energy's continued development will most certainly be its integration into power generation.

Wind farms are popping up all over the map, and they will do so for decades to come. But the way that this has come about, through the efforts of a small, driven group of people who knew they were right, who believed in wind energy and worked alone to drive down its costs, remains a story of people taking control over their won destinies and shaping the destiny of the nation and of the world.

2.4.1.8 Wind Energy Problem

Wind energy had several problem they are wind power output varies over time that's mean it isn't dispatch able. The wind power is location-dependent which is whether it is rural or urban where it is needed most. Wind power is transmission-dependent for tie-in to the grid and has environmental impacts which have pro and con that we already have been discuss before. Wind power can only meet part of the electrical load. Then wind turbines are only generating electricity about one third of the time. Mean that wind turbines generate electricity essentially all the time, but only at their rated capacity about 30-40% of the time.

2.4.1.9 Wind Turbine Schematic

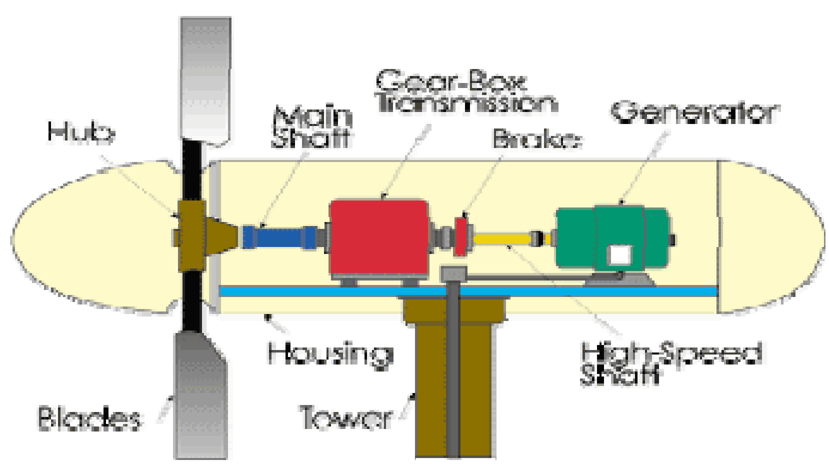

Figure 2.8: Wind turbine schematic

Wind turbines can be separated into two types based by the axis in which the turbine rotates. Turbines that rotate around a horizontal axis are more common. Vertical-axis turbines are less frequently used.

2.4.2 Horizontal axis

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount.

Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds, the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since turbulence leads to fatigue failures, and reliability is so important, most HAWT’s are upwind machines. There are several types of HAWT:

2.4.2.1 Types of horizontal axis

Figure 2.9: Doesburger windmill, Ede, The Netherlands

This windmill had been built in 12th century. This type typically had at least four bladed that usually with wooden shutter or fabric sails. This windmill was developed in Europe. These windmills were pointed into the wind manually or via a tail-fan and were typically used to grind grain. In Netherlands, they were also used to pump water from low-lying land and were instrumental in keeping its polders dry.

Figure 2.10: Water pumping rural windmill in Germany

This windmill had been built in 19th century. This type typically had many blades and can operate at top speed ratios. This type has a good starting torque. Some of this type had small direct-current generators used to charge storage batteries to provide a few lights or to operate a radio receiver. Widely used in Beloit, Wisconsin, American, South Africa and Australia for farm water pumping and railroad tank filling. However, such devices are still used in locations where it is too costly to bring in commercial power.

Figure 2.11: Three bladed wind turbine

This is a modern type of wind turbines. This type typically had three-bladed and pointed into the wind by computer-controlled motors. This type is produced by Danish and other manufacturers for commercial production of electric power. These have high top speeds of up to six times the wind speed, high efficiency, and low torque ripple which contribute to good reliability. The blades are usually colored light gray to blend in with the clouds and range in length from 20 to 40 meters (65 to 130 ft) or more. The tubular steel towers range from about 200 to 300 feet (60 to 90 meters) high. The blades rotate at 10-22 revolutions per minute.

A gear box is commonly used to step up the speed of the generator, though there are also designs that use direct drive of an annular generator. Some models operate at constant speed, but more energy can be collected by variable-speed turbines which use a solid-state power converter to interface to the transmission system. All turbines are equipped with high wind shut down features to avoid over speed damage. In Schiedam, the Netherlands, a traditional style windmill (the *Noletmolen*) was built in 2005 to generate electricity. The mill is one of the tallest Tower mills in the world, being some 42.5 meters (139 ft) tall.

2.4.3 Vertical axis

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable. VAWTs can utilize winds from varying directions.

With a vertical axis, the generator and gearbox can be placed near the ground, so the tower doesn't need to support it, and it is more accessible for maintenance. Drawbacks are that some designs produce pulsating torque. Drag may be created when the blade rotates into the wind.

It is difficult to mount vertical-axis turbines on towers, meaning they are often installed nearer to the base on which they rest, such as the ground or a building rooftop. The wind speed is slower at a lower altitude, so less wind energy is available for a given size turbine. Air flow near the ground and other objects can create turbulent flow, which can introduce issues of vibration, including noise and bearing wear which may increase the maintenance or shorten the service life.

However, when a turbine is mounted on a rooftop, the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence. There are several types of VAWTs:

2.4.3.1 Types of vertical axis

Figure 2.12: 30 m Darrieus wind turbine in the Magdalen Islands

This wind turbine also called "Eggbeater" turbines. They have good efficiency, but produce large torque ripple and cyclic stress on the tower, which contributes to poor reliability. It required some external power source, or an additional Savonius rotor, to start turning, because the starting torque is very low. The torque ripple is reduced by using three or more blades which results in a higher solidity for the rotor. Solidity is measured by blade area over the rotor area. Newer Darrieus type turbines are not held up by guy-wires but have an external superstructure connected to the top bearing.

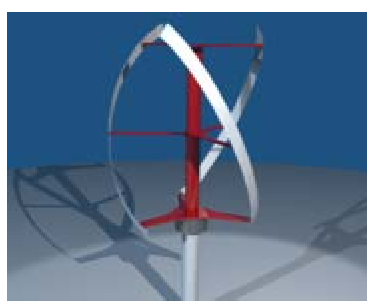

Figure 2.13: A helical twisted VAWT

This is a subtype of Darrieus turbine with straight, as opposed to curved, blades. The cyclic turbine variety has variable pitch to reduce the torque pulsation and is self-starting. The advantages of variable pitch are they have high starting torque, a wide relatively flat torque curve, a lower blade speed ratio, a higher coefficient of performance, more efficient operation in turbulent winds and a lower blade speed ratio which lowers blade bending stresses. There are three types of blade which straight, V, or curved blades may be used. Recently, this type of turbine has been advanced by former Russian rocket scientists who claim to have increased the efficiency of the VAWT up to 38%. A company, SRC Vertical Ltd. has been formed, and has begun selling the new turbine.

Figure 2.14: 12 m Windmill with rotational sails in Osijek, Croatia

This is a Savonius wind turbine. These are drag-type devices with two (or more) scoops that are used in anemometers. Flatter vents (commonly seen on bus and van roofs) and in some high-reliability low-efficiency power turbines. They are always self-starting if there are at least three scoops. They sometimes have long helical scoops to give a smooth torque. The Alvin Benesh rotor and the Hamid Rahai rotor improve efficiency with blades shaped to produce significant lift as well as drag.

