ANALYSIS OF WIND ENERGY POTENTIAL ON SELECTED STATES IN PENINSULAR MALAYSIA: COMPARATIVE STUDY OF WEIBULL AND RAYLEIGH DISTRIBUTION

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in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "ANALYSIS OF WIND ENERGY POTENTIAL ON SELECTED STATES IN PENINSULAR MALAYSIA: COMPARATIVE STUDY OF WEIBULL AND RAYLEIGH DISTRIBUTION is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 2nd JULY 2021

APPROVAL

I hereby declare that I have checked this report entitled "ANALYSIS OF WIND ENERGY POTENTIAL OF SELECTED STATES IN PENINSULAR MALAYSIA: COMPARATIVE STUDY OF WEIBULL AND RAYLEIGH DISTRIBUTION" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : .....

Supervisor Name : DR. NUR ZAWANI BINTI SAHARUDDIN

Date : 5 JULY 2021

DEDICATIONS

To my beloved mother and late father

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ABSTRACT

Nowadays, the growing concern about electricity generation by fossil fuels that harmed the environment makes renewable energy becoming a demand. Renewable energy is well known from around the world as a renewable technology for grid power generation. Wind energy is the leading source of renewable energy for electricity production. Therefore, wind energy is becoming one of the renewable energy resources in general, and it can be one of the eligible renewable energy sources for electricity generation in Malaysia. Thus, the purpose of this analysis is to determine the wind energy potential on the selected states in Peninsular Malaysia. There are tow main objectives of this analysis. Firstly, to develop Weibull and Rayleigh Probability Density Function (PDF) for assessing wind power density on selected states in Peninsular Malaysia. Next is to analyse, compare and propose the best method for calculating wind power density between the Weibull and Rayleigh probability distributions. This study analyse the average wind speed data from the selected states in peninsular Malaysia in 2018, 2019, and 2020. Wind speed, also known as average wind velocity is an important component for the analysis of wind energy potential. The probability distributions proved to be a useful technique when analysing the wind speed at any place. In the study, two different probability distributions are considered: Weibull distribution and Rayleigh distribution. The shape, k, and scale, c, parameters of the area were determined based on the data. The parameters of the density distributions are calculated by the Maximum Likelihood Estimation method. From the statistical analysis of the distributions, the Weibull distribution is best suited to the calculated probability density distributions than the Rayleigh distribution for the entire years.

ABSTRAK

Pada masa kini, kebimbangan yang semakin meningkat mengenai penjanaan elektrik oleh bahan bakar fosil yang merosakkan alam sekitar menjadikan tenaga boleh diperbaharui menjadi permintaan. Tenaga boleh diperbaharui terkenal dari seluruh dunia sebagai teknologi yang boleh diperbaharui untuk penjanaan kuasa grid. Tenaga angin adalah sumber utama tenaga boleh diperbaharui untuk pengeluaran elektrik. Oleh itu, tenaga angin menjadi salah satu sumber tenaga boleh diperbaharui secara umum, dan ia boleh menjadi salah satu sumber tenaga boleh diperbaharui yang layak untuk penjanaan elektrik di Malaysia. Oleh itu, tujuan analisis ini adalah untuk menentukan potensi tenaga angin di negeri-negeri terpilih di Semenanjung Malaysia. Terdapat objektif utama analisis ini. Pertama, untuk mengembangkan Weibull dan Rayleigh Probability Density Function (PDF) untuk menilai kepadatan kuasa angin di negeri-negeri terpilih di Semenanjung Malaysia. Seterusnya adalah menganalisis, membandingkan dan mencadangkan kaedah terbaik untuk mengira ketumpatan kuasa angin antara taburan kebarangkalian Weibull dan Rayleigh. Kajian ini menganalisis data kelajuan angin purata dari negeri-negeri terpilih di semenanjung Malaysia pada 2018, 2019, dan 2020. Kelajuan angin, juga dikenali sebagai purata kecepatan angin adalah komponen penting untuk analisis potensi tenaga angin. Taburan kebarangkalian terbukti menjadi teknik yang berguna ketika menganalisis kelajuan angin di mana-mana tempat. Dalam kajian ini, dua taburan kebarangkalian yang berbeza dipertimbangkan: Taburan Weibull dan taburan Rayleigh. Bentuk, k, dan skala, c, parameter kawasan ditentukan berdasarkan data. Parameter pembahagian ketumpatan dikira dengan kaedah Anggaran Kemungkinan Maksimum. Dari analisis statistik taburan, taburan Weibull sangat sesuai dengan taburan ketumpatan kebarangkalian yang dikira daripada taburan Rayleigh selama bertahun-tahun.

