SIMULATION FOR SMALL SCALE WIND TURBINE SYSTEM WITH ULTRA LOW POWER CONVERTER

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DEDICATION

This thesis is dedicated to my family, friends and supervisor for their endless supports, kind words and encouragements that made the completion of this project possible.

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ABSTRACT

Maximizing the power output harvested from the wind turbine is a big challenge as the output power depends largely on the wind speed. It is an option to consider an ultra-low DC/DC converter for a wind turbine system. By carrying out this study, it will help to improve the low power output from the wind turbine so it can be used to power up batter or home application. The concept is to simulate a small-scale wind turbine system using MATLAB Simulink and LTSPICE to simulate integrated circuit of ultra-low converter and boost converters. The system consists of wind turbine, generator with pitch control, rectifiers, ultra-low converter and boost converter. The function of the ultra-low converter is to step up the wind turbine output while the boost converter is to step up the output from the ultra-low converter. The impact of using the ultra-low converter towards the whole system is done under two scenarios, which are simulation with ultra-low converter and without the usage of the ultra- low converter. Further simulation for various wind speed is done to study the performance of the ultra-low converter. From the study, the system is able to step up the output voltage from the wind turbine up to 11.57 VDC. As an implication, the ultra-low power converter combine with the dc converter is capable to boost the small power output from the wind turbine system thus capable to power up home small home appliance or battery system.

ABSTRAK

Memaksimumkan keluaran kuasa yang diperoleh daripada turbin angin adalah satu cabaran besar kerana kuasa keluaran sebahagian besarnya bergantung kepada kelajuan angin. Ia adalah pilihan untuk mempertimbangkan penukar DC/DC ultra-rendah untuk sistem turbin angin. Dengan menjalankan kajian ini, ia akan membantu untuk menambah baik keluaran kuasa rendah daripada turbin angin supaya ia boleh digunakan untuk menghidupkan adunan atau aplikasi rumah. Konsepnya adalah dengan mensimulasikan sistem turbin angin berskala kecil menggunakan MATLAB Simulink dan LTSPICE untuk mensimulasikan litar bersepadu penukar ultra rendah dan penukar rangsangan. Sistem ini terdiri daripada turbin angin, penjana dengan kawalan padang, penerus, penukar ultra-rendah dan penukar rangsangan. Fungsi penukar ultra rendah adalah untuk meningkatkan keluaran turbin angin manakala penukar rangsangan adalah untuk meningkatkan keluaran daripada penukar ultra rendah. Kesan penggunaan penukar ultra-rendah terhadap keseluruhan sistem dilakukan di bawah dua senario, iaitu simulasi dengan penukar ultra-rendah dan tanpa penggunaan penukar ultra-rendah. Simulasi lanjut untuk pelbagai kelajuan angin dilakukan untuk mengkaji prestasi penukar ultra-rendah. Daripada kajian, sistem ini mampu meningkatkan voltan keluaran daripada turbin angin sehingga 11.57 VDC. Sebagai implikasi, penukar kuasa ultra-rendah bergabung dengan penukar dc mampu meningkatkan output kuasa kecil daripada sistem turbin angin dengan itu mampu menghidupkan perkakas rumah kecil atau sistem bateri.

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LIST OF ABBREVIATIONS

RE	-	Renewable Energy
μSWT	-	Micro-scale wind turbine
SSWT	-	Small-scale wind turbine
MSWT	-	Mid-scale wind turbine
LSWT	-	Large-scale wind turbine
VAWT	-	Vertical-axis Wind Turbine
HAWT	-	Horizontal-axis Wind Turbines
WECS	-	Wind Energy Conversion Systems
PMSG	-	Permanent Magnet Synchronous Generator
CCM	-	Continuous Current Mode
DCM	-	Discontinuous Current Mode
UTM	-	Universiti Teknologi Malaysia
AC	-	Alternating Current
DC	-	Direct Current
EMF	-	Electric and Magnetic Field
SEPIC	-	Single Ended Primary Inductor Converter