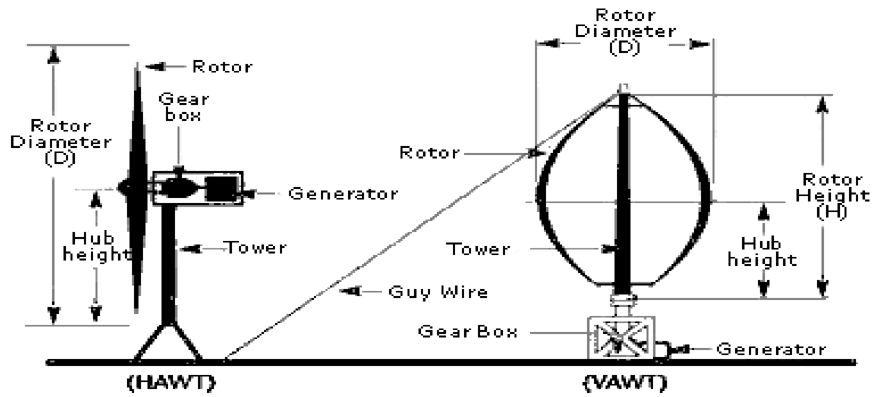

Figure 2.15: Type of wind turbine

2.4.4 HAWT advantages

The advantages of this HAWT type are they have variable blade pitch, which gives the turbine blades the optimum angle of attack. Its allowing the angle of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season. The tall tower base allows access to stronger wind in sites with wind shear or wind gradient, that is a difference in wind speed and direction over a relatively short distance in the atmosphere.. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.

2.4.5 HAWT disadvantages

HAWT have several disadvantages that HAWTs have difficulty operating in near ground or turbulent winds. Then the tall towers and blades up to 90 meters long are difficult to transport. The transportation can now cost 20% of equipment costs. There are difficult to install a tall HAWTs that needing very tall and expensive cranes and skilled operators. Massive tower construction is required to support the heavy blades, gearbox, and generator. Tall HAWTs may affect airport radar. Their height makes them obtrusively visible across large areas, disrupting the appearance of the landscape and sometimes creating local opposition.

Furthermore downwind variants suffer from fatigue and structural failure caused by turbulence. HAWTs required an additional yaw control mechanism to turn the blades toward the wind. The yaw drive is an important component in horizontal axis wind turbines. This component to ensure the wind turbine is producing the maximal amount of electrical energy at all times, the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. This only applies for wind turbines with a horizontal axis rotor. The wind turbine is said to have a yaw error if the rotor is not aligned to the wind. A yaw error implies that a lower share of the energy in the wind will be running through the rotor area. The generated energy will be proportional the cosine of the yaw error.

Then cyclic stresses fatigue the blade, axle and bearing. The material failures were a major cause of turbine failure for many years. It is because wind velocity often increases at higher altitudes. The backward force and torque on a horizontal-axis wind turbine HAWT’s blade peaks as it turns through the highest point in its circle. The tower hinders the airflow at the lowest point in the circle, which produces a local dip in force and torque. These effects produce a cyclic twist on the main bearings of a HAWT. The combined twist is worst in machines with an even number of blades, where one is straight up when another is straight down. Teetering hubs have been used to improve reliability, which allow the main shaft to rock through a few degrees, so that the main bearings do not have to resist the torque peaks.

2.4.6 VAWT advantages

This type doesn’t need massive tower structure. Its also don’t need yaw mechanism as the rotor blades are vertical. It can be located nearer the ground that making it easier to maintain the moving parts. This type has a higher airfoil pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures. Straight bladed VAWT designs with a square or rectangular cross section have a larger swept area for a given diameter than the circular swept area of HAWTs.

VAWTs have lower wind startup speeds than HAWTs. Typically, they start creating electricity at 6 m.p.h. (10 km/h). VAWTs usually have a lower top speed ratio and so are less likely to break in high winds. It may be built at locations where taller structures are prohibited. VAWTs situated close to the ground can take advantage of locations where mesas or elevated area of land with a flat top and sides that are usually steep cliffs, hilltops, ridgelines, and passes funnel the wind and increase wind velocity. VAWTs do not need to turn to face the wind if the wind direction changes. VAWT blades are easily seen and avoided by birds.

2.4.7 VAWT disadvantages

Most VAWTs produce energy at only 50% of the efficiency of HAWTs in large part because of the additional drag that they have as their blades rotate into the wind. VAWTs do not take advantage of the stronger wind at higher elevation. Most VAWTs have low starting torque, and may require energy to start the turning. A VAWT that uses guy wires to hold it in place puts stress on the bottom bearing as all the weight of the rotor is on the bearing. Guy wires attached to the top bearing increase downward thrust in wind gusts. Solving this problem requires a superstructure to hold a top bearing in place to eliminate the downward thrusts of gust events in guy wired models. While VAWTs' parts are located on the ground, they are also located under the weight of the structure above it, which can make changing out parts near impossible without dismantling the structure if not designed properly.

2.4.8 Small Wind Turbine

A small wind-powered electricity generation system, providing regulated AC electric power from wind energy to a power system grid. It has a wind turbine that produces less than 10kW of peak electric power in a permanent magnet generator that produces generator power with a frequency that varies with the wind speed. The wind turbine utilizes a cross-wind type rotor having a power coefficient that varies with the operating top speed ratio and has an optimal top speed ratio where in the power coefficient is maximum.

A power converter for converting generator power to regulated electric power by applying a controlled load to the generator controls the operation of the wind turbine rotor such that the operating top speed ratio in a low wind speed region is approximately equal to the optimal top speed ratio in a medium wind speed region and is greater than the optimal top speed ratio in a high wind speed region.

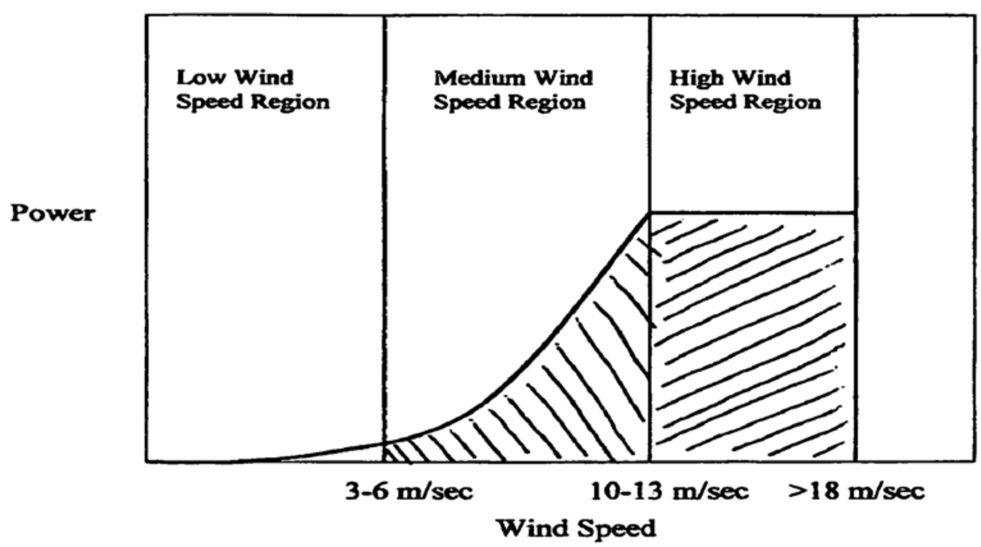

Figure 2.16: Power generate based on wind speed region

A small wind turbine can be installed on a roof. Installation issues then include the strength of the roof, vibration, and the turbulence caused by the roof ledge. Small-scale rooftop wind turbines have been known to be able to generate power from 10% to up to 25% of the electricity required of a regular domestic household dwelling.