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LIST OF SYMBOLS AND ABBREVIATIONS

PDF	-	Probability Density Function
RE	-	Renewable Energy
MMD	-	Malaysian Meteorological Department
MLE	-	Maximum Likelihood Estimation
RMSE	-	Root Mean Square Error
MPD	-	Mean Power Density

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CHAPTER 1

INTRODUCTION

1.1 Overview

Renewable energy, particularly solar and wind power, are increasingly being used and becoming the dominant target of investment in new electricity generation. It is estimated that $10.2 trillion will be spent on new power generation worldwide by the year 2040, with 72% investing mainly in new wind and solar power plants [1]. According to [1], although wind technology faces rivalries from solar, hydro, and nuclear energy in the retrospective, it still focuses as one of the most important technologies for the generation of electricity in the future especially because of its benefits compared to other green technologies and because of its low intermittent existence. Based on [2], the wind is a power source that is more powerful than solar energy. In contrast to solar panels, wind turbines emit less CO2 to the environment, absorb less electricity and generate more energy overall. In fact, one wind turbine will potentially produce the same amount of electricity per kWh as around 48,704 solar panels [2].

The dependence on fossil fuel sources has so far harmed the availability of resources and the environment, as stated in [1], [2]. Alternatively, as a safe, eco-friendly, and affordable green energy resource, wind energy is a potential way of providing both developed and emerging countries with electricity. Based on the analysis in [3], it is generally acknowledged that non-renewable fuel sources such as coal and petroleum continue to be used for electricity generation. As a substitute for fossil fuels, renewable energy offers pollution-free energy from limitless supplies that are harmless to the atmosphere and humanity. Renewable energies can provide renewable energy sources that are efficient and safe for society. As stated by [3], it is much more affordable than fossil fuels energy options, in particular the expenses of purchasing, sustaining, and running centralized power plants, and the release of pollutions may be avoided.

Among renewable sources of energy, the wind is one of the most popular and promising energy resources. Recent technological advancements, the use of fossil fuels, effects on the environment, and the constant rise of traditional energy supplies have made wind energy prices commercially profitable and as a result, wind turbines are seen to be an alternate source of energy in many industries [3]. At the end of 2016, the overall global wind power capacity was 486.8 GW, reflecting a combined demand increase of 12 percent [4]. Wind power is currently one of the world's fastest-growing renewable energy technologies [4]. According to [4], wind energy is growing rapidly, becoming more affordable than conventional power generators, and the number of installations is increasing exponentially fast, with China, which used to have one of the highest carbon footprints, now generating 486 GW of wind power alone. The wind is likely to be a good power generation option because of its unlimited and free factors.

1.2 Problem Statement

Currently, the world's energy needs are rising at an alarming rate, and electricity demand is running ahead of supply [4]. Burning fossil fuels releases emissions that are blamed for global warming and greenhouse gas impacts. The negative impacts on the environment resulting from fossil fuel combustion, in addition to its limited stock, have forced many countries to explore and switch to renewable energy [4].

