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Determination of Optimal Time-Average Wind Speed Data in the Southern Part of Malaysia

Daniel Derome^{1, 4*} 

*Alias Jedi*² 

Halim Razali^{1*} 

*Katie Purvis-Roberts*³ 

*Ahmad Fazlizan*¹ 

¹ Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi Selangor Malaysia

² Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi Selangor Malaysia

³ W.M. Keck Science Department of Claremont McKenna, Pitzer, and Scripps Colleges, 925 N. Mills Ave.

Claremont, CA 91711

⁴Department of Mathematics, Science & Computer, Sultan Idris Shah Polytechnic, 45100 Sabak Bernam Selangor Malaysia

*Corresponding author: muhammaddanielderome@gmail.com

E-mails address: drhalimrazali@ukm.edu.my , a.fazlizan@ukm.edu.my , aliasjedi@ukm.edu.my ,

kpurvis@kecksci.claremont.edu

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Abstract:

Mersing is one of the places that have the potential for wind power development in Malaysia. Researchers often suggest it as an ideal place for generating electricity from wind power. However, before a location is chosen, several factors need to be considered. By analyzing the location ahead of time, resource waste can be avoided and maximum profitability to various parties can be realized. For this study, the focus is to identify the distribution of the wind speed of Mersing and to determine the optimal average of wind speed. This study is critical because the wind speed data for any region has its distribution. It changes daily and by season. Moreover, no determination has been made regarding selecting the average wind speed used for wind studies. The wind speed data is averaged to 1, 10, 30, and 60 minutes and used to find the optimal wind speed average. This study used Kolmogorov-Smirnov and Chi-Square as the goodness of fit. The finding shows that the wind speed distribution in Mersing varies according to the time average used and the best fit distribution is Gen. Gamma. In contrast, the optimal average wind speed is 10 minutes due to the highest similarity results with 1-minute data. These affect the reliability of the finding, accuracy of the estimation and decisions made. Therefore, the implementation of this study is significant so that the wind distribution in a particular area is more accurate.

Keywords: Distribution, Renewable energy, Time-average, Wind power, Wind speed.

Introduction:

Renewable energy is something familiar to us today and this energy is produced by nature and never runs out. In addition, it also produces only minimal secondary pollution. Among the key factors that cause renewable energy to be popular are the world oil crisis and the emission of carbon dioxide gas, which results in global warming. In order to limit the impacts of climate change, many countries are very keen to develop renewable energy. Malaysia participates in renewable energy as it does not want to be left behind by other countries. According to ^{1,2}, Malaysia has embarked on the first step in searching and using renewable energy since the Eighth Malaysia Plan (RMK8). It

cannot be denied that this renewable energy has some advantages, including a clean, virtually no pollution and cost-effective energy source.

Various types of renewable energy have been identified and implemented, including solar and wind energy. According to ^{2,3}, it can be observed through the speed in technology development for both types of energy. However, wind power is a preferable choice for renewable energy ^{1,4,5}. The wind has been used since ancient times (2800 BC), generally for sailing ships in the oceans and the agricultural sector ⁶. Nevertheless, nowadays, it can also generate electricity.

From the Asian region, India and China are the pioneers in this wind energy field⁶. Given the success of India, which is also close to the equatorial line, Malaysia could also be a good location for the implementation of wind power⁷. Among the advantages is that Malaysia has a large amount of wind every year. Wind power is one of the renewable energies available in Malaysia. However, wind power implementation is still low compared to other Asian countries such as Indonesia and Thailand. This situation can be proved through a report issued by⁸. The use of wind power for the production of electricity is very high around the world. According to a report submitted by the International Renewable Energy Agency (IRENA) 2017, there has been a fourfold increase in the implementation of wind energy from 2007 to 2016.

Based on previous researcher's findings, wind speed is the most crucial parameter⁹. This parameter is due to it being a crucial factor in determining the success of a wind study¹⁰. It is known that the wind speed changes frequently and it is a type of energy that is not fixed¹¹. Therefore, more research about wind energy needs to be done to ensure the use of wind power for energy production in Malaysia. According to previous studies, many factors need to be considered to enable wind power generation to become a reality in Malaysia. The factors include the wind speed at a different altitude, wind direction, and the distribution of the wind itself¹. Some researchers are studying the selection of wind distribution for a particular area¹²⁻¹⁵. Through the findings of past studies in which each area has a different distribution of wind. Many wind data distributions were obtained from previous research findings, including Weibull, Rayleigh, Burr and Gamma.

Besides that, the average selection of wind speed to determine the wind distribution is essential. The literature studies show that some researchers use the 10 minutes^{16,17}, 30 minutes³, one hour^{18,19} and one day^{2,20,21} as average wind data for their studies²². Moreover, no determination has been made regarding the average wind speed used for wind studies. However, recommendations from the previous study indicate that when the data is analyzed using a smaller time average, the results are much better²³. This recommendation is because feature characteristics of the data are less affected. On the other hand, using the more extensive data average causes the results to be less accurate. This is inaccurate due to the small amount of information

obtained when the data is averaged over a more extensive data span.

In a study involving each data set, the critical point is to determine data distribution²⁴. This critical point is due to each data having its distribution. In this study, the process of determining the distribution of wind speed is fundamental. This process is essential because the wind speed prediction process will be more accurate by obtaining an appropriate distribution. After all, determining such a distribution becomes extremely difficult due to the wind's constant change. These changes result in the forecasting process becoming more complex. Then, to ensure that the distribution runs smoothly and accurately, it depends entirely on the form of data. Thus, the nature of the data distinguishes it. However, to date, no determination or standard of wind average can be used for this purpose to ensure that the distribution can be determined accurately. Therefore the primary purpose of this study is to identify the distribution of the wind speed of Mersing and determine the optimal selection of average wind speed.

Materials:

Selection of the Mersing, located in the southern part of Peninsular Malaysia as a suitable area for power generation from wind power, began as early as 1995²⁵. The selection of the study area is based on several factors. Among the factors is the location itself, which is higher than the other places in Malaysia. Its location is 43.6m above the mean sea level². In addition, the geographical area, which lies opposite the South China Sea, allows to experience a large amount of wind throughout the year. Thus, Mersing encounters both the sea breeze and land breeze and is affected by the monsoon seasons.

