Data Article

Wind shear data at two different terrain types

Aliashim Albani a, b, Mohd Zamri Ibrahim a, b, *, Kim Hwang Yong a, b

a Eastern Corridor Renewable Energy (ECRE), Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia
b Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia

A R T I C L E   I N F O

Article history:
Received 5 June 2019
Received in revised form 12 July 2019
Accepted 16 July 2019
Available online 24 July 2019

Keywords:
Wind shear
Wind energy
Extrapolation
Malaysia

A B S T R A C T

The measurement of this data aims to evaluate the wind shear variability at three selected sites in Malaysia. The sites are Kudat in Sabah, Kijal in Terengganu and Langkawi in Kedah. Both sites in Kudat and Kijal is located in coastal areas with few buildings or trees, while the site in Langkawi is a coastal area with many buildings or trees. The variables were measured using the sensors that mounted on the wind mast with the maximum height from 55 m to 70 m from ground level. The variables measured were wind speed, wind direction, temperature, and pressure, while the wind shear data were directly generated using the power law equation. The averaged wind shear based on measured multiple height wind speed at selected sites is larger than the 1/7 law (0.143). Also, the value of wind shear was higher in order Langkawi > Kudat > Kijal. Ultimately, the wind shear data are essential and can be reused in the wind energy potential study, especially for data extrapolation to desired wind turbine hub height.

© 2019 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
Four variables were measured using the different sensors, which mounted on the same mast tower. Some wind masts have two or three variables, as not all of them have all four variables. However, all measurement masts should have important variable wind speed and direction. Also, essential data, namely as wind shear, was directly computed using the power law equation (See Eq. (1)).

The description of filtered and analyzed data was presented in Tables 1–5, and Figs. 1 and 2. The following are measured and computed variables:

a. Wind Speed

The wind speed is measured using the mechanical RNRG 40C model of anemometer, which commercially designed with three conical-shaped cups mounted on short arms connected to a rotating vertical shaft. The three-cup anemometer chosen as this design has a more uniform torque throughout a revolution. The anemometer rotates by the wind and generates a signal proportional to wind speed in meter per second.

b. Wind Direction

Wind direction defined as the direction from which the wind speed is coming from, and it is measured in degrees clockwise from true north. It is measured by an RNRG 200P model of wind vane, which consists of a tail attached to one end of a horizontal shaft.
c. Temperature

Ambient temperature is measured using the NRG 110S model of the temperature sensor. The temperature data were used to calculate air density.

Table 1
The coordinates, heights of the wind masts, and the period of data for every selected site.

| Station Sites and Coordinates | Data Parameters, Heights and Accuracies | Measurement Periods, Number of Data and Data Recovery | Sites Descriptions |
|-------------------------------|------------------------------------------|------------------------------------------------------|-------------------|
| Kudat (7°1’45.33” N, 116°44’47.98” E) | Wind speed, 10 m, (±0.4 m/s) Wind speed, 35 m, (±0.4 m/s) Wind speed, 50 m, (±0.4 m/s) Wind speed, 70 m, (±0.4 m/s) Wind direction, 10 m, (±1°) Wind direction, 70 m, (±1°) Temperature, 10 m, (±0.5 °C) Pressure, 10 m, (±0.5 mbar) | May 2014—April 2015 (12 Months) Recovery: 99% | Coastal, few buildings/trees Located at a site facing the ocean wind from West (W) to South (S) direction. Few trees observed on the North (N) and the East (E), where the surface wind speed was predominantly blowing. |
| Kijal (4°20’50.70” N, 103°28’34.74” E) | Wind speed, 10 m, (±0.4 m/s) Wind speed, 15 m, (±0.4 m/s) Wind speed, 40 m, (±0.4 m/s) Wind speed, 55 m, (±0.4 m/s) Wind direction, 10 m, (±1°) Wind direction, 55 m, (±1°) Temperature, 10 m, (±0.5 °C) Pressure, 10 m, (±0.5 mbar) | May 2013—April 2014 (12 Months) Recovery: 99% | Coastal, few buildings/trees Located at a site facing the ocean wind from North (N) to East (E) direction. However, a few trees and buildings observed on the South (S) and the West (W), where the surface wind speed was predominantly blowing. |
| Langkawi 6°21’37.92” N, 99°41’16.62” E | Wind speed 10 m (±0.4 m/s) Wind speed 30 m (±0.4 m/s) Wind speed 40 m (±0.4 m/s) Wind speed 70 m (±0.4 m/s) Wind direction 10 m (±1°) Wind direction 70 m (±1°) Temperature 10 m (±0.5 °C) Pressure 10 m (±0.5 mbar) | May 2014—April 2015 (12 Months) Recovery: 99% | Coastal, Many buildings/trees Located at a site facing the ocean wind from West (W) to North (N) direction. Many trees observed on the East (E) and the South (S), where the surface wind speed was predominantly blowing. |

