SIMULATION STUDY OF MICRO WIND TURBINE

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Alternating Current
A	Ampere
CFD	Computational Fluid Dynamic
cm	Centimeter
DC	Direct Current
HAWT	Horizontal Axis Wind Turbine
J	Joule
k	Kilo
m	meter
m/s	Meter per Second
SWEPT	Small Scale Wind Energy Portable Turbine
VAWT	Vertical Axis Wind Turbine
V	Volt
W	Watt

Pembelajaran Simulasi Untuk Turbin Angin Mikro

ABSTRAK

Turbin angin mikro adalah teknologi inovasi yang boleh menjana elektrik dengan kelajuan angin yang rendah. Tenaga elektrik dihasilkan daripada tenaga kinetik yang dijana oleh turbin angin dan tenaga itu ditukar kepada tenaga elektrik. Pada masa kini, teknologi konvensional turbin angin tidak sesuai digunakan di kawasan bandar dan luar bandar kerana turbin angin jenis ini perlu menjana kuasa elektrik dengan kelajuan angin minimum sekitar 4 m/s dan untuk meningkatkan kadar kecekapan penjanaan tenaga angin, kelajuan angin yang diperlukan ialah lebih dari 7 m/s. Oleh itu, pengunaan turbin angin mikro membolehkan tenaga dijana pada kelajuan angin serendah 2 m/s dan penjanaan tenaga dapat dihasilkan dengan lebih berkesan. Melalui projek ini, perisian MATLAB digunakan untuk merekabentuk sistem turbin angin mikro dengan menggunakan penjana DC. Penyusunan penjana DC turbin bagi turbin angin mikro dikonfigurasikan secara siri, selari dan siri selari untuk mengkaji keberkesanan setiap susunan. Penukar penggalak digunakan untuk meningkatkan tenaga elektrik yang dihasilkan oleh turbin angin mikro. Voltan keluaran dan kuasa yang terhasil dianalisa dengan mengubah kelajuan angin dari minimum 1.9 m/s sehingga maksimum 2.5 m/s. Rumusannya, voltan keluaran yang dihasilkan oleh penjana DC turbin angin yang dikonfigurasikan secara siri boleh digunakan untuk sistem pencahayaan didalam bangunan dimana ia memerlukan voltan yang tinggi untuk berfungsi dengan baik. Manakala, aplikasi yang sesuai untuk menggunakan penjana DC turbin angin yang dikonfigurasikan secara selari ialah sistem mengecas bank kuasa yang memerlukan untuk menghasilkan arus keluaran yang tinggi. Sementara itu, kuasa keluaran yang tinggi boleh terhasil apabila penjana DC turbin angin mikro dikonfigurasikan secara siri selari. Hal ini kerana, kesemua konfigurasi tersebut mempunyai voltan keluaran, arus dan kuasa yang tinggi iaitu sebanyak 30.58 V, 1.596 A dan 21.86 W masing masing. Oleh itu, penjana kuasa DC turbin angin mikro sangat sesuai digunakan untuk kawasan yang mempunyai kelajuan angin yang rendah kerana sistem ini boleh menghasilkan kuasa elektrik yang mencukupi walaupun mempunyai kelajuan angin yang rendah iaitu 1.9 m/s.

Simulation Study of Micro Wind Turbine

ABSTRACT

The micro wind turbine is an innovative technology that can generate electricity with a low wind speed condition. This electricity is produced from a kinetic energy which is harvested by the wind turbine and the particular energy is converted into electrical energy. Currently, the technology of conventional wind turbine cannot be used at an urban area or rural area because that type of turbine is large in sizing and only will be generating electrical power at the minimum wind speed of around 4 m/s and in order to be efficient, its require wind speed over 7 m/s. Therefore, by using the micro wind turbine, it allows energy to be harvested at wind speed as low as 2 m/s and the energy have generated effectively. In this project, MATLAB software is used to design the arrangement of micro wind turbine system by using wind turbine DC generator. The configuration arrangement of micro wind turbine generator is in parallel, series and series-parallel for wind turbine DC generator in order to investigate the effectiveness of each arrangement. The boost converter is used to step-up the electrical energy that generated by the micro wind turbine. The output voltage, current and power are analysed by varying the wind speed in a range 1.9 m/s to 2.5 m/s maximum. In summary, the series wind turbine DC generators configuration arrangement can be applied to lighting system where it require an adequate level of voltage to function properly. Meanwhile, the suitable application for parallel configuration for DC generators micro wind turbine is a charging system such as power bank where higher level of output current is required. Furthermore, highest output power can be produce, when the micro wind turbines DC generator is connected in series-parallel configuration. This can be seen from the simulation result, these configurations had higher output voltage, current and power which were 30.58 V, 1.596 A and 21.86 W respectively. Therefore, DC power generation with the micro wind turbine is suitable for low wind speed since the system can produce adequate electrical power with wind speed as low as 1.9 m/s.