Furthermore, previous studies have suggested Mersing as one of the ideal places for generating electricity from wind power^{1,2,25,26}. This wind power capacity research was conducted utilising data from 2007 to 2013 and found that the wind power density in Mersing is approximately 14-25 W/m^2 ²⁷. The data was obtained from a weather station installed at the University Kebangsaan Malaysia (UKM) - Mersing Marine Ecosystem Center (EKOMAR) (Fig. 1). In this study, wind speed data measured and recorded at 20 m height from the ground was used for the analysis. The data used is wind data from May 2017 to November 2017.

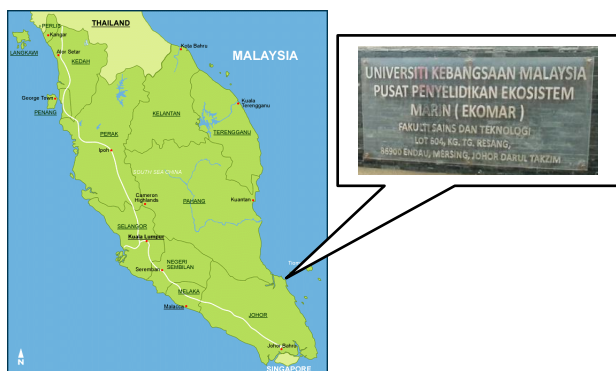


Figure 1. Location of Mersing (Image from Google).

The average humidity and temperature for the study area are shown in Table 1. Additionally, it can be utilised to give a general idea of the location's various features and characteristics. With this information in hand, it is reasonable to conclude that the study location has a moderate temperature and a high humidity level that remain constant over the length of the research (May 2017 to November 2017). Aside from that, the excessive humidity is a result of an abundance of rain.

Table 1. The average temperature and humidity for each month.

Month	Temperature (°C)	Humidity (%)
May	27.84	84.80
Jun	27.97	83.23
July	27.62	82.57
August	27.08	84.54
September	27.40	82.08
October	27.39	83.29
November	26.83	86.87

Methods of Work:

Wind data is divided into several average groups, including 1, 10, 30 and 60 minutes averages. The data went through a quality control process and missing data was not taken into account as analysis. The data were analyzed using the software, EasyFit 5.6 Professional. This software was used to obtain the corresponding distribution of the wind data obtained. In addition, R software was used to obtain descriptive values for the data. Statistical data is required for the comparison of the different group averages. The average value of wind speed, standard deviation and ultimately data skewness was analyzed.

Estimation Distribution

For this study, the Maximum Likelihood Method (MLM) was used to determine the parameter's value and determine the distribution. This method has proven to be one of the best estimating methods in predicting parameters in

various locations in the world²⁸⁻³¹. This method was proposed by Steven & Smulders in 1979. It involved the most numerical iterations in computing the value of the parameter²⁹. For this calculation, let v_1, v_2, \dots, v_n be a random sample size of n drawn from a probability density function $f(v_i, \theta)$ where θ an unknown parameter is.

The likelihood function,

$$L = \prod_{i=1}^n f_{v_i}(v_i, \theta) \quad 1$$

The Maximum Likelihood Estimator (MLE) of θ is the value of θ that maximizes L or, equivalently, the logarithm of L . According to³², often but not always, the MLE of θ is a solution of

$$\frac{d \text{Log} L}{d\theta} = 0 \quad 2$$

The value of the parameters obtained substitute in the distribution that is deemed appropriate to obtain the probability density function (pdf) value. In contrast, the pdf be plotted together with the histogram of the data. This analysis aims to observe the best fit distribution that corresponds to the histogram.

Statistical Tools (Goodness of Fit)

The selection of the best distribution also involves statistical analysis. The reason to use a statistical tool is to see the effectiveness of each selected distribution. Based on the literature, at least two statistical tools need to be used as analysis. Different statistical tools provide different results³³. In this study, Chi-Square (χ^2) and Kolmogorov-Smirnov (KS) are used as the goodness of fit (GOF):

The formula for Chi-Square is,

$$\chi^2 = \frac{(O_i - E_i)^2}{E_i} \quad 3$$

where O_i is the observed data and E_i is the expected data³³.

The formula for Kolmogorov-Smirnov (KS) is,

$$KOL = \text{Max}|F(v) - F_n(v)| \quad 4$$

where v identifies the set of the velocity to be considered, $F(v)$ is the cumulative probability distribution for specific distribution and $F_n(v)$ is the experimental histogram.

Results:

Wind speed descriptive analysis is a critical issue that researchers must address. Descriptive analysis can provide a comprehensive picture of the characteristics of data. The importance of descriptive analysis can be seen based on many frequencies of its use for any study. Table 2 summarises descriptive statistics for this study, including mean, standard deviation, and skewness.

Mean is an essential element in assessing wind energy in a location³⁴. The mean for each average is almost identical. For example, the highest mean wind speed was recorded in July (2.1634 m/s), while the lowest was in October (1.3970 m/s). Based on Table 2, standard deviation values decrease when the averages wind speed over increases. Apart from that, the value of standard deviation for this study is relatively large.

On the other hand, the mean value of the data obtained is not suitable for assessment. This is because the large standard deviation value causes the mean value to be unstable. However, since this value was not used to achieve the study's primary objective, it was noted and used as additional information. As a result, the data is skewed to the right due to positive values for the entire data. Furthermore, it is observed that the larger of average value used, the lower the value of skew is.

Table 2. The descriptive statistic for each month and average.

