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The Significant of Efficient Wind Turbines Arrangement in Mersing

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Abstract: In this work, the results of wind velocity and its impact on wind energy power are reviewed. It incorporates statistical study of the wind regime, power analysis, and the probability distribution of wind speed. A thorough probability distribution selection yields a clear power analysis. Weibull and Gama probability distribution is the primary distribution used. The wind power equation is created using a transformation approach, and the results of the research to show that Malaysia may effectively collect wind energy especially when the wind turbines are located at the coastal area. The Mersing area's potential for producing wind energy with the exact location and direction for placing the wind turbine is suggested in this paper.

Keywords: Wind energy, wind turbine, wind speed, weibull distribution, gama distribution, significant

1. Introduction

A wind turbine is an apparatus that transforms the kinetic energy of the wind into electrical energy. There are various sizes of wind turbines available, having either horizontal or vertical axes. Simple rules govern how wind turbines work instead of utilizing power to create wind, like a fan would, wind turbines generate energy from wind. Wind drives a turbine's blades to rotate around its rotor, which then spins a generator to produce power [1].

Aerodynamic force is used by the rotor blades of a wind turbine, which operate similarly to an airplane wing or a helicopter rotor blade, to transform wind energy into electricity. When the wind blows across the blade, the air pressure on that side decreases [2]. The differing air pressure on the two sides of the blade creates both lift and drag. Because the force of the lift is higher than the force of the drag, the rotor spins. A gearbox, which speeds up rotation and enables a physically smaller generator, is used to link the rotor to the generator instead of directly. Electricity is produced as a result of the conversion of aerodynamic force into generator rotation [3].

The average yearly wind speed in Malaysia is only 2 m/s. But not everywhere in Malaysia does the wind constantly blow in the same direction. The southwest monsoon, which lasts from May through September, and the northeast monsoon, which starts in November and lasts until March, are Malaysia's two primary monsoon seasons. During the southwest monsoon, wind speeds are frequently below 7 m/s, while during the northeast monsoon, wind speeds may reach up to 15 m/s, especially along Peninsular Malaysia's east coast. So, even though Malaysia as a whole has modest wind speeds, some locations encounter severe winds at specific times of the year. Based on the wind speed data, the beginning and end of the year are when Malaysia receives greater winds. The average annual wind speed in Malaysia is 1.8 m/s. Mersing, a town on Peninsular Malaysia's east coast, is subject to harsher winds. The average monthly wind speed in some areas may reach more than 3 m/s [4].

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The usual wind speed distribution for a day can be shown in clear weather. In Malaysia's idealized daily wind speed distribution, the daytime wind speed is greater than the morning and evening winds. Throughout the day, wind speed follows a sine curve and is constant just before and just after dawn. Consequently, the window of time when the wind is blowing faster than 3 m/s, which is necessary for windmills to produce energy [4].

The work involve in this study includes to analyse meteorological data in Mersing and then to identify suitable location and wind turbine arrangement in Mersing by proposing a simple design of a suitable wind turbine for the wind condition in the said area. The study focuses on the arrangement of wind turbine in Mersing only, so monthly data of wind speed were collected from Malaysian Meteorological Department at the height of 10m.

This study is to see the potential of installing wind turbine in Mersing using a suitable wind turbine at that particular area to ensure efficient wind energy production. Since the data used in this study are quite up-to date, the findings of this paper will be beneficial in order to expand the wind studies in Malaysia.

2. Methodology

Wind data were collected and analyse in the first part of this study to understand the wind condition at the selected area. Wind data were provided by Malaysian Meteorological Department (MMD). It has information on wind direction and wind speed at Mersing meteorological station at the height of 10 meters above sea level which covers the years of 2020 through 2021.

