



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A DEVELOPMENT OF WIND TURBINE GENERATOR USING WASTE ENERGY FOR DOMESTIC USER.

This report is submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology

(Industrial Power) with Honours

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:



ABSTRAK

Turbin angin adalah alat penjana kuasa yang digerakkan oleh tenaga kinetik angin. Tenaga kinetik akan ditukar kepada tenaga mekanikal dengan memutar aci penjana dan menjana elektrik. Turbin angin adalah penjana yang mempunyai kos permulaan yang rendah berbanding dengan penjana kuasa lain. Projek ini akan memperkenalkan teori operasi penjana turbin angin yang jarang digunakan di Malaysia. Selain itu, kajian ini menjalankan eksperimen pembinaan yang mudah untuk turbin angin. Selain menjana elektrik daripada turbin angin, kertas ini membawa kemungkinan baru untuk membangunkan turbin angin menggunakan tenaga terbuang dari udara berlebihan dikeluarkan dari unit luar penghawa dingin. Untuk proses ini, 60% daripada bahan-bahan yang digunakan untuk membina turbin angin ini adalah paip PVC bermula dari menara sehingga asas dan 20% daripada bahan CPVC yang digunakan untuk pembinaan bilah. Selebihnya terdiri daripada penggunaan motor dan komponen elektronik yang digunakan untuk menstabilkan dan menapis voltan keluaran daripada penjana. Prestasi kelajuan angin berlebihan, voltan dan output semasa telah direkodkan untuk menganalisa prestasi data. Oleh itu untuk memastikan bahawa semua objektif bagi Projek Sarjana Muda dicapai, eksperimen yang dibuat mestilah dilakukan dengan betul dengan merujuk skop projek.

ABSTRACT

A wind turbine is a power generating device that is driven by the kinetic energy of the wind. The kinetic energy will be converted into mechanical energy by rotating the generator shaft and generating the electricity. Wind turbine generator is a generator that has a low initial cost compared to other power generators. This project will introduce the theoretical operation of wind turbine generators which are rarely used in Malaysia. Moreover, this study presents an experiment by running a simple construction of wind turbines. Besides generating electricity from a wind turbine, this paper brings a new possibility to develop wind turbines using wasted energy from the excess air released from outdoor unit of air-conditioner. For this process, 60% of the materials used to build this wind turbine is a PVC pipe started from tower to the foundation and 20% from the CPVC material used for blade construction. The rest consist of the used of motor and electronic components that are used to stabilize and filter the output voltage of the generator. The performance of the wind speed of excess air release, voltage and current output were recorded in order to analyze data performance. Therefore to make sure that all the objectives for the Bachelor Degree Project is achieved, the experiment and procedure must be done properly by referring the scope of the project.

DEDICATION

This project is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time. Last but not least, I sincerely thanks to my project supervisor and all my friends for being my great pillars of support throughout my journey of education.



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اونیورسیتی تکنیکل ملیسیا ملاک

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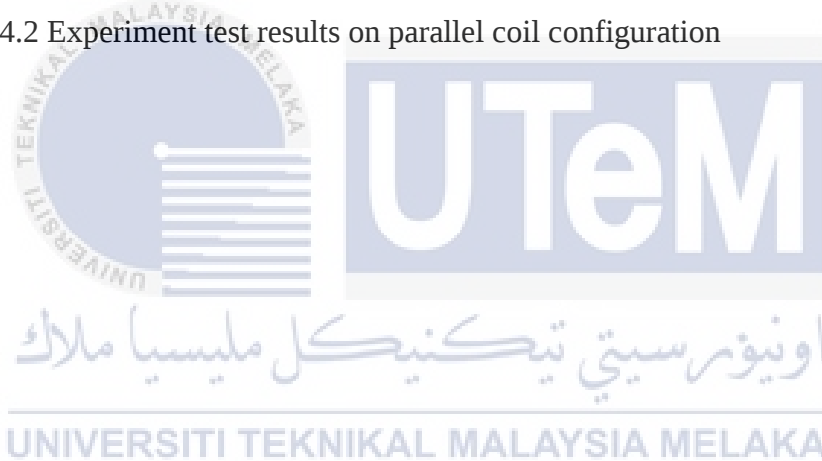
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LISTS OF SYMBOLS AND ABBREVIATIONS

DC	- Direct current
AC	- Alternating current
rpm	- Revolutions per minute
m/s	- Metre per second
HAWT	- Horizontal Axis Wind Turbine
VAWT	- Vertical Axis Wind Turbine
kW	- kilo watt
V	- volt
A	- ampere
mA	-mili ampere
mAh	- milliamp hour
PVC	- Polyvinyl chloride
CPVC	- Chlorinated polyvinyl chloride
UTeM	- Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.0 Introduction.

This chapter focus more about the background and problem statement. Then followed by objective and scope have been identified. Finally, the proposed solution for this project are briefly discussed.

1.1 Background of Project.

Energy sources are classified as non-renewable and renewable energy. Renewable energy defined as the energy collected naturally where the energy source is not reduced or can be replenished within a human lifetime. This energy gained worldwide attention as the price of raw material for non-renewable energy soaring. Furthermore, renewable energy are considered to be important in control of fuel consumption which is cannot be renew and reducing the emissions of greenhouse gases. Reduction of greenhouse gas emissions will helps to protect the Earth from pollution. Examples of renewable resources can be seen daily around the world such as wind, solar, hydropower, geothermal and biomass.

Wind is air in motion due to the irregular energy of solar radiation to the surface of the earth. Today, people taking advantage of this wind natural energy to generate electricity. Impact than the use of this energy source can help minimize fuel consumption and air pollution control. Wind has played a long and important role in the history of human civilization. This power energy has been used for pumping water,

milling grain and driving other mechanical devices start from thousand years ago. These wind flow can be harvested using wind turbines and used to make electricity. Nowadays wind farm commonly employs groups of wind turbine, located either on land, near-shore and off-shore. A wind turbine is a device that is equipped with a blade, working to convert the kinetic energy into rotational motion to turn the electrical generator and produces electricity.

Wasted energy from wind resources available a cooling tower, air ventilation system, humidification plant or any system that produces strong and consistent winds. (Chong et al., 2014). A cooling tower is a semi-enclosed device commonly used to dissipate heat from power generation units, water-cooled refrigeration, air conditioning and industrial processes. The cooling tower will cools the hot water that can reduce product output at greater energy input. Therefore, generating plants, chemical processes and refrigeration loops, which use the cooling system can save most of the money if understand well the process of cooling system. (Burger, 1996). The study on the energy-saving benefit and economic evaluation analysis shows the results indicate that cooling tower with flue gas injection is more economical than the conventional cooling tower compare to conventional cooling tower under the same condition. (Han et al. 2009). A blower also one of the cooling system used in Malaysia industrial. Blower is a machines to provide a large flow of air by rotating a blades which connected to a hub and the shaft, driven by a motor to various processes in industries.

1.2 Problem Statement

Wind energy gained attention in European countries which have high average wind speeds since it is free in terms of energy resources and free from the environmental pollution. However, the limitless of natural resources in Malaysia becomes a major problem when dealing with renewable electricity generation. Malaysia has two main seasons weather southwest monsoon in May / June to September and the northeast monsoon from November to March. Overall, the mean

daily wind speed in Malaysia is about 1.8 m / s. (Basil, 2013). Figure 1.1 will shows the mean daily speed in Malaysia. Most of wind turbine generator need high wind speed in order to generate high power output. High wind speed acquired at higher altitudes where there is less friction slowing the velocity of the wind down. Therefore, HAWTs usually have high cost for the construction and the maintenance because it must be mounted on a long towers to maximize the power efficiency. (Dang, 2009).

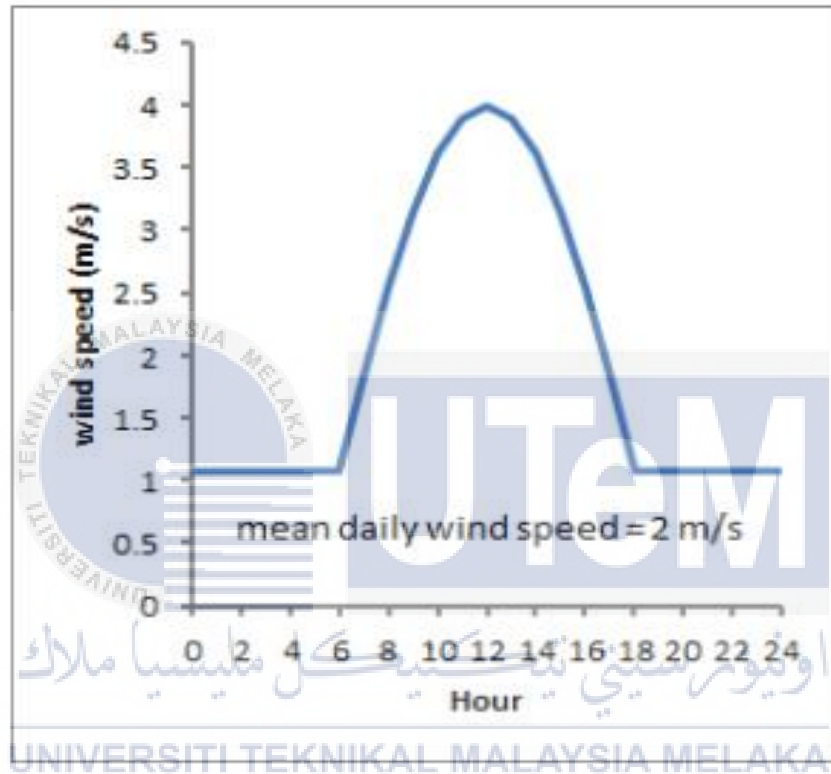


Figure 1.1 Daily wind speed in Malaysia.(Basil, 2013).

1.3 Objective

The objectives of this project are to:

- i. To develop a model of wind turbine generator by reuse wasted energy from a cooling system.
- ii. To produce electricity from wind speeds released by the cooling fan system.

1.4 Scope

Scope of the project is to design a wind generator by using wasted energy from excess air produced by a cooling system for domestic purposes. Afterwards, this project will use a three blade wind turbine which is a type of horizontal-axis wind turbine (HAWT) in order to convert the kinetic energy to mechanical energy. An example of three blades horizontal wind turbine illustrated in the Figure 1.2.



Figure 1.2 A horizontal with three blades wind turbines. (T. Al-Shemmeri, 2010).

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter relates to the reading material of the literature review that will discuss about the history and the different types of wind turbine. Besides that, in this chapter we also able to discuss the components used and the operation of wind turbines. The information obtained from this literature will be used to assist the implementation of the next process.

2.1 Wind Turbine

History of the emergence of a wind turbine system starting from application of driving a sailboats and sailing ships. Then the use of natural energy is growing over time, evolving from movement of ships to operating irrigation pumps to finally generating electricity for general use. Wind power get the world focus today because its fuel costs is free in comparison with the use of oil and coal for energy sources non-renewable. Constraints of this energy source, they will run out eventually and become exhausted, since it cannot be replenished in a short period of time. (Dang, 2009).

Anderson P.D. has conduct two studies about the historical and modern utilization of wind power. Wind part of renewable energy sources which do not have fuel costs. Power output from wind generators can be categorized into two parts through the use of mechanical shaft power directly (a gearing ratio) or by allowing the wind turbine power generators, and the electrical power generated as power. Current wind generator technology has revealed many modern applications such as hybrid

energy, water pumping and battery charging and heating. This non-conventional energy sources widely accepted among consumers.

Wind energy has very low external and social costs, also it is clean and safe. In Europe and America, both had been investigated about the environmental impact of wind energy. Noise emission is one of the environmental impact that has been discussed, especially in the late 1980's noise became a crucial issue. Other important issue is sun's reflection in the fiberglass blades but it has been solved in the early year. Also, to design and construct a wind turbine the important thing to be considered is it must fit into the landscape. (Anderson, 2007).