Month/ average	Mean	Standard deviation	Skewness
May	1 minute	1.6148	1.0880
	10 minutes	1.6150	0.9983
	30 minutes	1.6150	0.9553
	60 minutes	1.6150	0.9238
Jun	1 minute	1.8833	1.1059
	10 minutes	1.8833	1.0178
	30 minutes	1.8832	0.9802
	60 minutes	1.8834	0.9481
July	1 minute	2.1630	1.2785
	10 minutes	2.1630	1.1815
	30 minutes	2.1633	1.1418
	60 minutes	2.1634	1.1065
Aug	1 minute	2.0258	1.2653
	10 minutes	2.0258	1.1759
	30 minutes	2.0257	1.1406
	60 minutes	2.0257	1.1088
Sept	1 minute	1.7681	1.1151
	10 minutes	1.7681	1.0343
	30 minutes	1.7680	1.0040
	60 minutes	1.7680	0.9777
Oct	1 minute	1.3975	0.8634
	10 minutes	1.3974	0.7842
	30 minutes	1.3973	0.7406
	60 minutes	1.3970	0.6991
Nov	1 minute	1.6388	1.0037
	10 minutes	1.6388	0.9198
	30 minutes	1.6388	0.8739
	60 minutes	1.6388	0.8381

Statistical Tools– Chi-Square (χ^2)

Based on Table 3, the initial conclusion that can be made is that the selection of average wind speed influences the distribution of Mersing, Malaysia. Besides that, there is no single data range that resembles the Weibull distribution. Weibull is a famous distribution that has been used for decades, especially for wind speed research³⁵. For July, it is essential to note that the average selection of either 1 minute, 10 minutes, 30 minutes or 60 minutes does not affect the distribution (Table 3).

For May, June and November, the results were almost the same. Selection of average 1, 10 and 30 minutes give the same distribution result while the

result is not the same for the average of 60 minutes. Whereas for September and October, the results were roughly the same. Results for the average selection of 1 and 10 minutes are the same. However, for August it shows pretty differently compared to the others month. This difference is due to the distribution results are constantly alternating between the average selections used.

Based on Table 3, there are 28 analyses conducted. The analysis refers to the frequency of obtaining the same wind distribution between 1 minute by 10 minutes, 1 minute by 30 minutes, and 1 minute by 60 minutes. For the average data 1 minute by 10 minutes, the per cent of similarity is

85.71%. While for data 1 minute by 30 minutes, the result was 71.43%. However, for the data, 1 minute by 60 minutes gave a 14.29% similarity.

In conclusion, these analyses show that in addition to using a 1-minute average, the researchers can also use 10 minutes average data.

This use is due to the highest similarity compared to others' averages. Apart from that, this study shows 60-minute mean selection is less accurate. Possibly this is because of the overwhelming amount of missing information when an average of 60 minutes is used.

Table 3. Best fit distribution by Chi-square (χ^2) based on average.

Month/ average	Best fit distribution (number of the parameter)	
May	1 minute	Inv. Gauss (3)
	10 minutes	Inv. Gauss (3)
	30 minutes	Inv. Gauss (3)
	60 minutes	Gamma (3)
Jun	1 minute	Gen. Gamma (4)
	10 minutes	Gen. Gamma (4)
	30 minutes	Gen. Gamma (4)
	60 minutes	Rayleigh (1)
July	1 minute	Gen. Gamma (4)
	10 minutes	Gen. Gamma (4)
	30 minutes	Gen. Gamma (4)
	60 minutes	Gen. Gamma (4)
Aug	1 minute	Gamma (3)
	10 minutes	Burr (4)
	30 minutes	Gamma (3)
	60 minutes	Burr (4)
Sept	1 minute	Gamma (3)
	10 minutes	Gamma (3)
	30 minutes	Burr (4)
	60 minutes	Gen. Gamma (4)
Oct	1 minute	Gen. Gamma (4)
	10 minutes	Gen. Gamma (4)
	30 minutes	Inv. Gauss (3)
	60 minutes	Burr (4)
Nov	1 minute	Gen. Gamma (4)
	10 minutes	Gen. Gamma (4)
	30 minutes	Gen. Gamma (4)
	60 minutes	Normal (2)

Figure 2 (a-d) shows an example of the histogram by probability density function (pdf) for the selected month (May). The selected month is based on the average (1 minute, 10 minutes, 30 minutes and 60 minutes) used, showing the distribution wind speed data variability. Based on

Fig. 2, it can be observed that the distribution findings for each average used are derived from the same distribution family. The similarity can be seen from the distribution skewed to the right. Nevertheless, the difference of each distribution lies in the width of each mode class.