Fossil fuels are granite, fuel, or liquid products that are burned to produce power. These include coal, oil, and natural gas and are used in the electricity and transportation industries as a source of energy. These are a leading cause of global warming emissions into the atmosphere as well, as stated in [5]. Environmental impacts, such as pollution and land loss, are often clear to see, and sometimes less noticeable, such as the cost of asthma and cancer or the effects of sea levels rising. Expenses accumulate at any step in the supply chain of fossil fuels, based on [5]. Processes of extraction will produce air and water pollution and damage local communities. The fuels emit pollutants and global warming effects as they are burnt. According to [4], even waste products are harmful to the environment and public health.

Therefore, there is broad public encouragement for the use of renewable energy, in particular solar and wind power, which provides electricity without producing any

emissions of carbon dioxide [5]. In seeking clean energy, wind power provides an effective solution. However, in order to produce more power from wind energy, it would be necessary to analyse the wind speed of particular areas. In recent years, probability distributions have been used, as shown in [3], to analyse wind speed and obtain specific wind power. There are various types of probability distributions. Some of these include normal distribution, binomial distribution, chi-square distribution, and Poisson distribution. Even then, these distributions had certain drawbacks of offering an analysis of wind speed that the probability would not fit the real-life data and the parameters would not be precise. In this analysis, Weibull and Rayleigh distributions would be used to show the performance of the probability that matches the actual life data as well the parameters that be more accurate would be evaluated.

1.3 Motivation

Renewable energy sources are solar, wind, wave, geothermal, and biomass. In Malaysia, all these renewable energy resources are available. Therefore, more electricity demands can be provided from renewable energy sources. Wind power is an important source of renewable energy, since it is clean and available on Earth, and also cost-effective for some applications such as power generation. Malaysia has a broad variety of wind energy sources that are not yet thoroughly explored.

Exploring and testing the right approach has also become a popular issue for engineers. As stated in [5], using wind energy can significantly reduce fossil fuel combustion and the subsequent emission of carbon dioxide. The wind is a clean, reliable, renewable energy source that provides many benefits to human beings. The aim of this wind energy analysis, which is focused on a few states in Peninsular Malaysia, is to maximise the usefulness of wind energy in Malaysia.

1.4 Objective

The objectives for this research are:

1. To develop Weibull and Rayleigh Probability Density Function (PDF) for assessing wind power density on selected states in Peninsular Malaysia.
2. To analyse, compare and propose the best method for calculating wind power density between the Weibull and Rayleigh probability distributions.

1.5 Scope

To achieve the objectives, the scope projects are:

1. To analyse the wind power density in Mersing, Kuantan, Langkawi and Terengganu.
2. Use MATLAB Simulink software to perform the analysis.
3. Utilize Weibull and Rayleigh distributions method.

1.6 Outline

This report consists of five chapters that begin with Chapter 1, which explains the introduction of the project. The literature review of the previous study is discussed in Chapter 2. Chapter 3, which is the methodology part, explained the processes of the project, such as the method of finding the parameters and simulates also testing of the project. This analysis applies only to simulations carried out using the MATLAB Simulink software. Chapter 4, which represents the result of the analysis. This report will show the prediction result. Lastly, Chapter 5 is the conclusion of the project and will include the suggestion for improvisation for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The literature review provides a brief review of the general knowledge on wind energy sources, the distribution of wind in Malaysia, and the Weibull and Rayleigh distributions. Based on the study, wind speed probability density functions are influenced by variable parameters. The literature review then showed the parameters used to analyse the probabilities of wind speed to produce wind power.

2.2 The Fundamentals of Wind Energy

Wind energy is a source that is immeasurable and economically safe. Furthermore, wind energy is free. There is no competition for the production and availability of wind power, it can be used by anybody and is one of the lowest price sustainable technologies available today, depending on the wind resource and the practicality of the individual project. Wind energy describes the process of generating electricity from the wind. Wind energy is, in fact, well-developed, manageable, and accessible based on [5].

