Evaluation of Wind Shear at Three Selected Windy Sites in Malaysia

Aliashim Albani, Mohd Zamri Ibrahim, Kim Hwang Yong

Eastern Corridor Renewable Energy (ECRE)

School of Ocean Engineering, Universiti Malaysia Terengganu

Presentation Outline

- Motivation
- Introduction
- Methodology
- Result & Discussion
- Conclusion

Motivation

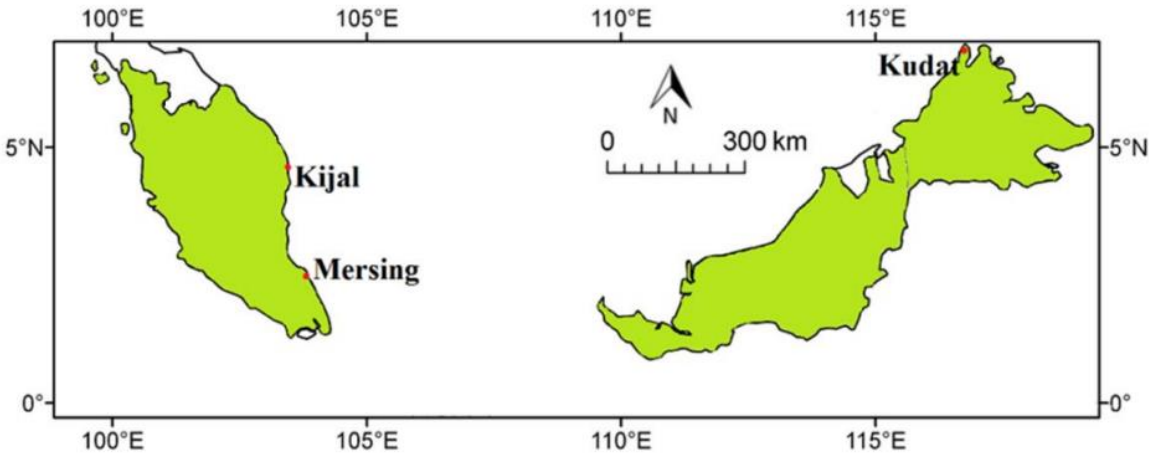
- The wind turbine has **the specific hub height**, from 30 m to 100 m
- Usually the available wind data were measured at single height, e.g. 10 m.a.g.l etc., includes purchased data from Malaysia Meteorological Department
- Thus, the wind data will be vertically predicted or extrapolated to the desired height of wind turbine hub-height.
- Commonly, the method used for extrapolation is a power law equation.
- Inside the power law equation, there is one coefficient that is very crucial during the extrapolation. It is known as **wind shear** or power law index.

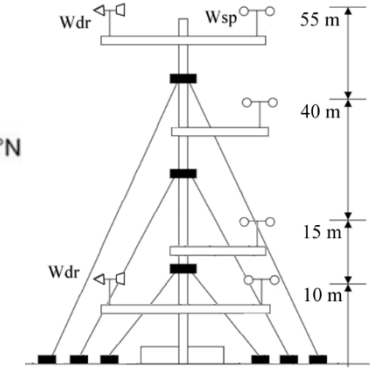
Introduction

- This paper investigated the wind energy potential by analysing a certain amount of gathered 10-min measured data at 3 stations located at coastal sites in Malaysia, i.e., **Kudat, Mersing, and Kijal**
- The wind data are collected from a total of **3 wind measurement masts** with sensors mounted at various heights on the tower. The measured data have enabled the establishment of wind resource maps and the power law indexes (PLIs) analysis.
- In addition, the **dependence of PLI upon surface temperature** is studied, as they are associated to the form of exponential fits.
- Moreover, the accuracy of exponential fit is assessed by comparing the results with the 1/7 law via the **capacity factor (CF) discrepancies**.
- In order to do so, the wind turbine with a hub-height similar to the maximum height of the measured data at each site is selected to simulate energy production. Accordingly, the discrepancy of CF based on the extrapolated data by employing 1/7 laws and exponential fits, in spite of being computed using measured data, is determined as well.