2.4.8.1 Basic Component of Commercial Small Wind Turbine

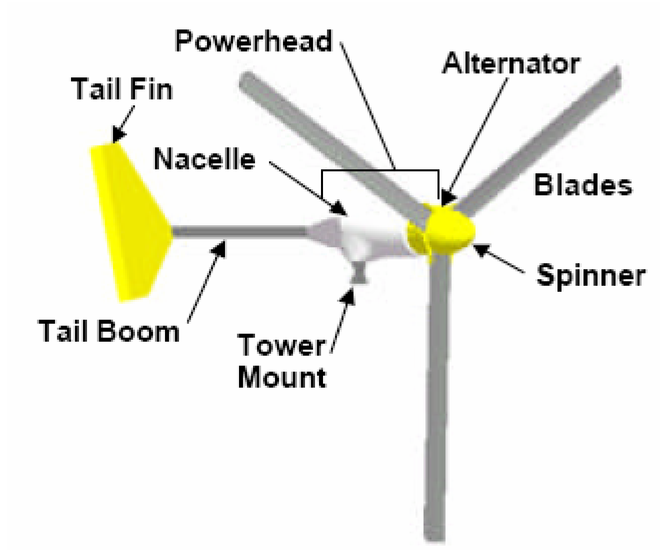

Figure 2.17: Component of wind turbine

2.4.8.2 Blades / Rotor System

The rotor system consists of three fiberglass blades. Acting like aircraft wings, the blades convert the energy of the wind into rotational forces that can drive a generator. The fiberglass blades are exceptionally strong because they are densely packed with glass reinforcing fibers that run the full length of the blade. The rotor has three blades because three blades will run much smoother than rotors with two blades.

2.4.8.3 Alternator

The alternator converts the rotational energy of the rotor into electricity. The alternator utilizes permanent magnets and has an inverted configuration in that the outside housing (magnet can) rotates, while the internal windings and central shaft are stationary and produces power at low speeds, eliminating the need for a speed-increasing gearbox. The output from the alternator is alternating current (AC), but it is rectified to direct current inside the nacelle. Since it uses permanent magnets, the alternator is generating voltage whenever the rotor is turning.

2.4.8.4 Nacelle

The nacelle is the fiberglass housing around the main body of the machine. It contains the main structural “backbone” of the turbine called the mainframe, the rectifier, the slip-ring assembly, the yaw bearings, and the tower mount. The yaw 3 bearings allow the wind turbine to freely pivot around the top of the tower so that the rotor will face into the wind. The slip-ring assembly is the electrical connection between the moving as it orients with the wind direction of wind turbine and the fixed tower wiring. The slip-rings and yaw bearings are located just above the tower mount.

2.4.8.5 Tail Assembly and AutoFurl Operation

The tail assembly, composed of a tail boom and the tail fin, keeps the power head and therefore the rotor aligned into the wind at wind speeds below approximately 12.5 m/s (28 mph). At about 12.5 m/s the AutoFurl action (see Figure below) turns the rotor away from the wind to limit its speed. The tail appears to fold, but in reality the tail stays stationary as the power head turns sideways to the wind. The rotor does not, however, furl completely sideways. This allows the turbine to continue to produce power in high winds. When the high winds sub side the AutoFurl system automatically restores the turbine to the normal straight position.

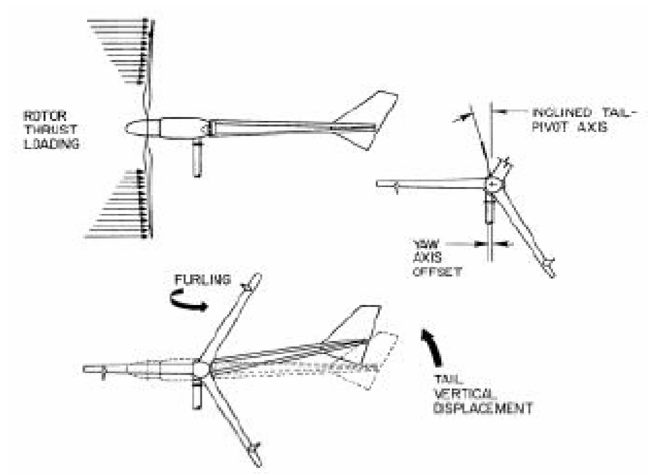

Figure 2.18: AutoFurl system

2.4.8.6 Power Center

The Power Center, shown in Figure below serves as the central connection point for the electrical components in the system and it provides a number of necessary and valuable control functions that consist transformer, voltage regulator and other related controller device. The Power Center also provides status lights for the system and a handy light-bar "fuel gage" for the battery bank.

Figure 2.19: Power Center box

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this project, the work methodology can be shown by block diagram below:

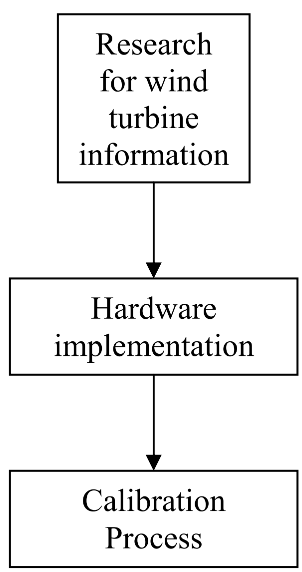

Figure 3.1: Methodology block diagram

3.2 Research for wind turbine information

In this project there are 3 methods to gather the information about wind turbine. There are by using books, articles and information in internet and by doing practical research at Tasek Kasturi Company.

3.2.1 Books

There are many books about wind turbine with many languages in many difference perceptions. Almost the books are about the research on the potential and renovation of wind turbine. These books are easily to get because there are big development in renewal energy especially in wind turbine. These are 2 books that really helped in this project that elaborate more detail about wind turbine. They are “Wind Turbine operation in electric power system” by Z.Lubosny and “Wind Turbines Fundamental Technologies, Application Economic” 2nd Edition by Erich Hau.

“Wind Turbine operation in electric power system” by Z.Lubosny gives more focus on how the wind turbine operates. There are detail explanations on mechanism and the related equipments that must be used in wind turbine operation. It also complete with pictures and any related figures such as graph, block diagram, flowchart and appendix that related. Also the history of wind turbine development.

“Wind Turbines Fundamental Technologies, Application Economic” 2nd Edition by Erich Hau also discuss about the history of wind turbine development since before century until nowadays. The differences are in this book we can know more detail about the fundamental technologies based on wind turbine. The basic technologies those are really good for more advanced invention. Furthermore it discuss about wind turbine application in economic term that have a detail information about why we must replace already energy sources with wind turbine based on expert research economic data.

3.2.2 Internet

There are many website that we can get the information of wind turbine. Some are invention articles, some are research article, some are basic information of wind turbine, and more about everything related to the wind turbine. The difference between internet and books are they are worldwide and more information for just a click. Those are really helped for this project and more information has been gathered. Also we can use it as reference for advanced the project.

3.2.3 Practical Research at Tasek Kasturi Company

Both of methods above just about information and knowledge about wind turbine but this method is more relevant and practically to this project. Since Jun 2008, practical task are started. The employees of Tasek Kasturi Company are really helped either in theory or practical task for developing a synchronous generator for wind turbine. Starting with basic theory then used a dynamo bicycle as study material. The entire generator concept had been applied into the experiment. Then the experiment result used for developing a real synchronous generator.

3.3 Hardware implementation

3.3.1 Picture of overall project

Figure 3.2: Complete set of wind turbine

3.3.2 Synchronous generator

This synchronous generator is customized product by using car spare part equipment. There are 2 prototypes of generator that already done at Tasek Kasturi Company.

3.3.3 Synchronous generator (first prototype)

This prototype is shown in figure below that used totally car spare part components. The casing is from car alternator casing. The rotor and magnets also from car alternator. But the stator winding is used a magnetic coil from Tasek Kasturi Company. Based on experiment that already done, the magnetic coil have been rewinding about 3000 turns by using winding machine at the company.

