DEVELOPMENT OF ENERGY CONVERSION FOR HYDROKINETIC AND WIND ENERGY FOR PORTABLE ENERGY HARNESSING DEVICES

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for the award of the degree of
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ABSTRAK

Projek ini mengetengahkan perihal peranti jana tenaga hibrid yang meliputi hidrokinetik dan tenaga angin. Penggunaan system turbin hibrid boleh dilaksanakan dalam kedua-dua keadaan untuk menjana elektrik sebagai sumber alternatif. Projek ini mengambil fokus keupayaan peranti mudah alih yang mudah dibawa dan digunakan. Justeru, beberapa faktor utama harus diajukan dari segi saiz dan kebolehupayaan pengekstrakan tenaga. Selain itu, ciri-ciri halaju angin dan turun naik halaju air juga merupakan cabaran yang harus dipertimbangkan. Tesis ini akan menerangkan perihal reka bentuk turbin Savonius dengan empat (4) bilah dan juga reka bentuk bekas rangka di samping juga menerangkan perihal jana tenaga menggunakan penjana DC dalam membina peranti jana kuasa mudah alih hibrid hidrokinetik dan tenaga angin. Proses pembuatan peranti ini menggunakan bantuan perisian TinkerCAD untuk reka bentuk teperinci di samping menjalankan beberapa aktiviti tambah nilai sepanjang proses pembuatan. Hasil projek ini menunjukkan kesan halaju angin pada janaan voltan penjana dan juga kesan beban pada penjana DC.

ABSTRACT

This project emphasizing hybrid energy harnessing device which covers hydrokinetic and wind energy. The use of hybrid turbine system can be implemented in both condition to generate electricity as an alternative. This project focusing on the portability of the device to be mobile and easy to configure. Hence, several keys are being highlighted in term of size and possible energy extraction for the proposed device. Also, the characteristic of wind speed and fluctuation of water velocity are the challenges to be consider. This thesis will explain about the design of horizontal Savonius turbine with four (4) blade and device casing as well as the raw energy harnessed via DC generator to develop a hybrid hydrokinetic and wind energy for portable energy harnessing device. The development of the device implement the usage of TinkerCAD software for designing and fabricated thoroughly through assembly process while several value-added process were included along the way. The results shows that the effects of velocity on voltage generated and the effects of load on DC generator.

TABLE OF CONTENT

LIST OF SYMBOLS

ω	angular velocity in radians per second
R	rotor radius in meters (m)
v	wind velocity in meters per-second
σ	solidity of the turbine
z	number of the blades
c	chord (width) of the blade
p_{ideal}	ideal power
ρ	density of the fluid (water)
A	frontal area of the hydrokinetic turbine
V	velocity
C_p	turbine power coefficient
v_0	outlet velocity of the fluid
v_i	inlet velocity of fluid

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MPPT	Maximum Power Point Tracker
CAD	Computer-Aided Design
VAWT	Vertical Axis Wind Turbine
HAWT	Horizontal Axis Wind Turbine
RCECS	River Current Energy Conversion Systems
STL	STereoLithography / Standard Tessellation Language
OBJ	Wavefront OBJect
SVG	Scalable Vector Graphics
ABS	Acrylonitrile Butadiene Styrene
WMO	World Meteorological Organization
EMF	Electromagnetic Field
RPM	Revolutions Per Minute
DC	Direct Current
IoT	Internet of Things
RBDO	Reliability-Based Design Optimization

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Hydrokinetic energy are often recognized as the most clean and efficient renewable energy. The energy created by the movement of water is such rivers, canal, waterways and others. As the water stream pass through turbine, it rotates on a shaft connected to a generator. The rotational speed of the turbine are determine proportional to the velocity of the water.

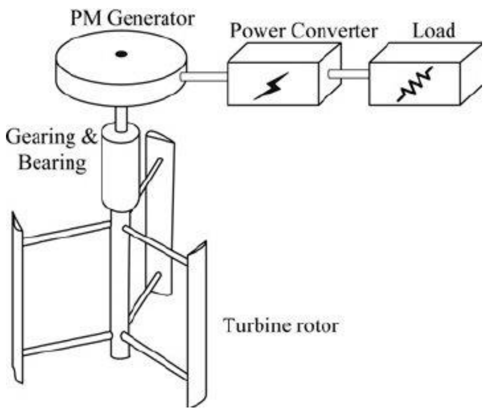


Figure 1.1 Simplified Structural Component in Hydrokinetic System
Source: Ibrahim et al. 2021

Figure 1.1 shows a hydrokinetic component in a device include a hydrokinetic turbine to draw kinetic energy coming from water flow, a generator ,power electronic converter and load/battery/grid-tie connection system (Ibrahim et al. 2021). The resource potential for hydrokinetic energy have been investigated for three different cases as in river, tidal and wave energy. While in this project, a river was chosen. To predict the power available in river, temporal and spatial flow analyses are needed to be conducted. The area, depth, velocity and other related characteristic are also in great consideration.

The use of hydrokinetic as a source of renewable energy benefits in the term of economically as water resources are free. Besides, hydrokinetic serves as a long-lasting technology with very low running cost (Kusakana 2014). While in term of sustainability, the energy available can be readily predicted and the power is usually continuously available on demand. The efficiency of hydrokinetic plant are deem satisfactory, making them to be among the most efficient energy conversion technologies.

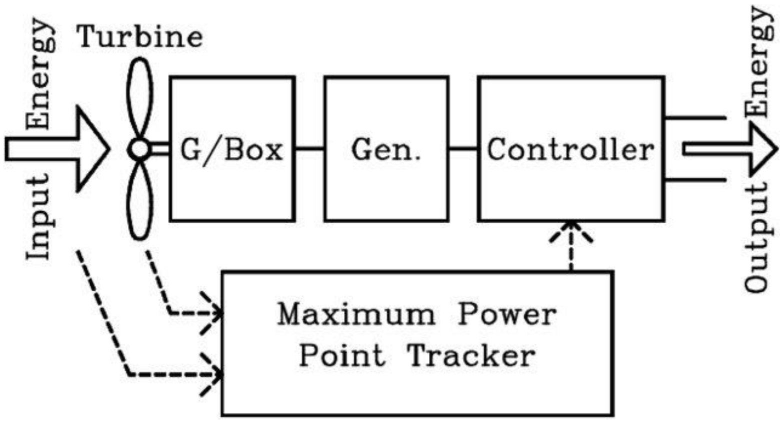


Figure 1.2 Block Diagram of Hydrokinetic or Wind Harnessing System
Source: Tuckey, Patterson, and Swenson 1997

Renewable energy harnessing system need to maximize the efficiency due to the size of the turbines and mechanical parts. Hence, it is important to harness as much energy passing through the turbine as possible by making all stages of the conversion system highly efficient (Tuckey, Patterson, and Swenson 1997). Figure 1.2 shows a block diagram of a wind or in-stream generator system that includes turbine, gearbox, generator and controller. While implementing a control system to harness maximum power is referred to as Maximum Power Point Tracker (MPPT).

The amount of power harvested from an in-stream type hydrokinetic turbine can also be compared with equally sized wind turbine. A hydrokinetic turbine operates with a rated speed of 2 - 3 m/s can be seen producing four times energy of similarly rated wind turbine (Yuce and Muratoglu 2015). The power densities comparison for wind and water turbine are given in Figure 1.3. As results, energy harnessing system based on free-flowing stream or wind are potentially promising to provide sustainable energy in remote are with no access to grid power.