2.2 Types of Wind Turbine.

The wind turbine fall into two type namely vertical and horizontal axis wind turbines. Concept and function is the same, which distinguish the two wind turbines are in terms of efficiency, noise factor, axis rotation of rotor shafts and the cost of construction.

2.2.1 Horizontal Axis Wind Turbines (HAWT).

A HAWT has main rotor shaft which is the rotating axis of wind turbine and an electric generator placed on the tower and the rotor position must be towards to the wind. Blades of HAWT spin horizontally as shown in Figure 2.1. HAWT has a variable blade pitch to allow the turbine to adjust the blades and it receives power from the entire blade rotation. This will enhance the efficiency of wind turbines power for the season and circumstances. HAWT requires fast wind speeds to start producing sufficient power, usually this types of wind speeds are generally acquired at higher altitudes. Thus, the HAWTs have to be mounted on high towers where there is not much friction slowing the velocity of the wind down to maximize the power efficiency. A sensor are used to detect the direction of wind is blowing from to maximize HAWT

power output. The HAWT frequently used by the commercial energy to provide power to customers compare to VAWT. (Dang, 2009).

Nevertheless, a study was done provided in Northern Shaanxi, China shows two inland of Yulin and Yan'an convenient with VAWT type wind turbine. This is because of, the average wind speed is only about 4 m/s in rural areas in China. HAWT operate at wind speeds of 8 to 10 m/s and it is difficult to work when the average wind less than 3-4 m/s. HAWT will lose the power output in time to adjust to the wind direction. As a result, the output power by HAWT are lower than the use of VAWT. (Cheng et al. 2012).

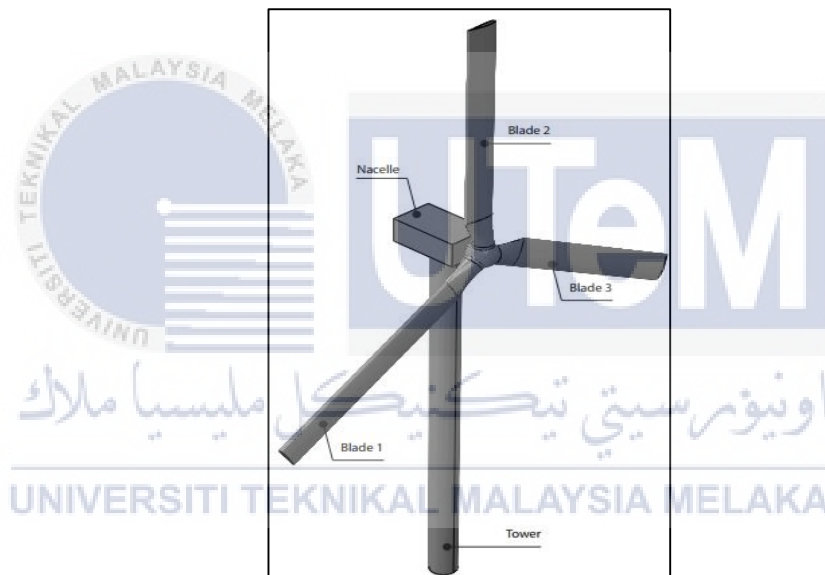


Figure 2.1 Horizontal axis wind turbine prototype design.(Ben Hassena et al., 2015).

2.2.2 Vertical Axis Wind Turbines (VAWT).

The main rotor shaft for a VAWT is stands vertical or perpendicular to the land. Figure 2.2 shows types of VAWT. Furthermore, VAWT can start generate power at lower speed and its does not have to be mounted high in the sky. The VAWT also spins quieter and do not have to change directions to catch the wind compare to the HAWT. VAWTs usually not been adopted for commercial power because it provide less power

and have less efficiency than HAWTs. (Dang, 2009). However VAWT has attracted most attention of researchers because of the good performance on the starting-torque and low starting wind speed and VAWT don't need faced towards the wind compared with the HAWT. (Cheng et al. 2012). In contrast, due to the absence of low starting torque, extra components or external electricity feed-in are needed particularly when in urban areas. This do not give good returns regarding to the investment returning. (Batista et al. 2015).

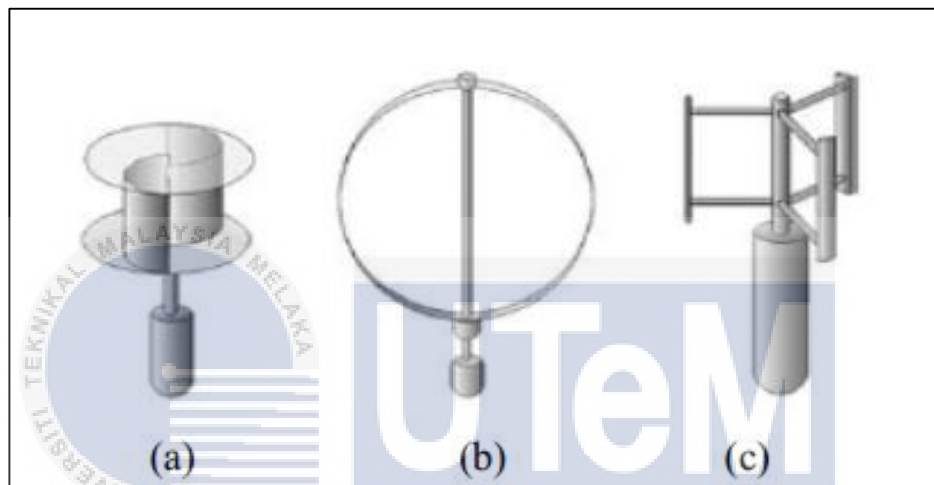


Figure 2.2 Type of VAWT turbines: (a) Savonius rotor; (b) Darrieus rotor; (c) H-Darrieus rotor. (Sunyoto et al., 2013).

2.3 Components of Wind Energy Systems.

Wind generation requires several components that are important in energy production. Main components of wind turbine consists of six parts which is the rotor, the gearbox, the generator, the control and protection system, the tower and the foundation. Figure 2.3 shows the main components of wind turbines.

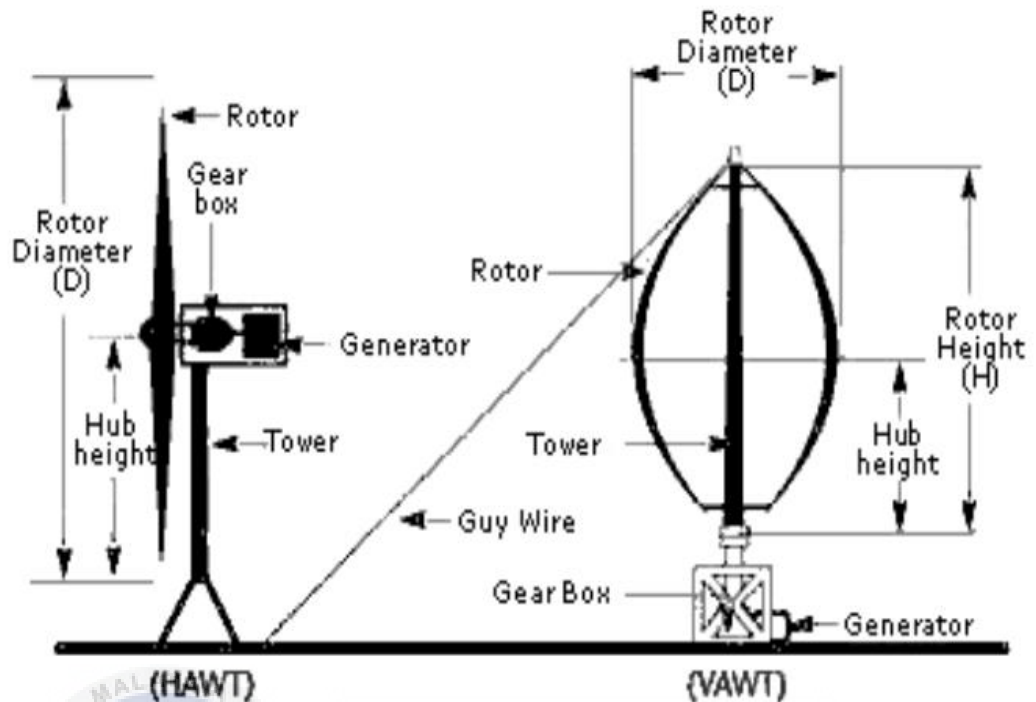


Figure 2.3 Wind turbine components. (T. Al-Shemmeri, 2010).

2.3.1 Rotor

Rotor is define as a rotating part of an electrical or mechanical device which is the heart of wind turbines. Rotor consist several of rotor blades that connected to hub. Blades catch the wind to start rotating and create rotational shaft energy. It basically converts kinetic energy into mechanical energy then converted to electrical energy by other parts in the wind turbine. Output power generated by the wind turbine can be adjusted by changing the size of the rotor diameter. Amount of the energy output against the rotor size available in Table 2.1. (Dang, 2009).

Table 2.1 Diameter size of rotor relative to the amount of power generated. (Dang, 2009).

Rotor Size and Maximum Power Output	
Rotor Diameter (meters)	Power Output (kW)
10	25
17	100
27	225
33	300
40	500
44	600
48	750
54	1000
64	1500
72	2000
80	2500
Sources: Danish Wind Industry Association, American Wind Energy Association	

2.3.2 Gearbox

Gearbox is a device that changes the rotational velocity of the shaft to suit with the generator. (T. Al-Shemmeri, 2010). The power energy from the rotation of the wind turbine rotor blades is transferred to the generator through the gearbox. Maintenance of the gear box is high due to the large pressure on the wheels and bearings in the gearbox during wind turbulence and any defect in a single component can bring the turbine to a standstill. Conversion of gearbox to direct drive may eliminates the technically complicated part of the machine, but it has been twofold in terms of cost and weight. (Morris, 2011).

2.3.3 Generator.

The generator is a device that produces electricity when a mechanism is given to the system. A study conducted in Dabancheng, China on three types of generator which is squirrel cage induction generator (SCIG), doubly-fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) found that properties of wind turbine with DFIG or PMSG is better than wind turbine with SCIG. But, the SCIG wind turbine is cheap and the control system is simple. (Zhang et al., 2010).

2.3.4 Control and protection system

Protection system is a safety feature to ensure that the turbine will not work under hazardous conditions. The system includes a brake system signal triggered by higher wind speed to stop rotor from moving under excessive wind. (T. Al-Shemmeri, 2010).

2.3.5 Tower.

Tower is perhaps one of the most important parts of a wind turbine. Most of the use of steel in the construction of wind turbines, is a tower. Wind turbine tower carries nacelle and rotor of the wind to turn blades and generate electricity. Tower is designed to support other parts and hold them in the air. Therefore, the construction of the tower structure must be robust to withstand the weight of the components supported. Height and construction of tower as shown in Figure 2.4 are important in order to prevent tower bend or break by the forces of the wind flow. (Hemami, 2009). The basic requirement to be considered for the design a tower are the gravity loads, blades rotating and wind pressure. (Chaoyang et al., 2005). Centrifugal impeller is typically gear-driven and rotates as fast as 15,000 rpm.