Methodology

Station sites and coordinates	Data parameters & heights	Measurement periods
Kudat **7˚ 1' 45.33" N** **116˚ 44' 47.98" E**	Wind speed, 10 m Wind speed, 35 m Wind speed, 50 m Wind speed, 70 m Wind direction, 10 m Wind direction, 70 m Temperature, 10 m	1 October 2012 - 31 May 2015 (32 Months)
Mersing **2˚ 34' 50.00" N** **103˚ 48' 23.60" E**	Wind speed, 10 m Wind speed, 20 m Wind speed, 40 m Wind speed, 60 m Wind direction, 60 m Temperature, 10 m	1 October 2012 - 31 May 2015 (32 Months)
Kijal **4˚ 20' 50.70" N** **103˚ 28' 34.74" E**	Wind speed, 10 m Wind speed, 15 m Wind speed, 40 m Wind speed, 55 m Wind direction, 10 m Wind direction, 55 m Temperature, 10 m	1 April 2013 - 31 January 2015 (22 Months)





- Wind measurement masts with different heights (m.a.g.l) were installed at 3 selected sites; Kudat, Kijal, and Mersing.
- The recorded data were collected and temporarily stored in a field station. After that, each 10-min averaged data was transmitted to the monitoring station located at Universiti Malaysia Terengganu, where the data were processed and analysed.
- Moreover, the data that had been collected at 10-min averaged values displayed varied periods and number of data for different sites.

Methodology

Wind shear:

$$v_2 = v_1\left(\frac{z_2}{z_1}\right)^{\alpha} \qquad \alpha = \frac{\ln\left(\frac{v_2}{v_1}\right)}{\ln\left(\frac{z_1}{z_2}\right)}$$

Energy computation:

Power:

$$p(v)_{pitch} = \mathrm{P_r} \times \begin{cases} 0 & v < v_c \text{ or } v > v_f \\ \left(\sum_{i=0}^{n} a_i v^i\right)_{asc} & v_c \le v \le v_r \\ 1 & v_r \le v \le v_f \end{cases}$$

Energy:

$$AEP_{pitch} = \mathrm{P_r}\int_{V_c}^{V_r}\left(\sum_{i=0}^{n} a_i v^i\right) f(v)dv + \mathrm{P_r}\int_{V_r}^{V_f} f(v)dv$$

The specification of four selected wind turbines.

Sites	WTG	P_r (kW)	z (m)	RD (m)	v_c (m/s)	v_r (m/s)
Kudat	Dewind D4/48-600	600	70.0	48.0	3.0	12.0
Mersing	Unison U54-750	750	60.0	54.0	3.0	12.0
Kijal	Gamesa G58-850	850	55.0	58.0	3.0	12.0

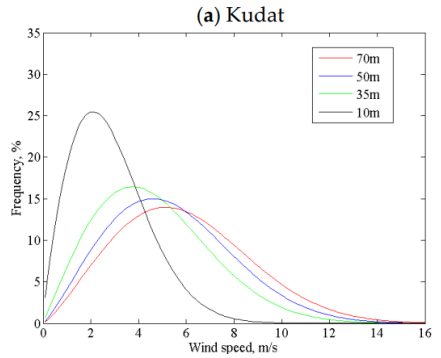
WTG: Wind turbine model; P_r: Wind turbine rated power; z: The hub height of wind turbine; RD: Rotor diameter; v_c: Cut-in wind speed; v_r: Rated wind speed

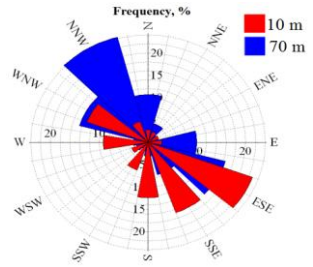
Result & Discussion

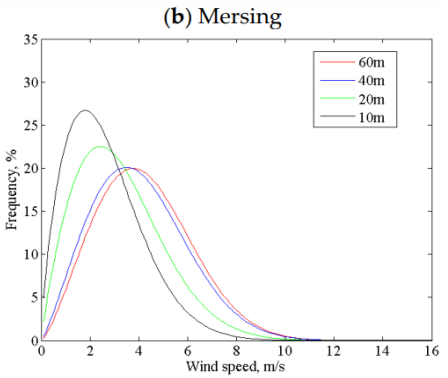
the statistical analysis of measured wind data

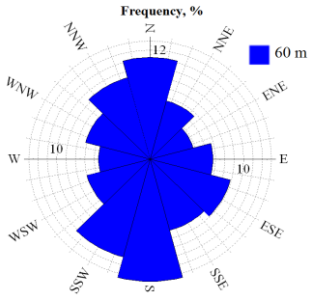
Sites	Heights, m	Temperature, ˚C	Air density, kg/m^3	Scale parameter, c, m/s	Shape parameter, k	Mean speed, m/s	Wind power density, W/m^2
Kudat	10	27.00	1.1688	3.20	1.84	2.72	11.76
	35			5.26	2.02	4.60	56.88
	50			6.08	2.19	5.32	87.99
	70			6.67	2.25	5.86	117.60
Mersing	10	27.00	1.1750*	2.95	1.73	2.47	8.85
	20			3.65	1.87	3.18	18.89
	40			4.58	2.21	4.06	39.32
	60			4.79	2.33	4.24	44.78
Kijal	10	27.1	1.1661	2.77	1.76	2.31	7.19
	15			3.44	1.78	2.92	14.52
	40			3.81	1.81	3.37	22.31
	55			4.57	1.78	4.02	37.88