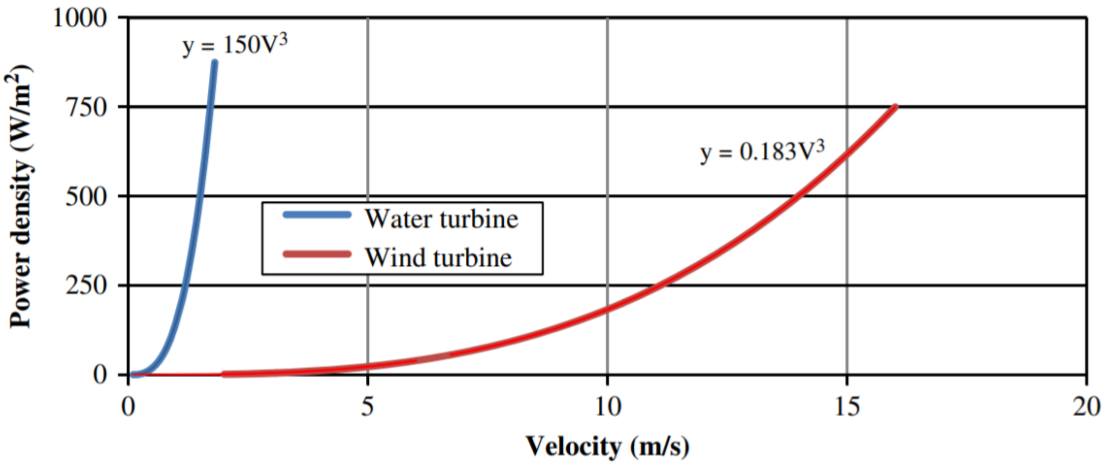


Figure 1.3 Power Densities Comparison between Water (In-Stream) and Wind Turbine
Source: Yuce and Muratoglu 2015

This project will discuss harvesting electric energy by using a turbine, which is hydrokinetic power and wind energy. These two types of power convert kinetic energy into electric power. The predominant concept is to use a turbine to transfer power from the flowing wind and water to a shaft, and the use of a generator to convert the mechanical torque on the shaft to electricity, which can be transferred and stored. The idea concerning this project is to develop a hybrid hydrokinetic and wind energy for portable energy harnessing device; where the turbine and energy harvesting system can be used in both hydrokinetic and wind.

1.2 Problem Statement

i. Mobility of the energy resources due to available energy resources are too big and not portable.

ii. The characteristic of wind speed and fluctuation of water velocity causing a low energy extraction.

1.3 Objective

i. To design a suitable turbine that can be used in both energy harvesting system using any Computer-Aided Design (CAD) software.

ii. To design and develop a vertical axis turbine for portable hybrid energy harnessing.

1.4 Scope

i. The size of the turbine is limited and not exceeding 15cm in diameter and 30cm in length.

ii. The raw generation voltage exceeding 5V

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the introduction of wind energy and hydrokinetic energy, advantages and disadvantages of wind energy and hydrokinetic energy, and some related works. The examples of hardware and software used in this project will also mentioned in this chapter.

2.2 Wind Energy

Based on research by Donald et al, (2010), the windmills has been used to pump water for farms and ranches, and later, to generate power for homes and enterprise during the 19th century. Industrialism caused a gradual decline in the use of windmills. The steam engine replaced ecu water-pumping windmills, and within the 1930s, the rural Electrification management's applications delivered inexpensive electric powered energy to most rural regions in the United States. (Gravelle and Marples 2013)

Windmills first arose in the Middle Ages in Holland, Spain, Portugal, France, and Italy. The windmills were used in Holland to pump water from regions where the ground level was lower than the sea level (Manwell, McGowan, and Rogers 2009). Figure 2.1 show the multi blade of wind turbine.

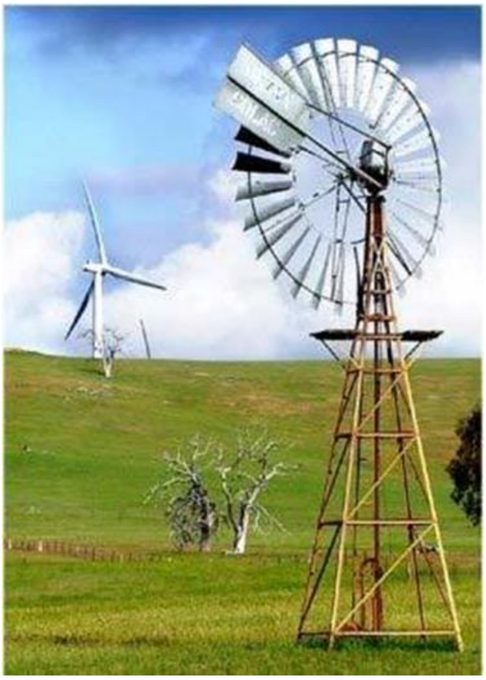


Figure 2.1 Multi Blade Wind Turbine
Source: Manwell, McGowan, and Rogers 2009

Windmills with a metallic construction were used to generate energy in Denmark around the turn of the century, whereas windmills with a wooden frame were employed in America. From 1870 to 1930, Chicago was the largest industrial center for windmill manufacture, with an estimated 6 million units produced during that time.

Under the leadership of professor P.La.Cour, an experimental wind turbine with two electric generators and a rotor blade with a diameter of 22.8 meters was operated in Denmark in 1891. In addition, under the design supervision of Sabanin and Yuriev, the Baltic machine with a power potential of 100 KW was constructed in 1930. Finally, in 1940, an experimental two-bladed wind turbine was built in Vermont, USA, and was rated at 1.25 MW in gusts of roughly 30 mph. (Jain 2011)

The utilization of atomic energy, along with low oil costs, greatly reduced interest in wind energy development in the years following WWII. However, environmental contamination and the energy problem have piqued the attention of technologically advanced countries in this clean and ancient energy source. (Wagner and Marthur 2009)

2.2.1 Structure of Wind Turbine

A wind turbine is made up from of the following structure:

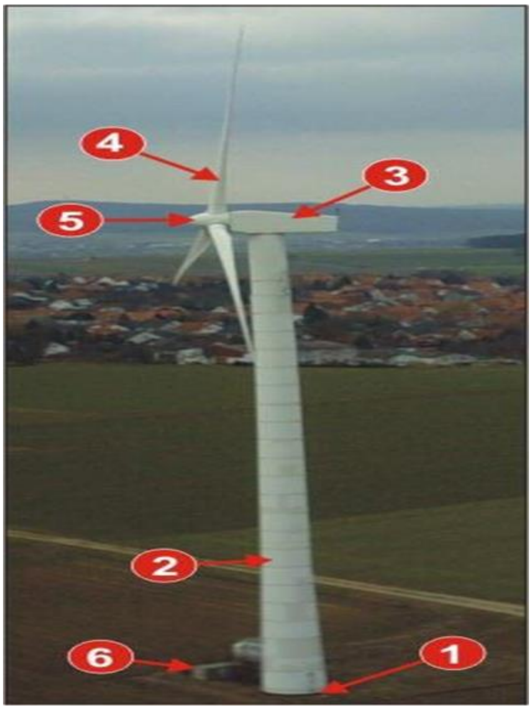


Figure 2.2 Wind Turbine
Source: Jain 2011

1. Tower
2. Foundation
3. Nacelle
4. Rotor Blade
5. Hub (generator inside)
6. Transformer

2.2.2 Wind Turbine Classification

Wind turbines are equipment that were designed to harness the energy of the wind. Wind turbines are classified based on the orientation of their axes in relation to the wind flow. Modern wind turbines are classified into two categories: horizontal axis turbines and vertical axis turbines. According to a non-dimensional number known as the tip speed ratio, which is defined as the ratio of the speed of the extremities of a windmill rotor to the speed of the free wind and is represented below, modern wind turbines can be categorized as high rotation speed or low rotation speed. This ratio provides a helpful benchmark against which the various properties of wind turbines may be evaluated.

$$\lambda = \frac{\omega \text{ x } R}{v} \qquad 2.1$$

Where v is the wind velocity in meters per-second, represent by R is the rotor radius in meters, and ω is the angular velocity in radians per second.