In addition, wind power generation technology able to be one of the most impressive sources of renewable energy for future production, as stated in [6]. The wind is one of the most widely accepted and promising renewable energy sources. As wind generation technology becomes more advanced, it can be a great substitute for standard energy sources. Because of technological innovations and efficiency advancements, the percentage of energy generated by wind is growing rapidly. The sustainable energy mix chart below specifically indicates that wind power contributes the most renewable energy to global customers and that this pattern is expected to continue [7]. Wind energy is growing at a rapid pace around the world. As seen in Figure 2.2, wind energy has the highest percentage of electricity production among all renewable sources of energy according to the year 2020 [7].

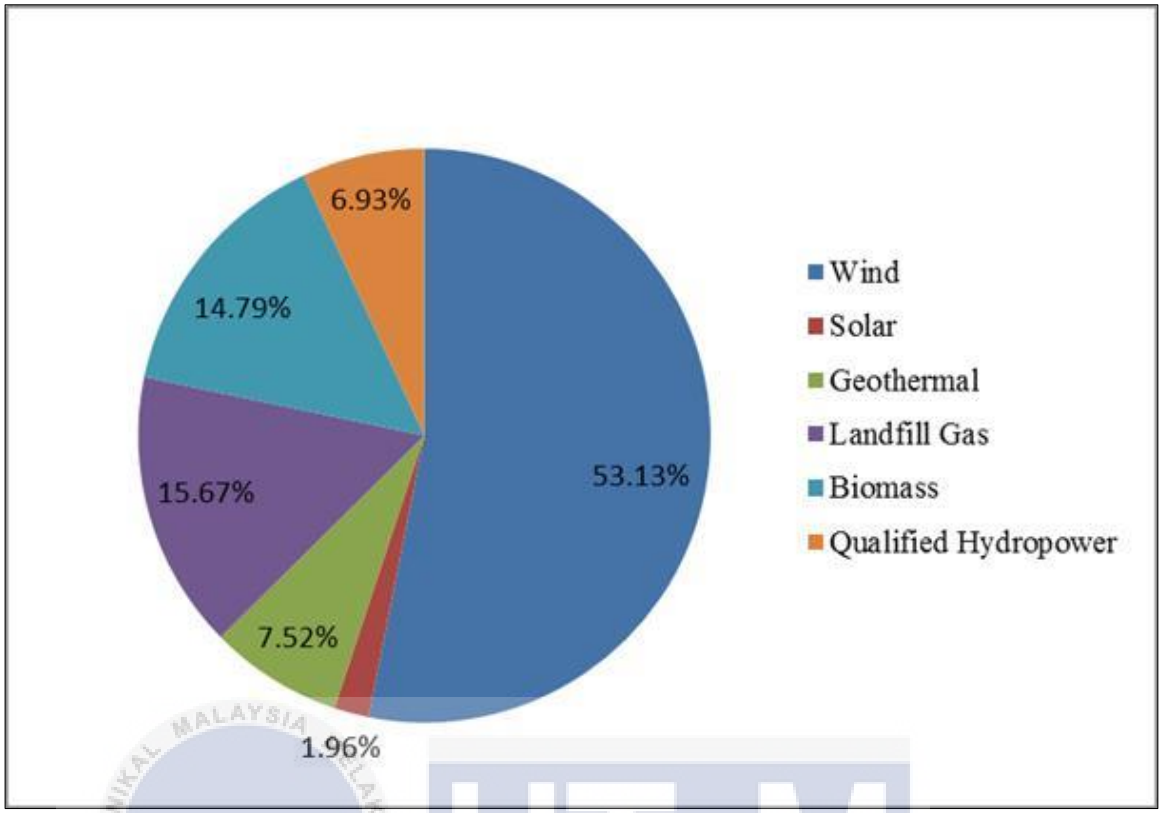


Figure 2.2: Chart of different types of renewable sources [7]