LIST OF SYMBOLS

Pm	-	Mechanical Output of Turbine
Cp	-	Performance Coefficient of Turbine
ρ	-	Air Density
λ	-	Tip Speed Ratio of Rotor Blade
β	-	Blade Pitch Angle
A	-	Area
Vwind	-	Wind speed
ω_m	-	Rotor speed
r	-	Rotor radius
D	-	Duty Cycle
Vo	-	Output Voltage
Io	-	Output Current
P_o	-	Power Output
R	-	Resistor
C	-	Capacitor
L	-	Inductor

CHAPTER 1

INTRODUCTION

1.1 Project Background

Malaysia has been listed as a developed country for the year 2020, by World Population Review [1]. One of the main exports of the country is electronic parts, which contributed to the share of 79.9% economic demand under Services and Manufacturing sector in 2019 [2]. With the growing demand due to the economic growth and expanding population, the demand of electricity usage is also increasing. The aftermath of these growth is the climate change. Conventional energy sources such as fossil fuel, natural gases and coal are not reliable to be the only primary source of energy due to the fact that they're depleting and their impacts towards global warming. For example, the usage of the natural gases as one of energy source has been associated with air pollution which resulted in health problems such as heart disease, asthma, lung cancer and bronchitis, affecting thousands of Americans [3].

The conventional energy resources such as fuel and natural gases are no longer dependable as the depletion of fuel is inevitable. Therefore, actions must be taken to overcome the shortage of the non-renewable energy sources and at the same time, reduce the impact towards climate change. With increasing population and growing number of industries, the demand for electricity also increases. In Malaysia, the demand of electricity has risen by 653.33% in 2018 since 1990, as seen in Figure 1.1 [4]. In line with the increasing demand, the production of electricity also increases by 105.76% in 2018 since 1990, as seen in Figure 1.2 [4]. 96% of energy resources in Malaysia are contributed by non-renewable energy [6]. As a second largest oil and natural gas producer in Southeast Asia and the fifth–largest exporter of liquefied natural gas (LNG) in the world [4], petroleum and natural gases are one of the most precious mineral resources that can be found along the northeast coast of Sarawak the west coast of Sabah and the east coast of the peninsular [5]. Besides that, other sources of energy in Malaysia are hydro power, coal and coke. The deprivation of non-renewable energy resources is inevitable. Based on the statistic, Malaysia's primary energy resources has dropped by 13% in 2015 since 1995 as seen in Figure 1.3 [6].

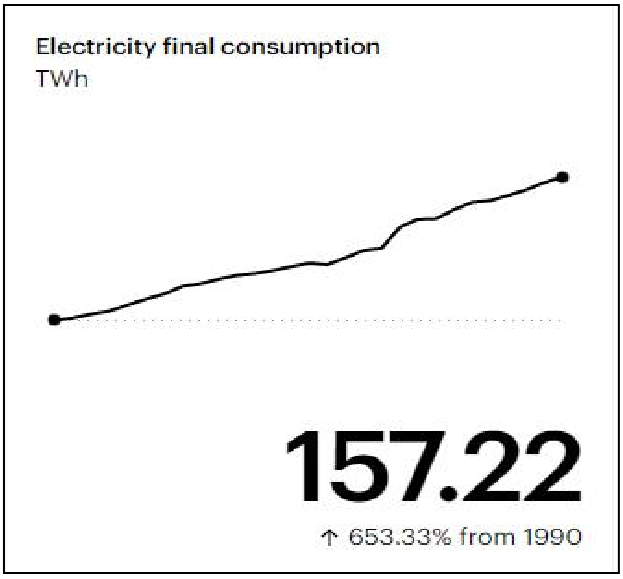

Figure 1.1 Electricity Consumption in Malaysia [4]