CHAPTER 1 : INTRODUCTION

1.1 Project Background

This project is aimed to study and analyse the simulation of micro-wind turbine system configuration by using MATLAB. The micro-wind turbine is an innovative technology that can generate electricity from a kinetic energy with a low wind speed condition.

In the late 20th century, there are many potential sources of energy generation that have developed in the world. Wind energy is one of the most attractive renewable energy resources in the world besides solar and geothermal energy. The electrical power that been generated by wind energy is clean and environmental-friendly because it does not harmful to the environment unlike non-renewable energy such as fossil fuel, coal and natural gas. However, the development of wind energy is not evenly distributed around the world because about 80% of worldwide wind capacity is installed in only 5 main countries which are Germany, USA, Denmark, India and Spain. Hence, most of wind energy knowledge is based in these countries because these countries have high wind speed which can be used for conventional wind turbine (Benbouzid M., 2010).

These days, even though wind energy has been used in the large-scale generation, there are numerous issues for their sustainable development. As an example, the main obstructions of the large-scale on-shore wind farm to its developments are grid-connection, public acceptability and a big loss on transmission and distribution of electricity to consumers (Ling D., 2010). The micro wind turbine can be classified as small distributed generation with the capacity below 3 kW for domestic installation. Physical sizing of the micro wind turbine technology is being designed small enough for private use such as in residential area, farms or rural area. Unlike large scale wind turbines, the micro wind turbine is light and compact, thus, the installation is flexible and have simple maintenance.

1.2 Problem Statement

In Malaysia, the micro wind turbine is less known or not much explored by the researcher as compared to the conventional wind turbine. This country has only experienced stronger winds in the early and the end of the years due to northeast monsoon. Overall, the annual mean wind speed in Malaysia is only 1.8 m/s, while at the east coast of Peninsular Malaysia such as Mersing, Kota Baharu and Kuala Terengganu, the wind speed could exceed 3 m/s when strong wind occurs (Sung C. T. B., 2013). However, for a conventional wind turbine. It needs a minimum wind speed of around 4 m/s and required wind speed over 7 m/s to generate electrical power in order to be efficient (Dr. Leung D., 2007). Therefore, by using micro wind turbine, it can allows energy to be harvested at minimum wind speed as low as 2 m/s effectively.

The residents in housing area barely install the wind turbine at residential area due to the fact that conventional wind turbine usually required large space to operate and for safety reason, it need to locate away from the populated area. The worse issue that occurred for the workers and residents nearby is when large wind turbine with height 50 meter and above are collapsed due to the bad weather or malfunction. The collapsed turbine also will have affected the other turbines and generation system if do not have enough protections. This will make the cost to maintain the turbine and its system increased.

Moreover, the conventional wind turbine installation cost is very expensive. Thus, the residential owner and the industrial user could not afford to install this kind of wind turbine. Concerning to overcome this problem, the new technology of micro wind turbine had been developed at low cost and it is allowing for a wide range of practical application. The design for the micro wind turbine is simple, light, easy to install and maintenance. Hence, the development of micro wind turbine can reduce the cost of wind power installation and operation and make it is more economical and efficient.

Therefore, this project is aimed to investigate the optimum configuration and arrangement to install the micro wind turbine on the rooftop of home residential, commercial and industrial building in an urban and rural area. This will give the residents opportunity to install the micro wind turbine at their home in order to generate electricity with green energy and reducing the electric bill.

1.3 Project Objective

There are several objectives to be achieved on this project which are:

i. To design and simulate the arrangement and configuration of the micro wind turbine system for low load devices.

ii. To observe and analyse the output power and voltage by designing variant circuit configuration arrangement of micro wind turbine generator.

iii. To propose an optimum configuration of micro wind energy harvester system for low wind speed.