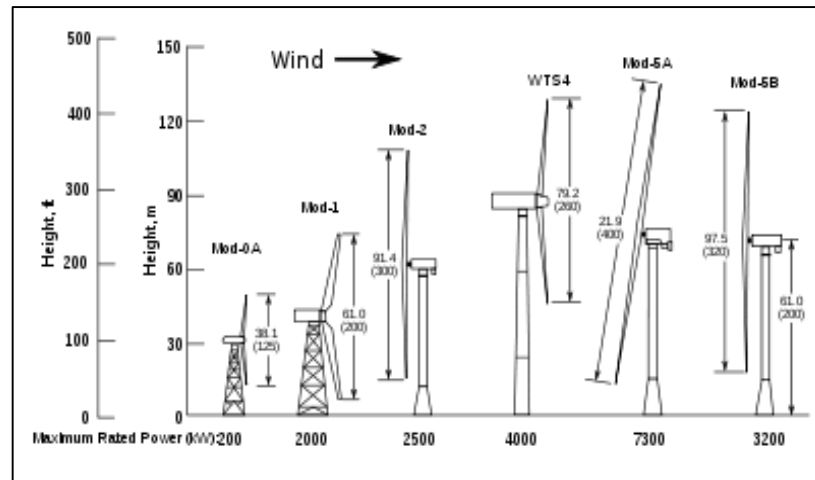


Figure 2.4 Types of wind turbine tower

2.3.6 Foundation

The foundation is base supports the entire wind turbine to make sure that it is well fixed onto ground or the roof for small household wind turbines. This base support consists of a solid concrete assembly around the tower to maintain its structural integrity. (T. Al-Shemmeri, 2010)

2.4 Working principle.

A rotor is design as an elegant aerofoil shaped blades. When wind blows over the blades, rotor turns and converts wind from kinetic mechanical energy through a connected shaft. Low wind speed rotation cannot produced any meaningful electricity frequency from a generator. Gearbox changes the rotational velocity of the shaft to suit with the generator. A break includes in control and protection system to arrest wind blade rotation during excessively windy conditions. The function of control and protection system is to ensure that the turbine will not work under hazardous conditions. (T. Al-Shemmeri, 2010). The electricity generated then travels down large cables from the nacelle through the tower and into underground cables. The cables take the electricity generated from all the wind turbines to a substation. Transformer

will step up the electricity before the transmission line connects the electricity output at the substation to the electrical grid serving to a communities.

2.5 Cooling system.

The cooling system applications often used in power generation, air conditioners or manufacturing processes. (Unep, 2006). Most commonly used cooling system in Malaysia are cooling tower, ventilation fan and a blower.

2.6 Cooling tower

A cooling tower is an equipment that uses the evaporation process where it reduces the temperature of the water flow to remove heat from the water to the atmosphere, Evaporation process in detail is the process in which water is evaporated into the moving air stream as shown in Figure 2.5. Furthermore, a cooling tower can increase the energy efficiency and cost-effective of the system by reducing the water temperature to reject heat. (Unep, 2006). Wind speeds for Direct-contact induced-draft cooling towers recorded are about 18 m/s at a distance 0.3 meter above the outlet the of cooling tower, which is sufficient to generate electricity. (Chong et al., n.d.).

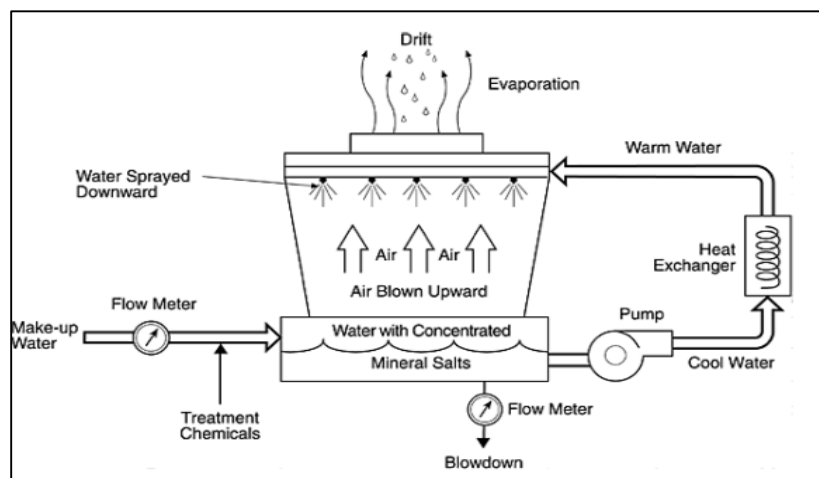


Figure 2.5 Process of cooling tower. (Unep, 2006).

2.6.1 Industrial ventilation system

Ventilation systems are important in giving priority to the air in the industrial work environment clean and not contaminated with the use of chemicals by modern industry today. Ventilation can also be used to control odour, moisture, and other undesirable environmental conditions for worker health care. (Industrial Ventilation, 1998). The ventilation system fans divided into two types, centrifugal fan and axial fans. Based on the study of Murphy J. in Table 2.2, most of centrifugal fan peak total efficiency are higher compare to axial type. (Murphy, 2010).

Table 2.2 A fan type and the percentage of peak total efficiency. (Murphy, 2010)

Fan Type		Peak Total Efficiency %
Centrifugal	Airfoil	88
	Backward Curved	84
	Backward Inclined	80
	Forward Curved	70
Axial	Vane Axial	86
	Tube Axial	75
	Propeller	55
Mixed Flow		75
Tangential		25

2.6.2 Centrifugal Fans & Blowers

Centrifugal fans is an equipment with a rotating impeller to move air first radially outwards by centrifugal action. Air received and moving parallel to impeller

hub and it turns radially outwards towards the perimeter of the impeller and the blade tips. Moreover, centrifugal fan are often used in material handling applications at a higher temperature and capable of generating a relatively high pressure. Figure 2.6 shows the configuration of centrifugal fans and blower and a ventilation process are shown in Figure 2.7. (Cunha et al., 2008.)



Figure 2.6 An examples of centrifugal fans.

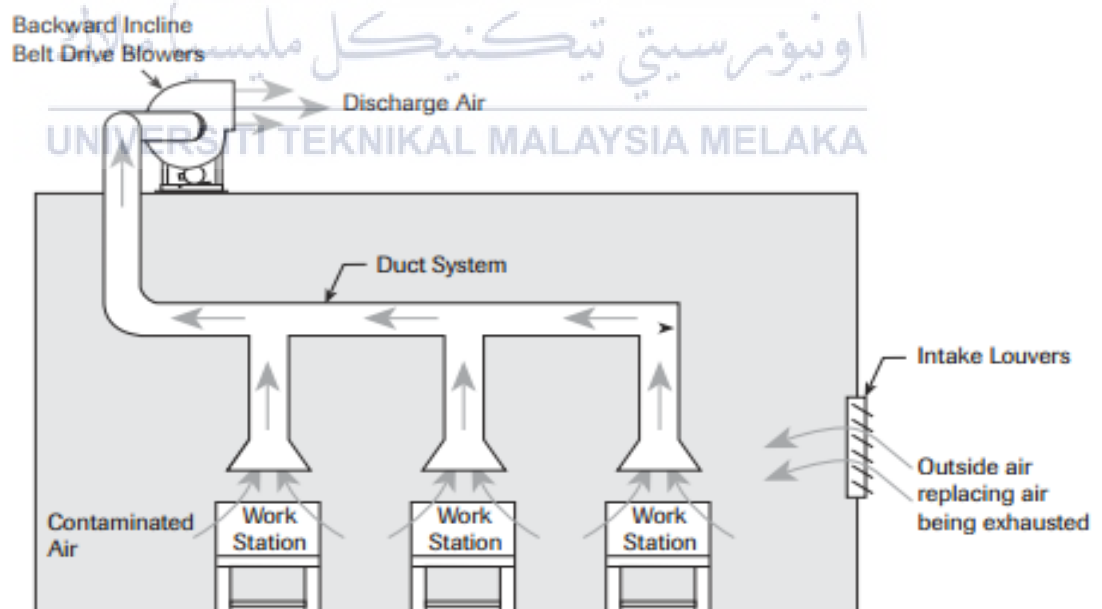


Figure 2.7 A ventilation process by using centrifugal fan.

2.6.3 Axial fans

An axial blades look like a propeller or air plane wing and its move the airstream along the shaft of the fan. The air pressure are lower and require a higher rotational speed and a bit noisy from the centrifugal fan in accordance with the same capabilities. (Cunha et al.,2008). Figure 2.8 shows type of axil fan and Figure 2.9 shows the ventilation process using axial fan.



Figure 2.8 An axial fan type. (Cunha et al., 2008).



Figure 2.9 The axial fan ventilation process. (Cunha et al., 2008).

2.7 The study of existing project.

There are several study on electric generation using a wind turbine concept to produce energy without relying on natural energy sources, to saving cost in terms of fuel consumption for mobile battery charger application and for supplying the electrical requirements of the coaches.

2.7.1 Design mobile battery charger by wind driven.

The study of K. Sudhakar and Priyank S. discusses a novel type of energy converter that use wind energy technology to produce electricity. Objective of this study is to harvest energy from low-speed wind flows in order to power mobile electronics applications devices. Figure 2.10 below shows the block diagram of the study.

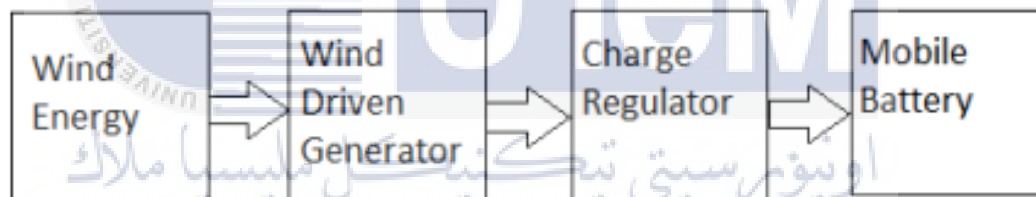


Figure 2.10 The block diagram of the study. (Sudhakar & Saxena, 2016).

Major component to build this model consists of a propeller, generator, chip integrated on PCB, and suitable mobile charging pin. Authors mention a propeller divided into two type, high rpm with four wing type and slow fly propeller with low rpm. A 12 volt DC generator is preferred compare to AC generator in this model to reduce the cost of using rectifier. For charging circuit, there is a combination between of a capacitor, I.C 7805 and the charging pin to charging the battery. The specification of the components are show on Table 2.3.

Table 2.3 Specification of the components for experimental. (Sudhakar et al., 2016).

S. No	Module	Specifications
1.	Wind Driven Generator	Gen. voltage (12V max.)
2.	Wind Speed Range	35 kmph (min.)
3.	Bypass Capacitor	6V/22 μ f
4.	Voltage Controller	Ic 7805
5.	Battery	3.7V,970mAh

Generator case is connected with the blade and placed on the vehicle. Polarity of the output terminal will remain fixed until the generator direction is changed. This project uses the constant voltage charging for high voltage charging. When the battery is approaching full charge, the battery voltage rise and against charging current. Battery capacity reached is around 4.2 volts per cell which is only about 40 to 70 % fixed. Figure 2.11 and 2.12 shows the results charging and power stored against speed of vehicle. The batteries are charged for eight hours, the initial battery voltage was 2.9V and the final voltage reached 3.8V after charging time. Figure 2.13 presented the charging status against voltage stored.