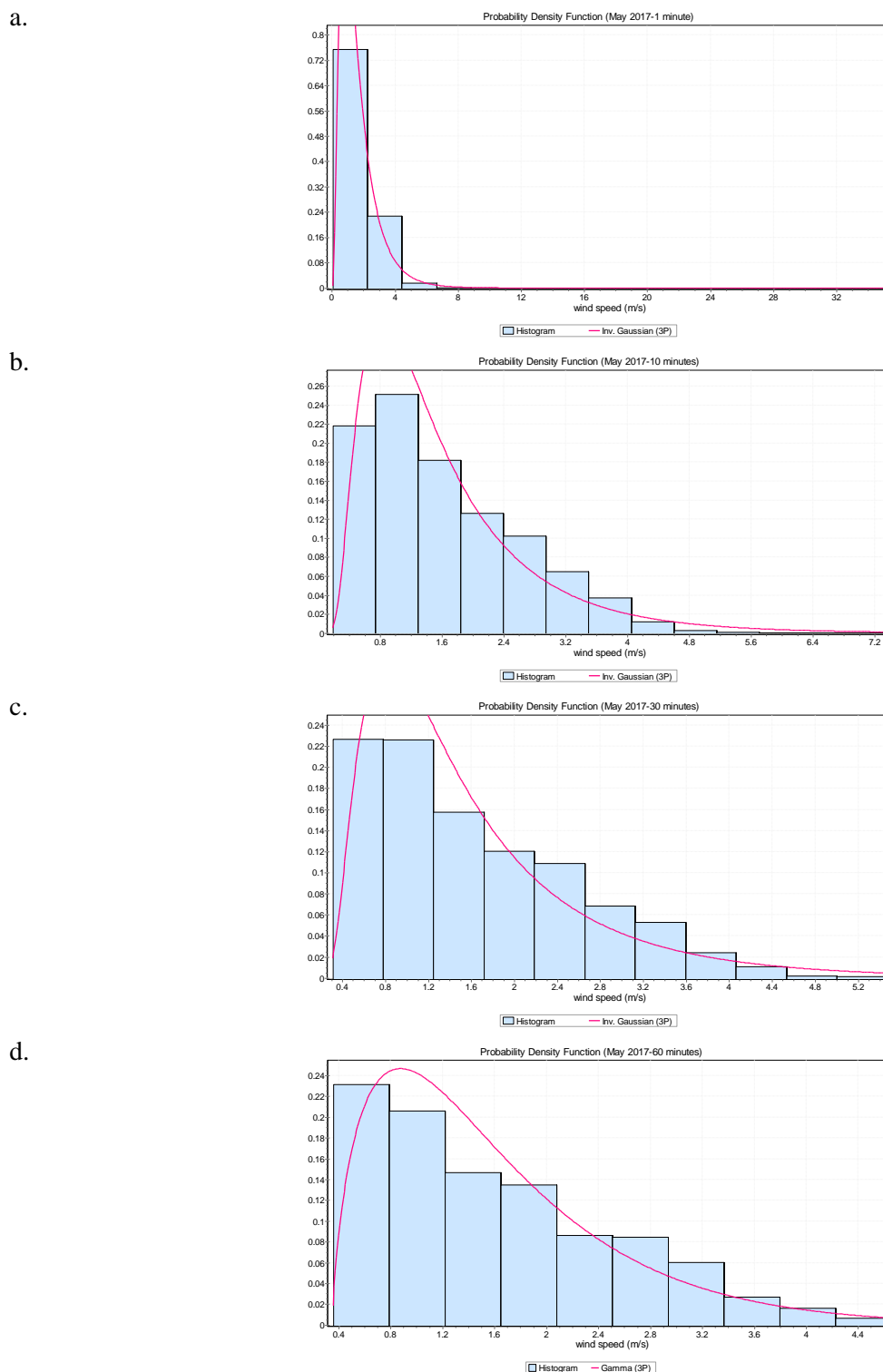


Figure 2. Example of best-fit distribution for wind speed in May by Chi-Square (a) Inv. Gauss (3) (b) Inv. Gauss (3) (c) Inv. Gauss (3) (d) Gamma (3)

Statistical Tools– Kolmogorov-Smirnov (KS)

Table 4 indicates the best fit distribution by Kolmogorov-Smirnov. It is initially concluded that having more parameters does not guarantee the best fit for any data. However, Table 4 shows that the distribution with a few parameters is better than those with many parameters.

For May, the results obtained for 1-minute averages are equal to the result for an average of 10 minutes. While for an average of 30 minutes, it has the same result with an average of 60 minutes. The results for July through October have the same pattern. For July, it has the distribution that has two parameters only, which is Nakagami. In standard

practice^{15,36,37}, Weibull distribution is the most likely distribution for wind power studies. However, there is only one Weibull distribution from 28 analyses conducted. Furthermore, it only takes place in August.

Table 4 was also used to calculate the frequency of obtaining the same distribution for average data of 1 minute by 10 minutes, 1 minute by 30 minutes, and 1 minute by 60 minutes. For the average 1 minute by 10 minutes data, the similarity of the frequency is 57.14%. While for data 1 minute by 30 minutes, the result was 42.86% and for the data, 1 minute by 60 minutes gave a 28.57% similarity.

Additionally, these results also support the conclusion from Table 3. It shows that the 60 minutes average selection is less accurate. This inaccurate is due to the missing information when an average of 60 minutes is used.

Nevertheless, the comparison of the findings between Chi-square (χ^2) and Kolmogorov Smirnov (KS) shows that the percentage of similarity for the average usage 10 minutes and 30 minutes is decreasing except for the average usage of 60 minutes where the percentage is increasing.

Table 4. Best fit distribution by Kolmogorov-Smirnov based on average.

	Month/ average	Best fit distribution (number of the parameter)
May	1 minute	Inv. Gauss (3)
	10 minutes	Inv. Gauss (3)
	30 minutes	Gamma (3)
	60 minutes	Gamma (3)
Jun	1 minute	Gen. Gamma (4)
	10 minutes	Nakagami (2)
	30 minutes	Gen. Gamma (4)
	60 minutes	Gen. Gamma (4)
July	1 minute	Gen. Gamma (4)
	10 minutes	Gen. Gamma (4)
	30 minutes	Gen. Gamma (4)
	60 minutes	Rayleigh (1)
Aug	1 minute	Gamma (3)
	10 minutes	Gamma (3)
	30 minutes	Weibull (3)
	60 minutes	Gen. Gamma (4)
Sept	1 minute	Gen. Gamma (4)
	10 minutes	Gamma (3)
	30 minutes	Gamma (3)
	60 minutes	Gamma (3)
Oct	1 minute	Gen. Gamma (4)
	10 minutes	Gen. Gamma (4)
	30 minutes	Gen. Gamma (4)
	60 minutes	Inv. Gaussian (3)
Nov	1 minute	Gen. Gamma (4)
	10 minutes	Gamma (3)
	30 minutes	Gamma (3)
	60 minutes	Gen. Gamma (4)

A sample histogram by probability density function (pdf) for the selected month (October) is shown in Fig. 3 (a-d). In this case, the selected month is based on average use (1 minute, 10 minute, 30 minute, and 60-minute intervals), demonstrating the variability of the wind speed

distribution data. Figure 3 indicates that the distribution for each type of average used is derived from the same distribution family as the finding in Fig. 2. The similarity is noticeable in the right-skewed distribution. Nonetheless, each distribution differs in terms of the width of each mode class.

