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A Study on Horizontal Axis Wind Turbine and Vertical Axis Wind Turbine Effectiveness in Malaysia

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Abstract:

Wind are one of the sources of renewable energy that were widely used around the world especially in the Western and European countries as their wind speed are relatively high. In this study, wind energy performances are analysed and evaluated with the low wind speed in Malaysia. Low wind speed condition in Malaysia is vital in determining the wind turbines performance. A comparative study of horizontal axis wind turbine (HAWT) and vertical axis wind turbines (VAWT) applications were carried out and concluded that VAWT is the most suitable machine to be applied in Malaysia. The wind speed data for several cities in Malaysia were gathered using RetScreen software. Four small wind turbine commercial models were selected, and the output power curve were recorded. The power curves were compared between cities with monthly mean wind speed data to determine the power generated from the wind turbine models. The results showed Langkawi has the highest annual wind speed and capable to produce 800W of power in December to January. This power was produced by ReDriven wind turbines.

Keywords: *Renewable energy, Wind energy, Low wind speed, Wind power generation*

I. INTRODUCTION

WIND are a blow of air that occurs by the form of solar energy. The uneven heat that heated the atmosphere air by the sun causes the by the variations of the earths surfaces, the earths rotations are the causes of wind energy occurs. The strength of the winds depends on the locations of the earth that was the elevations, the moisture content of the air and vegetative cover. This wind flow or airflow energy can be utilized and convert into electrical energy that are very clean with no pollution.

Mechanical energy from the rotational movement of the shaft that was connected to the blades of the turbine are generated from the wind. Mechanical energy is then converted to electrical energy as the turbine shaft connected to the generator. The higher the velocity of the wind, the higher the rotational of the shaft thus the electrical energy produced. The air foil shaped of the blades assist the rotational movement as the blades generate lift from the air foil shape to exerts a turning force. The present of gearbox can also assist the power production, this enable the wind turbine to adjust the speed of the generator in order to have the optimum speed required.

This paper is arranged as the following, the introduction is given in I, the project background is explained in II, the methods are described in III, results are shown in IV and discussed in V and the paper is concluded inVI.

II. BACKGROUND

Power generation system by using wind is one of the fastest renewable energy sources that are rapidly expanding in the world today, but this type of source has its own limitations on certain area of the world such as Malaysia. The situation of the terrain and geographical conditions of Malaysia that are currently having low wind speed mostly throughout the years making this renewable energy types are slow in its utilizations in Malaysia.

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A study on the background of the wind turbine situation in Malaysia was published by [1] in 2016. The paper presented the wind data in several cities in Malaysia and also discussed about the wind generation in countries in Europe and Asia. It stated that the wind energy generation in Malaysia is low and requires more support from the government. One of the reason is Malaysia is situated nearby the equator where the pressure is not as high as the high latitude countries. However, wind energy still has the potential to become one of the sustainable energy contributor in Malaysia.

Thus, the purpose of this project is to study on the efficiency of the HAWT and VAWT wind turbine for low wind speed in Malaysia. The importance of this study is it can benefit further research to identify the best wind turbine design that is suitable for low wind speed condition to produce optimum power with high efficiency.

III. Methods

The methods applied for this study is shown in the flowchart in Figure 1. Basically, the study is divided into two parts. Part A was the study of comparison between the application of HAWT and VAWT. This study includes several related aspects regarding both wind turbines types application in relatively low wind speed condition in Malaysia. The aspect in this comparative study was size, design, performances, overpower controls and the cost of the wind turbines. Part B described the simulation method used to study of the effectiveness of wind turbine in related to the wind speed in the area of the study that had been selected. Four types of wind turbine with different manufacturer and two different sites location were selected.