2.3 Basic wind speed

Wind is the movement of air. The wind is an atmospheric phenomenon caused by the sun's heating. The actual source of wind is the event of solar radiation that is received by the earth [1]. The wind is created when the sun heats one side of the earth differently from the other. Due to differences in temperature, energy is transmitted from the surface of the earth to air molecules which in turn, move by convective effect and leading to the forming of wind. The Earth emits the heat that is received from the Sun, but it is homogeneous. Air is often moving from high to lower pressures, and this air flow is wind. According to [1], The sun radiates a total of 1.74x 1017 Watts onto the Earth, with only 2% of that converted into wind energy. The wind formation from the radiation of sunlight is shown in Figure 2.3.

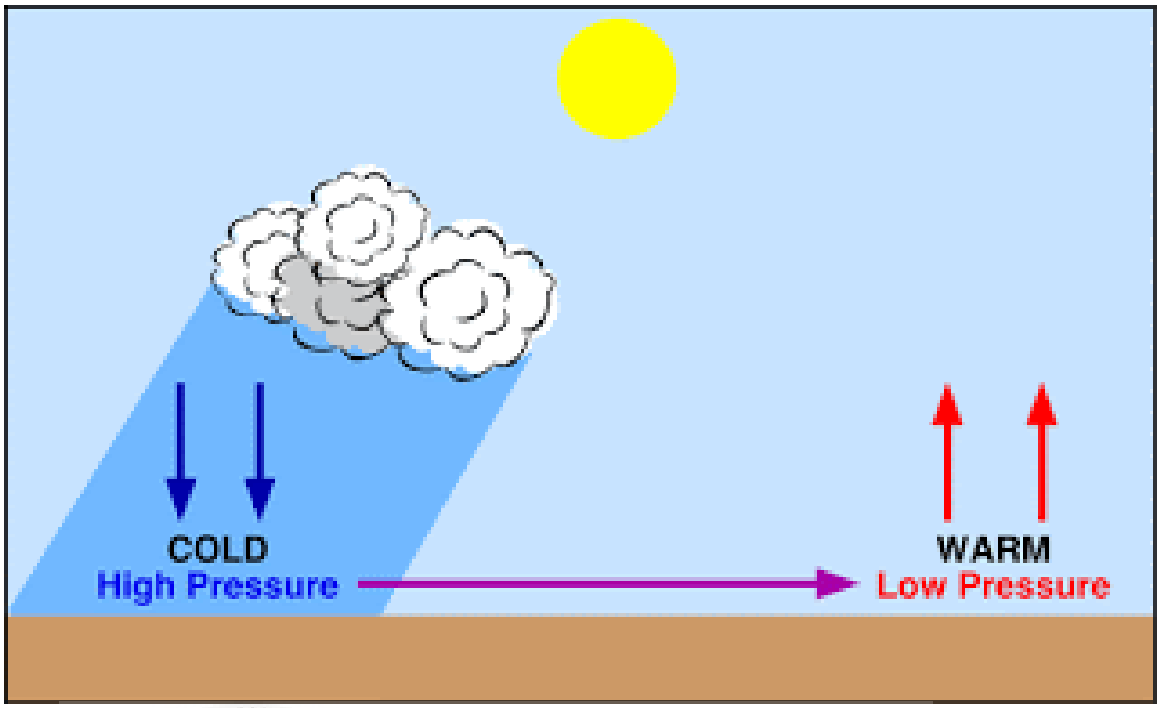
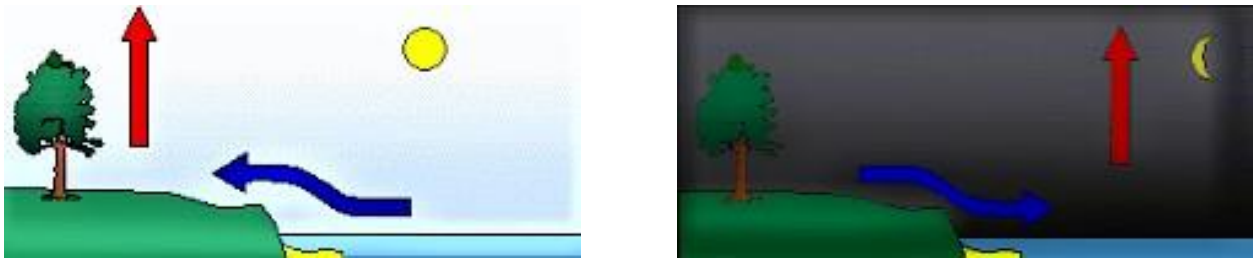