1.4 Project Scope

Basically, the scope of this project is to generate the electrical energy by using the micro wind turbine in a range 1.9 m/s until 2.5 m/s wind speed. Besides that, this project is to simulate of micro wind turbine configuration and arrangement by using MATLAB software. The type of generator that has been used to simulate the micro wind turbine system is a DC generator. The number of generators that been used in the system is one, four and eight generators. The arrangement of these generators is in series, parallel and series-parallel configuration in order to investigate the effectiveness of each arrangement in producing optimum power. Then, the electrical energy that has generated by the micro wind turbine will be step-up by using boost converter. The output power that generated by micro wind turbine is used for low load application.

1.5 Project Outline

This outline of this report is divided into five chapters which elaborated and discussed in detail in every chapter about the simulation study of micro-wind turbine.

i. Chapter 1 explain the project background, problem statement, project objectives and project scopes in order to configure the most suitable micro-wind turbine arrangement for producing optimum output power.

ii. Chapter 2 discussed in the literature review and the previous work done on the micro-wind turbine development.

iii. Chapter 3 described the methodology used to complete the project from the very beginning till the end.

iv. Chapter 4 elaborated on the results obtained throughout the project.

v. Chapter 5 discussed the overall conclusion and recommendation for the future development of micro-wind turbine.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature review that related to this project is discussed. The history of wind turbine technology and other part that related to this project such as type of turbine, generator and converter are covered. This chapter also briefly discusses the research from other researcher about micro-wind turbine energy harvester concept.

2.2 Wind Power Generation

Wind energy is a clean energy and non-pollutant renewable energy source that has developed rapidly in recent years especially for wind power generations. According to the statistical data, the cumulative installed wind power capacity in 2006, 2009 and 2012 were 74.0, 158.86 and 282.43 GW respectively, which is almost doubled in every three years (Md. Islam R., 2013). The fastest growing of wind power has made wind technology more competitive among others renewable energy generation such as solar and geothermal energy. Thus, it is important for scientists and researchers to find out the effective technologies for wind power generation systems.

Generally, the wind energy can be harvest by using wind turbine. Based on Figure 2.1, the winds blow the rotor blades which make the rotation of the shaft. In this process, the kinetic energy was converted into mechanical energy. The shaft transfers mechanical energy from rotor blades to the generator. Then, the generator converts the mechanical energy to electrical energy. Then, the rectifier continues the process of converting generator output from alternating current (AC) into direct current (DC). The power supply was stabilizing by the regulator before power supply was received by the load. Normally, the energy produced by the generator can be stored in batteries before supplied to load or connected directly to a grid system.

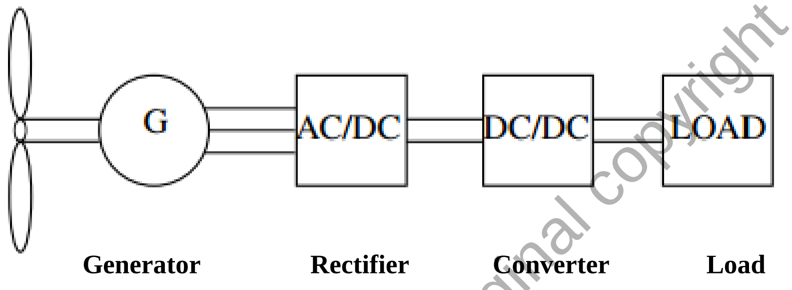

Figure 2.1: Basic diagram of wind power system (Luz T.G., 2014).

The electrical energy of wind turbine continuously generates as long as there is an existence of wind blowing at a reasonable speed. The most average speed to operate micro and small scale of a wind turbines is 4 m/s. Usually, these both types of wind turbines are mounted on the tower or rooftop of a building which is exposed to more consistent wind with a higher average speed. The small wind turbines are commonly combined with other energy generators in a grid-connected or off-grid power system which also known as stand-alone power system because of wind blow intermittently (EECA,2017).

Basically, wind turbine is classified on its power rating and rotor diameter. The small wind turbines are rated up to 10 kW and its usually used in homes, farms and remote applications. The power ratings for intermediate wind turbines are range from 10 kW to

250 kW and large wind turbines have power capacities from 600 kW to 1000 kW. The large scale of wind turbines is a very attractive substitute to the conventional grid because of the small scale per kilowatt of wind turbine is very economical (Ud Din S. M., 2016). Table 2.1 shows the power rating and rotor diameter for each size of a wind turbine.