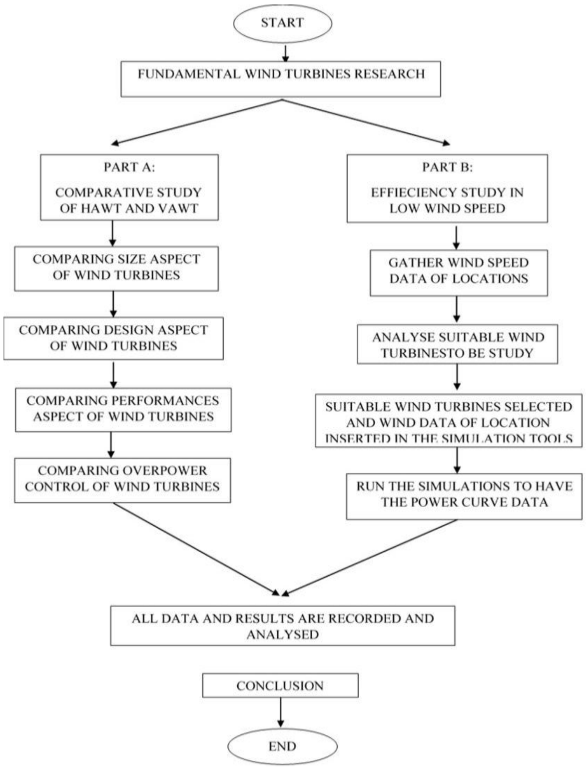

Figure 1 Flowchart for the study approach

A. *Part A*

A comparative study of three different wind turbines (HAWT, Derrieus and H-rotor) are being conducted for several important aspects of wind turbines this includes structural dynamics, control system, maintenance, manufacturing and electrical components. The wind turbine performance is represented in Eq 1:

$$P = \frac{1}{2}\rho A U^3 C_p \qquad (1)$$

where Cp is the power coefficient, ρ is the of air density, A is the swept area of the turbine and U is the wind speed. Cp plays major role in wind turbine power productions where it translates how much wind that had been absorbed by the turbine that can produce power. According to Betz, the maximum power coefficient is 0.59 for an ideal wind turbine which is called Betz Limit [2]. The Cp value for HAWT are usually between 0.4 and 0.5 [3], while the Cp for VAWT are hard to determine as they have various mechanical and turbines operating.

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But it is known that the Cp for VAWT is much lower compared to HAWT.

Therefore, the Cp value for VAWT are determined by theoretical studies and other experiments results that are in the range of 0.40, the VAWT Cp values are almost equal to the HAWT values after he conducted an extensive experimental and theoretical studies for these two wind turbines [4].

From S.Erikson studies [5], three different types of wind turbine which are H-rotor at 100kW, two-bladed wind turbine, a Derrieus turbine rated at 500kW are studied to determine the power curve of each wind turbine for three different data sources. All the turbines are operating at different optimum tip speed ratios that could affect the noise level.

Based on Figure 2 below, VAWT has almost equal efficiency value as HAWT. HAWTs slightly higher value of Cp may contributed by the greater design technologies available which causes better efficiencies. Equation (2) shows the relationship of λ;

$$\lambda = \frac{\omega R}{U} \qquad (2)$$

Where, λ is the tip speed ratio, ω is the rotational speed of the blade, R is the blade radius and U is the wind speed.

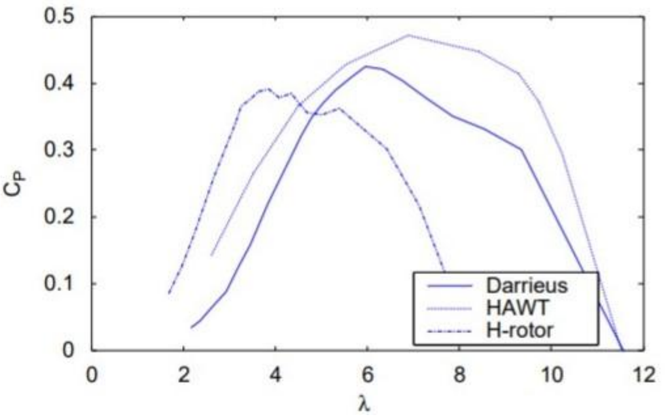

Figure 2 Relationship between Cp and tip speed ratio, λ

The size of HAWT are the largest due to the cyclically reversing gravity loads on the blades, which increases with an increasing turbine size. This is different for VAWT as the blades are not cyclically reversing gravity loads makes VAWTs are good alternative to HAWT. Apart from that, from the study of Riegler, VAWTs can be the main wind turbines in the areas where HAWT are not able to operate efficiently such as in the mountain areas or roof tops [6].

VAWT is designed with generator located at the bottom of the tower which makes installations, operations, and maintenance more convenient and less costly [7]. Without nacelle in VAWT causes tower to be lighter than HAWT thus reduce structure weight and difficulty during installation process. Thus, more room to design a generator that has the adequate efficiency, less cost and less maintenance as the size of the generator is not the main concern. Longer bending durations of H-rotor blades due to the centripetal acceleration. The bending durations suffer by the H-rotor turbines are longer than the Derrieus turbines due to its long and straight blades [8]. The effects of bending could be larger if the radius of turbine is smaller, since the centripetal acceleration increases with smaller turbine radius. HAWT blades are exposed to a gravity-induces reversing stress at the root of the blades, but for VAWT this issue does not present [9]. Wind shear causes a periodical load to the HAWT blades as these extra loads are also causes the blades to be fatigue.