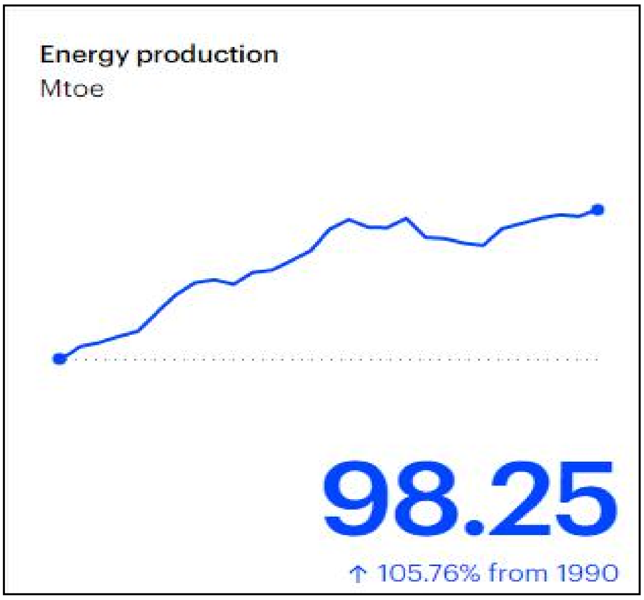

Figure 1.2 Energy Production in Malaysia [4]

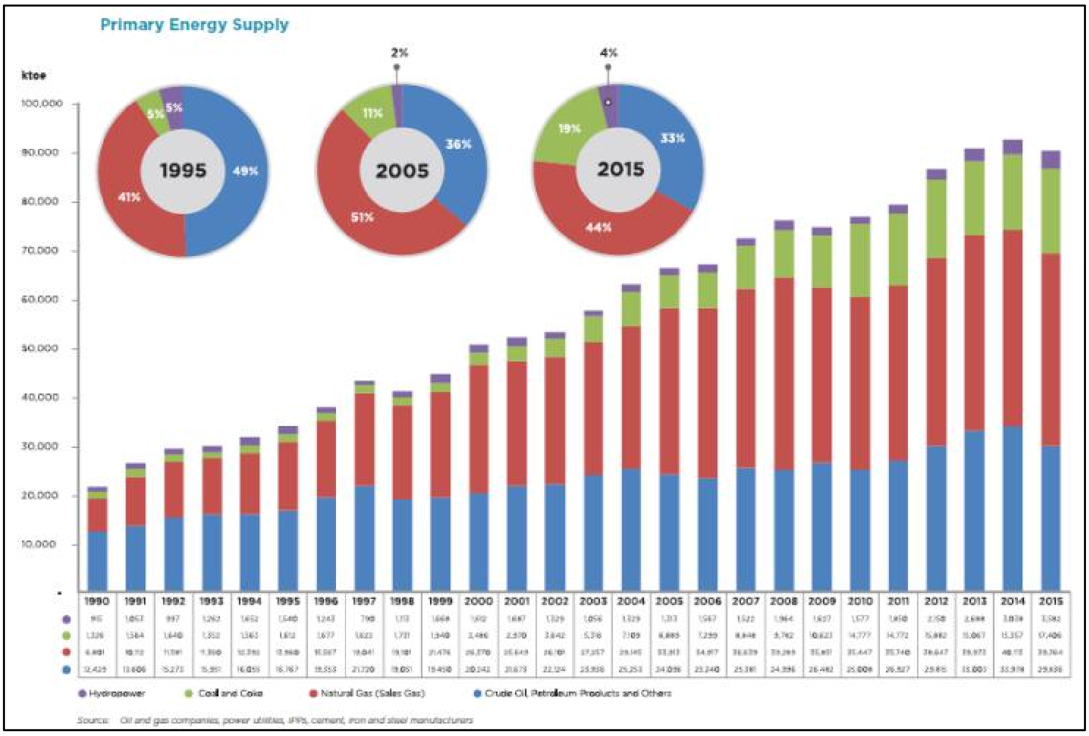

Figure 1.3 Primary Energy Supply in Malaysia [6]