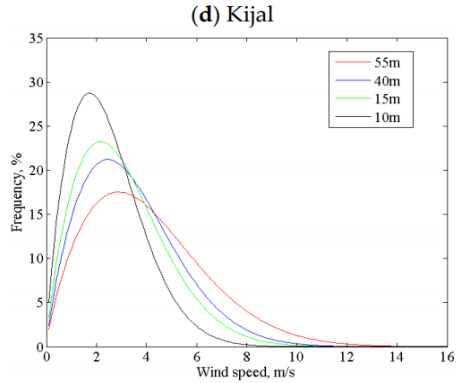
*The air density computed using the WAsP Air Density Calculator, with 10 m altitude

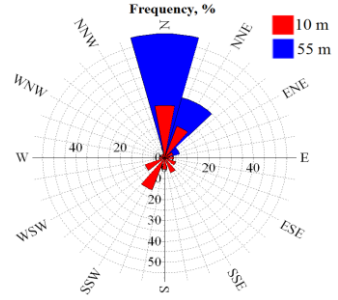




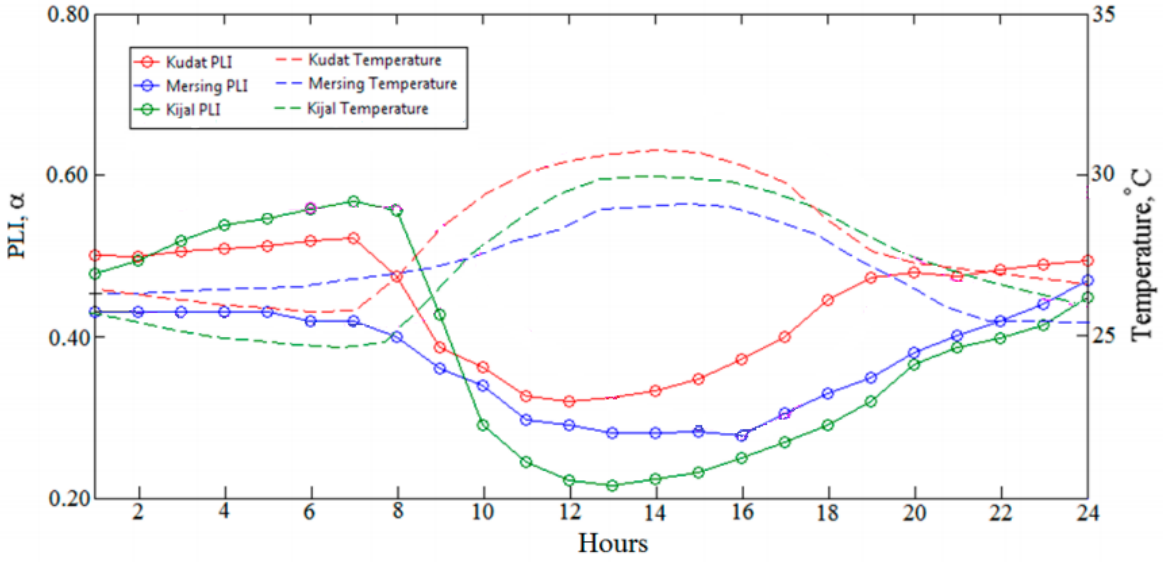


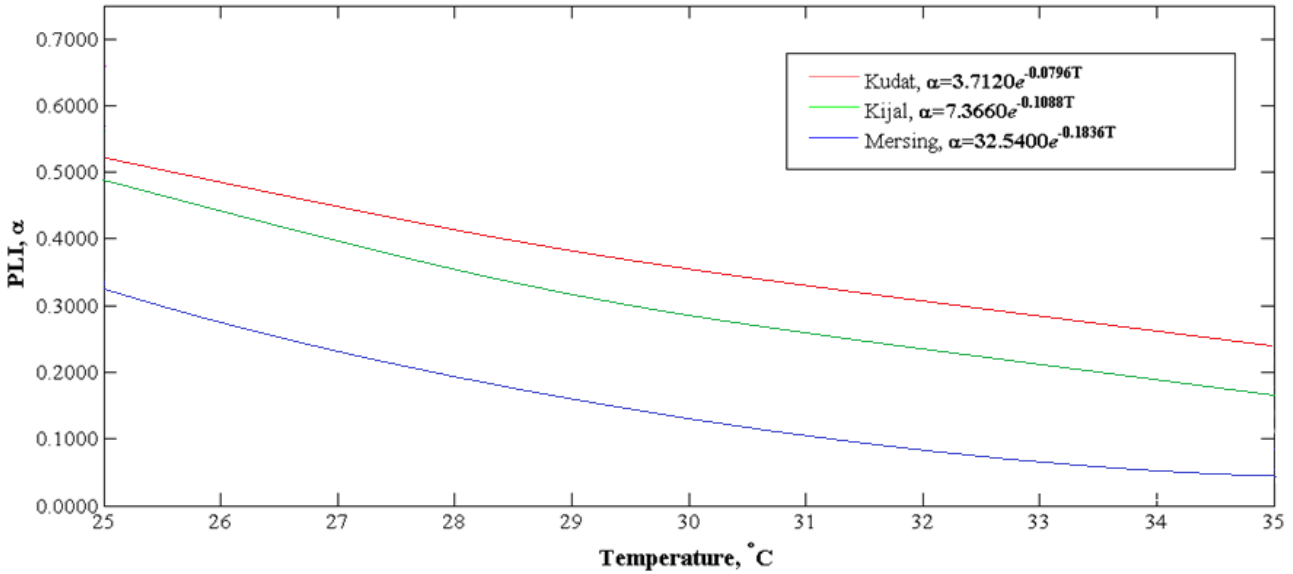






The diurnal variation of PLI





The PLI is higher during the night stable conditions, but it starts to reduce after sunrise. These lowest values remain all day, but begin to rise during the evening, as the air above the ground starts to cool with unstable conditions slowly turning into neutral and then, into stable ones.

Sites	Mean PLI	Terrain Type	Exponential Fit
Kudat	0.38	Coastal, few buildings/trees	$\alpha = 3.7120e^{-7.9600\times10^{-2}\,T}$
Kijal	0.25	Coastal, few buildings/trees	$\alpha = 7.3660e^{-1.0880\times10^{-1}\,T}$
Mersing	0.20	Coastal, flat	$\alpha = 32.5400e^{-1.8360\times10^{-1}\,T}$

Wind resource and energy yield parameters calculated at **70 m** by the **Kudat** site using a single **600-kW** rated power Dewind D4/48-600 wind turbine.

Parameters	Wind Data		
	Measured	1/7 Law, $\alpha = 0.143$	Exponential Fit, $\alpha = 3.7120e^{-7.9600\times10^{-2}\,T}$
v, m/s	6.06	3.78	6.22
AEP, MWh/year	1156.85	399.46	1240.42
CF, %	22.01	7.60	23.60
FLH, hour/year	1928.08	665.76	2067.36
GHG, Tonne CO_2/Year	763.52	263.64	818.68

Wind resource and energy yield parameters calculated at **60 m** by the **Mersing** site using a single **750-kW** rated power Unison U54-750 wind turbine.

Parameters	Wind Data		
	Measured	1/7 Law $\alpha = 0.143$	Exponential Fit, $\alpha = 32.5400e^{-1.8360\times10^{-1}\,T}$
v, m/s	5.89	5.06	6.07
AEP, MWh/year	1517.67	893.52	1550.52
CF, %	23.10	13.60	23.60