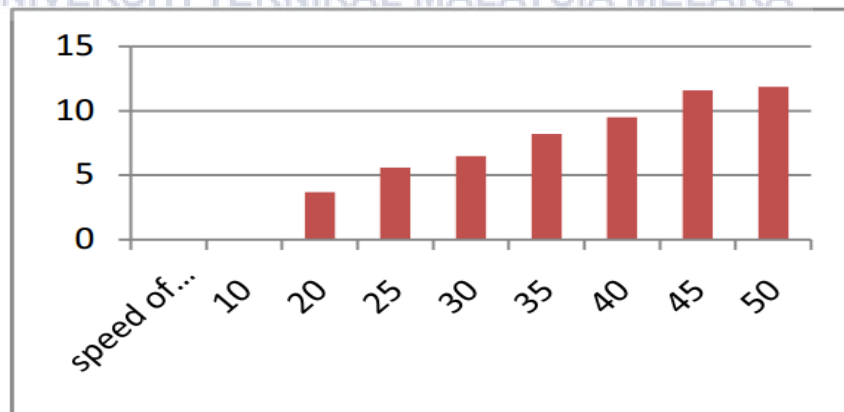


Figure 2.11 Voltage generated Vs Vehicle speed without using IC 7805. (Sudhakar, 2013)

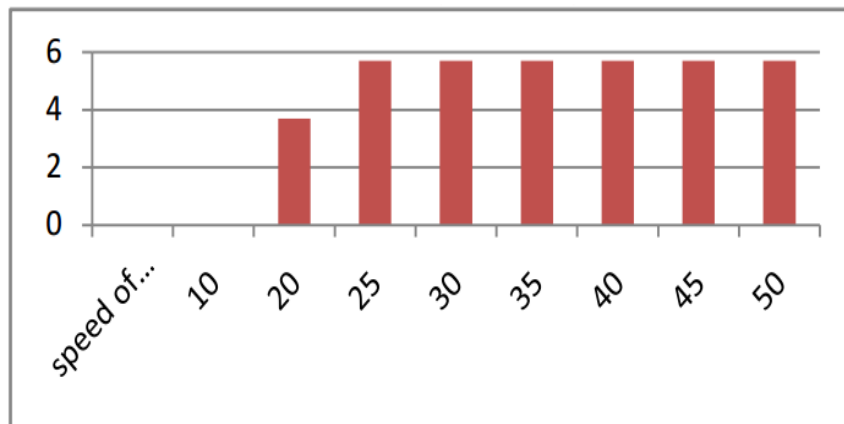


Figure 2.12 Voltage generated Vs Vehicle speed with using IC 7805. (Sudhakar, 2013)

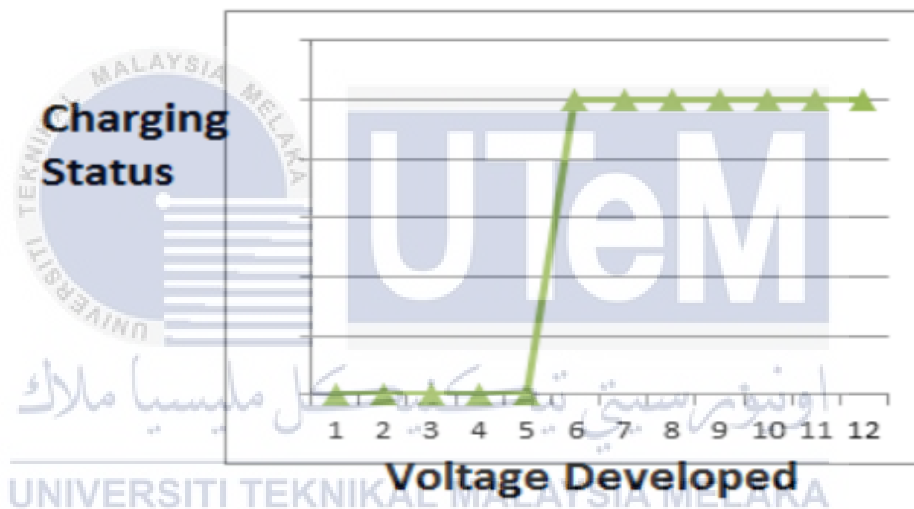


Figure 2.13 Voltage developed against charging status.(Sudhakar & Saxena, 2016).Generated electricity from a fan.

2.7.2 Generated electricity from a fan.

MD Saquib G., Khemchand K., Mrunal J., Akash V., and Beatrice S. used concept of wind turbine motor and the permanent magnet motor to design generator using mechanical of a fan. Electromagnets that are surrounded by heavy coils of copper wire inside generators are turn by the spinning shaft. Electrons in the copper wire move from atom to atom then creating electricity caused by magnetic field. Voltage produced by the generator can be adjusted by changing the number of turns in the coil,

magnet strength, and the rate at which the magnetic switch. The higher number of turns in the coils, the higher value of voltage is produced.

Author used AC dynamo to generate current and it will be interconnected with a ceiling fan through a mechanism in which the rotating ceiling fan motor will rotate dynamo's shaft. The higher number of rotations of ceiling fan, it will increased the rotation of the shaft of AC dynamo and by the mean time the voltage is also generated. Voltage generated will be converted to dc by using charging circuit shows in Figure 2.14. Then it will be given to the 1 volt battery and this 1 volt may be converted to around 250 volts and used for other external purpose by using an inverter circuit and step up transformer. The project concept will be explained visually in Figure 2.15.

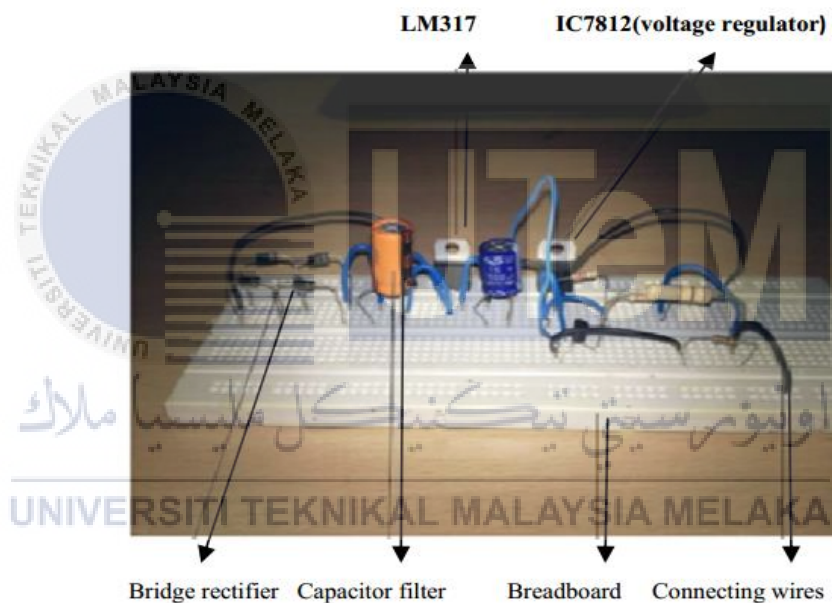


Figure 2.14 Components in charging circuit. (Gadkari et al., 2014).

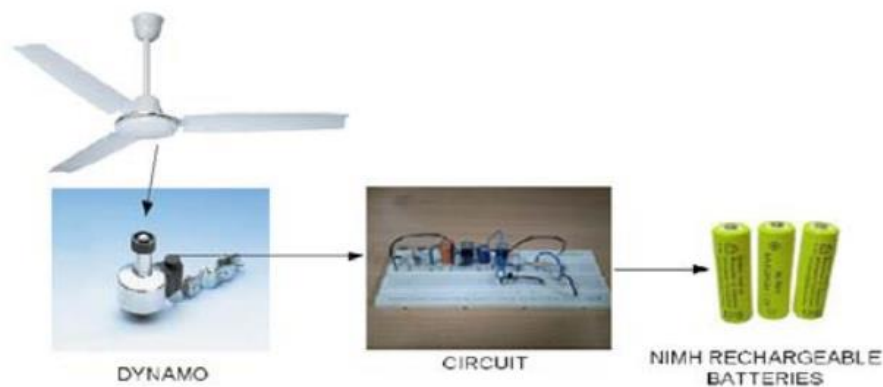


Figure 2.15 Block diagram of the project. (Gadkari et al., 2014)

2.7.3 A novel development for generating Electricity by setting up turbines over train rail.

P. K. Sharma et al. has carried out an experiment to produce electricity using the wind turbines placed on the roof of moving rail locomotives (trains). Wind turbine suggested in this experiment, the axis of rotor rotation is perpendicular to wind stream. The pressure generated between the aerofoil blades due to movement of wind causes the rotation of blade to the hub. Power which is sent to DC battery through bus-bar arrangement generates by shaft of turbine which is directly coupled with a DC generator that rotates due to rotation of blade. The generator output can be fed to a chopper with an appropriate control strategy, to feed the loads in train coaches which require DC as input. For coaches requiring ac load, output generator is passed through an inverter to convert it into AC (Sharma et al., 2014). The block diagram for this experiment are shown in Figure 2.16.

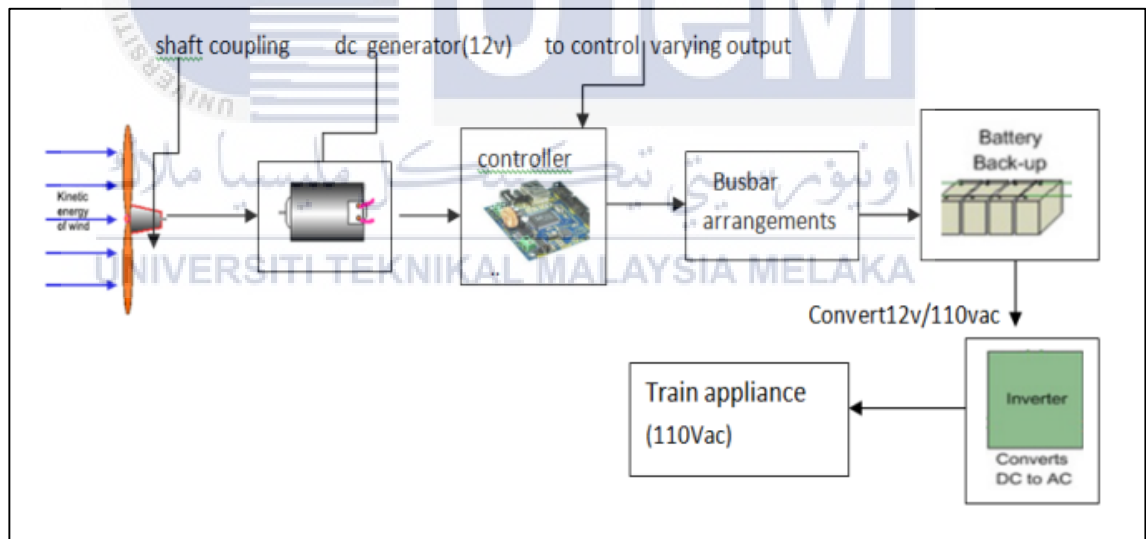


Figure 2.16 The block diagram of the project.

2.7.4 Design of an exhaust air energy recovery wind turbine generator for energy conservation in commercial buildings.

Authors for this work conduct take the advantages of discharged air from an exhaust air energy which is strong to rotate two VAWT blades. Types of exhaust air energy used for this experiment are direct-contact induced-draft types of cooling towers. The air released flow are vertically from the ground. Wind speeds of heat released to the atmosphere recorded about 18 m/s at 0.3 meter distance above the outlet the of cooling tower. This air speed through the outlet channel are capable to generate an electricity. A laboratory test was carried out to evaluate the effectiveness of the energy recovery VAWT with 0.3 m diameter of 5-bladed H-rotor generator on a cooling tower model. The results obtained on this experiment shows cooling tower with VAWTs and enclosure has higher VAWT rotational speed compare to cooling tower with VAWTs without enclosure. Figure 2.17 and Table 2.4 shows the configuration of the experiment and the results from the experiment.