It can be seen by the production of petroleum production that has reached its peak in 2004, where the petroleum production has been decreasing for the later years as seen in Figure 1.4 [7]. Even though the production of natural gas in Figure 1.5 [7] is increasing each year, as the basis of natural gas also comes from fossil fuel, dependency to this source is also not dependable. As oil and gas from natural source depletes, the price increment is also one of the impacts Malaysia has to face. Focusing on coal-based plant is one of the ways to mitigate the dependency of oil and gas. As seen in Figure 1.6 [7], Malaysia's coal production has increased over the years. However, the downside of using coal is the increase of carbon dioxide's emissions. As seen in Figure 1.7 [4], Malaysia's CO2 production has increased by 359.76% since 1990. Coal has a big impact in climate change that impact globally in the long run. As the carbon produced by coal burning resulted in carbon and when reacted with oxygen, carbon dioxide is produced [8]. Therefore, to address and mitigate climate's change and depletion of natural resources, a new sustainable energy source needs to be use.

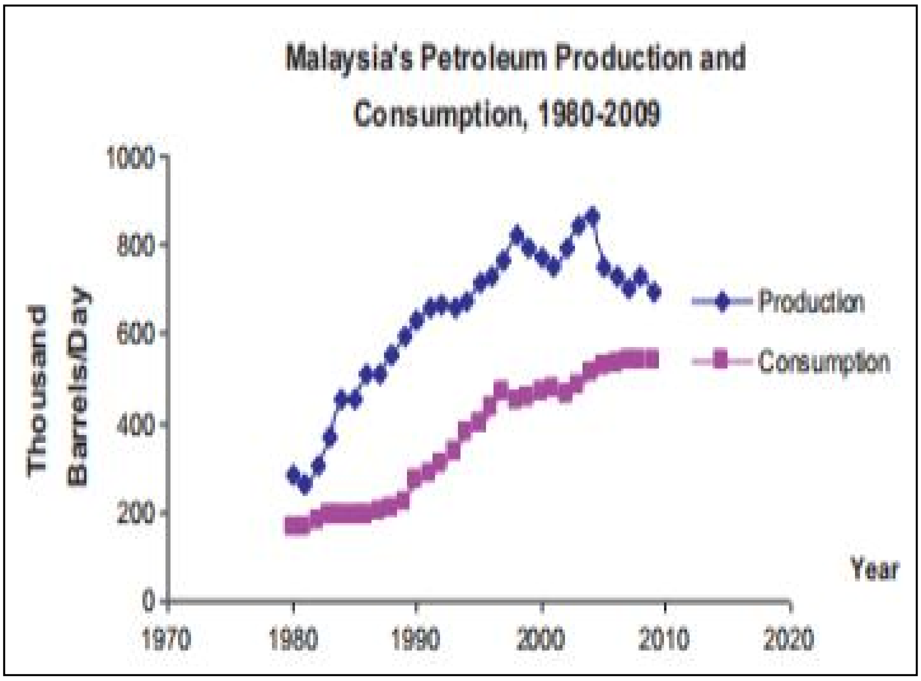

Figure 1.4 Malaysia's Petroleum Production and Consumption [7]