Furthermore, the rotation speed of a wind turbine is determined by its aerodynamic properties and the size of its wind blades. Furthermore, the turbine's connection to the electric grid is critical since all modern wind generators that are linked to the grid produce electric current with the same frequency as the central grid. (Manwell, McGowan, and Rogers 2009).

Finally, the solidity parameter is utilized to identify amongst wind turbines. Solidity is commonly expressed as the percentage of the rotor's surface area that is made up of substance rather than air (Tzanakis 2006).

Horizontal axis:

$$\sigma = \frac{(z \times c \times R^2)}{\pi \times R} \qquad 2.2$$

Vertical axis:

$$\sigma = \frac{(z \times c)}{R} \qquad 2.3$$

Where parameter σ is the solidity of the turbine, z is the number of the blades, R is the radius of the rotor and c is the chord (width) of the blade.

2.2.2.1 Vertical Axis Wind Turbine

The main axis of vertical axis wind turbines is perpendicular to the ground, unlike ordinary wind turbines. Their design makes them suitable for both rural and urban environments, and it allows the owner to offset growing power costs while also preserving the environment. Furthermore, they do not require the complex head mechanics of traditional horizontal axis turbines (Fernando, Hernán, and Ricardo 2007).

The direction of the wind has little effect on vertical axis wind turbine, which is beneficial in places where the wind changes direction frequently or fast. Vertical axis wind turbine can better capture turbulent air flow around buildings and other impediments. This is a more regular occurrence in residential neighbourhoods. Vertical axis wind turbine is suitable for use in both rural and urban areas, including roof top installations.

The generator and other components can be positioned at ground level, making installation and maintenance easier. Because vertical axis wind turbine is slow moving and extremely visible, they do not kill birds or other animals. Building vertical axis wind turbine can be much less costly. When compared to horizontal ones, they emit less noise. Vertical axis wind turbine is more appealing to the eye.

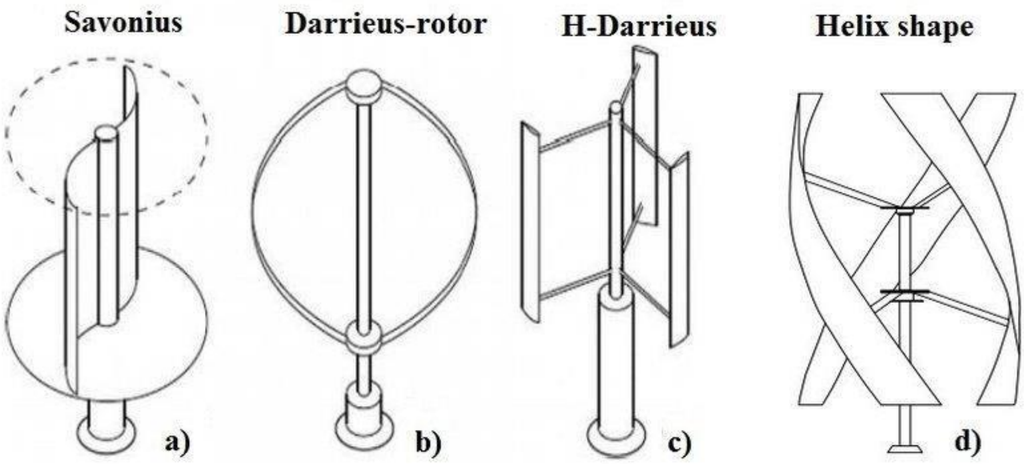


Figure 2.3 Vertical Axes Wind Turbine
Source: Fernando, Hernán, and Ricardo 2007

2.2.2.2 Horizontal Axis Wind Turbine

Horizontal axis turbines are either upwind (the wind strikes the blades before the tower) or downwind (the wind strikes the blades after the tower) (the wind hits the tower before the blades). A yaw drive and motor components are also included in upwind turbines, which turn the nacelle to maintain the rotor towards the wind as the wind direction changes.

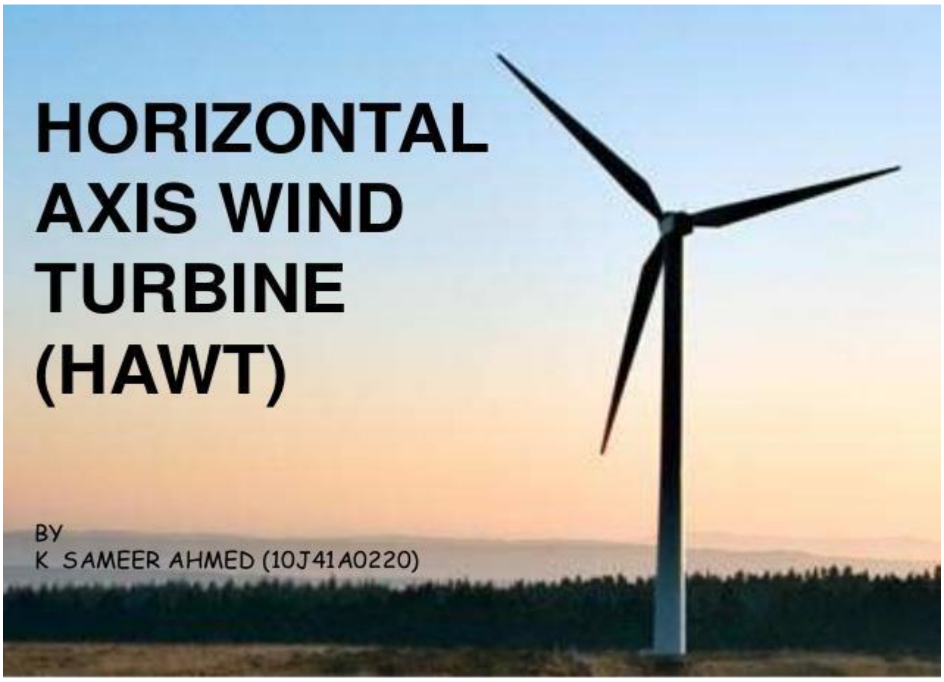


Figure 2.4 Horizontal Axis Wind Turbines
Source: Ahmed 2014

2.3 Hydrokinetic Energy

A hydrokinetic system is an electromechanical device that uses a generator and power electronics converter to transform the kinetic energy of water flow into electrical energy (Close Khan, Iqbal, Quaicoe 2008). Even if the output capacity is limited, an array or modular installation can be used to boost capacity (Alvarez et al. 2018). Furthermore, a hydrokinetic system does not require the building of a reservoir or impoundment because it is based on free-flowing water. Because of its tiny size, the system is simple to move and relocate. Furthermore, the system can be moored to a stationary building or deployed on a floating pontoon along the riverbank (Anyi and Kirk 2010).