Furthermore, VAWT have inherent torque ripple [10]. The constant changing of angle of attack between the blades and the wind are the main causes of this torque ripple. This causes fatigue to the blades and could reduce the life span of the drive train component of the wind turbines and producing lower quality output power. Aerodynamics stress on the blades that caused from continuous changes in angle of attack of blades are also contributes to the stress and fatigue to the blades [11]. The aluminum made blades were then replaced by better fatigue properties of composite blades today [7]. All the problems faced above are not applicable for HAWT as HAWT have a constant torque value.

B. Part B

In part B, four types of wind turbines were studied for selected location in Malaysia. The four types of wind turbines were Eoltec SAS, Endurance Wind Power, ReDriven and Wind Energy Solutions Canada. These were available in RetScreen software.

The simulated wind turbine is a small-scale wind turbine which has rated power range from 2.5kW to 6kW. The WES 5 Tulipo was manufactured by Wind Energy Solution Canada has the lowest rated power which at 2.5kW.

The selected locations were Subang International Airport, Kuala Lumpur and Kuah, Langkawi, and several other cities around Malaysia such as Ipoh, Bayan Lepas, Cukai, Seremban, Kudat, Limbang, Sri Aman and Kuching. Figure 3 and Figure 4 show the data for said locations. From the data provided by the National Aeronautics and Space Administration (NASA), the annual wind speed of Kuah, Langkawi is at 3.7 m/s. While the annual wind speed in Kuala Lumpur is at 1.1 m/s

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the monthly mean speed of the area is also provided for both locations.

Country		Malaysia	
Province/State			
Climate data location	See map	Kuah	
Latitude	°N	6.3	
Longitude	°E	99.8	Source
Climate zone	0A	Extremely hot - Humid	NASA
Elevation	m	18.1	NASA
Heating design temperature	°C	23.0	NASA
Cooling design temperature	°C	30.1	NASA
Earth temperature amplitude	°C	5.5	NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	27.2	77.5%	48.67	5.98	100.8	4.8	28.1	0	533
February	27.8	75.2%	47.04	6.46	100.8	4.1	28.8	0	498
March	28.3	76.0%	121.83	6.30	100.7	3.4	29.4	0	567
April	28.7	78.2%	171.60	5.95	100.7	2.8	29.8	0	561
May	28.6	79.7%	202.74	5.10	100.6	2.9	29.7	0	577
June	28.5	79.1%	172.50	4.94	100.6	3.2	29.7	0	555
July	28.2	79.2%	185.38	4.85	100.7	3.3	29.3	0	564
August	28.0	80.0%	213.28	4.80	100.7	3.6	29.2	0	558
September	27.6	81.6%	247.50	4.72	100.8	3.5	28.7	0	528
October	27.4	82.6%	280.24	4.52	100.8	3.5	28.5	0	539
November	27.4	82.7%	231.90	4.92	100.7	3.9	28.4	0	522
December	27.0	81.2%	140.12	5.29	100.8	5.0	28.0	0	527
Annual	**27.9**	**79.4%**	**2,062.80**	**5.31**	**100.7**	**3.7**	**29.0**	**0**	**6,530**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		

Figure 3 Annual wind distribution in Kuah

Country		Malaysia	
Province/State			
Climate data location	See map	Kuala Lumpur/Subang	
Latitude	°N	3.1	
Longitude	°E	101.6	Source
Climate zone	0A	Extremely hot - Humid	Ground+NASA
Elevation	m	22	Ground
Heating design temperature	°C	22.7	Ground
Cooling design temperature	°C	33.9	Ground
Earth temperature amplitude	°C	7.3	NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	26.1	79.8%	184.45	4.29	100.8	0.9	24.8	0	499
February	26.5	78.8%	166.60	4.80	100.8	1.1	25.3	0	462
March	26.8	79.7%	224.75	4.99	100.8	1.1	25.8	0	521
April	27.0	82.1%	240.60	4.77	100.7	1.0	26.2	0	510
May	27.2	81.2%	181.97	4.62	100.6	1.1	26.1	0	533
June	27.0	79.7%	128.70	4.47	100.7	1.2	25.6	0	510
July	26.6	79.5%	146.94	4.45	100.7	1.3	25.2	0	515
August	26.6	79.7%	168.95	4.48	100.7	1.3	25.3	0	515
September	26.4	81.0%	197.40	4.49	100.8	1.2	25.4	0	492
October	26.3	82.3%	247.69	4.55	100.8	1.2	25.5	0	505
November	26.1	84.3%	297.30	4.15	100.8	1.1	25.3	0	483
December	26.0	82.9%	256.37	4.05	100.8	0.9	24.9	0	496
Annual	**26.5**	**80.9%**	**2,441.72**	**4.51**	**100.7**	**1.1**	**25.4**	**0**	**6,041**
Source	Ground	Ground	NASA	Ground	Ground	Ground	NASA	Ground	Ground
Measured at					m	10	0		