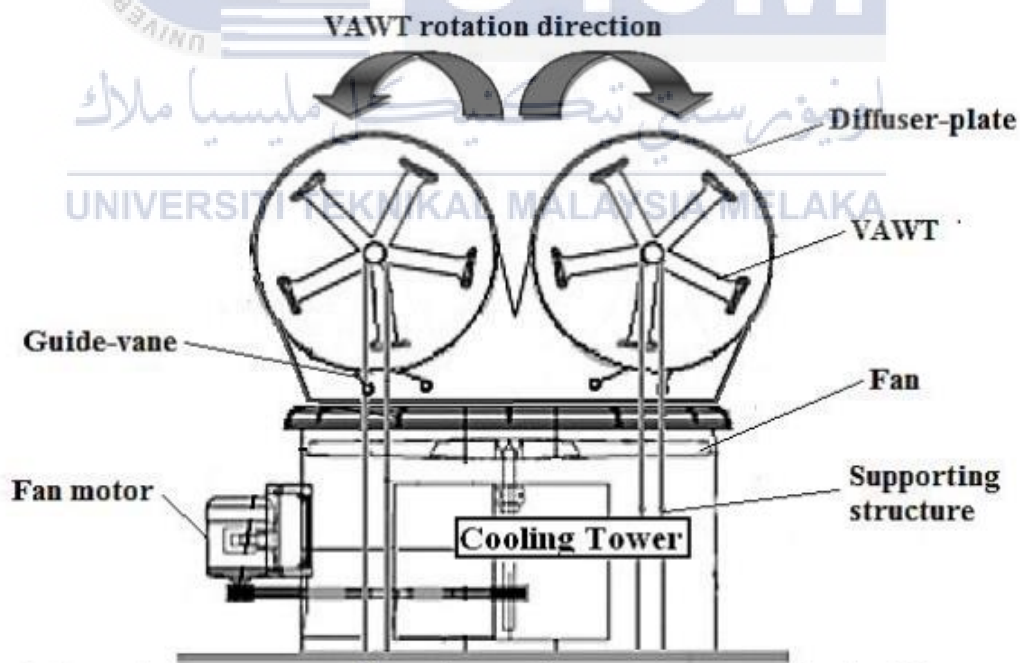


Figure 2.17 An experiment configuration.

Table 2.4 Result obtained from the experiment

Test configuration	Intake wind speed (m/s)	Fan motor power input (W)	Fan rotational speed (rpm)	Rotational speed (rpm)		Response time (s)	
				VAWT 1	VAWT 2	VAWT 1	VAWT 2
Cooling tower only	1.90	203.84	1364.33	-	-	-	-
Cooling tower with VAWTs	2.15	200.20	1366.00	438.0	444.7	101.7	150.0
Cooling tower with VAWTs and enclosure	2.52	198.86	1369.67	472.2	475.3	59.6	87.8



CHAPTER 3

METHODOLOGY

3.0 Introduction

In this chapter, the methods that have been designed in the beginning to be discussed in order to prepare this report systematically. Part of the plan was implemented in the Bachelor Project I and others followed with a Bachelor Degree Project II.

3.1 Process Flow Chart

The flow chart in Figure 3.1 shows the beginning of the process initiated with the project research based on the reading from published journals and other reading resources related to the case study. The reading helps in terms of the introduction of the concept and operation of the wind turbine where the generator system was very rarely used in Malaysia. Study was also carried out to identify the average wind speed in Malaysia and type of wasted energy that will be used as the main source of this project. Afterwards, the process continued with the development of the project based on research done. As hardware is completed, the research will continue with data analysis and make a discussion based on analysis results regarding to the output performance. Finally, conclusions and recommendations carried out in the next stage.

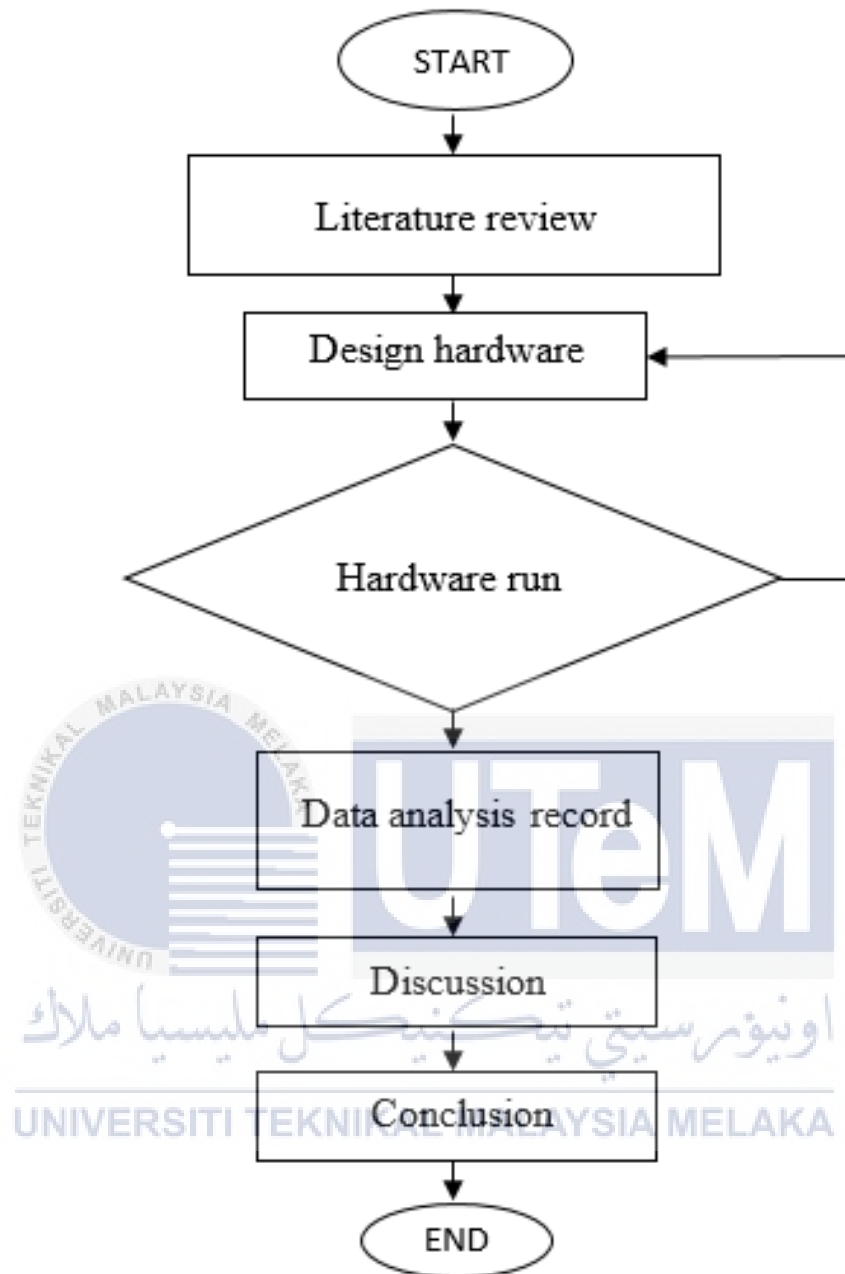


Figure 3.1 Flow chart progress.

3.2 Component

A wind turbine generators require several components to convert the kinetic energy into mechanical energy and then to electrical. The components used for this project is:

3.2.1 Blade

Blades are an important part of the wind turbine used to convert the kinetic energy into mechanical energy. Axis rotation for HAWT are parallel to the ground while VAWT rotates perpendicular to ground. Figure 3.2 shows the direction of rotation according to the type of wind turbine blades. A HAWT has a blades like a fan, and rotates horizontally. Furthermore, efficiency HAWT is higher than VAWT because it receive power from the whole number of rotating blades. Types of blades for horizontal axis wind turbines divided into three consists of single blades, two blades and a maximum of three blades. Efficient percentage of a wind turbine, depending on the number of blades used. The higher the number of blades used, the higher the output will produce. The efficiency of the wind turbine shows in Figure 3.3.

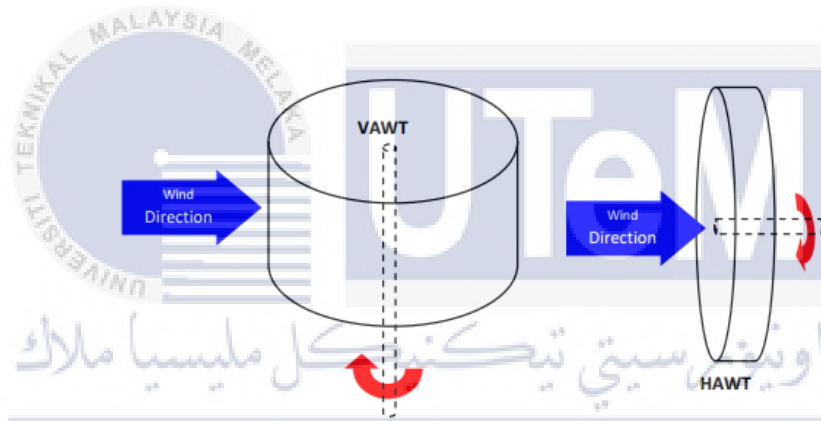


Figure 3.2 Direction of blades rotation for HAWT and VAWT. (Schubel et al., 2012).

Table 3.1 HAWT efficiency varies with number of blades. (Schubel et al., 2012).

Quantity of blades	Efficiency percentage
1	43 %
2	47 %
3	50 %



Single blade of HAWT are low cost wind turbines and have a light structure. However, the turbine is not stable because it needs to handle the weight on the other side of the blade. HAWT with two blade also unstable wind turbine compared with the stability of three wind turbine blades. Three blades structure produces a high output power and high strength to withstand a heavy storm. Figure 3.4 shows the examples of single blades, two blades and three horizontal wind turbine blades.



Figure 3.3 Structure of single, two and three horizontal wind turbine blades.

3.2.2 Stepping Motors M55S

A stepper motor is a special type of brushless DC motor and the electromagnetic coils are arranged around the outside of the motor. Iron or magnetic core attached to a shaft was placed to the center of the motor. By sequencing the voltage of the coils precise rotational control can be achieved at relatively low cost. The drawback is, the control is generally open loop, so the system does not know if the motor stalls or gets out of sync with the controller. Stepper motor for M55S have 4 wire connections for the motors, but steppers motors can have 4, 6 and 8 wire versions. Motor wiring and the connection methods were depends on electrical purpose and speed requirements of your system.



Figure 3.4 A stepping motor M55S-2NK with the label.

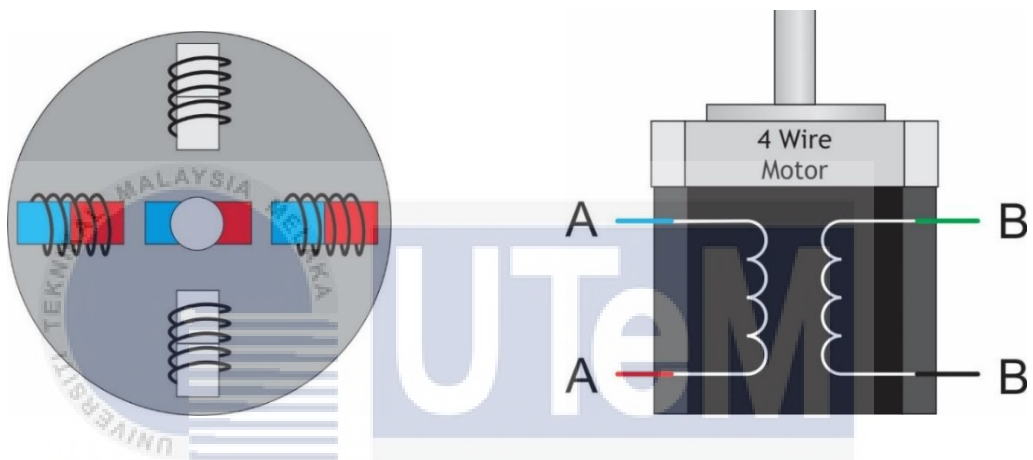


Figure 3.5 Motor construction and wiring

3.2.3 Charging controller

Figure 3.7 below shows the charger circuit for wind turbine that is used to charge batteries using the wind energy power. The circuit used to charge a 6 volt rechargeable battery for low electrical appliance. The charger has voltage and current regulation and over voltage cut-off facilities

The circuit uses a variable voltage regulator IC LM 317 to regulate the DC input voltage from the generator to charge the battery. Charging current passes through D1 from input supply to the voltage regulator IC LM 317. To regulate the output

voltage and current, the pin adjuster must be adjusted. In order to provide an output voltage of 6 volts to the battery, a variable resistor is placed between the adjust pin and ground. Afterwards, the resistor R3 prevents the charging current and diode D2 to prevent current discharge from the battery. A transistor T1 and the Zener diode used to cut-off current when the battery is full. When T1 is off, battery will start charging until the terminal voltage of the battery rises above 6.8 volts. Then Zener diode conducts and provides base current to transistor. LM317 will stop charging when it then turns on grounding. Figure 3.6 shows the full circuit of charging controller circuit.