Figure 3.3: Casing and stator winding

Figure 3.4: Bar permanent magnet and rotor

Figure 3.5: Stator winding had been varnish

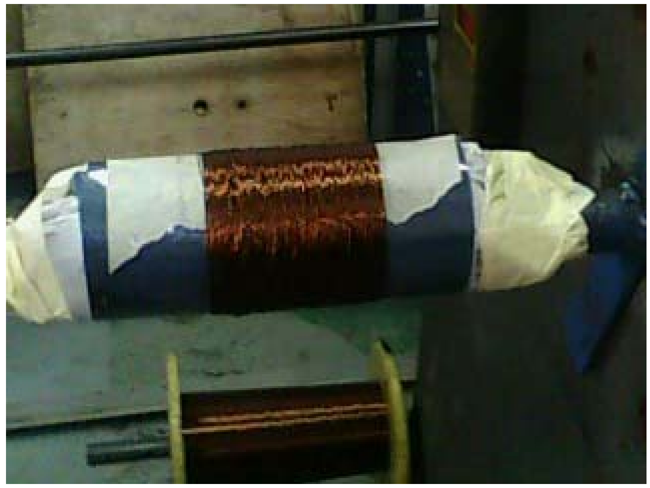

Figure 3.6: Magnetic coil winding using winding machine

Figure 3.7: Winding machine screen play controller

Figure 3.8: Interior view for casing and stator winding

3.3.4 Synchronous generator (second prototype)

This prototype is only use basic concept of synchronous generator. The major part is using bicycle's dynamo and rewinding the stator winding with new size of magnetic coil and increase the number of turn about 70 turns. The prototype as shown below:

Figure 3.9: Original dynamo from manufacturer

Figure 3.10: Modified dynamo

Figure 3.11: Permanent magnet

Figure 3.12: Stator

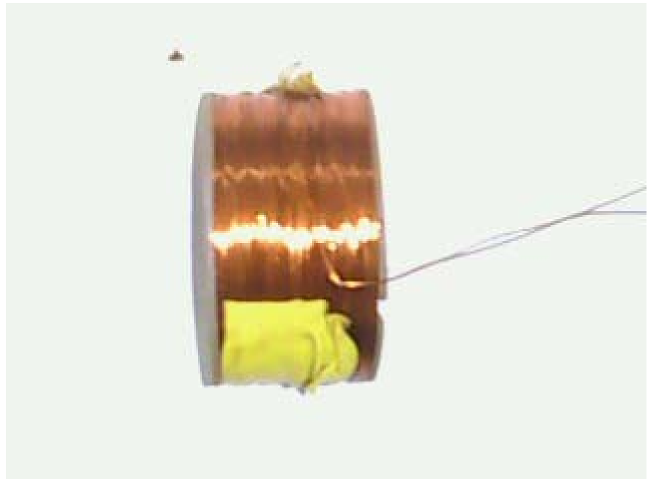

Figure 3.13: Stator winding with new magnetic coil

3.3.5 Fan

These fans blades are made from PVC pipe. That is because PVC has strength and the quickest and cheapest way to get started. Also they are light and was home made from 6 inch PVC pipe. The figure below show the fan.

Figure 3.14: Wind turbine PVC blades

3.3.6 Boost Converter

Boost converter is additional circuits in this project. Basic boost converter consists of inductor as the energy storage device, MOSFET as a power switch, diode, and capacitor is used to limit the output ripple and output resistor as show in figure 3.13. The design of boost converter need to be consider the Continuous Current Mode (CCM), input and output voltage, current, output ripple and component rating. Basic design starts with a detail calculation on every value of component need to be used to produce a desired output. Select a suitable frequency range and find a component according to all value collected in the calculation.

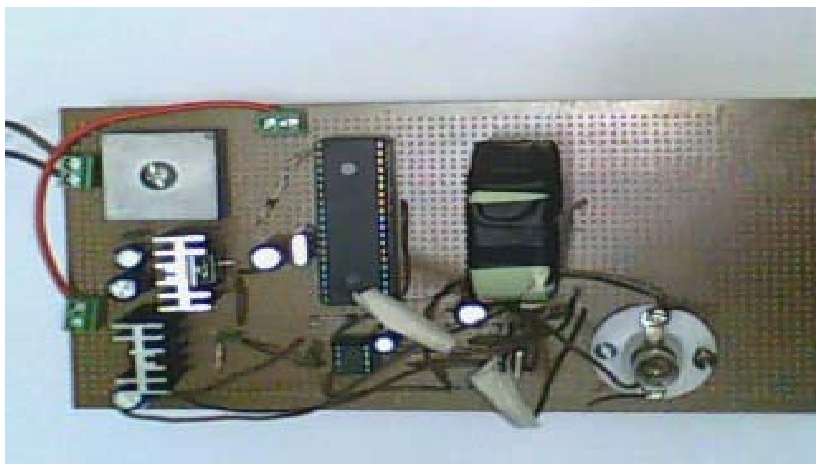

Figure 3.15: Boost Converter Circuit

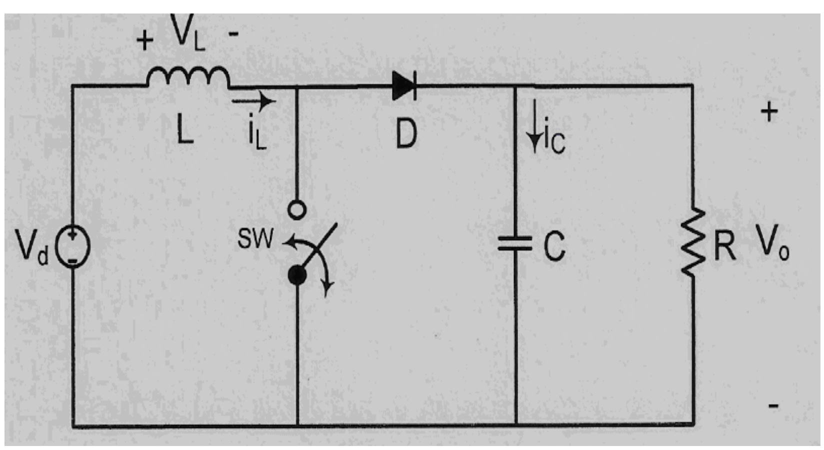

Figure 3.16: Basic circuit of boost converter

3.3.6.1 Boost Converter Calculation

Vin = 14Vdc

Vout = 30Vdc

Assuming ripple voltage, Vr = 2%

Load resistance, R = 1000 Ω

Duty Cycle, D:

$$D = 1 - \frac{V_i}{V_o}$$

$$= 1 - \frac{14}{30}$$

$$= 0.533$$

To find frequency range, f:

Using MOSFET driver IRF740

$t_r = 150ns$	$t_{on(\min)} = 750ns$	$D_{\max} = 90\%$
$t_f = 50ns$	$t_{off(\min)} = 200ns$	$D_{\min} = 10\%$

$$\frac{4(1-D_{\max})}{3(t_r + t_f) + 4t_{off(\min)}} \le f \le \frac{4D_{\min}}{t_r + t_f + 4t_{on(\min)}}$$

$$\frac{4(1-0.533)}{3(150\times10^{-9} + 50\times10^{-9}) + 4(200\times10^{-9})} \le f \le \frac{4(0.533)}{(150\times10^{-9}) + (50\times10^{-9}) + 4(750\times10^{-9})}$$

$$1.3MHz \le f \le 666.25kHz$$

Frequency choose, f = 1MHz

Minimum inductor value, L:

$$L_{\min} = \frac{D(1-D)^2 R}{2f}$$

$$L_{\min} = \frac{0.533(1-0.533)^2(1000)}{2(1\times10^6)}$$

$$L_{\min} = 58.12\mu H$$

Standard inductor value, L= μH

Inductor current, IL:

$$T = \frac{1}{f}$$

$$T = \frac{1}{1\times10^6}$$

$$T = 1\mu s$$

$$I_L = \frac{V_{in}}{(1-D)^2 R}$$

$$I_L = \frac{14}{(1-0.533)^2(1000)}$$

$$I_L = 0.064A$$

$$\frac{\Delta i}{2} = \frac{V_i DT}{2L}$$

$$\frac{\Delta i}{2} = \frac{14(0.533)(1\times10^{-6})}{2(58\times10^{-6})}$$

$$\frac{\Delta i}{2} = 0.064A$$

Capacitor value, C:

$$C = \frac{D}{RfV_r}$$

$$C = \frac{0.533}{(1000)(1\times10^6)(0.02)}$$

$$C = 26650\,pF$$

Standard value of capacitor, C = 22000 pF

3.3.6.2 Regulator Circuit

Voltage regulator is needed because not every component in the circuit is using a same value of voltage to operate. In this project there are two voltage regulators to be use. One to produce an output of 5 volt and the other one will produce an output of 15 volt. The main power supply in this circuit is 24volt direct current from the power supply in the laboratory. Where from the 24volt main supply will be the input for the first voltage regulator circuit using IC LM7815 and than produce an output of 15volt. The output from the first voltage regulator and than be the input for the second voltage regulator and a power supply for the switch driver IRF740. For the second voltage regulator we were using IC LM7805 to produce an output of 5volt so it can be the input power of PIC microcontroller.