Figure 4 Annual wind distribution in Subang

IV. RESULTS

In Part A, it stated that VAWT is an advantage compared to HAWT where H-rotor has a better prospect compare to the Derrieus turbine [5]. The simple structural design is the strength for H-rotor wind turbine. VAWT works better than HAWT in high intensity wind, for example at a rooftop, and area with gusty wind such as in hillside area. HAWTs are proven on the worldwide market but VAWT still needs its own time to prove to the world what it is worth in the renewable energy world and could be the turnover for wind turbine technology as it can provide a potential alternative.

In Part B, the simulation results showed that Kuala Lumpur has the lowest annual mean wind speed with 1.1 m/s, while Kuah, Langkawi has the highest annual mean wind speed in Malaysia with 3.7 m/s.

Based on Figure 5 below, monthly mean speed of Kuah are at its lowest in April recorded at 2.8 m/s. The speed increases from May to December with 5 m/s as the highest wind speed.

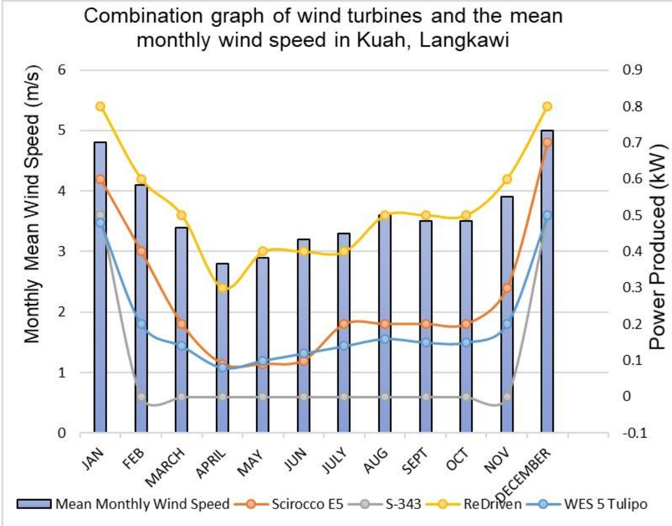

Figure 5 Combination graph of wind turbines and wind speed in Kuah.

Figure 6 to 9 are the results of the possible power generated by all the wind turbines studied with the respective locations of cities around Malaysia.

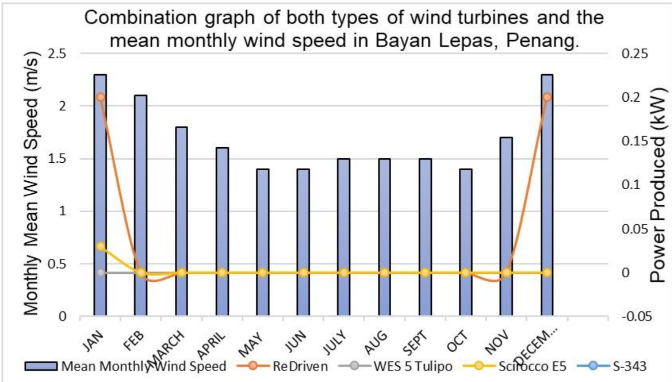

Figure 6 Combination graph of wind turbines and wind speed in Bayan Lepas.

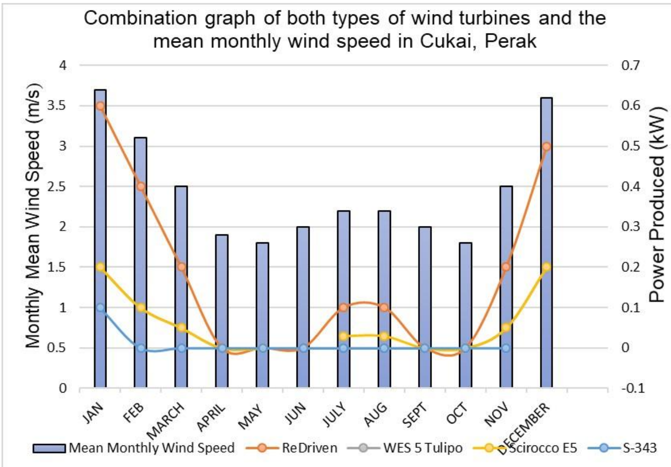

Figure 7 Combination graph of wind turbines and wind speed in Cukai.