Figure 2.3: The wind formation through the effects of solar heating [8]

2.4 Land and Sea Breezes

Sea breezes happen during hot summer days due to uneven levels of land and ocean heating. During the day, the ground surface heats more than the surface of the water. The air above the land is therefore warmer than the air above the water. The warmer air is lighter than the colder air. Consequently, hot air rises. Thus, the warmer air is then rising over the surface of the ground. The cooler air over the ocean is moving over the surface of the land to replace the rising warm air as the warm air over the land rises to the cloud. This is the sea breeze which can be seen on the left side of Figure 2.4 below. The land breeze that happens at night is illustrated by the right part of the following figure. At night the surface of the soil cools more than the surface of the sea. As a result, the hot air above the ocean is lighter and rising makes the air travel from the ground to replace the air above the ocean.



Sea breeze in daytime Land breeze at night

Figure 2.4: Land and sea breeze

2.5 Importance of Wind Energy

Investment in renewable energy sources, – for example, wind power plants, is highly relevant due to the growing efficiency of clean energy as well as the need to reduce pollution and carbon emissions. Wind energy is a clean, sustainable source of energy that has many advantages. It is also a good alternative, renewable source of energy that has a much lower environmental effect in contrast to the burning of fossil fuels. It is considered green energy because it produces no carbon emissions, resulting in less pollution. The advantages of using wind energy for providing electricity including it does not pollute the air or water and may reduce the amount of electricity generation from fossil fuels, which results in lower carbon dioxide emissions as stated in [8]. In addition, the use of wind power is a benefit to those living in rural areas and remote islands where it is far from the national grid electric [8].

2.6 Operation of Wind Turbine

Wind turbines absorb kinetic energy. It converts wind kinetic energy into mechanical energy, and the amount of this mechanical energy that has been transformed depends on the speed and density of the wind, according to [6]. Using a wind turbine, wind power is produced where turbine blades play a significant role in wind turbines. Wind turbines use two or three propeller-like blades mounted on a rotor to capture and convert wind energy into electricity. The blade also functions similarly to an airplane wing. The wind will rotate the blade of the fan on the wind turbine, as a result, the rotor will turn which is referred to as lift. The lift force is greater than the drag force, which is the force of the wind against the front side of the blade. The rotor spins like

a propeller due to the effect of lift and drag, and the turning shaft spins a generator allowing the wind turbines to generate electricity.

The turbines are mounted high on hills to reap the full benefits of the stronger and less turbulent wind at 100 feet (30 meters) or more above ground level [4]. The energy the wind produces depends on the wind speed. A wind turbine's energy output is proportional to the geometry and wind speed as well as the selection of the wind turbine generator. The stronger the wind blows, the greater the energy it generates. These can be measured based on the height of the center of the wind turbine, as stated in [4]. There are two major types of wind turbines: The Vertical and the Horizontal Wind Turbine. Figure 2.6.1 depicts a graphical representation of the differences between these two main types of turbines, while Figure 2.6.2 illustrates the operation of wind turbines to the grid.

Figure 2.6.1: Horizontal Axis Wind Turbine (Left) and Vertical Axis Wind Turbine (Right) [2]