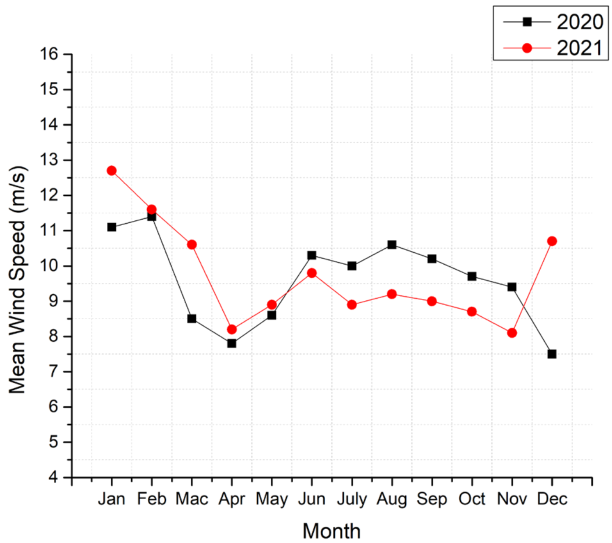

Fig. 1 - Monthly mean wind speed at Mersing for the year 2020 to 2021

Using the daily wind speed data, the average wind speed for each month and year has been computed. For a region in Mersing, the graph showing this average wind speed is presented in Fig. 1. It can give a preliminary account of Malaysia's East Coast's wind energy potential.

The wind data were then further analyse to incorporate the mean, variance, and skewness of wind speed for descriptive analysis. This investigation seeks to demonstrate the Mersing wind speed characteristic using following equations.

Mean wind speed is calculated using the equation below.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

Variance wind speed is calculated using the equation below.

$$s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})}{n-1} \qquad (2)$$

Skewness of the wind speed is calculated using the following equation.

$$g_1 = \frac{\sum_{i=1}^{n} (x_i - \overline{x})^3}{(n-1)s^3} \tag{3}$$

The calculated data are important to further analyse two types of probability distribution which are Weibull and Gama distribution in explaining the shape of wind speed distribution in this area.

2.1 Weibull Distribution

It is preferable to explain the fluctuations in wind speed using statistical functions in order to reduce the time and costs needed to interpret long-term, often hourly, wind speed data. Equation presents a Weibull's probability density function

The probability distribution function for wind speed shows the percentage of time that a certain wind speed may conceivably be present in the area under examination. The equation may be used to get the wind speed probability density function (4).

$$h(v) = (\frac{k}{c})(\frac{v}{c})^{(k-1)}\ e^{-(\frac{v}{c})^k} \quad for\ 0 < v < \infty \tag{4}$$

The determination of the cumulative distribution function is necessary to do this. It is feasible to measure the functional time of the wind turbine since the cumulative distribution function of the velocity (v) reveals the percentage of time the wind speed is equal to or lower than velocity (v) by taking the difference of their values. Equation may be used to represent the cumulative distribution since it is the integral of the probability density function (5).

$$F(v) = 1 - e^{-(\frac{v}{c})^k} \tag{5}$$

In this method, by calculating the mean wind speed ($\bar{v}$) and the variance (σ) of the known wind speed data, the parameters c and k of the Weibull distributions may be approximated by the formula below:

$$\bar{v} = \frac{1}{n}[\sum_{i=1}^{n} v_i] \tag{6}$$

$$\sigma = \left[\frac{1}{n-1}\sum_{i=1}^{n}(v_i - \bar{v})^2\right]^{1/2} \tag{7}$$

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} (1 \le k \le 10) \tag{8}$$

$$c = \frac{\bar{v}}{\Gamma(1=\frac{1}{k})} \tag{9}$$

When c is greater, it means that month's wind speed is greater than the wind speed for the previous months. Additionally, k value indicators show wind stability.