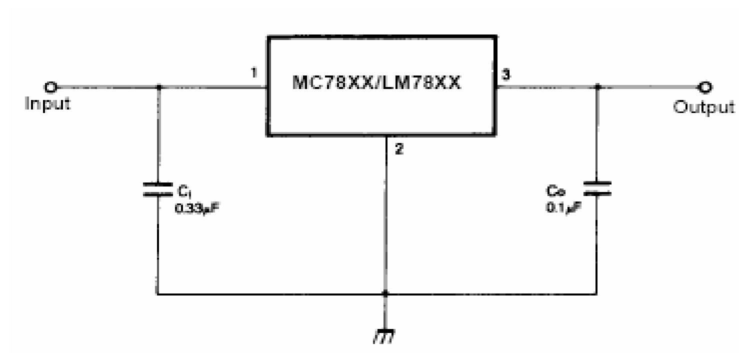

Figure 3.17: Voltage Regulator Circuit

The circuit in Figure 3.15 above shows the basic component in voltage regulator. Where the circuit consists of input power, input capacitor (C_i), voltage regulator IC (LM7805/LM7815), and output capacitor (C_o). The IC used in this circuit is a Fixed Regulator ICs where the output voltage produce is smaller than the input voltage. The voltage different between the input and output appears as heat and dissipated through head sink. The capacitor attached at the input and output is used to remove an unwanted noise and spike.

3.3.6.3 Driver Circuit

Driver circuit function is to generate pulse needed by the switch so the switch can operate appropriately. IC IRF740 is used as a driver in this project as an MOSFET switch driver. IRF740 has dependent high and low side referenced output channels. Different driver will produce different output result depending to the driver characteristic.

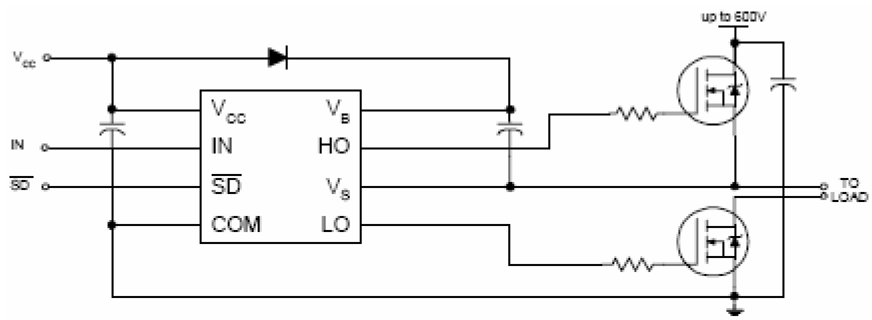

Figure 3.18: Driver Circuit

As in MOSFET switch for boost converter only the high side referenced channel is used. The output result by using this driver is invert from the input supply. Since using the high side referenced channel the output result will turn low and this happen because of the characteristic of the driver itself.

3.3.6.4 Inductor

Boost topology circuit contain an inductor as an energy storage device. Based on calculation, 60 μH inductor value is needed to produce an output voltage of 30Vdc. But there is no 60 μH inductor standard value from manufacturer, the nearest standard value available is 12 μH inductor with a specific current rating. According to the calculation have been made the maximum current flow through the inductor circuit is low about 0.06A. The solution to this problem is by built an inductor that is suitable to be use in this circuit.

There are several things need to be consider to designing the inductor. For this project ferrite core have been choose to produce an inductor of 60 μH. However in order to determine the AL value of a Ferrite core, we must have inductance meter or other method to determining the inductance. Below are the steps to know turns of different value of inductance.

.

1. First, wind a specific number of turns on the unknown core such as 10 or 20 and recommended turns are 100 turns because more turns will result in a more accurate answer. Then, measure the value of inductance
2. Now using the formula in the equation below, we can determine the AL Value depend the value that want either in µH or mH.
3. After that, we can know the actual number of turns using formula in Equation below

$$\text{AL value} = \left(\frac{100}{no.ofTurn}\right)^2 (Lin\mu H)$$

$$\text{Number Of turn} = \sqrt{\frac{L(\mu H)}{A_L(\mu H/100Turn)}}(100)$$

First, wounded 20 turns of enameled copper wire on a Ferrite Rod and then measured inductance was 100 μH.

$$\text{AL Value} = \left(\frac{100}{10}\right)^2 (100)$$

$$= 10000$$

The value of inductance that need in this project is equal to 60μH, based on the above AL value. Using the appropriate formula for the number of turns from the equation above.

$$\text{Number of turns} = \sqrt{\frac{60}{10000}}(100)$$

$$= 7.75 \text{ turns}$$

However, the actual number of turns for 60μH is 11 turns

Since this project is low power, smaller wire diameters are used to support the input current 0.06A.

3.3.6.5 PIC Microcontroller Circuit

PIC microcontroller is grouped by the sizes of the instruction word and their instruction set. For this project microcontroller based boost, PIC 18F4550 is used, where this PIC is an enhanced 16-bit instruction word length. Each part of the devices can be places in three of the groups, core, peripherals and special feature. The core contains the basic features that are required to make the devices to operate. In the peripherals contains a features added to different from a microprocessor. These make the interfacing to the external world and internal task easier. For special feature group unique features added to make the system cost less, increase system reliability and increase design flexibility. PIC 18F4550 memory type is indicating in the part number by the first letter after the family affiliation designation for example PIC 18 'F'4550. The letter 'F' indicate the device have a flash type of memory, where this devices is electrical erasable. Being electrical erasable make the devices can be erased and reprogrammed without removal from the circuit.

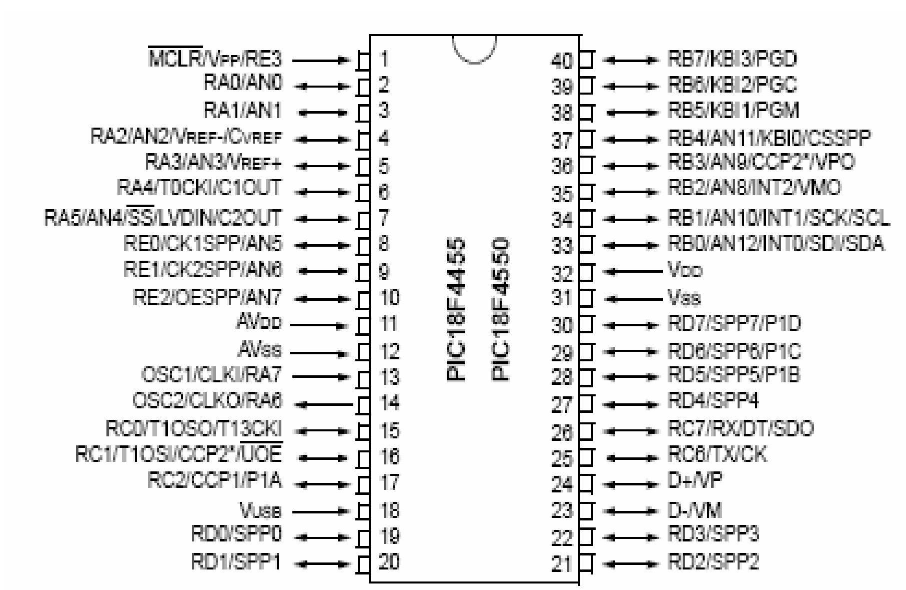

Figure 3.19: PIC 18F4550

The **Figure 3.19** above shows the pin diagram of PIC 18F4550. To implement PIC microcontroller in this project there is a need to build the circuit in figure 12 below.