Table 2
The statistical analysis of measured wind data.

| Sites | Height of wind mast | Averaged Temperature | Pressure | Air density | Scale parameter, c | Shape parameter, k | Averaged wind speed | Wind power density |
|-------|---------------------|----------------------|----------|-------------|--------------------|-------------------|-------------------|-------------------|
| Kudat | 10 m, 35 m, 50 m, and 70 m | 27.00 °C | 1007.00 mbar | 1.1688 kg/m³ | 10 m: 3.20 m/s | 10 m: 1.63 m/s | 10 m: 2.72 m/s | 10 m: 11.76 W/m² |
|       | 10 m, 15 m, 40 m, and 55 m | 27.10 °C | 987.40 mbar | 1.1661 kg/m³ | 10 m: 2.77 m/s | 10 m: 1.63 m/s | 10 m: 2.31 m/s | 10 m: 7.19 W/m² |
| Langkawi | 10 m, 30 m, 40 m, and 70 m | 28.20 °C | 990.00 mbar | 1.1445 kg/m³ | 10 m: 3.44 m/s | 10 m: 3.60 m/s | 10 m: 2.97 m/s | 10 m: 14.52 W/m² |
|       | 10 m, 30 m, 40 m, and 70 m | | | | 10 m: 3.81 m/s | 10 m: 3.60 m/s | 10 m: 3.29 m/s | 10 m: 10.53 W/m² |

A. Albani et al. / Data in brief 25 (2019) 104306
d. Pressure

Absolute pressure is measured using the NRG BP20 model of the barometric pressure sensor. The pressure data were used to calculate air density.

e. Wind shear

The wind shear, $z$, is generated by direct computation using the power law equation of two different heights of measured wind data.

2. Experimental design, materials, and methods

The selected sites are Kudat in Sabah, Kijal in Terengganu and Langkawi in Kedah, as shown in Fig. 1. The sites were selected based on field inspection trips and preliminary wind resource maps, which are developed using meteorological wind data. The selection of sites also considers the difficulties of access, the availability of grid connection, and the wind quality. At least one additional anemometer should be mounted on the tower to generate the wind shear. The mounting of these additional
eliminated are listed as the following [4]:

checks and other screening criteria are revised based on experience. The criteria of data that would be
threshold or local atmospheric historical data. As an example, it is impossible to obtain a negative value
comparisons of measured values to upper and lower limits; these limits may be the instrument
module in WindPRO program [3]. Generally, the procedures of data screening and validation include
September).

monsoonal seasons; (i) Northeast Monsoon (October to March), and (ii) Southwest Monsoon (May to
speed. The wind data were measured using the NRG System equipment, which is a technology from the
Higher measurement heights will reduce the uncertainty of the vertical extrapolation of the wind
maximum height of wind mast tower is different for every site, ranging from 55 m to 70 m (m.a.g.l).

anemometer follows the IEC 61400-12-1 [1], as well as a recommendation in the IEA guidelines [2]. The
maximum height of wind mast tower is different for every site, ranging from 55 m to 70 m (m.a.g.l).