FLH, hour/year	2023.56	1191.36	2067.36
GHG, Tonne CO_2/Year	1001.66	589.72	1023.34

Wind resource and energy yield parameters calculated at **55 m** by the Kijal site using a single **850-kW rated power Gamesa G58-850** wind turbine.

Parameters	Wind Data		
	Measured	1/7 Law, $\alpha = 0.143$	Individual Fit, $\alpha = 7.3660e^{-1.0880\times10^{-1}\,T}$
v, m/s	4.81	3.21	4.98
AEP, MWh/year	1109.45	416.98	1399.85
CF, %	14.90	5.60	18.80
FLH, hour/year	1305.24	490.56	1646.88
GHG, Tonne CO_2/Year	732.24	275.21	923.90

v: Mean wind speed; **AEP:** Annual Energy Production; **CF:** Capacity factor; **FLH:** Full load hours; **GHG:** Greenhouse gases emission saving.

Conclusion

- The wind shear, which is associated to temperature, displayed exponential fit for all the stations tested under the present study. Besides, parameters A and b depend on the location. The exponential fit were found to offer good estimation of wind shear. Meanwhile, the 1/7 law showed larger discrepancy of wind speed value prediction; leading to a huge error in energy estimation.
- The large discrepancy of the wind data and the CF, which has been determined with the application of 1/7, is compared to the exponential fits. This is because; discrepancy in estimation of vertical wind speed could lead to inaccurate CF computation. Meanwhile, from the energy potential analysis based on the computed CF, only Kudat and Mersing display a promising potential to develop a medium capacity of wind turbine power, while the other sites may be suitable for wind turbines at a small scale

UNIVERSITI MALAYSIA TERENGGANU

UMT

TERIMA KASIH / *THANK YOU*

www.umt.edu.my

OfficialUMT