2.3.1 The Principles of Hydrokinetic Energy Conversion

The approach usually used in the field to evaluate the power extraction capabilities of a hydrokinetic energy extraction device is to utilize an ideal power calculation as per Eq.1. Because both systems use fluids and either air-foils or hydrofoils, the power equation of a hydrokinetic turbine is comparable to that of a wind turbine (Kirk 2013) (Khan, Iqbal and Quaicoe 2006). The power equation for a hydrokinetic turbine is as follows:

$$p_{ideal} = \frac{1}{2} \rho AV3Cp \qquad 2.4$$

P is the power from HEED, ρ is the density of the fluid (water), A is the frontal area of the hydrokinetic turbine, and Cp is the turbine power coefficient.

$$C_p = \frac{(1 + \frac{v_0}{v_i})(1 - \frac{v_0}{v_i})}{2} \qquad 2.5$$

Where, Vo is outlet velocity of the fluid and Vi is inlet velocity of fluid.

It's an estimation of how much energy a wind turbine can collect, but a more complete examination of blade form and surface, as well as the accompanying fluid interactions, might yield more precise findings (Alvarez et al. 2018). Through a fluid stream tube approach, Cp is a factor of mass conservation. Cp tends to attain a Betz limit of 0.59 for an ideal turbine in an unlimited free stream. The Betz limit denotes the potential maximum power output from a fluid-based hydro kinetic turbine (Alvarez et al. 2018). The power coefficient curves of HKT turbines are shown. The technology for converting tidal energy into electricity, which works on the same principle as river turbines, has advanced considerably (RCECS). RCECS (river current energy conversion systems) are compact power units with floating constructions that may be simply deployed in a river channel. Tidal turbines, on the other hand, are typically bigger, permanently anchored, and work in response to periodic tide action. Nonetheless, knowledge of tidal energy systems is essential for comprehending river turbine technology.

2.3.2 Hydrokinetic Turbine Classification

There are two types of turbine that commonly used for hydrokinetic turbines that are:

1. Horizontal Axis Turbine
2. Vertical Axis Turbine

2.3.2.1 Horizontal axis turbines

Cross-flow turbines (Figure 2.5) feature rotor axes that are parallel to the water surface but orthogonal to the water flow. Vertical axes (axes parallel to the water plane) and in-plane axes can be distinguished (axis on the horizontal plane of the water surface). In-plane turbines I are thought to be less efficient than their lift-based counterparts since they are typically drag-based devices.

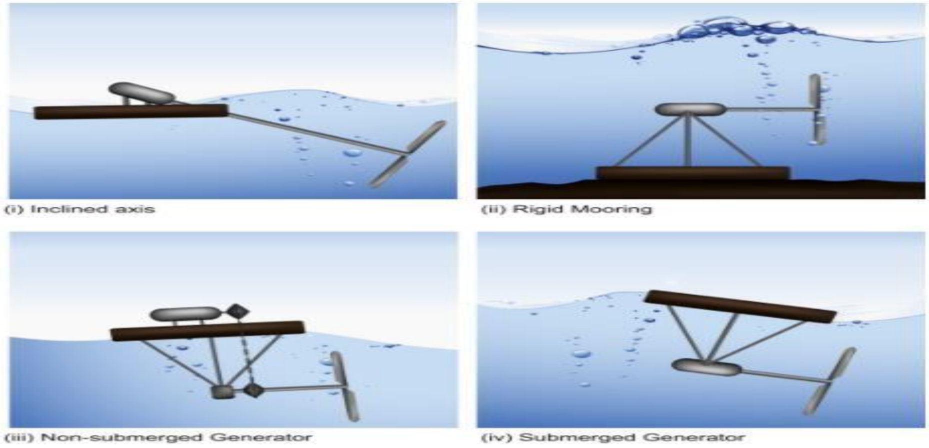


Figure 2.5 Horizontal Axis Hydrokinetic Turbines

Source: Fatemah et al. 2016

2.3.2.2 Vertical axis turbines

Darrieus, SC- Darrieus, H- Darrieus, Gorlov, and Savonius are examples of vertical axis turbine layouts. Darrieus turbines are the most visible of the vertical axis turbines. Despite the widespread usage of H-Darrieus (straight-bladed) turbines in hydro applications, there are no examples of Darrieus (curved or parabolic blades) turbines.

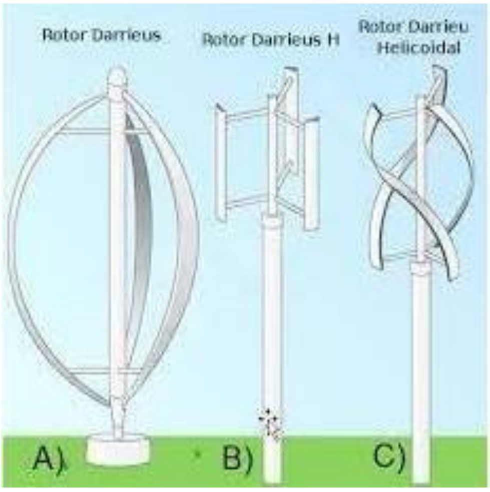


Figure 2.6 Vertical Axis Hydrokinetic Turbines

Source: https://www.mech4study.com/2016/01/what-is-wind-turbine-what-are-main-types-of-wind-turbines.html

2.4 Hardware and Software

2.4.1 Hardware List

1. Turbine
2. Generator
3. Stainless steel rod with threading
4. Tin case with upper lid
5. Bolt and nut

2.4.2 Software List

1. TinkerCAD
2. AutoCAD

2.4.3 Hardware and Software Description

2.4.3.1 Generator

The crucial part of designing any energy harvesting system is the power generator. Since this project objective to harvest energy for low-power applications, a direct current DC generator was chosen. A DC generator is a rotating machine that supplies an electric output with unidirectional voltage and current, which shares the same basic principle of operation as those for synchronous generator.

The components of DC generator can be listed down into;

1. Stator
2. Rotor
3. Armature winding
4. Yoke
5. Poles
6. Commutator
7. Brushes

Using Faraday's law of electromagnetic induction, it stated that when a current-carrying conductor is places in varying magnetic field, an electromagnetic field is induced in the conductor (Chang 1995). Hence using Fleming's right-hand rule, the induced current direction would change, accordingly to the direction of conductor motion (Honnel 1953).

A DC generator were used substantially due to the availability of economical rectifier systems supplied by alternators. A DC generator can be seen commonly used in charging batteries and supplying low-power load as in electrical devices. While in other applications, DC generator retain an advantage compared to alternator as it can operate motor, as well as reversing the direction of power flow.

Figure 2.7 DC Generator

2.4.3.2 TinkerCAD

Figure 2.8 TinkerCAD

TinkerCAD was launched in 2011 as a web based 3D modelling tools. This free-of-charge online 3D modelling program runs in a web browser. It uses a simplified construction solid geometry method of constructing model that can be imported by STL, OBJ and SVG that are ready for 3D printing. By accessing TinkerCAD as designing module, the accessibility to design made it possible to 3D print the model.

2.4.3.3 AutoCAD

Figure 2.9 AutoCAD

Computer-Aided Design is abbreviated as AutoCAD. This software is used for drafting and designing. It enables users in the manufacturing industry to conceptualize ideas, product designs, and drawings to the appropriate degree of technical correctness, as well as execute quick design calculations and simulations. For this project, the AUTOCAD are also use to design the shape of the turbine as well as the casing.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology is a system of broad principles or rules from which specific methods or procedures may be derived to interpret or solve. This chapter explained in detail the procedure of the implementation of the control system in the Development of a Hybrid Hydrokinetic and Wind Energy for Portable Energy Harnessing Devices for easy monitoring and easy to carry anywhere. The methods used in this chapter are aimed to achieve the objectives of the project which will give satisfying results on the performance of the control system.