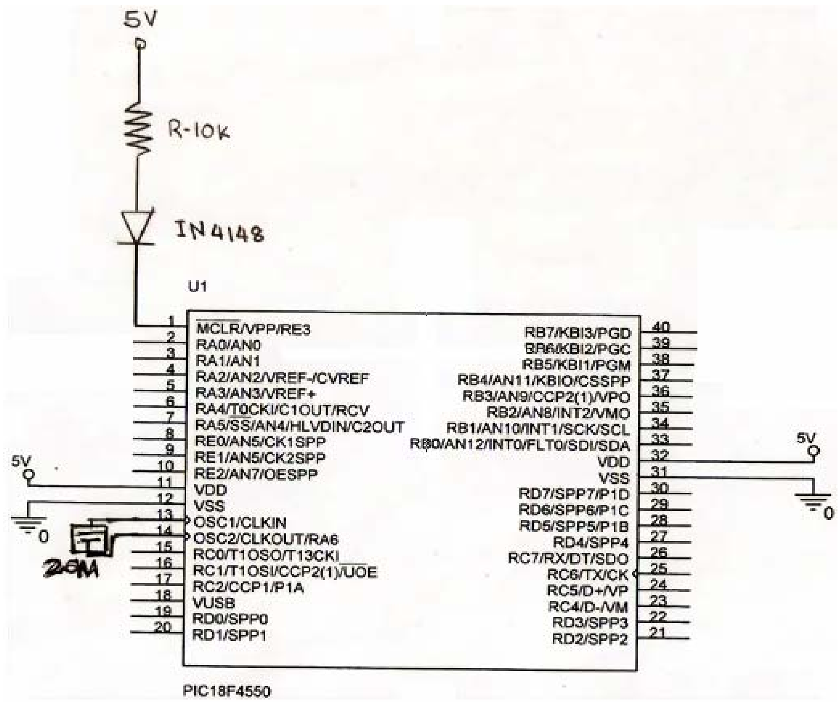

Figure 3.2: PIC Circuit

3.4 Calibration Process

Synchronous generator will provide output in AC voltage. AC voltage that is generated are varies depend to the wind speed. Then the output voltage will be step up in the boost converter. For this boost converter, it just multiply the input voltage about 2 times only so the target for this project just to get the output about 30Vdc.

The calibration process is the process to configure a device with respect to the standard value. The most simple calibration method is simply comparing both outputs, from the standard device with the uncalibrated device. The same way applied to this project. The output from the generator is compared to the other medium but same frequency of wind flow.

For this project, two comparing methods used to be calibrated with the generator. The first method is using an electric synchronous motor with varies speed by using inverter to control the frequency. The generator attached to the motor and the motor function as a puller for the generator to replace the medium of wind.

Table 3.1: Table for generator calibration

Frequency (Hz)	Output Voltage (V)
5	
10	
15	
20	

The result will be discussed on the next chapter.

The second comparison calibration is using the actual wind turbine. The wind turbine used PVC blades. It is small in size and light weight. The calibration technique used is attaching the generator with PVC blades and located it at open place to point the fan to the wind and readings are taken.

Figure 3.21: Calibration method 1

Figure 3.22: Calibration method 2

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This project has been successfully in achieving all scope. The output value can be displayed either on the multimeter or oscilloscope. However, this project only can proceed with prototype 2 because prototype 1 had been broken in a testing task. The magnetic coil had been broken after the output voltage value reach 50Vac. The assumption for that case are the magnetic coil that used is a small size and it can’t support the value of high voltage or high current. Since that the magnet size also bigger than prototype 2, the induction voltage also bigger. The worse case that this generator can’t be rebuilt because of the permanent magnet also broken and loss its strength cause by heated. So, the project proceeds with the prototype 2.

To calibrate the generator, calibration processes have been conducted. The calibration is done in several methods explained in previous chapter.

4.2 Calibration Method 1

The first calibration method is by using an electric synchronous motor with an inverter that can control the speed by varies the frequency. This motor used as a puller to replaced wind as a medium. For calibration using motor, the results are shown below;

Table 4.1: Result for generator calibration conducted on 8:30 pm, 11/10/2008

Frequency (Hz)	Output Voltage (V)
5	2
10	5
15	11
20	13

Table 4.2: Result for generator calibration conducted on 9:00 pm, 11/10/2008

Frequency (Hz)	Output Voltage (V)
5	1.8
10	6
15	10.5
20	13.8

Table 4.3: Result for generator calibration conducted on 10:30 pm, 13/10/2008

Frequency (Hz)	Output Voltage (V)
5	2.1
10	5.6
15	11.4
20	13.5

Table 4.4: Result for generator calibration conducted on 11:30 pm, 13/10/2008

Frequency (Hz)	Output Voltage (V)
5	2
10	6
15	12
20	14

4.3 Calibration Method 2

For more satisfaction in determining the sensor accuracy, another method of calibration was conducted. It compares the output of the generator using motor with the real wind turbine. As discussed in previous chapter, the wind turbine used PVC blades. It is small in size and light weight. The calibration technique used is attaching the generator with PVC blades and located it at open place to point the fan to the wind and readings are taken.

The result shown in table below;

Table 4.5: Result for generator calibration 2 conducted on 2:30 pm, 12/10/2008
Without give starting torque with pushing by hand (open place)

Duration (s)	Output Voltage (V)
Starting	0.2
5	1.2
10	2.3
20	2.7

Table 4.6: Result for generator calibration 2 conducted on 3:30 pm, 12/10/2008 giving starting torque with pushing by hand (open place)

Duration (s)	Output Voltage (V)
Starting	2.5
5	4.5
10	6.8
20	10.2

Table 4.7: Result for generator calibration 2 conducted on 2:00 pm, 14/10/2008 giving starting torque with pushing by hand (using lab fan)

Duration (s)	Output Voltage (V)
Starting	2.3
5	4.7
10	8.2
20	15

Table 4.8: Result for generator calibration 2 conducted on 3:00 pm, 14/10/2008 giving starting torque with pushing by hand (using lab fan)

Speed of fan	Output Voltage (V)
Starting	2.5
Low speed	5.6
Medium	15
Top speed	22.5

From the table, by comparing the output we can see the linearity of both methods. From the output value, its varies with the wind speed which mean the output value is proportional to the wind speed but for a good wind turbine its need a starting torque and constant wind speed.