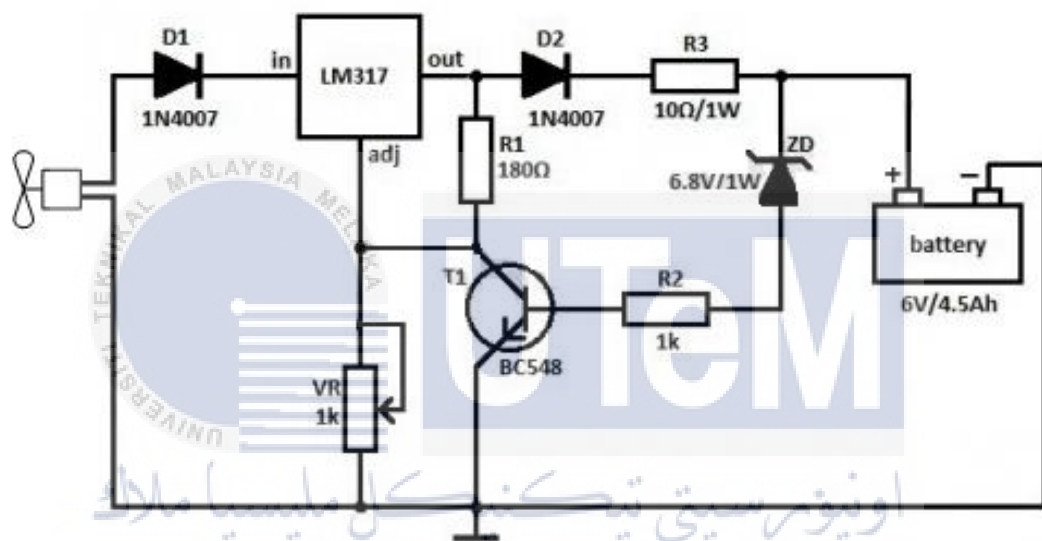


Figure 3.6 A charging controller circuit.

3.2.4 Battery

In recent years, energy storage on a large scale has been the subject significant research and development. Energy storage required for peak shaving, load levelling and uninterruptible power supply (UPS) applications. Static lead-acid batteries, have high reliability, high discharge rate, flexible performance and ease of recycling. Mostly, this type of battery is used to supply direct current power to electric vehicles and used in automotive applications. Nevertheless, it is not suitable to store large scale

of energy because of high costs, limited shelf-life, and practical difficulties in building large battery. (Zhang et al., 2011).

A batteries will allow current to flow into the battery when the input voltage is greater than the battery voltage. While the 12V lead-acid batteries require exposure to at least 14V to charge completely, if the voltage is higher it will cause it to gas out, drying cells that will, eventually, lead to damage.(Wilson, n.d.). Figure 3.7 shows different type of 6 volt lead-acid batteries.



Figure 3.7 Type of 6V lead-acid batteries.

3.3 Measuring instrument

A measuring instrument is a device for measuring a physical quantity or activity of obtaining and comparing physical quantities data in terms of number. The process of measurement gives a number relating to the item under study and state the referenced unit of measurement. The overall performance of an instrument is based on its static and dynamic characteristics. It indicates how well the accuracy of measuring instrument to measures the desired input and rejects the spurious (or undesired) inputs. Accuracy, Precision, Resolution and Sensitivity is an example of static characteristics for a good measuring tool. For this project, a digital multimeter and anemometer were used to record the data.

3.3.1 Digital multimeter

A multimeter is an electronic measuring instrument that combines several measurement functions in one unit. There are two types of multimeter on the market, i.e. analog and digital multimeter. A digital multimeter was used on this project to gives a numeric display and accurate data to measured DC output voltage and DC output current.



Figure 3.8 A digital multimeter.

3.3.2 Anemometer

An anemometer as shown in Figure 3.9 is a scientific instrument for measuring wind speed accurately and is a common weather station instrument. The cup anemometer is the most widely used. Three plastic cup attached to the ends of horizontal arms mounted on vertical shaft. Wind catching in the cups causes them to revolve then turns the shaft. The shaft connected to a device that gives the wind speed in miles per hour or in kilometers per hour reading.



Figure 3.9 A cup anemometer was used to measure wind speed.

3.4 Block diagram

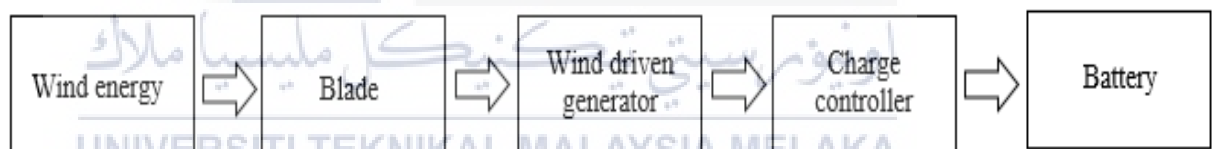


Figure 3.10 The block diagram of the wind turbine generator.

Figure 3.10 the process of wind turbine generator to convert the wind energy to an electrical output. Wind energy from air released by a cooling system will rotate the blades which attach to the hub. A maximum wind speed energy will rotate the blade faster and the rotation of the blades will be transferred to the shaft of a stepper motor. This process will convert the kinetic energy to mechanical energy from the rotation of the blades. A stepper motor may convert the mechanical rotation to an electricity. This electricity will stored to a battery by charging with the charger controller circuit.

3.5 Developing Process

In actual practice, the propeller is the functioning part and the most important parts of a wind turbine. They were made in such an aerodynamic shape to obtain the proper function. A perfect blade tip shape can have a beneficial effect on the efficiency of the blade. A 3 inches PVC diameter with length of 10 inches was used to form the blades. The PVC was cut into three pieces representing of three horizontal wind turbine blades. Each of three parts PVC pipe was cut into two then used three from six identical blades. The length and curve must be same to perform a good rotation of blades. Next the blade was formed into aerodynamic shape with an oblique cut to get a good performance. The blades were attached to the round base using cycle screws.

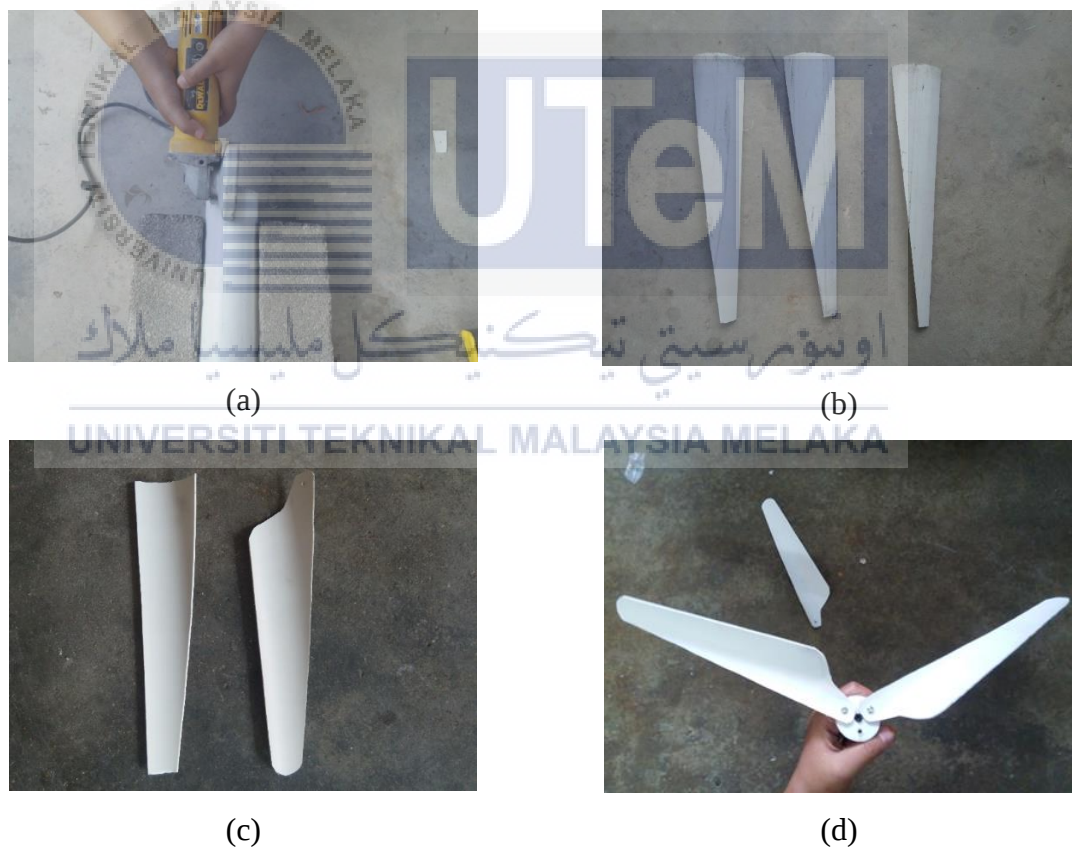


Figure 3.11 (a) The PVC was cut into three pieces using grinder. (b) Three of the six identical cut have been selected to make the blades. (c) Shaped the PVC in to aerodynamic blades. (d) The blades were joined to the round base using cycle screws.

The foundation is important to ensuring the stability of the wind turbine and the main factor for the lifespan of a wind turbine. This was done by transferring and spreading the loads acting on the foundation to the ground. Vertical force acting on the foundation is a load from the tower, nacelle and rotor blades, but the wind also can give rise to several vertical power. A four 90-degree PVC fitting, three PVC tees, six pieces of 11cm PVC pipe and two pieces of 28cm PVC pipe were used in order to build a solid foundation. All of these materials have been formed in to a square shape to build a strong base such as shown in Figure 3.12.



Figure 3.12 Structure of wind turbine foundation.



Figure 3.13 A wind turbine nacelle with a generator.

In real condition, a nacelle is a cover housing that houses all the generating components in a wind turbine, including the generator, gearbox, drive train, and brake assembly. Sweep bend PVC with 50mm diameter was used to build the nacelle cover and fitted the stepper motor into it. Since motor size is larger than tower size, a connector with 15mm x 25mm diameter size was used to connect nacelle and tower of the wind turbine. Figure 3.14 and Figure 3.15 shows a full assembled of wind turbine with nacelle, rotor blade and the foundation.



Figure 3.14 Full assembled model



Figure 3.15 Side view of wind turbines

3.6 Hardware testing

The experiments were set into two configurations, i.e. parallel coil and series coil configuration. Both configurations were implemented to the experimental data on outdoor air conditioner unit and centrifugal fan. A stepper motor are bipolar where it have internally two coil and each coil produces an AC voltage. Figure below shows both test configurations for parallel and series coil stepper motor. Two bridge rectifier was used for each coil to convert an AC output voltage from a stepper motor to DC output voltage. The capacitors were added to the dc output of both rectifier in order to filter and stabilize the output. A multimeter was connected in series and parallel to record and analyze the data as shown in both diagram below.