3.2 Flowchart

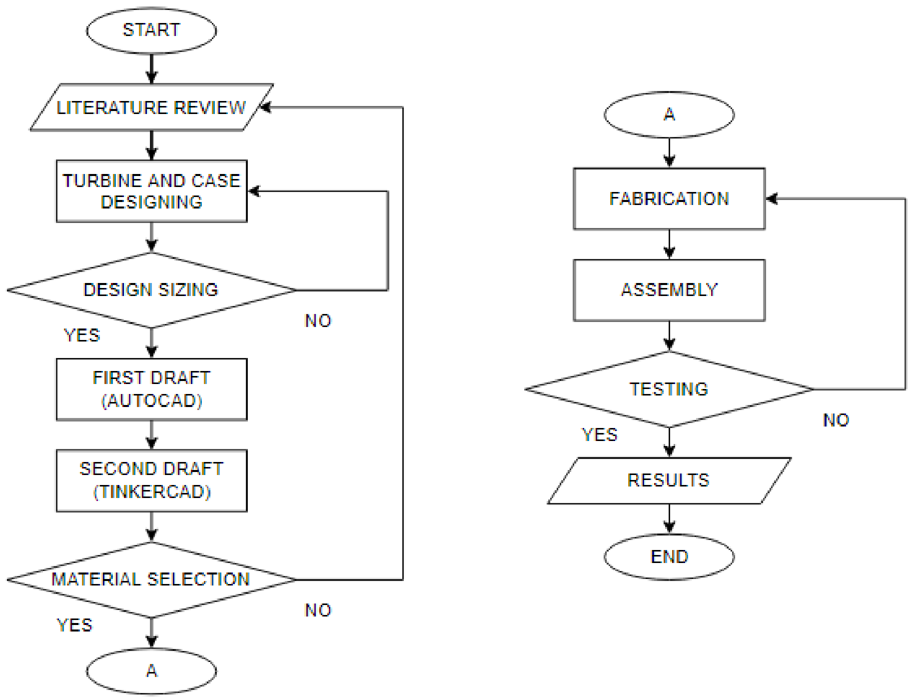


Figure 3.1 Flowchart of the Project

3.3 Turbine Research and Study

The devices that are proposed to harness any kinetic energy requires the need of a suitable turbine. Turbines are commonly categorized accordingly to their axes in comparison with the flow of the wind and/or water. Various types of modern turbine have been developed in the past decade which categories them into two major classification; vertical axis and horizontal axis turbine (Fernando, Hernán, and Ricardo).

The turbine proposed in this project were idealized based on existing Savonius turbine. Savonius turbine are known due to its simplicity and one of the simplest turbines. Basic Savonius turbine consist of two vertical blades (half cylinder) and look like a letter "S" in cross section. However, various development on this design have been made to fully utilize and exert the full capabilities of these blade (Kailash, Eldho, and Prabhu 2012) (Kumar and Saini 2015).

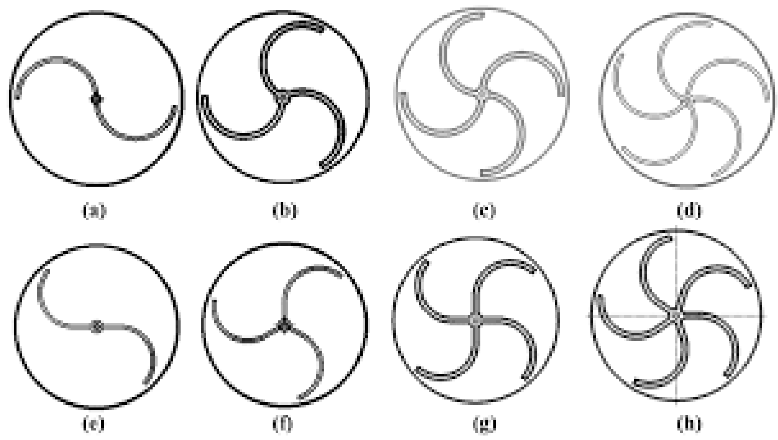


Figure 3.2 Savonius Blade on Modified Hydrokinetic Turbine
Source: Kumar and Saini 2015

The Savonius turbine have been used in both area of harnessing renewable energy that is hydrokinetic and wind (Prabowoputra et al. 2021) (Bachtiar 2019). The Savonius turbine works due to its difference in forces exert on each blade. Due to its blade curvature, a half cylinder experience less drag force when moving against wind/water flow while the other half experience more drag force than the other. The differences between these forces drag and forcing the turbine to spin (Abraham and Plourde 2012).

A thorough study has been developed to exert the efficiency of the blade in both water and wind flow. Prior to this, a development on the turbine using Computer-Aided Design (CAD) Tinkercad has been made. The idea regarding this proposed turbine type is a vertical savonius turbine with 4 blades.

3.4 Turbine and Casing Design

3.4.1 First Draft using AutoCAD

The project was build based on the priority of the sizing, as per stated in the objective which to make it portable for energy harnessing activity. On that account, prior to the design process, several main criteria were highlighted. The design of the turbine and casing shown in figure 3.3 and 3.4 was created using AutoCAD software.

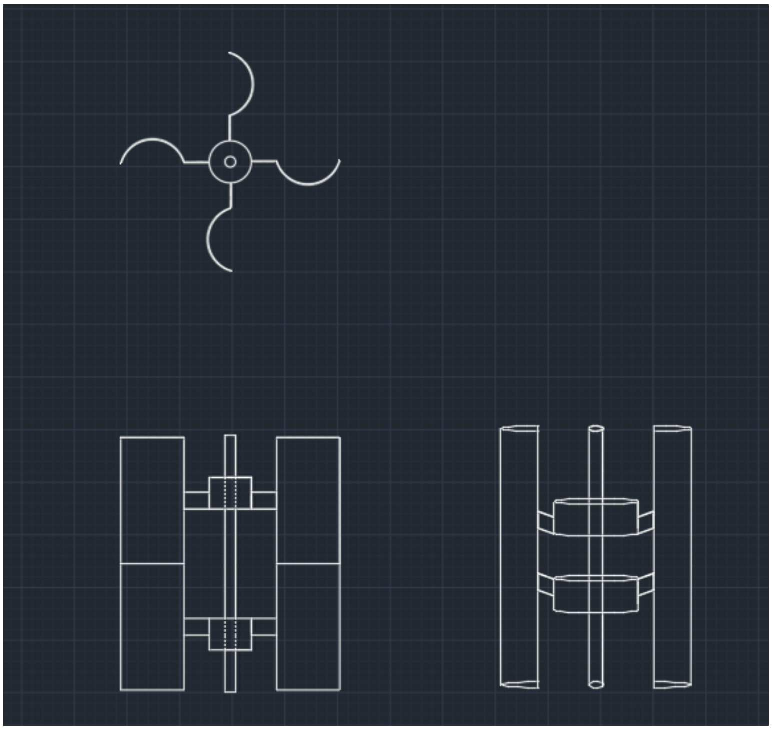


Figure 3.3 Turbine Drawing Using AutoCAD Software

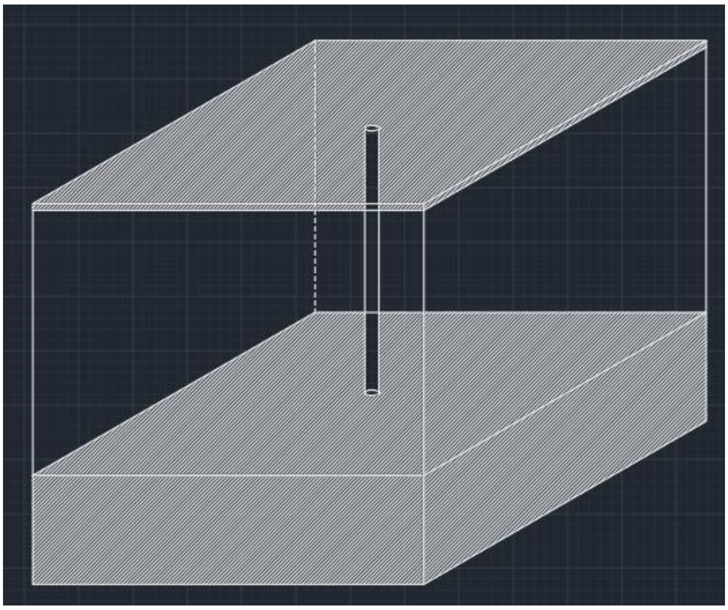


Figure 3.4 Casing Drawing Using AutoCAD Software

3.4.2 Second Draft using TinkerCAD

The entire sketch were idealized in TinkerCAD software for a clearer practical picture. The design of the turbine and the casing are specified in exact dimension to ease component installation. The second draft idea is an upgrade from the first one as it is more compact in term of sizing and also easier to carry as per justified in the objective of the project.