Table 2.1: Size of wind turbine (Kishore R. A., 2013)

Wind Turbine Size	Power Rating	Rotor Diameter
Micro	Below than 1 kW	Below than 10 cm
Small	1 kW – 10 kW	10 cm – 100 cm
Intermediate	10 kW – 250 kW	1 m – 5 m
Large	600 kW – 100 kW	More than 5 m

2.3 History of Wind Turbine

Historically, the wind turbines also known as windmills had been used by Persians in the period from 7th to 10th century. The Persians had designed windmills in the vertical axis and the sails of the turbine are made from reeds or wood with 5 m to 9 m tall (Meyers C. B., 2013), as shown in Figure 2.2. These windmills mainly used to pump water, grind wheat (D'Ambrosio M., 2010) and for sailing boat (Meyers C. B., 2013). However, this type of turbine has low efficiency of wind power due to air drag and the lower wind speed made the turbine difficult to rotate.

Figure 2.2: Persian windmills (D’Ambrosio M., 2010).

Around the 11th century, the first windmills were built in Europe, it has been designed in the horizontal axis. During the following centuries, many modifications had made especially for improvisation on the aerodynamics part in order to locate windmills in the areas that have varied of wind direction. In addition, the additional function of windmills besides grinding wheat is it can be applied for draining the water in the lands taken from the sea with the dams (D’Ambrosio M., 2010) as shown in Figure 2.3. This is because the turbines could be oriented in wind direction and increasing the efficiency of wind power.

Figure 2.3: Dutch windmill (D’Ambrosio M., 2010).

In early 1888, the first attempt of electricity generation by using wind turbines is at Scotland, where the turbine was used to charge a battery for lighting the home of James Blyth, a Scottish scholar. Only a few months later, Charles Brush, the American has developed the first automated wind turbine for generating electricity in Cleveland, Ohio, USA (Meyers C. B., 2013). Early development of wind turbine had three aerofoil shaped blades, battery and a wind vane for keeping the turbine blade against the direction of wind flow (Manwell J. F., 2010). This development has contributed into the effectiveness of wind turbine operation in order to generate more electrical energy.

Then, in the 20th century, horizontal axis wind turbines (HAWT) have been evolved, become bigger, modern and more advanced turbines have been introduced (Manwell J. F., 2010). The development of vertical axis wind turbines (VAWT) is slower as compared with HAWT even though VAWT were the first type of wind turbine that has been approached into the world. According to the research on VAWT in the 1980s demonstrated that aerodynamics of VAWT were more complex than HAWT (Dabiri J. O., 2015). Thus, VAWT becomes less interest in construction.

2.4 Type of Micro Wind Turbine

Micro wind turbine can be categorized into two types based on the rotational axis which are horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). This research is being done in order to understand the performance characteristic of micro wind turbine for various parameter since the large-scale wind turbine have potential impact on the climatic conditions.

2.4.1 Horizontal Axis Wind Turbine (HAWT)

The rotation axis of HAWT is parallel to the wind stream and the ground. The core components of HAWT are blades, rotor shaft and electrical generator. Most common HAWTs have two or three bladed, but in the new development of this micro wind turbines may have more blades. The main rotor shaft and electrical generator of HAWTs are at the top of tower and the turbines must be pointed into the wind which also known as upwind in order to have maximum efficiency. The HAWTs that are positioned away from wind is called downwind turbine and are pushed into the accurate orientation. The ideal efficiency for these turbines is between 50% and 60% of output power. Unlike VAWT, the HAWT have the ability to self-start and yaw. In the smaller upwind based turbines, accurate orientation is obtained via the use of simple wind vane while large turbines generally use a yaw motor and yaw meter (Saad M., 2014). Figure 2.4 shows the basic design of HAWT.