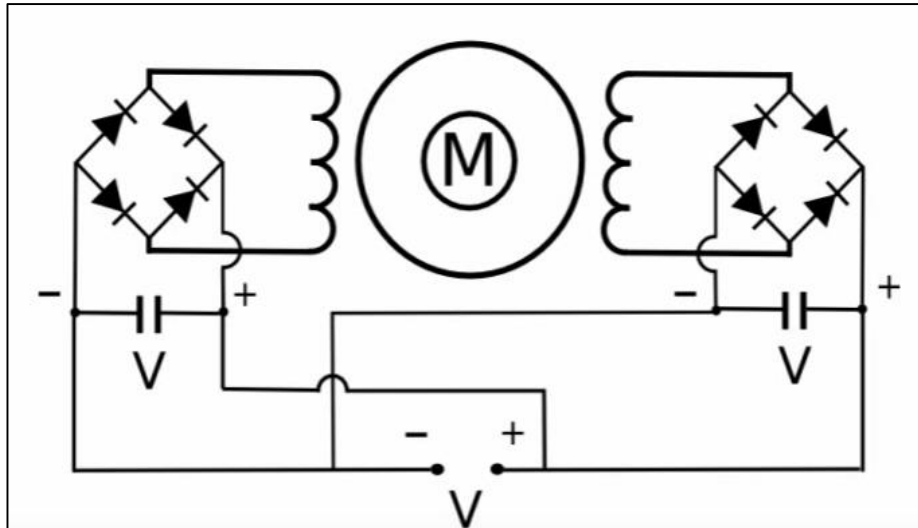


Figure 3.16 Parallel coil configuration.

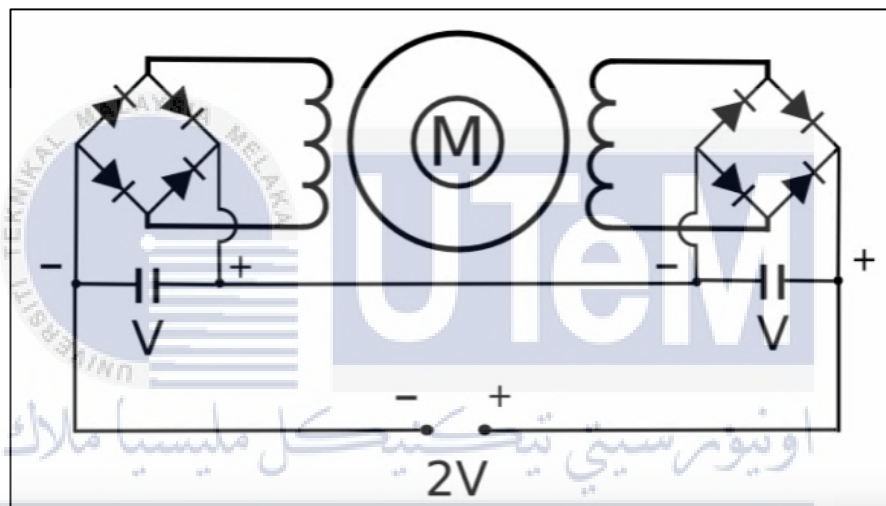


Figure 3.17 Series coil configuration.

3.6.1 Experiment test: Outdoor air conditioner.

The experiment for outdoor air conditioner unit was set at factory 2 in UTeM technology campus. Three parameters were measured to evaluate the performance of a wind turbine model, i.e. DC output voltage, DC output current and discharged air speed by the outdoor air conditioner. Anemometer was used to record the performance of air released speed of air conditioner outdoor unit. While, output DC voltage and DC current were recorded by using a digital multimeter.



Figure 3.18 Process of data measurement for outdoor air conditioning unit.



CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

This chapter will describes about the approach taken in order to achieve the objective of the project and also closer look on how the project is accomplished. Each achievement and selection taken when the project is implemented will be explain in detail for each state until the project succeeded.

4.1 Performance of wind turbine

A wind turbine converts wind energy into rotational energy by means of its blades. The basic principle of every wind turbine is to convert kinetic energy of wind into mechanical energy which is used to rotate the turbine of electrical generator to produce electricity. There were components that play a big role in generating electricity in a wind turbine. Problems and a modification have been identified and discussed on 4.1.1 and 4.1.2.

4.1.1 Motor

Initially, a DC motor was used as a generator for converting mechanical energy into electrical energy. However, the resulting output is very small about 0.01V then it was replaced with the stepper motor. Unlike small DC motors, steppers will generate power at very low rotation rates with a small size of a stepper motor. Most of DC motors run at a high RPM (revolutions per minute), so it was not suitable to use as a

generator since the mean daily wind speed in Malaysia are very low about 2 m/s. After substituting with a stepper motor, the output voltage produce rising dramatically with the same of construction of wind turbine model. During data recording process, there was a misunderstanding about the output voltage of the stepper motor. At first, the output voltage was measured with a DC voltage range and value are not displayed. After making a little review, the cause of the problem was identified. The output voltage generated by a stepper motor was an AC voltage, so it must measure with AC voltage range.

4.1.2 Rotor

For this wind turbine model, the manufactured of the rotor or blade was used a PVC material with 3-inch diameter and 5-inch length. The weakness of this construction was the (5-inch) length of the rotor because the amount of energy produced by your wind turbine is proportional to the size of the rotor used. A bigger size of rotor, certainly it will generates large value of power output. This can be refer to the theory of gear ratio which defined as the input speed relative to the output speed.

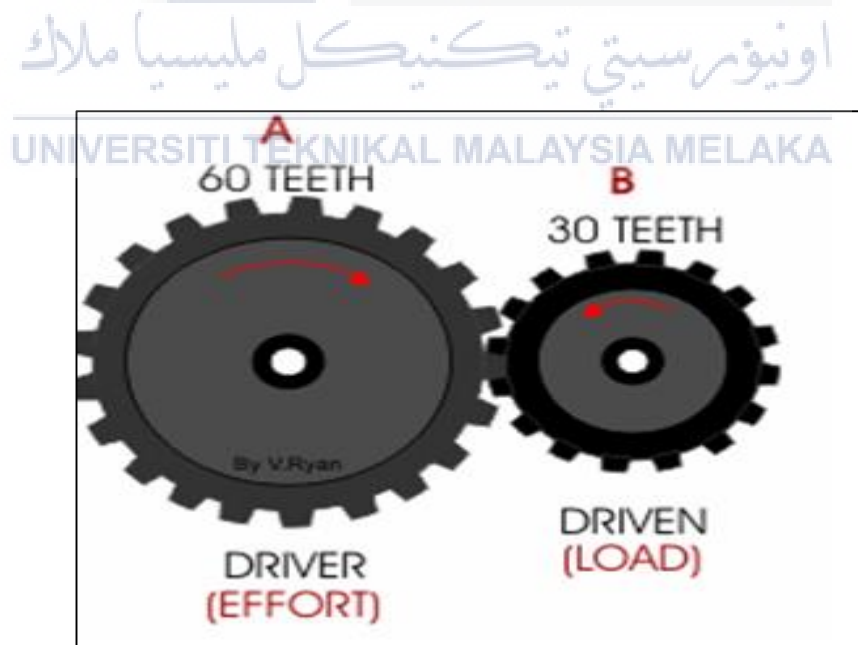


Figure 4.1 The example of gear ratio.

In this figure, the diameter of the gear on the left is twice then the gear on the right. The larger gear goes around once, the smaller gear goes around twice. The smaller gear was spinning twice as fast as the larger gear. So, this concept has be applied on the construction of wind turbine rotor. A 10-inch length of a PVC pipe with 3-inch diameter has been replaced to get a larger output value. The result, output voltage increased twice than before it was modified. The larger the diameter of rotor, the faster the shaft of generator will rotated and produce a large value of output power.

4.2 Parallel coil configuration data analysis.

Table 4.1 shows the results of data recorded through the output of capacitor based on the parallel configuration of the stepper motor coils and speed of wind released by an air conditioner. The duration of this experiment running was 5 minutes, means wind speed and the output of the capacitor stored is dependent on the time taken record.

Table 4.1 Experiment test results on parallel coil configuration

	1 minute	2 minute	3 minute	4 minute	5 minute
Wind speed (m/s)	2.7	2.6	2.81	2.4	3.1
Voltage (V)	2.27	2.72	2.8	2.90	3.03
Current Maximum	10.25mA				

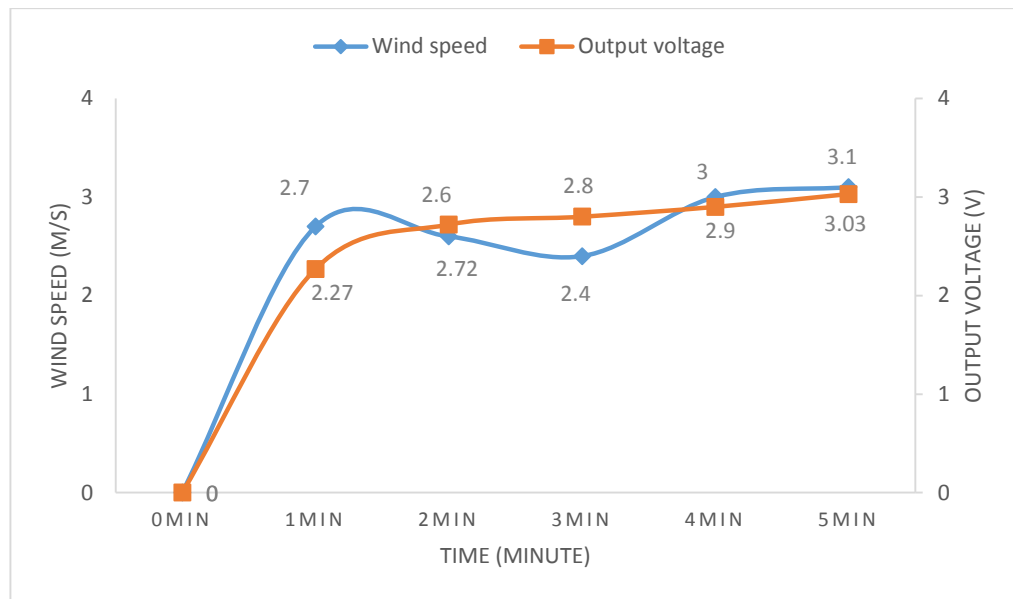


Figure 4.2 The comparison of wind speed line graph and the output voltage.

According to figure 4.2, the minimum value of wind speed for parallel coil configuration was 2.4 metre per second (m/s). The value of wind speed was increased about 22.6% from 2.4 m/s to 3.1 m/s after 2 minutes. The lowest value was obtained during 3 minutes of time taken and the maximum value measured for 5 minutes. The line graph shows, wind speed of the air conditioner was fluctuated to the time taken for 5 minutes.

Based on Figure 4.2, the output voltage significantly increased from 0 to 2.27V within 1 minute time taken. Then the output voltage remain increased about 16.5% from 2.27V to 2.72V. In the third minute, the output voltage increased by 2.86% from 2.72V to 2.8. Afterwards, the voltage stored in the capacitor increases up to 3.03Vdc output voltage. The output value were measured on the output from the capacitor.

From the graph of the output voltage, the pattern of performance data was directly proportional to the time taken while the pattern for wind speed performance was fluctuated. This is because, the wind speed of the air conditioner was unstable and lead to fluctuation line graph. The charging time of the capacitor affects the value of the output voltage. The longer the charging period the higher the ability of a capacitor to store an electrical charge.

Furthermore, the voltage stored on a capacitor was also influenced by the wind speed of the air conditioner. Based on the Figure 4.2, the maximum value of voltage stored on a capacitor was 3V with wind of 3.1 metre per second (m/s). Unfortunately, studies have found that average wind speeds for a small wind turbine in a particular location need to exceed at least 6–8 metres per second (m/s) to be economically used. Considering this low speed rotation we cannot produced any meaningful electricity voltage from a generator. So, the lower value of a wind speed will produce low electricity voltage. The resulting voltage was used to charge the capacitor. The greater the applied voltage the greater the charge stored on the capacitor plates. Likewise, the smaller the applied voltage the smaller the charge.

4.3 Series coil configuration data analysis.

The results from series configurations on wind speed performance, output voltage and current were tabulated in Table 4.2. The testing process was carried out similar to the process for parallel coil configuration with a period of 5 minutes.

Table 4.2 Experiment test results on parallel coil configuration.