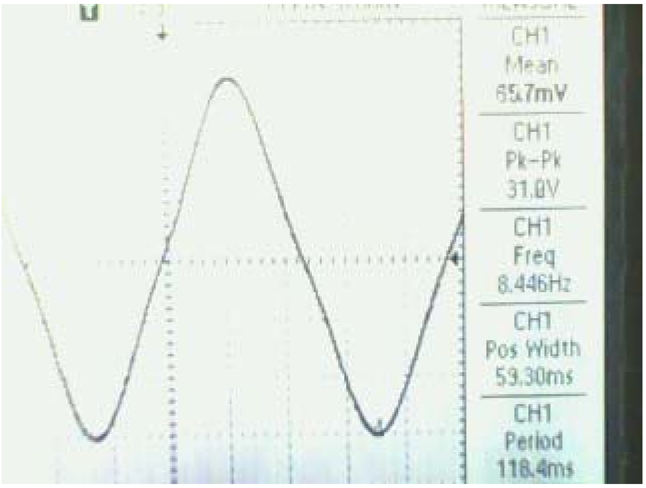

Figure 4.1: Result for generator calibration 2 conducted on 2:00 pm, 14/10/2008 giving starting torque with pushing by hand (using lab fan)

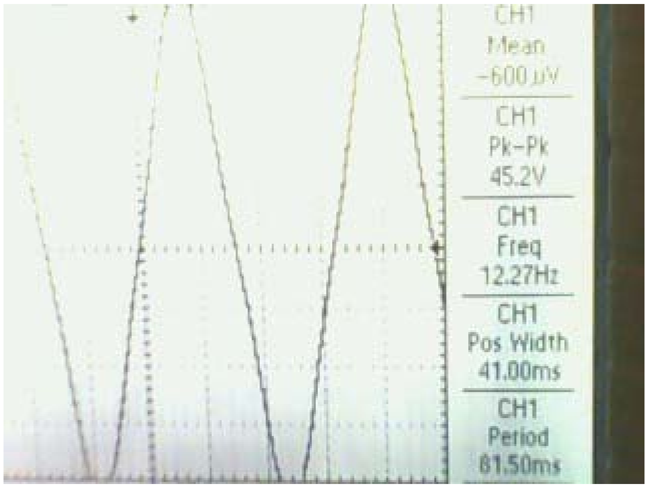

Figure 4.2: Result for generator calibration 2 conducted on 3:00 pm, 14/10/2008 giving starting torque with pushing by hand (using lab fan)

4.4 Boost Converter Result

Since that the output from generator was generated as calculation, the boost converter is properly works and can give the same value as calculation that step up the output voltage twice. There are the results below;

Figure 4.3: Result for boost converter on 3:30 pm, 14/10/2008
About times 2 from the generator output

Table 4.9: Input and output value

Generator value	Boost converter value
18 Vac	28.9 Vdc

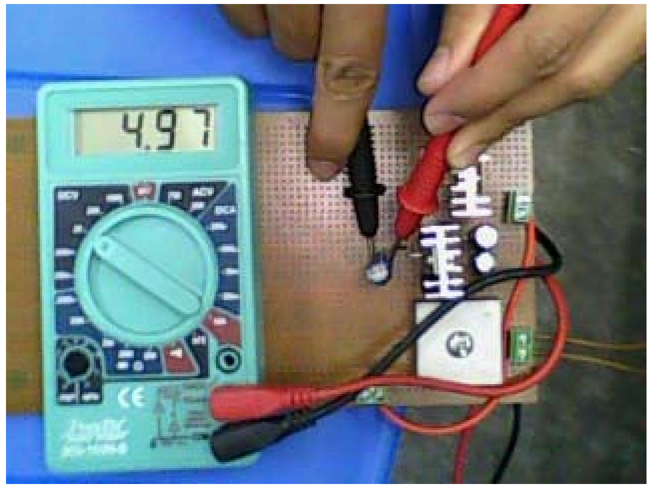

Figure 4.4: Result for boost converter at voltage regulator on 3:45 pm, 14/10/2008

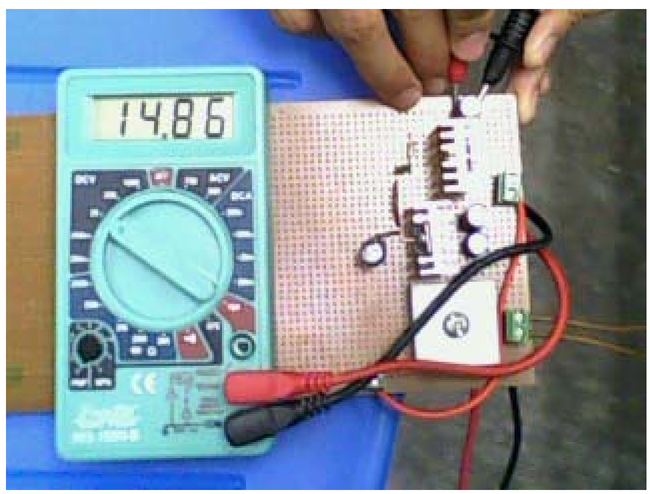

Figure 4.5: Result for boost converter at voltage regulator on 3:55 pm, 14/10/2008

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Nowadays, wind turbine is really known as alternative energy that can be found in numerous types and sizes. The wind turbine used in electricity utility for home, factory even for a village. The recent technologies have developed a wind turbine in numerous scales that suitable for the usage, easy to install, economic, reliability, naturally safe, and renewal. For example many manufacturers that offers a wind turbine product also with consultancy at economic price.

This project's objective is to develop a prototype of small scale wind turbine. The most important task in this project understands how wind turbine works by theory and how to fabricate the real model. The most in wind turbine is the generator. By understand how the generator works that is from the mechanical energy produces an electrical energy. Also understand the advantage and disadvantage by using the wind turbine that can make sure that this technology is relevant or not.

In conclusion, the prototype of small scale wind turbine is perfectly display the output values as expected. The objective and scope of the project is successfully fulfilled.

5.2 Problems

The major problem for this project is difficult to find a suitable permanent magnet due to the cost involved. In Malaysia, there is no company that manufactured the permanent magnet. Even though, there has a company that link to this product but only be a middle men for that product. Unfortunately, they only make a deal for 100 products and above. So that was too much and not relevant to this project. From the basic concept, we can use and permanent magnet to attach to the rotor but in practical consideration it is not perfect. If the suitable magnet was found, that is impossible to match it with other rotor or shaft and also the casing as stator. That mean this product must be fix by the manufacturer. The generator actually must be reused from permanent magnet motor but it's still too expensive and must be ordered from other company at overseas such as China, United Kingdom an many else. The smallest rate of permanent magnet motor in Malaysia is about half horse power and the size as big as real medium generator for wind turbine. For the solution, this project just reused the bicycle's dynamo and rewinding it with a new magnetic coil and increase it's number of turn to increase the output value.

5.3 Recommendation

Overall this prototype of wind turbine performance's can be considered good. However, for high level accuracy system, many aspects in generator and turbine design and supporting circuit must be taken into a proper ways.

For future development, some recommendations have been listed based on the problem encountered and unaffordable ideas.

1. Permanent magnet motor

For better performance, the best and suitable permanent magnet must be used. This is because the real problem based on this project is difficult to find a good set of generator part. Permanent magnet is most important because the bigger magnetic strength, the induced voltage is higher. So that are to make sure the magnetic strength can cross the stator winding to induce voltage and if the magnet strong enough, bigger size of magnetic coil can be used for higher current supported.

2. Starting torque

Since that wind turbine need a starting torque for the best performance, gearing system must be used in the generator. This gearing system used to ensure that the generator have enough starting torque and still can rotate in slow wind speed condition. For example, there doesn't have gearing system in this project because don't have suitable size gear for the dynamo. Mean that the blades only depend on wind speed to rotate and the generator can't produce output constantly. If the gearing system will use, it must be a ratio for example 1:10. Mean that 1 full rotation of blades same with 10 rotation for the generator. So a small air movement, the generator also will produce the output.

3. Protection and additional circuit

If this product is to be used in open area such as field or on the top of a building, lightning protection must be considered. The body must be plant grounding properly to avoid it collapsing during storm or heavy rain and draw lightning to ground. Sealing the join is also a must before the product can be used in open area. Brake system must be applied for protection that used it to stop the bladed for maintenance or for safety when something wrong happen to the generator. Additional circuit such as power stored and a stabilizer from varies output is required. Then there must have a control circuit to make sure those utilities produces from this product s safe and reliable.