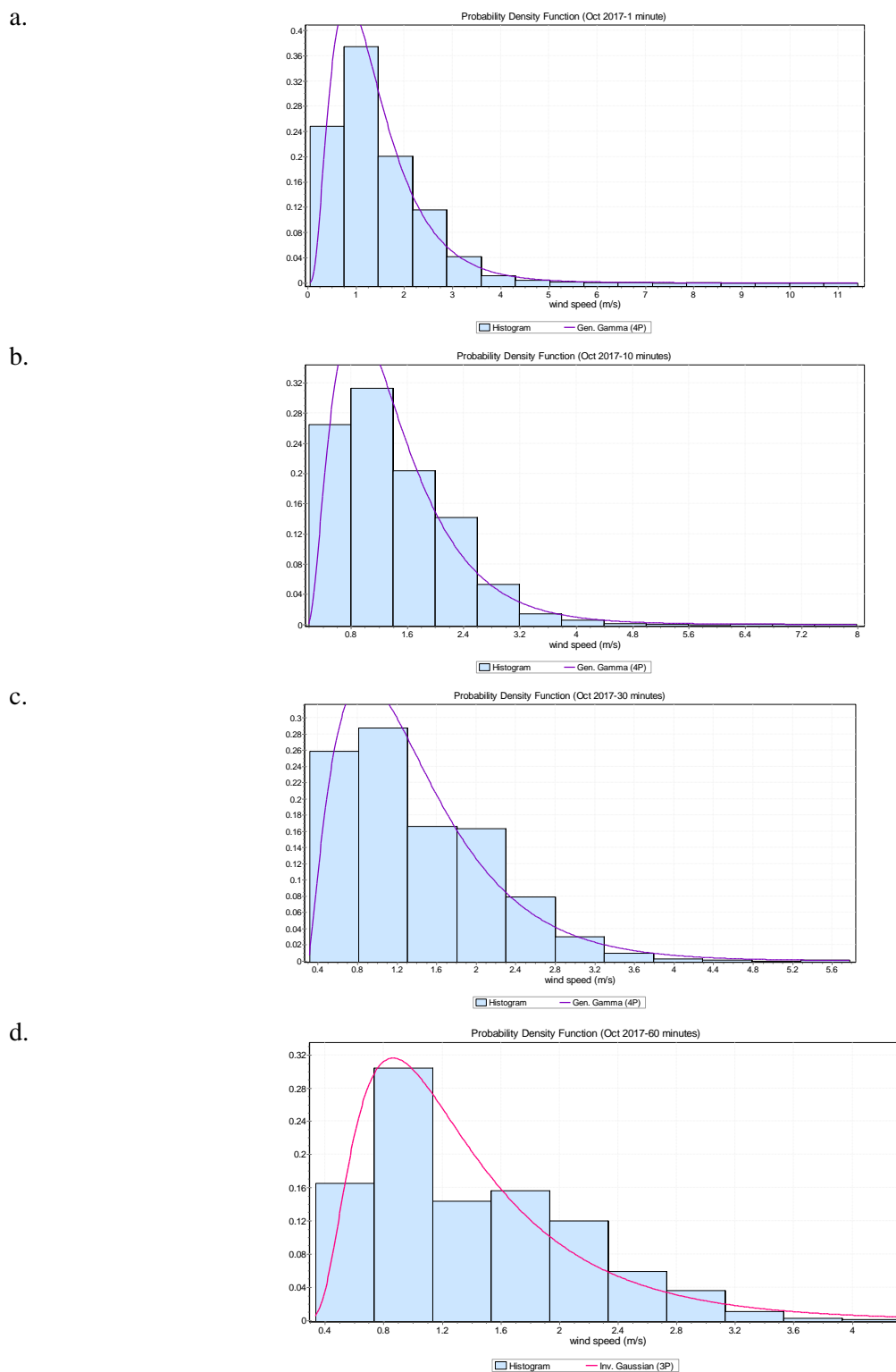


Figure 3. Example of best-fit distribution for wind speed in October by Kolmogorov-Smirnov (a) Gen. Gamma (b) Gen. Gamma (c) Gen. Gamma (d) Inv. Gaussian.

Discussion:

There are seven analyses for each goodness of fit (GOF) and each average. Since there are 2 GOF used in this study which is KS and χ^2 , then for this study, there are 14 analyzes in total for each average. Based on Fig. 4, analyses were conducted for an average of 1 minute to find the best

distribution. It shows three distributions that have the best fit for the 1-minute data. It can be concluded that Gen. Gamma distribution exhibits the best fit since it gets the highest percentage. It explains 64% of the data. While for Gamma and Inv. Gauss gets 22% and 14%, respectively.

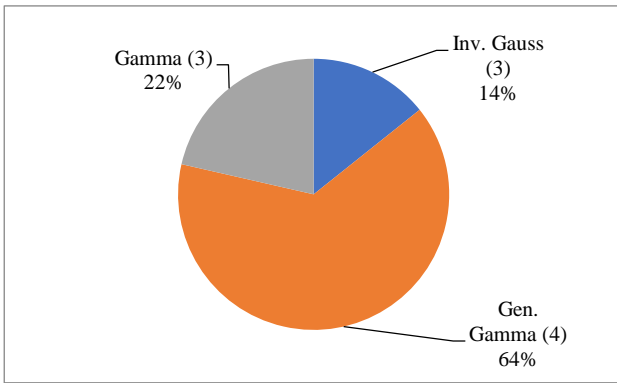


Figure 4. List of distribution that best fits the 1-minute data (Mersing)

Five different distributions were observed for the average use of 10 minutes of data (Fig. 5). Gen. Gamma distribution accounts for the large distribution for 10 minutes average data at 43%. While each of Gamma and Inv. Gauss explains 29% and 14%. As seen from previous findings (Fig. 4), all the distributions available for the average of 1 minute were also observed for the 10 minutes averages. This finding indicates a continuity of the distribution between using 1 minute or 10-minute average data. Therefore, to use a 1-minute average, we also can use 10 minutes average. These 10 minutes on average are also suggested by ^{22,38}. While for the last place, each of Nakagami and Burr distribution gets 6%.

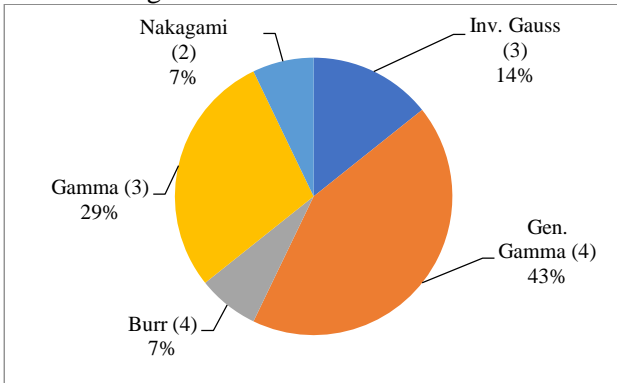


Figure 5. List of distribution that best fits the 10 minutes data (Mersing)

In total, 14 analyses were conducted for an average of 30 minutes to find out the best distribution. According to the 30-minute average data (Fig. 6), the results look similar to the average data for 10 minutes (Fig. 5), five distributions, such as Gen. Gamma, Gamma, Inv. Gauss, Weibull and Burr distribution. The only difference found between 10 minutes and 30 minutes was the lowest percentage, Weibull distribution. While Gen. Gamma distribution has the best fit distribution at 43%. In second place is the Gamma distribution with a value of 29%, while the Inv. Gauss occupies

third place with 14%. Meanwhile, the last position is represented by the Burr and Weibull distribution with a value of 7% each. Fig. 6 illustrates a conclusion that it is a continuation of the previous results, Fig. 4 and Fig. 5. This continuation can be seen from the best three distributions available for the average of 1 minute and 10 minutes also it can be seen on average 30 minutes, Gen. Gamma, Gamma, and Inv. Gauss.