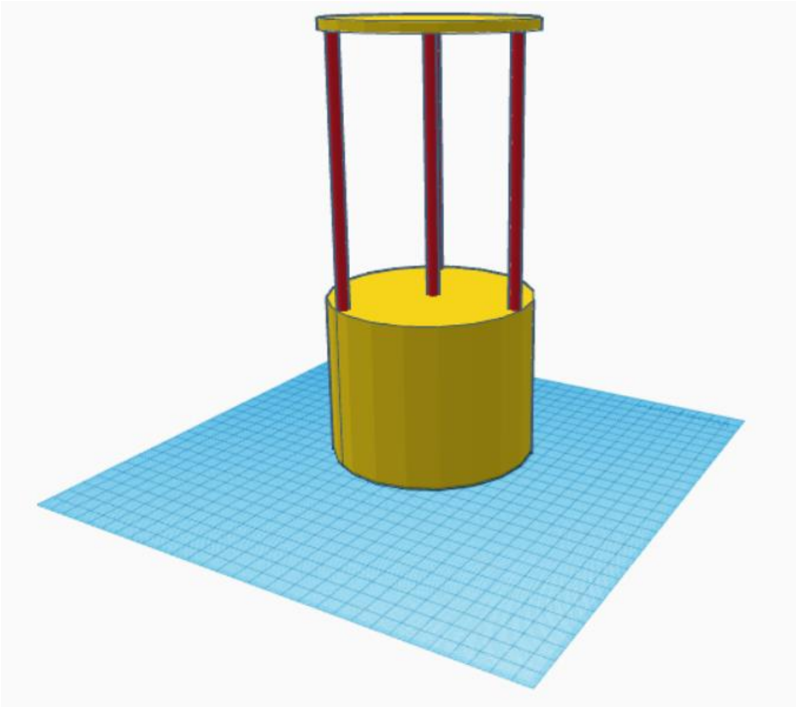


Figure 3.5 Casing drawing using TinkerCAD Software

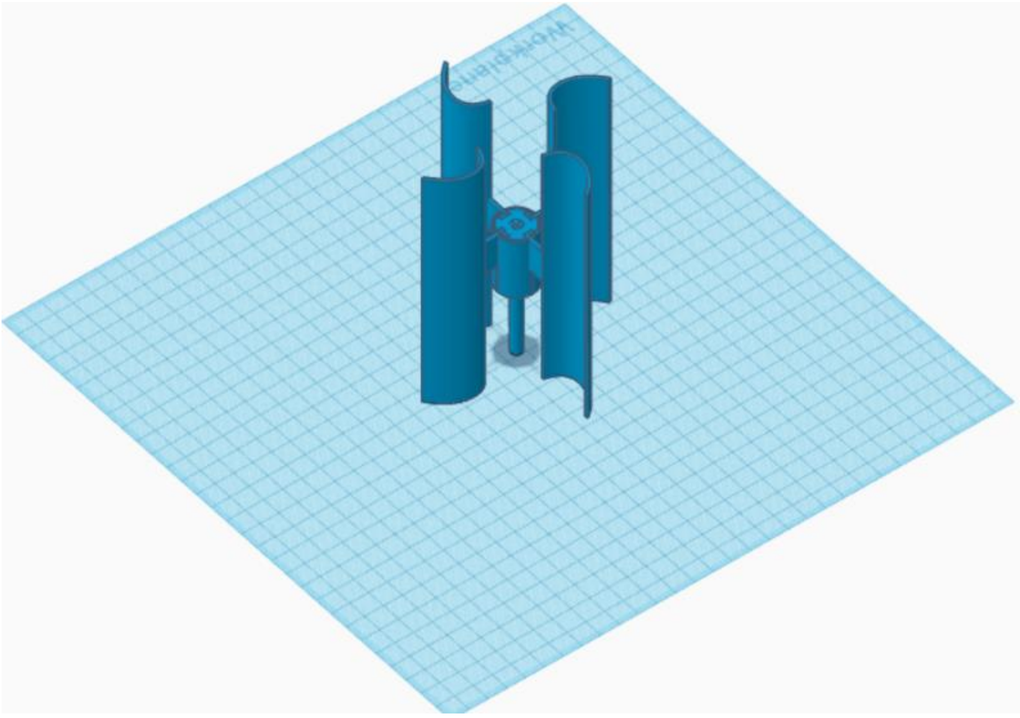


Figure 3.6 Turbine drawing using TinkerCAD Software

3.4.3 Material selection

Material build is also a major steps in the process of designing this project. The turbine proposed in this project were idealized based on existing Savonius turbine. Savonius turbine are known due to its simplicity and one of the simplest turbines. Basic Savonius turbine consist of two vertical blades (half cylinder) and look like a letter "S" in cross section. Prior to this, a development on the turbine using Computer-Aided Design (CAD) Tinkercad has been made.

The idea regarding the turbine type is a vertical savonius turbine with 4 blades. The blade material that was chosen are acrylonitrile butadiene styrene (ABS). ABS known as common thermoplastic polymer that is usually used for injection molding application. Comes with low production cost, ABS also proved its resistance upon impact, the structural strength and stiffness and also easy to paint and glue.

The casing material selected uses a tin frame in round shape for the base and top. Tin was use due to its availability and also lightweight. Stainless steel rod were attached to the top and the base of the structure to keep it stable. The use of a stainless steel material is also proven useful in this project due to its area exposure to water. The shape sizing were also justified in order to allow the turbine to rotate freely in designated area without colliding to the stainless steel rod.

The detail part of the component were shown on Appendix B.

Figure 3.7 Casing Tin and Metal Rod for Casing Structure

3.5 Turbine and Casing Fabrication

During fabrication process, the material were constructed by combing parts and component to obtain resultant product. Most of the fabrication process inducted by assembling parts with exact calculation and measurement. As the assembling parts completed, several value-added process were included to make sure the product are well presented.