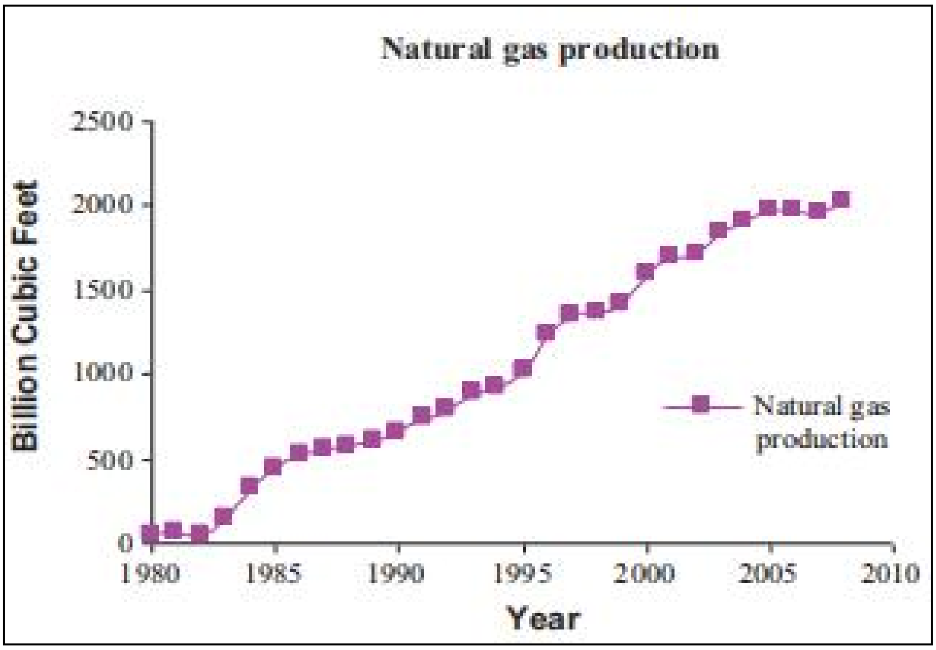

Figure 1.5 Malaysia's Natural Gas Production (S. M. Shafie et al., 2011)

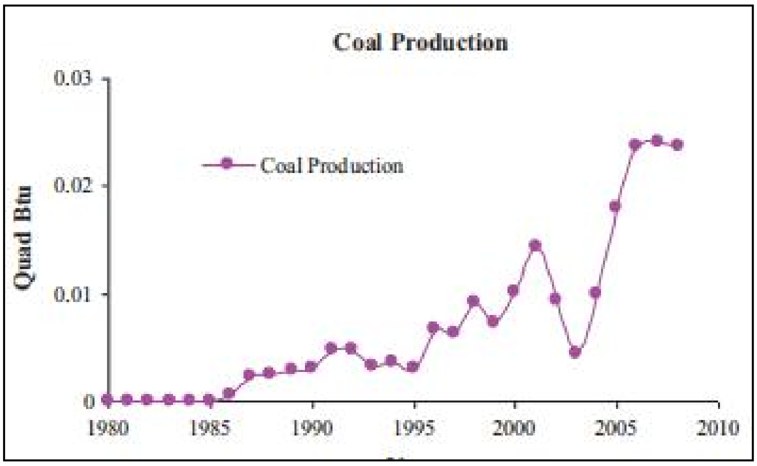

Figure 1.6 Malaysia’s Coal Production [7]

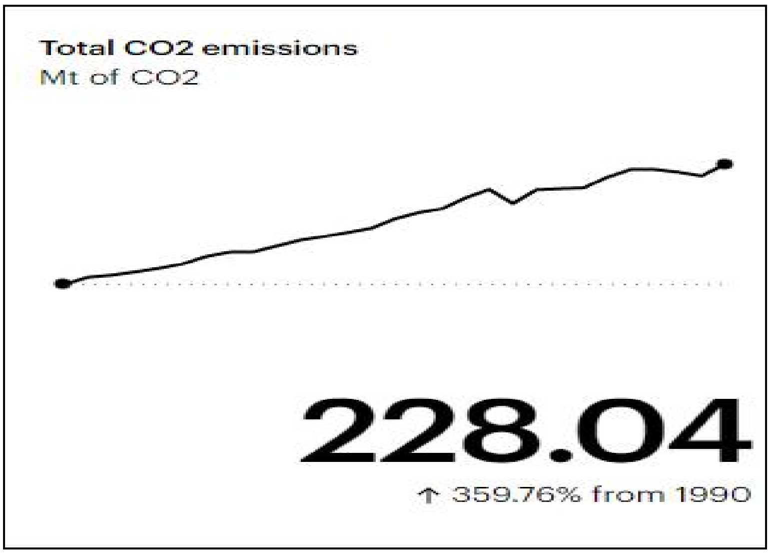

Figure 1.7 Malaysia’s C02 Emissions [4]