	1 minute	2 minute	3 minute	4 minute	5 minute
Wind speed (m/s)	3.8	4	4.5	3.9	5
Voltage (V)	3.5	4.2	4.5	5.09	6.8
Current Maximum	9.87mA				

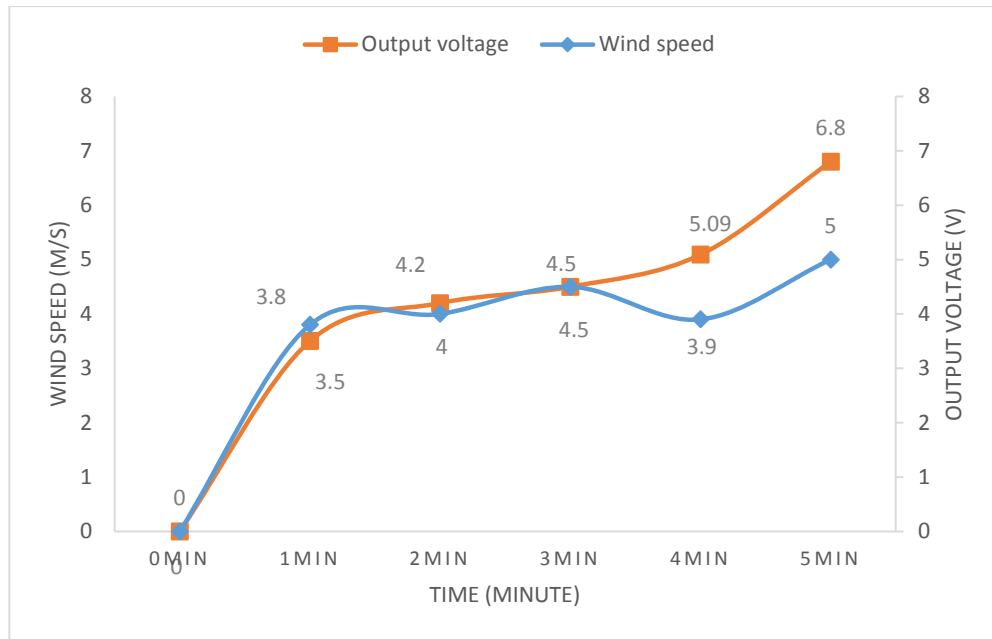


Figure 4.3 Performance of output voltage and the wind speed data.

Based on Figure 4.3, the maximum wind speed performance for the series coil configuration is 5 meters per second (m/s) and the minimum wind speed of 3.8 meters per second (m/s). There was a significant increase in the percentage of readings of wind speed between the starting point and the first minute. Between the third minute and the fourth, this figure was dropped about 13.3% from 4.5 m/s to 3.9 m/s. Then the percentage of wind speed data shot up dramatically from 3.9 m/s to 5 m/s.

Refer to Figure 4.3, the greater rise was start from the starting point to the first minute when it rose from 0 to 3.5V. For the second minutes, the charged voltage continued increased up to 12.5%. The period between third and fifth minutes saw a dramatic growth in the performance of stored voltage on the capacitor from 4.5V to 6.8V.

For series coil configuration, the pattern for both graph are same as the configuration of parallel coil. The output voltage was the dependent variables because it is dependent on the time taken variables. The stored voltage may be higher if the charging time was longer than 5 minutes.

Moreover, the output voltage most depend on the speed of wind and the force of the blades. The more wind speed and force you have got, the greater is the amount of power generated by a wind turbine. Even though the line graph of wind speed was fluctuated because of the unstable wind speed, the charged voltage stored on the capacitor continued increased up to 6.8V. The capacitor helps in order to maintain and to store the voltage produced by a generator.

4.4 Comparison data between series and parallel configuration.

A bipolar stepper motor have internal coils where each coil produces an AC voltage. The AC output voltage from a stepper motor was converted to DC voltage by using a bridge rectifier on each of coils then stored at the capacitor in order to filter and stabilize the voltage. Series and parallel coil configuration was conducted to record a different performance of the output voltage from a stepper motor. The performance of both configuration explained in detail on Figure 4.4.1 and 4.4.2.

4.4.1 Voltage stored on capacitor

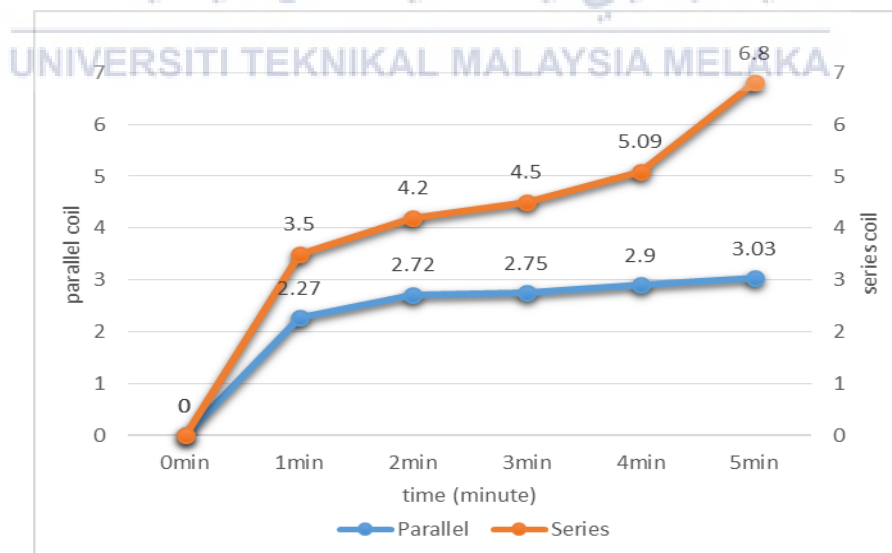


Figure 4.4 A comparison of voltage in a parallel and series coil configuration.

Based on data in Figure 4.4, the maximum value of series coil configuration are twice larger than parallel coil configuration. Maximum voltage stored in series configuration was 3.03 V and 6.8V for parallel coil. The difference of both values caused by the connection of capacitors. When the coil is arranged in series, the charge stored by every capacitor in the series chain is same. Therefore, the maximum value for series connection become twice of the maximum value in parallel connection. Meanwhile, the process become fast charging time for a series coil connection compared with parallel coil configuration. This can be referred in the first minute charging time, where for parallel it start with 2.27V while for series voltage charged was 3.5V.

4.4.2 Maximum current

If a voltage source is applied to the series combination of capacitors, then the current has only one path to flow. Since the voltage are larger for series connection the current value will be lower. While for parallel, current flow are larger compare to series configuration because of the sum of current flow in each capacitors. Figure 4.5 shows the maximum currents recorded for both configuration. For current, the reading ampere was changeable due to the fluctuation of wind speed line graph. Then, only the maximum reading of current has been be recorded for this experiment.

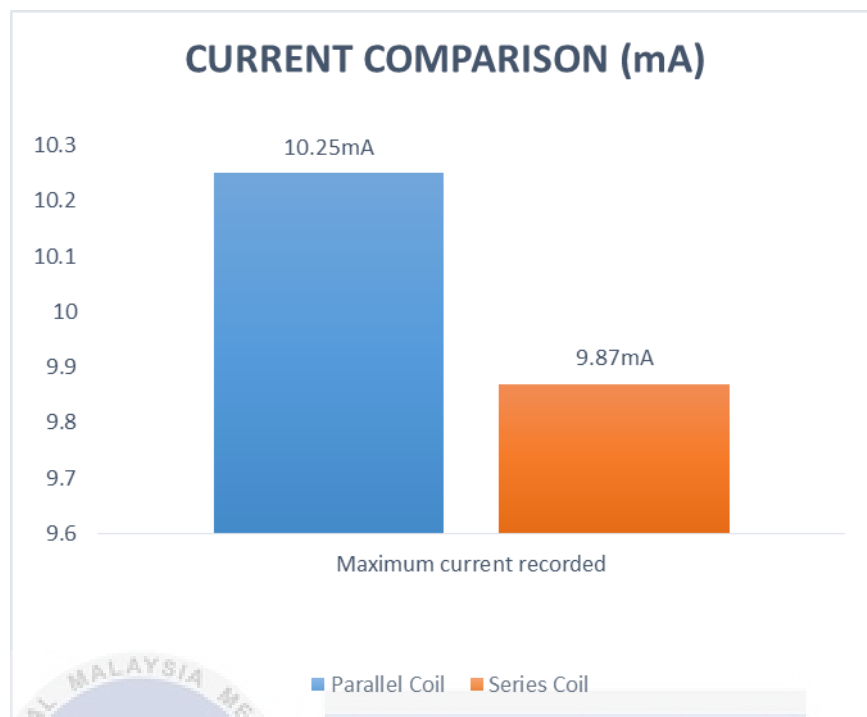
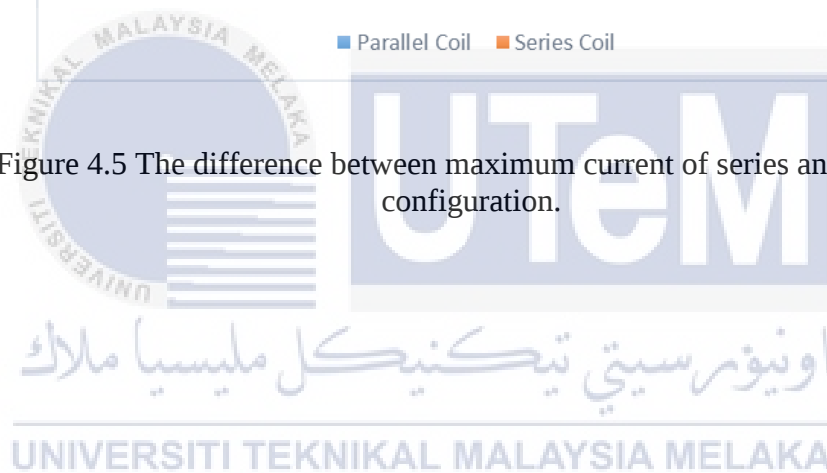


Figure 4.5 The difference between maximum current of series and parallel configuration.



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 Introduction

In this chapter, the results have been conclude and for the future study, the recommendation have been suggested.

5.1 Conclusion

This study presents the experimental evaluation on the performance of wind speed, output voltage and the maximum current value. Here are some of the conclusions resulting based on the experimental finding.

- i. The size for diameter of rotor was slightly influenced to the rotation generator shaft and will produce a large value of output power.
- ii. The charging time of the capacitor affects the value of the output voltage. The longer the charging period the higher the ability of a capacitor to store an electrical charge.
- iii. Voltage generated from stepper motor influenced by the wind speed of the air conditioner. Higher starting torque will affect the value of voltage output produced by a generator.
- iv. The greater the applied voltage the greater the charge stored on the capacitor plates. Likewise, the smaller the applied voltage the smaller the charge.
- v. Voltage charged on a capacitor can be increased by added amount of capacitor arranged in series.

5.2 Recommendation

There are few recommendations are provided as to extend the understanding on fundamental in wind turbine construction. Design of wind turbine model is still at new stage and not widely used in Malaysia. The weakness of the wind turbine model structure is occurred due to the instability of wind turbine foundation. For the next study, there are some improvements that can be done to improve the design of the wind turbine. The recommendations are:

- i. The experimental work in the present research is focused on the stability of the foundation and tower. Thus, it is recommended that further research need to change the structure design of foundation and tower in order to produce stable of wind turbine.
- ii. In the present research, speed of air released by air-conditioner outdoor unit is low and not sufficient to rotate the blade. Thus, the used of centrifugal fan blower instead of air-conditioner to get the strong wind speed are recommended.
- iii. Replacing the PVC pipe material of foundation and tower to the solid material such as steel in order to avoid wind turbine from swaying.
- iv. Obtain more detailed information on the aerodynamic concept to get the best performance of wind turbine blades.

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