2.2 Gamma Distribution

In engineering, research, and business, the Gamma distribution is frequently used to describe continuous variables with skewed distributions that are always positive. Any quantity that is always positive, like cohesion or shear strength, can benefit from the gamma distribution.

$$f(x;\alpha,\beta) = \frac{1}{\Gamma(\alpha)} x^{\alpha-1} \exp(-\frac{x}{\beta}) \tag{10}$$

Equation (10) represents the probability density function (pdf) for Gama distribution where $\alpha =$ shape parameter, $\beta =$ scale parameter and $\Gamma(x) =$ Gamma function.

2.3 Wind Power Analysis

The wind power density is the number of watts of electrical energy produced per square meter of air space (W/m²). The following equation may be used to compute the power P, which is proportional to the cube of the velocity in a wind stream [6].

$$P = \frac{1}{2} C_p \rho A V^3 \tag{11}$$

Where the mechanical output power (P) is a function of C_p is the performance coefficient of the turbine, ρ is the density of air, A is swept area by the turbine projected in the direction of the wind and V is the wind speed.

3. Results and Discussions

Table 1 shows that the mean wind speed for Mersing is within (9.59-9.7) m/s or (34.52-34.92 km/h for that respective year. In general, minimum 2 m/s of wind speed is required to start rotating most small wind turbines

Table 1 - Descriptive statistic for Mersing station

Year	Mean (m/s)	Variance $(m/s)^2$	Minimum (m/s)	Maximum (m/s)	Skewness Coefficient
2020	9.59	1.5827	0.00	11.4	-0.338
2021	9.7	2.0236	0.00	12.7	0.971

The variation values for all years are between (1.6-2.0) m/s, which is considered moderate (5.76-7.2). Variance is a sign that all the data collected are not significantly deviating from the mean value. When the skewness coefficient ranges from -0.338 to 0.971, it means that the data is largely following the Weibull distribution. The mean, variance, and skewness values for all years all have a pretty similar value without any outliers. It demonstrates that the raw wind speed data is evenly distributed and free of outliers.

The Weibull model's parameter estimations are confirmed using the maximum likelihood approach. Each parameter's maximum likelihood estimator (MLE) may be calculated numerically using the Newton-Raphson technique. The outcome of parameter estimate for the Weibull distribution is displayed in Table 2 below. The probability distribution function then makes use of these parameter estimation values [5].

Table 2 - Estimation parameter

Year	**Weibull distribution**		**Gama distribution**	
	Shape parameter k	**Scale parameter c**	**Shape parameter α**	**Scale parameter β**
2020	2.096	3.606	3.6838	4.6521
2021	1.655	32021.623	3.7564	5.7499

Then, using transformation techniques, it is changed into the wind power density function. The mean wind power or the wind power density per unit area (W/m2) are then determined using this updated version of the function.

When evaluating wind power projects, the evaluation of wind power and energy per unit area is crucial information. Fig. 2 displays the estimated annual wind power density at a height of 10 meters. This finding shows that the range for the estimated wind power density is 261.73 W/m2 to 1285.36 W/m2. Mersing can be a viable station for producing wind energy, according to the findings, and with little innovation, it can contribute to better energy harvesting.

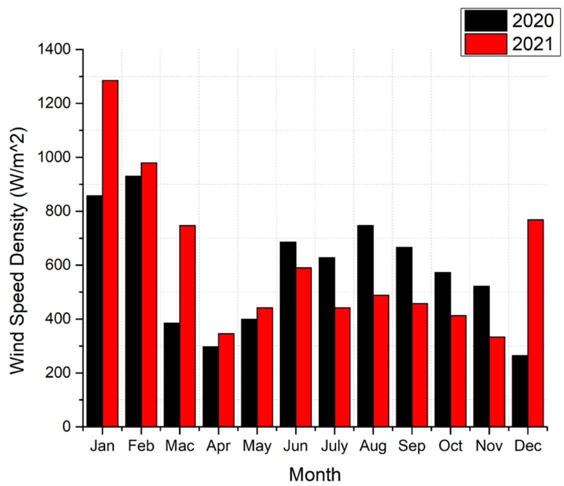

Fig. 2 - Estimation wind power density (W/m^2)

To maintain the consistently high wind speed at Mersing, several innovative measures must be done. Wind turbines of the proper size and scale may be able to catch more powerful wind and convert it to energy.