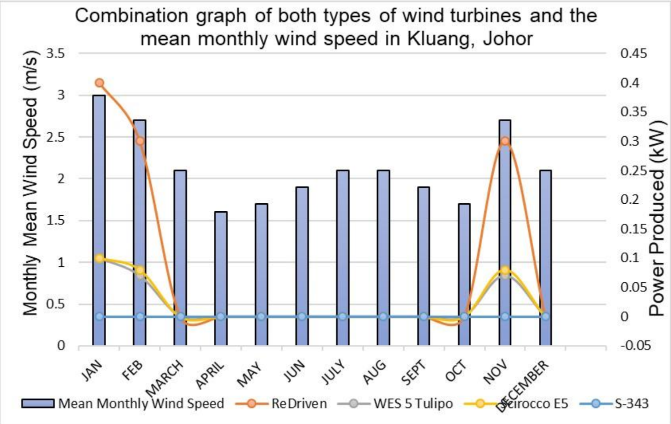

Figure 8 Combination graph of wind turbines and wind speed in Kluang.

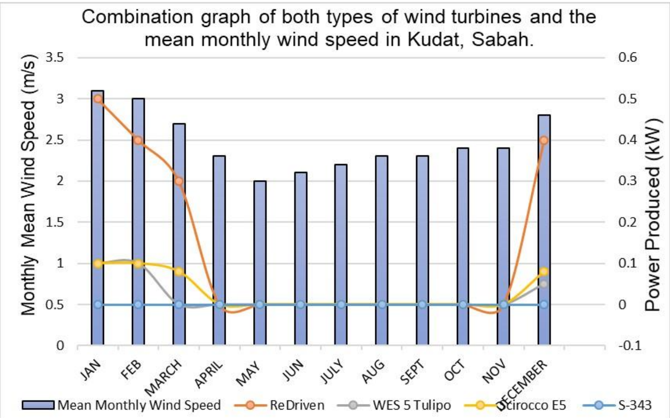

Figure 9 Combination graph of wind turbines and wind speed in Kudat.

V. DISCUSSIONS

In part A, VAWT seems as the most suitable types of wind turbine can be applied in Malaysia weather conditions and environment. Based on the study, the most suitable wind turbines to apply in Malaysia are the Derrius type. The compactness of Derrius really provides the upper hands compare to other types.

In Part B, at 5 m/s wind speed in Kuah, wind turbine produced about 0.8kW of power. For the S-343 and WES 5 Tulipo wind turbines, the operation along the year are limited as the wind turbine only operates when achieving the cut-in wind speed of 5 m/s for S-343 and 3 m/s for WES 5 Tulipo. This wind speed only can be achieved in December. With 5 m/s the both wind turbines could produce about 0.5kW of power. Opposite results produced by ReDriven wind turbine; the turbine produced the highest power among four of the wind turbines which recorded at 0.8kW of power from December until January.

Furthermore, Cukai, Bayan Lepas, Kluang and Kudat are the cities that are possible to produce energy. The energy produced other than those cities were too low due to the low wind speed of the locations. Bayan Lepas produced roughly around 200W of power from December to January, Cukai produced around 500W of power in December and 600W in January and this situation also happened in Kluang and Kudat, where Kluang produced 300W in December and 400W in January while Kudat produced 400W in December and 500W in January.

From the observations, all four locations share one similarity. That they can only produce power in December and January because of the monsoon season where the wind velocity is higher than normal. This boost the wind turbines blades to rotate much faster and at greater consistency and results in more energy production.

VI. CONCLUSION

As the conclusion, the geographical location is one of factors causing Malaysia experiencing low wind speed. It is a challenge for Malaysia to harness energy from wind gust.

VAWT is suggested as the best solution for low wind speed situation. This study suggested that, with the correct types and specifications of wind turbine, and accurate location of the wind turbine placement, sufficient amount of energy can be obtained. Thus, wind energy in Malaysia has the potential to be an alternative source of sustainable energy for a small-scale system.

In future, the VAWT design can be optimised by reducing the weight of the blades using carbon fibre material which would help the blades of the wind turbines to rotates easily at lower wind speed with less torque required and also by placing it at the location with the highest mean wind speed as suggested above.

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