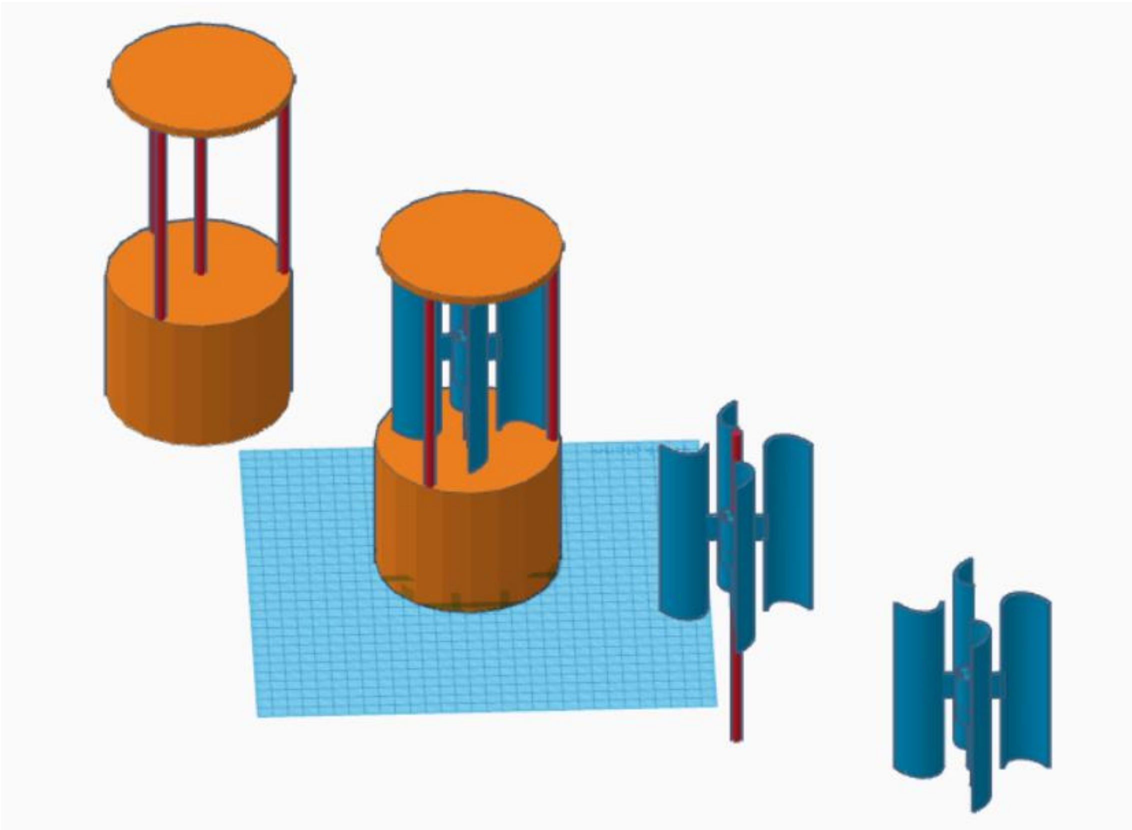
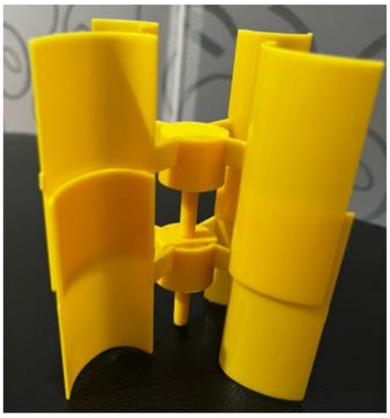


Figure 3.8 Fabrication Process Idealizing via TinkerCAD

The assembling process were made prior to the guided measurement using glue, washer, bolt and nut, in which hold the turbine and casing. The turbine part had to be secured by glue to keep them attached firmly while stainless steel rod were tied to the tin case using bolt, nut and washer to keep it stable and according to desired size. The illustration of the assembling activity are shown in figure 3.9.




(a) Turbine assemly using glue **(b) Silicone washer are used to seal gap**


(c) (d) Bolt and nut used to tie rod and tin top and bottom tin case

Figure 3.9 Fabrication Process

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

After completing all of the method from the previous methodology chapter, this chapter covers all the results that were obtained from the project. The discussion regarding the effect of velocity on voltage generation and the effects of load on DC generator are also provided in this chapter.

4.2 Velocity Effect on Raw Voltage Generation

The velocity of wind and speed of water immensely effect the production of raw voltage. Suitable velocity of wind for this project are needed to be located to make sure the turbine can rotate in higher rotational per minute, thus increasing the generator production.

4.2.1 Wind Velocity Characteristic

Beaufort wind scale were introduced in 1805 for marine environment use. However it was derived in 1874 to be use in the international telegram code in which to transmit wind information both from sea and land. The common language of the tongue in that day described wind in condition of 'gentle breeze', 'storm' or 'whole gaze' while the indication are based on the behaviour of flag or trees (Hasse 2003). The table below shows the Beaufort wind scale derived in meter per second.

Table 4.1 Beaufort Wind Scale

Force	WMO Classification	Wind Velocity (m/s)	Appearance of Wind Effect
0	Calm	< 0	Smoke rises vertically
1	Light air	0.5 – 1.5	Smoke drifts with air, weather vanes inactive
2	Light breeze	2 – 3	Weather vanes active, wind felt on face, leaves rustle
3	Gentle breeze	3.5 – 5	Leaves & small twigs move, light flags extend
4	Moderate breeze	5.5 – 8	Small branches sway, dust & loose paper blows about
5	Fresh breeze	8.5 – 10.5	Small trees sway, waves break on inland waters
6	Strong breeze	11 – 13.5	Large branches sway, umbrellas difficult to use
7	Near gale	14 – 16.5	Whole trees sway, difficult to walk against wind
8	Gale	17 – 20	Twigs broken off trees, walking against wind very difficult
9	Strong gale	20.5 – 23.5	Slight damage to buildings, shingles blown off roof
10	Storm	24 – 27.5	Trees uprooted, considerable damage to buildings
11	Violent storm	28 – 31.5	Widespread damage, very rare occurrence
12	Hurricane	> 32	Violent destruction

4.2.2 Velocity Against Raw Voltage Production

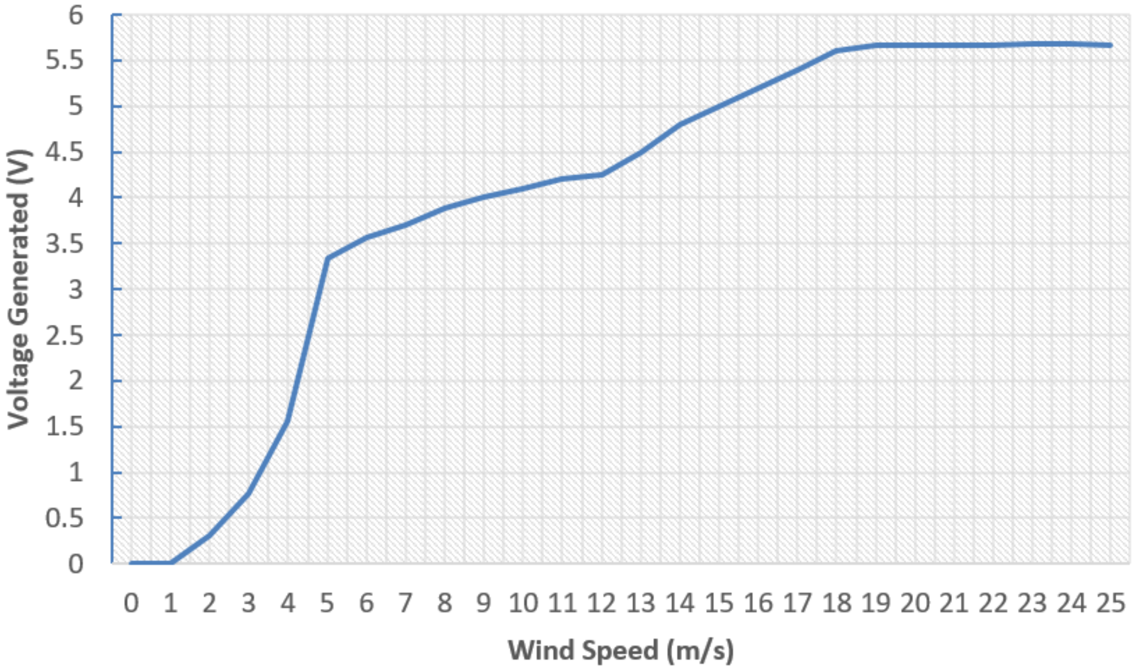


Figure 4.1 Voltage Generated Versus Wind Speed

Graph above shows the voltage generated versus the speed of wind (m/s). As per conducted, the optimum wind speed for 5V generation can be achieved around velocity of 15 m/s. The initial velocity of the wind can also be affected by the density of air and altitude of location.