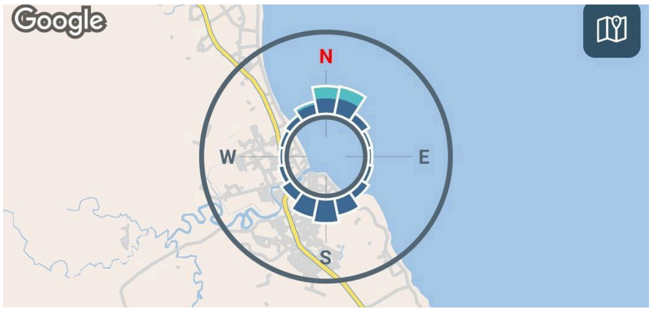

Fig. 3 - Direction of average wind speed density

The wind direction is an important aspect to determine the position of wind turbine to be install so that the wind turbine can generate electricity at full potential. The data collected from Malaysian Meteorology Department (MMD) shows there are a certain direction which there are greater wind blow in every year. From Fig.3 shows that the average wind power density come from direction 0˚-45˚ and 315˚-360˚ which can be used as a reference to initiate preliminary design of a suitable wind turbine at the particular area. Fig. 4 shows the proposed location for wind turbine installation at Mersing area due to its high potential of capturing more wind energy.

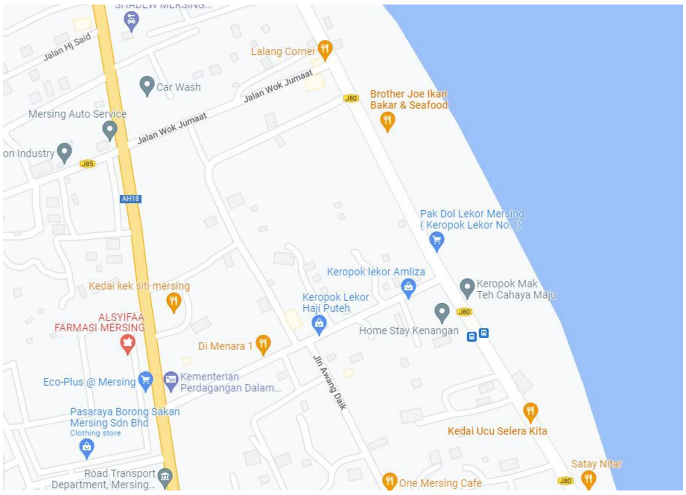

Fig. 4 - Proposed location for wind turbine installation

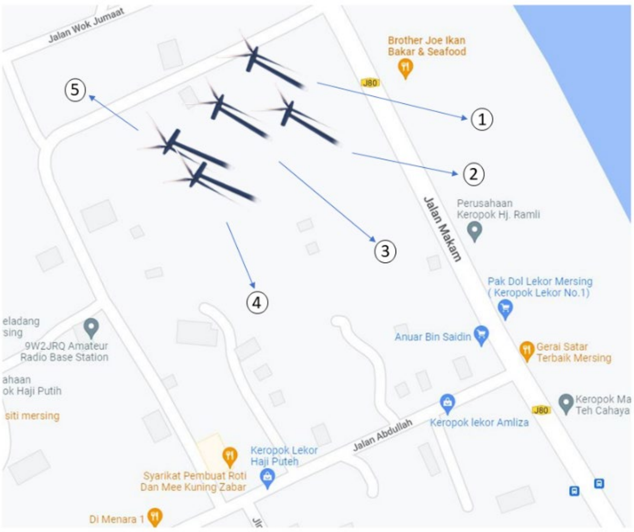

Fig. 5 - Placement of wind turbine

Location of the wind turbine placement is necessary in this project. Hence, the suitable place that have been chosen is beside Jalan Makam at the coordinate of 2.441554˚N and 103.834487˚E because it is close to the sea area which can provide good wind speed and it is vulnerable against sea breeze and land breeze. This area also provides a good open space for a few turbines to be install and it help to facilitate the installation or maintenance work since the area is close to the road.