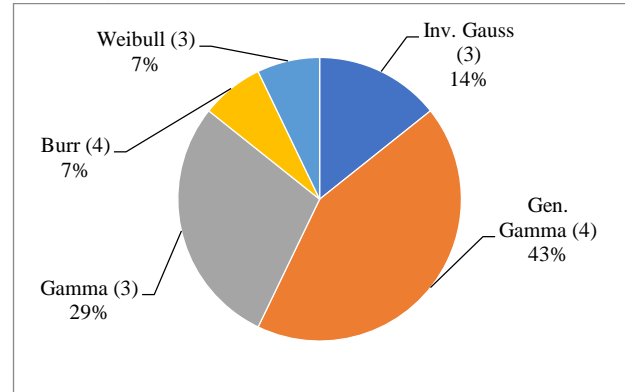


Figure 6. List of distribution that best fits the 30 minutes data (Mersing)

For the last average (60 minutes), then in total, there are 14 analyses as well. There were conducted to find out the best distribution for an average of 60 minutes. There are six different distributions that best fit the 60 minutes data, which are Gen. Gamma, Gamma, Inv. Gaussian, Normal, Burr and Rayleigh (Fig. 7). The best fit distribution is Gen. Gamma distribution since it has gained the highest percentage, 36%. In the second place with 22%, Gamma distributions while Rayleigh and Burr's distributions share in the third place with 14% each. Furthermore, the Normal and Inv. Gaussian distributions occupy the last place with a percentage of 7%. In conclusion, the best two distributions available for the average of 1 minute, 10 minutes and 30 minutes also is an average of 60 minutes, which are Gen. Gamma and Gamma distribution.

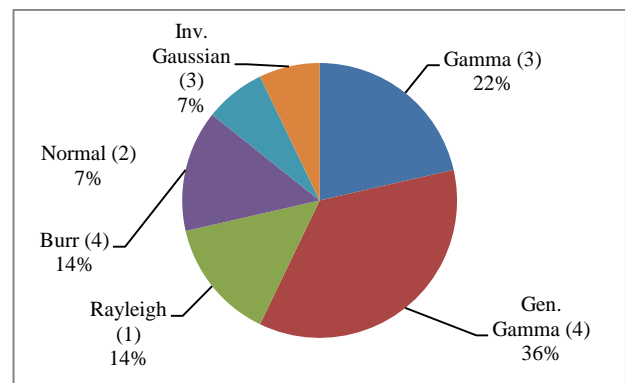


Figure 7. List of distribution that best fits the 60 minutes data (Mersing)

As a conclusion (Fig. 8), the best fit distribution for each type of average wind speed is the Gen. Gamma distribution. This is because it best represents the wind speed in Mersing. The percentage for Gen. Gamma distribution is 46.43%. Gamma and Inv. Gauss distributions come in second and third, with 25% and 12.5%. The Burr distribution has been chosen for four-time averages, which is equivalent to half of the Rayleigh distribution. In contrast, the last place represented by Nakagami, Normal and Weibull distribution receive only 1.8% respectively.

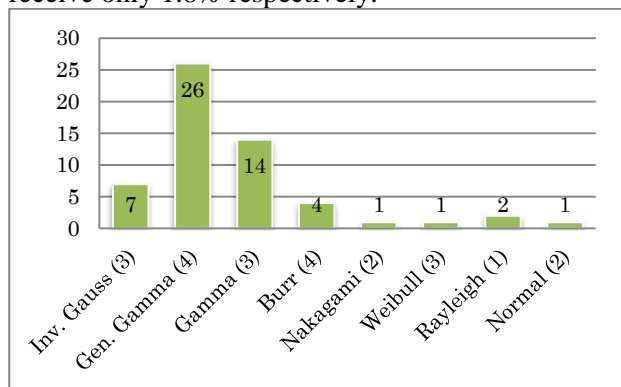


Figure 8. List of distribution that best fit the data (Mersing)

Conclusion:

This paper discusses the best fit distribution of wind speed for Mersing and the selection of optimal time average used for a wind speed study. In conclusion, the best distribution for Mersing is Gen. Gamma. In addition, this study also found that the selection of the type of average wind speed affects the distribution. Furthermore, the findings show the continuity of the best distribution based on the type of average used. Based on the finding, the optimal average wind speed other than 1 minute is 10 minutes. This optimal wind speed is due to both GOFs, which show the highest similarity compared to the other averages. The first GOF (χ^2) shows a similarity of 85.71%, while the second GOF (KS) shows 57.14%. This study needs to be continued to determine the optimal average wind speed that is suitable for assessment purposes. The selection of distribution for each data is a crucial requirement before proceeding to further analysis. If the selection of data is made incorrectly, it causes the overall findings to be inaccurate. Therefore, excellent optimal average data is used to reflect the best distribution selection process. Lastly, it helps researchers determine the approximate parameter and aid in better predictions.

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Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The local ethical committee approved the Solar Energy Research Institute project, Universiti Kebangsaan Malaysia.

Authors' contributions statement:

The manuscript was designed and written by D.D. and H.R. In addition, H.R. was involved in supervising the work, particularly funding acquisition. D.D. and A.F. processed the experimental data, analyzed it, and created the figures. A.J. assisted in the measurement of numerical calculations as well as the simulations. K.P.R. contributed to the final version, proofread the manuscript, and assisted in interpreting the findings. All authors provided constructive feedback and contributed to the development of the research, analysis, and manuscript.