To achieve green energy, Malaysia’s Government has adopted a new policy called The National Biofuel Policy that adopts the use of biofuels. The goal of this policy is to lessen dependency on fuel that has impact towards environment. In promoting usage of green technology, it is in line with the government’s new economic growth in economic model [9]. To implement this, the government has come out with Green Technology Financing Scheme as seen in Table 1.1 [10]. Despite the RM2 billion funds available for renewable energy, no wind energy project can be found under this initiative [10].

Table 1.1 Green Technology Financing Scheme [10]

Features	Producer of Green Technology	User of Green Technology	ESCOs
Purpose	To finance investment for the production of green products	To finance investment for the utilization of green technology	To finance investment or assets related to energy effiecient project and/ or energy performance contracting
Financing Size	Maximum: RM100 million per group of company	Maximum: RM50 million per group of company	Maximum: RM25 million per group of company
Financing Tenure	Up to 15 years	Up to 10 years	Up to 5 years
Eligibility	Company or Business must be legally registered Malaysian with a simple majority of at least 51% Malaysian shareholding Minimum paid-up capital must be10% or RM50,000 of project cost, whichever is higher		
Participating Financial Institutions (PFIs)	All Commercial Financial Institutions, Islamic Financial Institutions and Development Financial Institutions as per BNM & other participating entities duly approved by MOF		
Government Incentives	Rebate of 2% per annum on interest/ profit rate (limited to the first seven (7) years only) for each loan/financing. 60% government guarantee on Green Technology Cost.		

Wind energy harvesting in Malaysia also has a lot of potential to be look into. In a study of wind assessment using K-means wind prediction method for Kudat in 2016, it was found that Kudat has potential to have a wind turbine system with prediction of an average wind speed of 5.4 m/s [11]. The prediction was made based on the data sample taken from 2002 until 2010. In a study of wind assessment based on Weibull distribution method for Kudat and Labuan in 2011, based on data taken from 2006 until 2008, it was found that Kudat and Labuan has a yearly average wind speed for Kudat was 3.24 m/s and Labuan with 3.33 m/s. Although the findings were not suitable for a large-scale wind turbine, it is recommended for a smaller scale wind turbine at the height of 100m [12]. Based on the studies, the potential of harvesting wind energy is possible in a low wind speed area. However, a good wind turbine design and location can further boost the potential of the wind energy. The reason of no recent or ongoing projects undertaking wind turbine in Malaysia may come from the inconsistent and low wind speed availability of the area. As finding in the studies where large-scale of wind farm is not possible, converting energy from the wind might be possible using a small-scale wind turbine. However, it is yet to be proven.

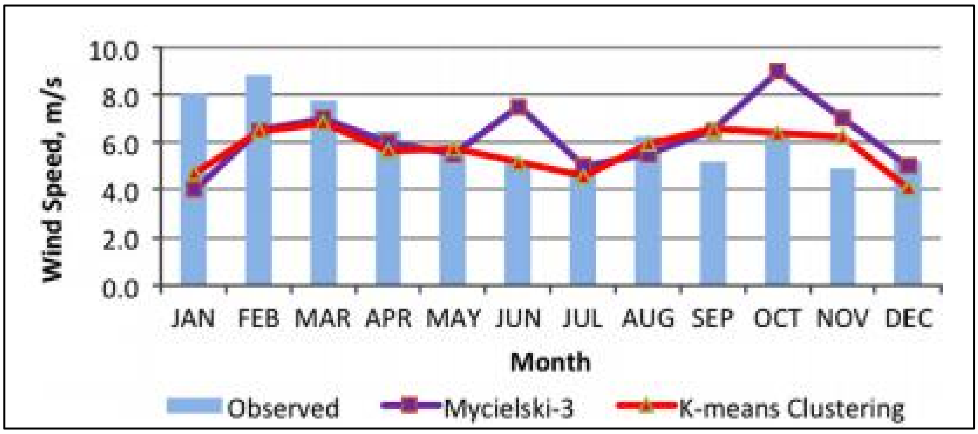

Figure 1.8 The combine graph analysis for observed and prediction wind speed for Kudat [11]