The placement of the wind turbine are shown in Fig. 4 and Fig.5 as tabulated in Table 3 which is there are three wind turbines install to direction 20˚ where the average wind speed blow mostly and two wind turbines were install at direction 220˚ which is the second average wind speed blow. The direction is chosen to gain the maximum wind speed potential for the wind turbine to generate electricity.

Table 3 - Location and direction of every wind turbine

No.	Coordinate	Direction
1	2.441770˚N, 103.835698˚E	020˚
2	2.44184˚N, 103.835899˚E	020˚
3	2.441612˚N, 103.835494˚E	020˚
4	2.441347˚N, 103.835164˚E	220˚
5	2.441154˚N, 103.835268˚E	220˚

3.1 Proposed Preliminary Design of Wind Turbine

SolidWorks software was used to design the small horizontal axis wind turbine (HAWT). The horizontal axis wind turbine (HAWT) design is shown in Fig.6 and Fig.7. The designed HAWT has three propellers. Fig.6 presents some parts of the HAWT. Fig.7 presents a render image of HAWT from SolidWorks. The design measured is based on the wind speed data from Malaysian Meteorology Department which is the height of the wind turbine design is 10m and 5m radius.

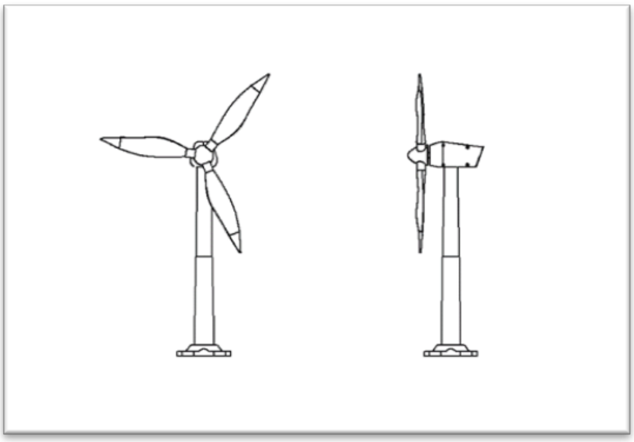

Fig. 6 - Design drawing of small HAWT using SolidWorks

Fig.7 - Render drawing from SolidWorks design

3.2 Material Selection

The base, pole, rotor, blade and other components were all constructed out of fiberglass. Due to its dimensional stability, good thermal properties, high tensile strength and product versatility. Additionally, it has strong resistance in terms of thermal and low moist absorption. The inside component mostly is stainless steel [7].

4. Conclusions

Overall, the purpose of this study is to highlight the suitable wind speed at Mersing by collecting data from Malaysian Meteorology Department to determine whether is it acceptable to apply a wind turbine. It is safe to construct and use this appliance for a source to generate and provide electric current for certain area and save much a lot of money from using electric that have been generate from power plant.

The data collected from Malaysian Meteorology Department have been analyses and wind speed data can be used as a reference to apply a small wind turbine by calculate the wind speed density itself to determine whether is it enough or not the wind speed to rotate the blade of the wind turbine.

The data were then further use to find and identify suitable location and wind turbine arrangement in Mersing and it can be concluded that there are several places that can provide a good wind blow to let the wind turbine fully operate. In addition, it is also to determine whether suitable to construct a small horizontal axis wind turbine in Mersing. The main purpose for this study is to prove that wind turbine is practical to be applied in Malaysia to help people in rural area save cost from electricity bills by ensuring that suitable location is selected and efficient wind turbine are installed.

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