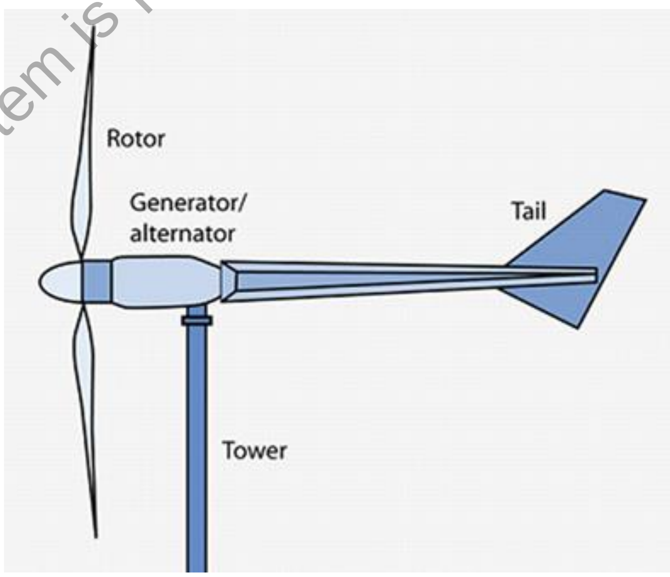

Figure 2.4: Horizontal Axis Wind Turbine (HAWT) (Saad M., 2014).

2.4.2 Vertical Axis Wind Turbine (VAWT)

The rotation axis of VAWT is perpendicular to the wind stream and the ground. The main advantage of VAWT arrangement is the wind turbine does not need to be pointed into the wind because it can harness the wind from all directions. These turbines do not have any yawing mechanism or self-starting capability. Commonly, VAWTs installed nearer to the ground and has benefits to placed components such as gearbox and generator closed to the ground level. So, tower does not need to support the components and also makes maintenance easier. However, the less power has generated because the wind flow near the ground and other objects can create turbulent flow. These causes can lead to vibration issues including noise and bearing wear which may increase the maintenance or shorten turbine's service life (EAI, 2017). Nevertheless, the wind speed that flow through the turbine can be double when VAWT is installed on a rooftop of a building. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, its can achieve the optimum for maximum wind energy and minimum wind turbulence (EAI, 2017). The ideal efficiency for these turbines is more than 70%. The VAWTs are classified into three major types which are Savonius Rotor, Darrieus Rotor and H-Darrieus Rotor as shown in Figure 2.5. This classification is due to the design of the turbine.

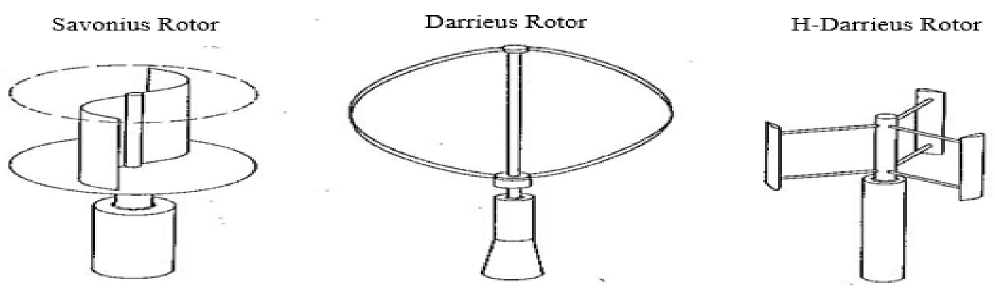

Figure 2.5: Types of VAWT (Bilgec M., 2013).

2.5 DC Generator as a Micro Wind Turbine Generator

DC generator can be driven mechanically as a simple generator to generate an output voltage and power which is ideal for use as a simple wind turbine generator. In DC generator, when the armature rotates, the current that has generated must pass through a commutator or slip-rings. The arrangement of carbon brushes had providing electrical power as its output terminal.

DC generator has a set of electromagnets and permanent magnets. Typically, the permanent magnet is mounted on the rotor with the electromagnets on the stator. The connection of coil in this generator will be wired in standard three-phase wye or delta. The efficiency of permanent magnet DC generators is around 70% and can be achieved until 95% which is very efficient. This kind of generator does not require controller because the power from the generator can be rectified easily. This generator is the common choice for a micro wind turbine (Meyers C. B., 2014).

Generally, permanent magnet DC generator is driven a lot of faster than its rated motor speed to produce anything near to its rated motor voltage. Therefore, high voltage, low rpm DC machines make better DC generators. The main advantages over other types of generator is the permanent magnet DC generator responds to changes in wind speed very quickly because their strong stator field is always there and constant.

The permanent magnet DC generator is a very suitable for micro wind turbine because generally this generator is lighter than wound DC generator for given power rating. This generator also has better efficiencies compare to wound generator because