References:

1. Ibrahim MZ, Yong KH, Ismail M, Albani A, Muzathik AM. Wind characteristics and GIS-based spatial wind mapping study in Malaysia. *J Sust Sci Manag.* 2014; 9(2): 1-20.
2. Belhamadia A, Mansor M, Younis MA. A study on wind and solar energy potentials in Malaysia. *Int J Renew Energy Res.* 2014; 4(4): 1042-1048. doi:10.1109/CEAT.2013.6775617
3. Azad K, Rasul M, Halder P, Sutariya J. Assessment of wind energy prospect by Weibull distribution for prospective wind sites in Australia. *Energy Procedia.* 2019; 160(2018): 348-355. doi:10.1016/j.egypro.2019.02.167
4. Beabpimai W, Chitsomboon T. Numerical study of effect of blade twist modifications on the aerodynamic performance of wind turbine. *Int J Renew En Dev.* 2019; 8(3): 285-292. doi:10.14710/ijred.8.3.285-292
5. Daoudi M, Abdelaziz ASM, Mohammed E, Elmostapha E. Wind speed data and wind energy potential using Weibull distribution in Zagora, Morocco. *Int J Renew En Dev.* 2019; 8(3): 267-273. doi:10.14710/ijred.8.3.267-273
6. Zaharim A, Najid SK, Razali AM, Sopian K. The Suitability of Statistical Distribution in Fitting Wind Speed Data. *WSEAS Trans Math.* 2008; 7(12): 386-

- 389.
7. Albani A, Ibrahim M, Yong K. Wind Energy Investigation in Northern Part of Kudat, Malaysia. *Int J Appl Sci Eng.* 2013; 2(2): 14-22. http://www.academia.edu/download/30886418/Technology_Engineering_2.pdf.
 8. IRENA. Data and Statistics - IRENA Resource (Capacity and Generation). International Renewable Energy Agency. 2017. <http://resourceirena.irena.org/gateway/dashboard/?topic=4&subTopic=16>.
 9. Didane DH, Ab Wahab A, Shamsudin SS, Rosly N. Wind as a sustainable alternative energy source in Malaysia - a review. *ARN J Eng Appl Sci.* 2016; 11(10): 6442-6449.
 10. Mohsen A-ZA, Al-Jiboori MH, Al-Timimi YK. Investigating the Aerodynamic Surface Roughness Length over Baghdad City Utilizing Remote Sensing and GIS Techniques. *Baghdad Sci J.* 2021; 18(2(Suppl.)): 1048. doi:10.21123/bsj.2021.18.2(suppl.).1048
 11. Sang LQ, Maeda T, Kamada Y. Study effect of extreme wind direction change on 3-bladed horizontal axis wind turbine. *Int J Renew En Dev.* 2019; 8(3): 261-266. doi:10.14710/ijred.8.3.261-266
 12. Pobočiková I, Sedláčková Z, Michalková M. Application of Four Probability Distributions for Wind Speed Modeling. *Procedia Eng.* 2017; 192: 713-718. doi:10.1016/j.proeng.2017.06.123
 13. Jung C, Schindler D. Global comparison of the goodness-of-fit of wind speed distributions. *Energy Convers Manag.* 2017; 133: 216-234. doi:10.1016/j.enconman.2016.12.006
 14. Sohoni V, Gupta S, Nema R. A comparative analysis of wind speed probability distributions for wind power assessment of four sites. *Turk J Elec Eng Comp Sci.* 2016; 24(6): 4724-4735. doi:10.3906/elk-1412-207
 15. Wais P. A review of Weibull functions in wind sector. *Renew Sustain Energy Rev.* 2017; 70(February 2015): 1099-1107. doi:10.1016/j.rser.2016.12.014
 16. Ozay C, Celiktas MS. Statistical analysis of wind speed using two-parameter Weibull distribution in Alaçatı region. *Energy Convers Manag.* 2016; 121: 49-54. doi:10.1016/j.enconman.2016.05.026
 17. Chaurasiya PK, Ahmed S, Warudkar V. Comparative analysis of Weibull parameters for wind data measured from met-mast and remote sensing techniques. *Renew Energy.* 2018; 115: 1153-1165. doi:10.1016/j.renene.2017.08.014
 18. Wang J, Li Y. Multi-step ahead wind speed prediction based on optimal feature extraction, long short term memory neural network and error correction strategy. *Appl Energy.* 2018; 230(April): 429-443. doi:10.1016/j.apenergy.2018.08.114
 19. Huang Y, Liu S, Yang L. Wind Speed Forecasting Method Using EEMD and the Combination Forecasting Method Based on GPR and LSTM. *Sustainability.* 2018; 10(10): 3693. doi:10.3390/su10103693
 20. Daut I, Razliana ARN, Irwan YM, Farhana Z. A study on the wind as renewable energy in Perlis, northern Malaysia. *Energy Procedia.* 2012; 18: 1428-1433. doi:10.1016/j.egypro.2012.05.159
 21. Rasham AM. Analysis of Wind Speed Data and Annual Energy Potential at Three locations in Iraq. *Int J Comput Appl.* 2016; 137(11): 5-16. doi:10.5120/ijca2016908862
 22. Murthy KSR, Rahi OP. A comprehensive review of wind resource assessment. *Renew. Sust. Energ. Rev.* 2017; 72(May 2015): 1320-1342. doi:10.1016/j.rser.2016.10.038
 23. Derome D, Razali H, Fazlizan A, Mat S, Elias MA. Wind Speed Distribution: A case study of Mersing, Malaysia. In: *Proceeding of 2nd Malaysia University-Industry Green Building Collaboration.* ; 2018: 269.
 24. Masseran N, Razali AM, Ibrahim K, Zin WZW, Zaharim A. On spatial analysis of wind energy potential in Malaysia. *WSEAS Trans Math.* 2012; 11(6): 467-477.
 25. Sopian K, Othman MY, Wirsat A. The wind energy potential of Malaysia. *Renew Energy.* 1995; 6(8): 1005-1016. doi:10.1016/0960-1481(95)00004-8
 26. Sanusi N, Zaharim A, Mat S. Wind energy potential: A case study of Mersing, Malaysia. *ARN J Eng Appl Sci.* 2016; 11(12): 7712-7716.
 27. Nortazi S. Analisis potensi tenaga angin di Malaysia: Suatu kajian terhadap taburan kebarangkalian angin. Doctoral dissertation, Universiti Kebangsaan Malaysia. 2019. doi: <http://ptsldigital.ukm.my:8080/vital/access/manager/Repository/ukmvital:120934>.
 28. Chaurasiya PK, Ahmed S, Warudkar V. Study of different parameters estimation methods of Weibull distribution to determine wind power density using ground based Doppler SODAR instrument. *Alex Eng J.* 2017.
 29. Siddiqui A, Khan J, Ahmed F, Uddin Z, Iqbal S, Jilani S, et al. Determination of Weibull Parameter by Four Numerical Methods and Prediction of Wind Speed in Jiwani (Balochistan). *J Basic Appl Sci.* 2015; 11: 62-68. doi:10.6000/1927-5129.2015.11.08
 30. Masseran N, Razali AM, Ibrahim K, Zaharim A, Sopian K. The Probability Distribution Model of Wind Speed over East Malaysia. *Res J Appl Sci Eng Tech.* 2013; 6(10): 1774-1779.
 31. Aries N, Boudia SM, Ounis H. Deep assessment of wind speed distribution models: A case study of four sites in Algeria. *Energy Convers Manag.* 2018; 155(August 2017): 78-90. doi:10.1016/j.enconman.2017.10.082
 32. Bhattacharya P, Bhattacharjee R. A Study on Weibull Distribution for Estimating the Parameters. *J Appl Quant Methods.* 2010; 33(5): 469-476. doi:10.1260/030952409790291163
 33. Azad AK, Rasul MG, Yusaf T. Statistical diagnosis of the best Weibull methods for wind power assessment for agricultural applications. *Energies.* 2014; 7(5): 3056-3085. doi:10.3390/en7053056
 34. Cetinay H, Kuipers FA, Guven AN. Optimal siting and sizing of wind farms. *Renew Energy.* 2017; 101: 51-58. doi:10.1016/j.renene.2016.08.008
 35. Saberi Z, Fudholi A, Sopian K. Fitting of Weibull