The quality of the measured data was assured by data screening and validation using the Meteo
module in WindPRO program [3]. Generally, the procedures of data screening and validation include
comparisons of measured values to upper and lower limits; these limits may be the instrument
threshold or local atmospheric historical data. As an example, it is impossible to obtain a negative value
of temperature in Malaysia as it is located in the equator line. Thus, those invalid data would be
considered to be eliminated from the datasets. The screening is an iterative process in which range
checks and other screening criteria are revised based on experience. The criteria of data that would be
eliminated are listed as the following [4]:

| Month   | 10m/15m | 10m/40m | 10m/55m | 15m/40m | 15m/55m | 40m/55m |
|---------|---------|---------|---------|---------|---------|---------|
| January | 0.67 ± 0.12 | 0.25 ± 0.03 | 0.32 ± 0.02 | 0.08 ± 0.04 | 0.21 ± 0.03 | 0.61 ± 0.01 |
| February| 0.58 ± 0.17 | 0.26 ± 0.04 | 0.33 ± 0.05 | 0.13 ± 0.06 | 0.25 ± 0.05 | 0.60 ± 0.23 |
| March   | 0.59 ± 0.19 | 0.29 ± 0.06 | 0.35 ± 0.05 | 0.17 ± 0.07 | 0.28 ± 0.05 | 0.59 ± 0.20 |
| April   | 0.67 ± 0.17 | 0.32 ± 0.06 | 0.37 ± 0.05 | 0.17 ± 0.08 | 0.27 ± 0.07 | 0.58 ± 0.38 |
| May     | 0.12 ± 0.23 | 0.20 ± 0.07 | 0.30 ± 0.04 | 0.23 ± 0.09 | 0.36 ± 0.06 | 0.76 ± 0.35 |
| June    | 0.10 ± 0.22 | 0.22 ± 0.05 | 0.25 ± 0.05 | 0.27 ± 0.09 | 0.30 ± 0.06 | 0.39 ± 0.17 |
| July    | 0.56 ± 0.16 | 0.25 ± 0.04 | 0.29 ± 0.04 | 0.13 ± 0.07 | 0.21 ± 0.05 | 0.47 ± 0.16 |
| August  | 0.62 ± 0.20 | 0.24 ± 0.05 | 0.29 ± 0.04 | 0.08 ± 0.05 | 0.19 ± 0.04 | 0.55 ± 0.13 |
| September| 0.68 ± 0.21 | 0.25 ± 0.07 | 0.30 ± 0.06 | 0.07 ± 0.08 | 0.18 ± 0.05 | 0.53 ± 0.15 |
| October | 0.60 ± 0.21 | 0.28 ± 0.07 | 0.30 ± 0.05 | 0.15 ± 0.08 | 0.21 ± 0.06 | 0.42 ± 0.19 |
| November| 0.74 ± 0.20 | 0.34 ± 0.07 | 0.36 ± 0.05 | 0.17 ± 0.08 | 0.24 ± 0.07 | 0.45 ± 0.17 |
| December| 0.70 ± 0.24 | 0.33 ± 0.07 | 0.37 ± 0.05 | 0.17 ± 0.09 | 0.27 ± 0.07 | 0.58 ± 0.16 |
Table 5
The diurnal and monthly wind shear in Langkawi, Kedah (Coastal, Many buildings/trees).

| Month      | 10m/30m  | 10m/40m  | 10m/70m  | 30m/40m  | 30m/70m  | 40m/70m  |
|------------|----------|----------|----------|----------|----------|----------|
| January    | 0.67 ± 0.07 | 0.68 ± 0.05 | 0.59 ± 0.04 | 0.71 ± 0.19 | 0.48 ± 0.09 | 0.36 ± 0.07 |
| February   | 0.62 ± 0.05 | 0.64 ± 0.05 | 0.56 ± 0.05 | 0.72 ± 0.23 | 0.48 ± 0.11 | 0.35 ± 0.11 |
| March      | 0.57 ± 0.06 | 0.59 ± 0.06 | 0.51 ± 0.04 | 0.64 ± 0.32 | 0.42 ± 0.09 | 0.31 ± 0.17 |
| April      | 0.57 ± 0.11 | 0.59 ± 0.10 | 0.52 ± 0.05 | 0.65 ± 0.40 | 0.45 ± 0.13 | 0.34 ± 0.20 |
| May        | 0.55 ± 0.12 | 0.58 ± 0.10 | 0.50 ± 0.06 | 0.69 ± 0.40 | 0.43 ± 0.14 | 0.30 ± 0.20 |
| June       | 0.45 ± 0.14 | 0.60 ± 0.08 | 0.50 ± 0.07 | 1.19 ± 0.52 | 0.57 ± 0.15 | 0.26 ± 0.20 |
| July       | 0.53 ± 0.11 | 0.57 ± 0.08 | 0.48 ± 0.06 | 0.70 ± 0.37 | 0.42 ± 0.11 | 0.28 ± 0.16 |
| August     | 0.55 ± 0.12 | 0.57 ± 0.12 | 0.51 ± 0.07 | 0.68 ± 0.40 | 0.46 ± 0.12 | 0.35 ± 0.19 |
| September  | 0.57 ± 0.12 | 0.61 ± 0.08 | 0.51 ± 0.07 | 0.77 ± 0.43 | 0.44 ± 0.15 | 0.27 ± 0.20 |
| October    | 0.53 ± 0.11 | 0.60 ± 0.09 | 0.49 ± 0.06 | 0.85 ± 0.50 | 0.45 ± 0.15 | 0.24 ± 0.20 |
| November   | 0.66 ± 0.10 | 0.66 ± 0.08 | 0.57 ± 0.06 | 0.66 ± 0.33 | 0.45 ± 0.11 | 0.34 ± 0.15 |
| December   | 0.74 ± 0.08 | 0.73 ± 0.08 | 0.63 ± 0.04 | 0.70 ± 0.27 | 0.48 ± 0.09 | 0.37 ± 0.19 |