With technology advancement, it is possible with usage of proper converters to be integrated in the small-scale turbine system. Current small-scale wind turbine implementation has integrated converter to boost the output power of the wind turbine system. In the market, the available converter of boosting for example 5V to 15V is widely available. However, there is no converter available for boosting the voltage for less than 5V. As the availability of wind in Malaysia is not constant, this scenario is possible to happen. A study and design on the ultra-low power converter implementation with cross flow water turbine system to generate electricity has been done by Mohd. Amirul bin Azlan [13]. It was observed, the ultra-low power converter successfully able to produce 5V output from water turbine's output as low as 20mV. The normal power converter successfully integrated with the ultra-low power converter. The output voltage produced from the system is 11.57V with overall power of 7.44W. The implementation of the ultra-low power converter is yet to be deployed on a small-scale wind turbine, but the possibility is promising.

1.2 Problem Statement

For an area with low wind speed, maximizing the power output harvested from the wind turbine will be a big challenge as the output power depends largely on the wind speed. For low wind speed, it is an option to consider an ultra-low DC/DC converter for wind turbine system. However, in the market, power converter available can convert from 5V to higher voltage level without problem, but, for very low voltage level e.g 0.5V to 5V, it is a big challenge and still under research and development. In a recent study by Mohd. Amirul Bin Azlan [13], an ultra-low power converter circuit has been proposed to work with cross flow water turbine system to generate electricity. However, the study and analysis done were simulation based (theoretical), simulated using LT-Spice and yet to applied in practical. For integration of an ultra-low power converter with wind turbine application, it is promising but no research has been done for this type of application. Therefore, it is good to investigate the outcome of implementing an ultra-low power converter in a small output wind turbine system.

1.3 Objectives

The objectives of this study are as the followings:

a) To simulate an ultra-low power converter system that can amplify voltage level from 0.5 to 5 volts and then integrated it with a higher power rating dc-dc boost power converter for small scale wind turbine system.
b) To compare the output of small-scale wind turbine system with and without an ultra-low power converter.

1.4 Scope

The scope of this study is as the following:

a) The scope will cover boosting the power output from small-scale wind turbine system using an ultra-low dc-dc boost power converter that amplify the voltage level from 0.5 to 5V and then 5V to 12 V using a dc/dc boost converter.
b) Horizontal small-scale wind turbine type is considered.
c) The proposed system will be simulated using MATLAB Simulink for the small-scale wind turbine system and LTSPICE for the power converters.

1.5 Thesis outline

Basically, there are five chapters in this project. The outline of each chapter of the project is as following:

Chapter 1 provides the general introduction which gives the idea to the reason of why this project is interesting to be studied before. Furthermore, this chapter also consist of the problem statements, objectives of the project and scope of works needed to succeed this project.

Chapter 2 contains the literature review of this project. This chapter will discuss the previous works that are related to this project. The works that will be discussed in this project are the concept of small-scale wind turbine, the working principle of dc-dc boost converter and the ultra-low power converter.

Chapter 3 discusses about the methodology of this project. This chapter will show how the wind turbine system, and the ultra-low voltage and dc-dc boost converter are simulated. The required components needed for the system are shown in this chapter. The complete system in this study can be seen in this chapter.

Chapter 4 contains the discussion of the project based on the results of the small-scale wind turbine proposed system.

Finally, chapter 5 presents the summary of the project. The conclusion on the simulated system is stated in this chapter.

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