- distribution method to analysis wind energy potential at Kuala Terengganu, Malaysia. J Adv Res Fluid Mech Therm Sci. 2020; 66(1): 1-11.
36. Marih S, Ghomri L, Bekkouche B. Evaluation of the wind potential and optimal design of a wind farm in the arzew industrial zone in Western Algeria. Int J Renew En Dev. 2020; 9(2): 177-187. doi:10.14710/ijred.9.2.177-187
37. Ouarda T B M J, Charron C, Shin J Y, Marpu P R, Al-Mandoos A H, Al-Tamimi M H, et al. Probability distributions of wind speed in the UAE. Energy Convers Manag. 2015; 93: 414-434. doi:10.1016/j.enconman.2015.01.036
38. Wais P. Two and three-parameter Weibull distribution in available wind power analysis. Renew Energy. 2016; 103: 15-29. doi:10.1016/j.renene.2016.10.041

تحديد بيانات السرعة المثلى للمتوسط الزمني لسرعة الرياح في الجزء الجنوبي من ماليزيا

دانيال ديروم^{1,4*} حليم رزالي¹ احمد فضليزان¹ الياس جدي² كاتي بورفيس روبرتس³

¹ معهد أبحاث الطاقة الشمسية ، جامعة كيبانغسان ماليزيا ، بانجي سيلانجور ماليزيا
² كلية الهندسة والبيئة المبنية ، جامعة كيبانغسان ماليزيا ، بانجي سيلانجور ماليزيا
³ قسم العلوم في كليرمونت ماكيننا وبيتزر وسكريبس ، N. Mills Ave 925. كليرمونت ، كاليفورنيا 91711
⁴ قسم الرياضيات والعلوم والحاسوب ، بوليتكنيك سلطان إدريس شاه ، ماليزيا

الخلاصة:

ميرسينغ هي واحدة من الأماكن التي لديها إمكانية تطوير طاقة الرياح في ماليزيا. غالبًا ما يقترح الباحثون أنه مكان مثالي لتوليد الكهرباء من طاقة الرياح. ومع ذلك ، قبل اختيار الموقع ، يجب مراعاة عدة عوامل. من خلال تحليل الموقع في وقت مبكر ، يمكن تجنب إهدار الموارد ويمكن تحقيق أقصى قدر من الربحية لمختلف الأطراف. في هذه الدراسة ، يتم التركيز على تحديد توزيع سرعة الرياح في ميرسينغ وتحديد المتوسط الأمثل لسرعة الرياح. هذه الدراسة مهمة لأن بيانات سرعة الرياح لأي منطقة لها توزيعها. يتغير يوميًا وحسب الموسم. علاوة على ذلك ، لم يتم إجراء أي تحديد فيما يتعلق باختيار متوسط سرعة الرياح التي يمكن استخدامها لدراسات الرياح. يتم حساب متوسط بيانات سرعة الرياح إلى دقيقة واحدة و 10 دقائق و 30 دقيقة و 60 دقيقة وتستخدم للعثور على متوسط سرعة الرياح الأمثل. استخدمت هذه الدراسة كل من توزيع Kolmogorov-Smirnov و Chi-Square كملاءمة جيدة. تظهر النتائج أن توزيع سرعة الرياح في ميرسينغ يختلف باختلاف متوسط الوقت المستخدم وأفضل توزيع مناسب هو Gen. Gamma. في المقابل ، متوسط سرعة الرياح الأمثل هو 10 دقائق بسبب أعلى نتائج تشابه مع بيانات دقيقة واحدة تؤثر هذه على موثوقية النتيجة ودقة التقدير والقرارات المتخذة. لذلك فإن تنفيذ هذه الدراسة مهم بحيث يكون توزيع الرياح في منطقة معينة أكثر دقة.

الكلمات المفتاحية: التوزيع ، الطاقة المتجددة ، متوسط الوقت ، طاقة الرياح ، سرعة الرياح