4.3 Effect of Load on Generator Speed

The DC generator rotational per minute differ in a condition where there is load or no load. The DC generator speed observed to be slower in a condition where there is load connected. The speed of the DC generator are known changed by the changes of current in the field or by the changes of current in the armature.

4.3.1 Generator on Observed Condition

In a no load condition where the field current decreases, the reduction of field flux is reduced proportionally while the counter electromagnetic field (EMF) decreases. Hence permitting more current coming from armature resulting the speed of the DC generator rotates freely without interference.

As when the field current increases with a load condition, the field flux increases and more EMF is to be developed that opposed the armature current. As the armature current decreases, the RPM of the DC generator are observed slower.

4.4 Design Outcome

Upon completing the fabrication process, several value-added process were included to make sure the product are well presented. The outcome of the design are shown in figure below.

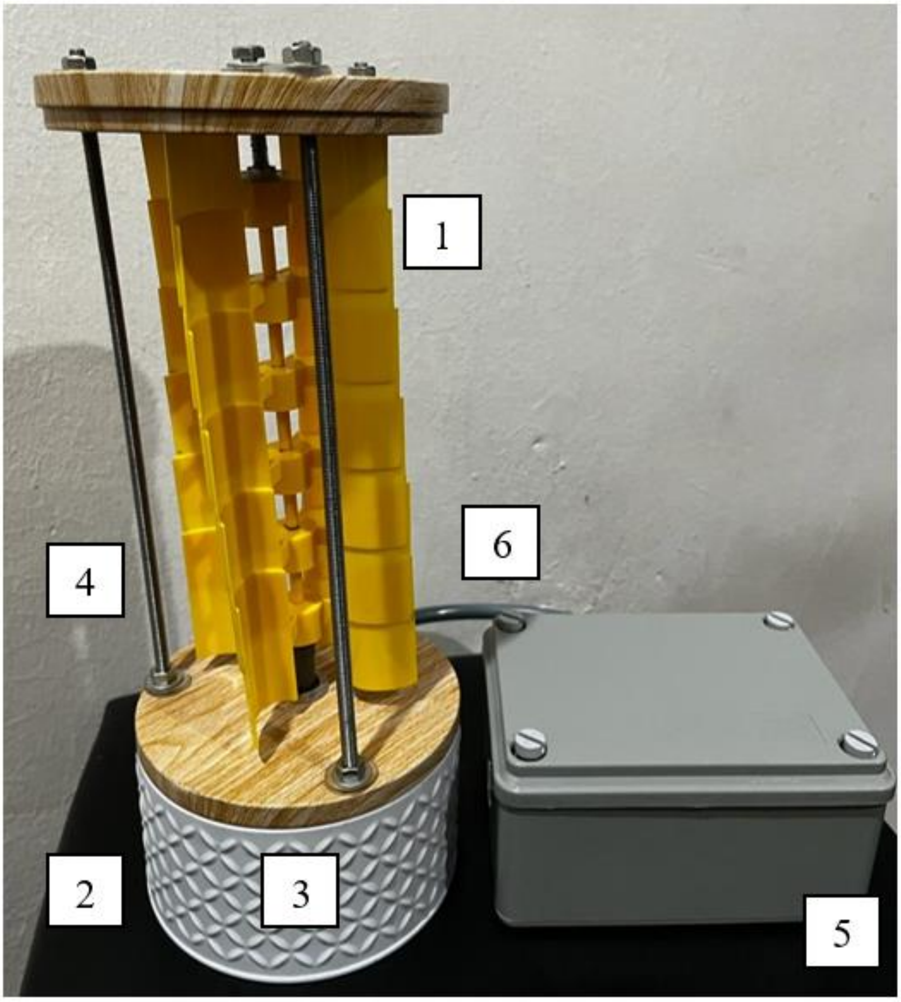


Figure 4.2 Hybrid Hydrokinetic and Wind Energy for Portable Energy Harnessing Device

1. Vertical Savonius Turbine with 4 blade
2. Tin casing
3. DC Generator (inside casing)
4. Stainless steel rod
5. Junction box for electronic component
6. Supply cable

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter summarised all the findings that have been discovered and learned during conducted research. This chapter also highlights the important findings of the study and limitations that can be issued for future recommendation research.

5.2 Conclusion

To develop a hybrid hydrokinetic and wind energy for portable energy harnessing devices that can be practically used in proposed situation has become the major objective of this project. The project has been conducted covers on several parts of development that covers the fabrication of a vertical Savonius turbine with 4 blades and casing designing for DC generator and turbine placement. The project then follows the performance of turbine under different velocity of wind to determine the optimum velocity for voltage generation. As per conducted, the optimum wind velocity of 15 m/s are needed for 5V generation.

The objective of this part are then continued with the implementation of a boost converter to increase the voltage production that controlled by a microcontroller board Arduino Uno. A lithium-ion rechargeable battery then stores the energy produced while being monitored by voltage and current sensor, while Internet of Things (IoT) implementation display the values wirelessly via smartphone.

5.3 Recommendation

Based on the wind characteristic for voltage generation and also DC generator observation, a development of a gearbox are seems reasonable for maximum efficiency. Gearbox mechanism are commonly used in energy harnessing device system to increase the rotational speed from a low speed main shaft to a high speed main shaft connected to a generator. Gears in turbine proves as a practical solution in connection with many industrial machineries. With the use of a gearbox, it can perform in a low kinetic energy supply.

However, a hybrid turbine is a complex multi physics system involving wind and water loads, turbine aerodynamics, gear dynamics, electrical generator and monitoring system. Although some studies have been conducted solely on wind turbine gear failure mode, limited studies have been carried out regarding design optimization including reliability-based design optimization (RBDO) (Li 2018).

5.4 Commercialization Potential of Project

Nowadays, the demand for renewable energy harnessing system can be seen escalate by time as the supply of oil, coal and natural gases fluctuate proportionally to the world population. As such the implementation of a hybrid energy harnessing system can be used to minimize the dependability of natural sources. Focusing on portability and minimal power harnessing capability, the product potential can be nurtured as a concept for future hybrid energy harnessing devices.

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APPENDICES

Appendix A: DC Generator

Specifications:

• Brand: MITSUMI

• Model: RM1-4617

• Categories: Direct-current (DC) generator

• Certification Certificate of Completion and Compliance (CCC)

• Voltage: 1.5V ~ 24V DC

• Wattage: 40W

• Torque: 2100 – 5000 RPM

• Dimension: 88mm x 35mm x 35mm

Appendix B: Component Detailed Specification

Part Design	Features
	Turbine is the main part of the project Size of the part • Diameter: 100 mm • Length : 230 mm Includes a middle shaft
	Stainless steel rod with threading Function to hold structure Size of the part • Diameter: 6 mm • Length : 240 mm Tied to tin case using bolt and nut
	Tin case with upper lid Function as a case for generator, turbine rotates in the middle Size of the part • Diameter : 135 mm • Length : 350 mm