5.4 Costing and Commercialization

The cost to develop one unit of this project is summarized in the table below;

Table 5.1 Overall cost for one set of wind turbine

Unit name	Component	Qty	Price/Qty(RM)	Total Price (RM)
Generator	Dynamo bicycle	1	12.00	12.00
Wind turbine model	1m PVC conduit pipe	1	8.00	8.00
	10mm screw & bolt	6	0.70	4.20
	5mm screw & bolt	8	0.50	4.00
	6m PVC conduit pipe	1	35.00	35.00
	8m cable	4	6.00	24.00
	Metal plate	1	5.00	5.00
Boost converter	PIC18F4550	1	30.00	30.00
	40-pin IC holder	1	1.00	1.00
	20MHz crystal	1	5.00	5.00
	LM7805	1	2.00	2.00
	LM7815	1	2.50	2.50
	Heat sink	2	1.50	3.00
	IRF740	1	5.00	5.00
	8-pin IC holder	1	0.70	0.70

Boost converter	Fullwave bridge	1	12.00	12.00
	Ferrite core	1	40.00	40.00
	Independent board	1	2.00	2.00
	IN4148	4	0.50	2.00
	Resistor 1kΩ	3	0.10	0.30
	Resistor 200Ω	3	0.10	0.10
	Capacitor 220µF	4	0.20	0.80
	Capacitor 4.7µF	1	0.10	0.10
	Capacitor 100µF	1	0.10	0.10
	Capacitor 0.1µF	4	0.10	0.40
			TOTAL	**199.20**

This project can be commercialized as small scale wind turbine for small appliances. It is suitable to be used in open areas such as fields and also on the top of building. However due to it's size, it might not be suitable for indoor use.

The production cost for this project is considered low because the materials used in this project are gathered from local shop. For mass production, lower production cost will be achieved by buying the materials in bulk quantity. Using an appropriate production machine to mass produce the product also will reduce the overall cost.

The prospect of this project is wide. It can be implemented for educational purposes, wind turbine potential to be alternative energy and even for personal usage at home.

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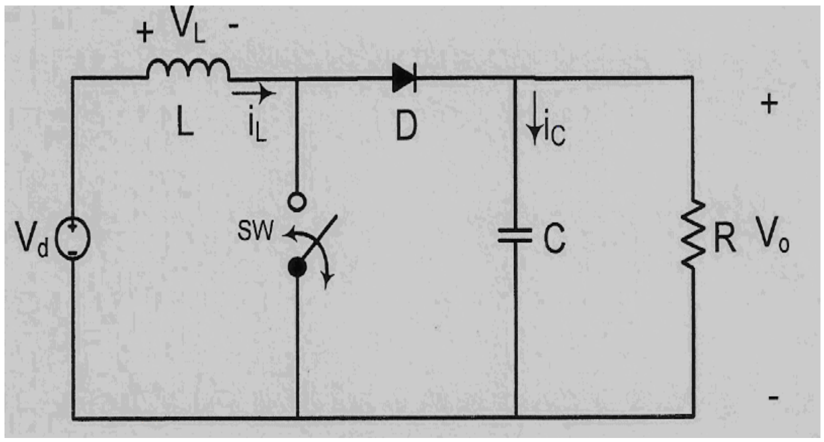
APPENDIX A

PIC PROGRAMMING

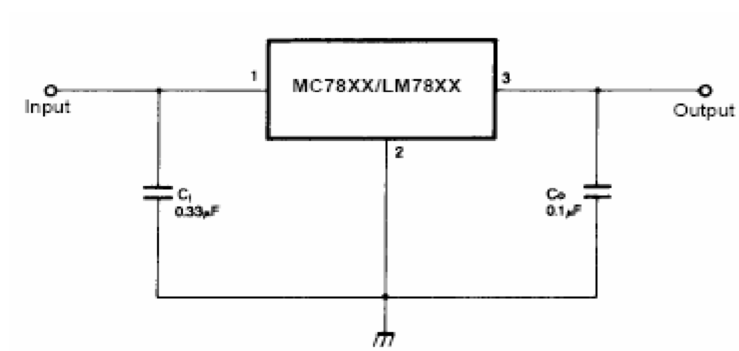
```
'*****************************************************************
'*        Name      : BOOST CONVERTER                            *
'*        Author    : MOHD SHAFARIN BIN HARUDDIN                 *
'*        Notice    :  TO EXECUTE DRIVER CIRCUIT                 *
'*        Date      : 17 SEPTEMBER 2008                          *
'*        Version   : 1.0                                        *
'*        Notes     :  FKEE LAB                                  *
''*****************************************************************

define OSC 20
TRISB.1=0
DRIVER VAR PORTB.1

MAIN:
   driver = 1
   PAUSEUS 16
   driver = 0
   PAUSEUS 24
GOTO MAIN
```

APPENDIX B

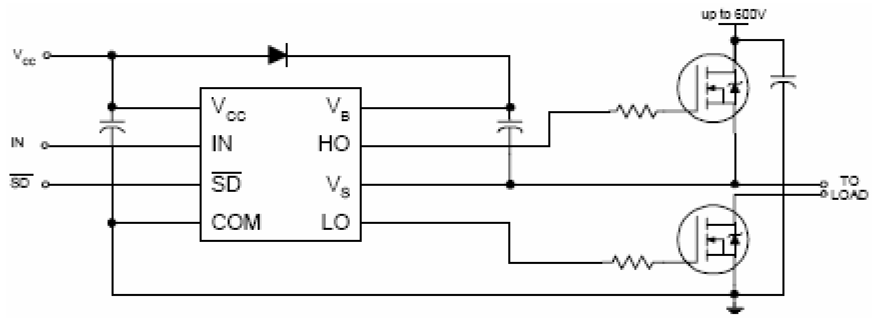
Overall project circuit



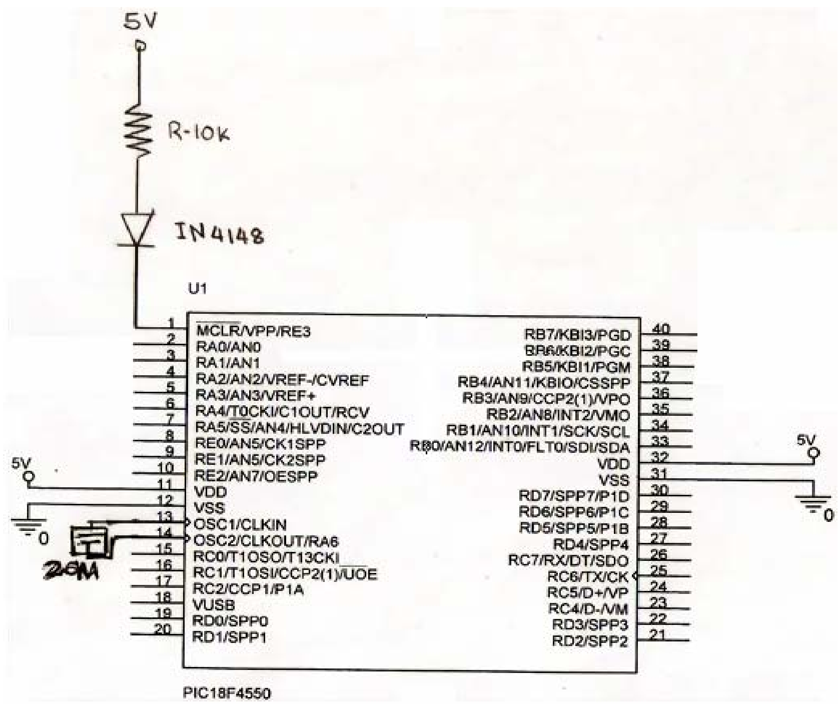
Circuit A: Basic circuit of boost converter



Circuit B: Voltage Regulator Circuit



Circuit C: Driver Circuit



Circuit D: PIC Circuit

APPENDIX C

Datasheet