Fig. 1. Map showing the selected sites.
a. The wind speed value is less than zero or greater than 25 m/s.

b. The wind direction is less than zero or greater than 360°.

c. The temperature value is greater than the local record high, which is the local maximum temperature of 35 °C and less than the local record low, which is the local minimum temperature of 10 °C.

d. The pressure value is greater than 1060 mbar (sea level) and less than 940 mbar (sea level).

The data are checked and validated every month to detect possible defects in time and to limit any data losses. The data validation was employed based on methods suggested by Refs. [5,6]. The missing data and outliers would affect the result of wind resource assessment [7]. The statistical analysis of measured data was presented in Table 2. The data analysis and plotting were conducted in MATLAB program.

The Hellmann Power Law is the most frequent model to determine the wind shear, which is used in several wind shear studies [8–13]. The following is the Hellmann Power Law to determine wind shear, α:

$$\alpha = \frac{\ln \left( \frac{\nu_2}{\nu_1} \right)}{\ln \left( \frac{z_2}{z_1} \right)}$$  \hspace{1cm} (1)$$

The extrapolation of wind speed data measured at a certain height to desired hub height of wind turbine is a point of interest to many wind energy applications. The extrapolation of wind speed data to different heights varies considerably, depending on whether the extrapolation is conducted over
complex or relatively flat terrain type. To do extrapolation, the proper estimation of wind shears was needed to reduce the inaccuracy of extrapolation results. The wind shear is the variation of wind speed with elevation. It is generally accepted that as terrain complexities (ruggedness) increase, the value of wind shear also increases. As presented by Ref. [13], the average wind shear for open and flat terrain type is up to 0.19, for few trees or buildings (0.24–0.43) and many trees or buildings (0.48 and above). The wind shear that generated by direct computation using wind data at two different heights were presented in Table 3 to Table 5 and Fig. 2. The diurnal and monthly wind shear were analyzed and found that the value is too large or negative. This phenomenon occurred because wind speed data at each altitude is variable, sometimes data at high altitude is lower than low altitudes. Accordingly, the best approach to determine wind shear was by averaging all of the value, which is also known as the overall mean averaging method [14]. The averaged wind shear for Kudat, Kijal and Langkawi are 0.38, 0.25 and 0.48 respectively. The averaged wind shear based on measured multiple height wind speed is larger than the 1/7 Law (0.143). The 1/7 Law (0.143) was introduced by Frost in 1974, and is the standard value used for data extrapolation for single height anemometer. It is a common practice among Malaysian researchers to use 1/7 Law (0.143) as the wind shear to determine the value of wind speed for the desired heights [15–19]. This practice leads to the inaccuracy of result data.

Acknowledgments

The authors would like to thank the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) for providing a research Technofund (Vot. 51002) and MOHE Fundamental Research Grant Scheme (FRGS), grant number (Vot. 59440).

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2019.104306.

References

[1] IEC, IEC61400-12-1 Wind Turbines-Part 12-1: Power Performance Measurement of Electricity Producing Wind Turbines, first ed., 2005, 2005.
[2] IEA, IEA Recommendation 11: Wind Speed Measurement and Use of Cup Anemometry, vol. 1, 1999.
[3] EMD, WINDPRO: METEO, EMD Int. A/S. (n.d.). https://www.emd.dk/windpro/windpro-modules/energy-modules/meteo/ (accessed July 1, 2019).
[4] USEPA, Meteorological Monitoring Guidance for Regulatory Modeling Applications, United States Environ. Prot. Agency, EPA-454/R-99-005, 2000. http://www.epa.gov/scram001/guidance/met/mngmrma.pdf. (Accessed 2 March 2015).
[5] P.K. Mueller, J.G. Watson, Eastern Regional Air Quality Measurements, Palo Alto, CA, 1982.
[6] J.G. Watson, P.J. Lioy, P.K. Mueller, The measurement process: precision, accuracy, and validity, in: Am. Conf. Gov. Ind. Hyg. Cincinnati, OH, 1989, pp. 51–57.
[7] W. Wettayaprasit, N. Laosen, S. Chevakidagarn, Data filtering technique for neural network forecasting, .. in: 7th WSEAS Int. Conf. Simulation, Model. Optim. Beijing, China, Sept. 15–17, 2007, 2007.
[8] H. Kikumoto, R. Ooka, H. Sugawara, J. Lim, Observational study of power law approximation of wind profiles within an urban boundary layer for various wind conditions, J. Wind Eng. Ind. Aerodyn. 164 (2017) 13–21, https://doi.org/10.1016/j. jweia.2017.02.003.
[9] S. Jung, O. Arda Vanli, S.-D. Kwon, Wind energy potential assessment considering the uncertainties due to limited data, Appl. Energy 102 (2013) 1492–1503, https://doi.org/10.1016/j.apenergy.2012.09.011.
[10] F. Rauhuelos-ruedas, C.A. Camacho, Methodologies used in the extrapolation of wind speed data at different heights and its impact in the wind energy resource assessment in a region, in: Wind Farm – Tech. Regul. Potential Estim. Siting Assess., InTech, Croatia, 2011, pp. 97–144.
[11] S. Rehman, N.M. Al-Abbadi, Wind shear coefficient, turbulence intensity and wind power potential assessment for Dhu-lom, Saudi Arabia, Renew. Energy 33 (2008) 2653–2660.
[12] M. Hussain, Dependence of power law index on surface wind speed, Energy Convers. Manag. 43 (2002) 467–472, https://doi.org/10.1016/S0196-8904(01)00332-2.
[13] S. Hsu, Determining the power-law wind-profile exponent under near-neutral stability conditions at sea.pdf, J. Appl. Meteorol. 33 (1993) 757–765.
[14] M.L. Ray, A.L. Rogers, J.G. Mcgowan, Analysis of Wind Shear Models and Trends in Different Terrains, Amherst, MA, USA, 2006.

[15] A. Albani, M. Ibrahim, K. Yong, The feasibility study of offshore wind energy potential in Kijal, Malaysia: the new alternative energy source exploration in Malaysia, Energy Explor. Exploit. 32 (2014), https://doi.org/10.1260/0144-5987.32.2.329.

[16] A. Albani, M.Z. Ibrahim, An assessment of wind energy potential for selected sites in Malaysia using feed-in tariff criteria, Wind Eng. 38 (2014), https://doi.org/10.1260/0309-524X.38.3.249.

[17] A. Albani, M.Z. Ibrahim, C.M.I.C. Taib, A.A. Azlina, The optimal generation cost-based tariff rates for onshore wind energy in Malaysia, Energies 10 (2017), https://doi.org/10.3390/en10081114.

[18] A. Albani, M.Z. Ibrahim, Wind energy potential and power law indexes assessment for selected near-coastal sites in Malaysia, Energies 10 (2017) 1–21, https://doi.org/10.3390/en10030207.

[19] M.Z. Ibrahim, A. Albani, Wind turbine rank method for a wind park scenario, World J Eng 13 (2016) 500–508, https://doi.org/10.1108/WJE-09-2016-0083.