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Vertical Axis Wind Turbine Application for Power Generation
(Aplikasi Turbin Angin Paksi Menegak untuk Penjanaan Tenaga)

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ABSTRACT

Concerns over security for energy sources have led many countries to concentrate on obtaining renewable energy sources. In fact, Malaysia has also studied various alternative energy sources including wind energy. However, the terrain of Malaysia does not allow strong winds to move the wind turbines. Therefore, initial efforts to harness energy from the wind were not very successful. Therefore, this study has improved previous studies by highlighting the concept of vertical axis wind turbine using Magnus effect concept.

Keywords: Energy security, renewable energy, Magnus vertical wind turbine, slow wind energy generation

ABSTRAK

Kebimbangan terhadap keselamatan untuk sumber tenaga menyebabkan banyak negara menumpukan perhatian untuk mendapatkan sumber tenaga yang boleh diperbaharui. Malah, Malaysia juga telah mengkaji pelbagai sumber tenaga alternatif termasuk tenaga angin. Walau bagaimanapun, kawasan di Malaysia tidak membenarkan angin kencang menggerakkan turbin angin. Oleh itu, usaha awal untuk memanfaatkan tenaga dari angin tidak begitu berjaya. Oleh itu, kajian ini telah meningkatkan kajian sebelumnya dengan mengetengahkan konsep turbin angin paksi menegak menggunakan konsep kesan Magnus.

Kata kunci: Keselamatan tenaga, tenaga boleh diperbaharui, turbin angin menegak Magnus; penghasilan tenaga dari tiupan angin perlahan

INTRODUCTION

Energy security is a topic that catches the interest of many nations nowadays. To ensure availability, a country needs to diversify fuels and technologies in energy production and minimizing dependence on imports. In addition, these sources of energy have to be affordable and efficient. Malaysia's current energy system is based primarily on hydrocarbons or fossil fuels: coal, oil, and gas. These are finite non-renewable resources that are only found in particular parts of the world. Nevertheless, many policies had been established along the years in order to intensify the development of renewable energy for Malaysia. While the focus on renewable energy in Malaysia was on solar, biomass and mini hydro, some studies had been conducted on the feasibility of tapping the wind energy as one of the sources (Soile 2014; Research Unit of Parliament of Malaysia 2013; Sahid et al. 2013; KeTTHA 2017).

Wind energy has many reasons to be chosen as a source of renewable energy to be installed in Malaysia. Although the average wind speed in this country is low which is about 2 m/s, it is viewed as one of cost-effective option and friendly to environments. The feasibility of wind turbine generators in Malaysia depends on the availability of wind speed that varies with location. Some factors that need to be considered are the geographical area which consist of offshore, on shore, mountain, and also land-based. Besides, the wind speed varies based on season and area. Northeast monsoon season which occurs on November to March at east coast of Peninsular Malaysia has wind speed that can reach up to 15 m/s (Mekhilef et al. 2012). A few wind turbines had already been installed in this country. They are located in Pulau Layang-Layang (Sabah), Pulau Banggi (Sabah), and Pulau Perhentian (Terengganu). All these wind turbines are no longer functioning because of low wind speed and has no maintenance. Generally, the minimum wind speed to rotate the installed wind turbine is 5 m/s and it will stop at 15 m/s to protect from damage (Daut et al. 2012).

As the conventional wind turbines normally function between wind speed 5 m/s to 15 m/s, this project aimed to achieve a proof of concept design that enables the turbine to function at lower speed but has a sturdy enough structure that can withstand strong wind. For that purpose, this project is designed to test the effectiveness of the Magnus effect on vertical wind turbine in producing power output. The Magnus effect can improve the wind turbine to be sturdier and can operate in higher wind speed. Besides, the vertical wind turbine is possible to turn the whole wind turbine from any wind direction and the two points that hold the cylinder make it strong and limit the risk of damage. Thus, it can withstand even strong wind energy.

WIND CHARACTERISTIC IN MALAYSIA

Generally, Malaysia is situated in a low wind speed region and therefore faces greater challenges in developing wind energy. As a consequence, the wind turbine generators to be utilised need to be suitable to take advantage of the wind speeds characteristics.

Many works had been done to measure the available wind speeds in Malaysia to include coastal and offshore regions. While these measurements may not be very accurate, they do provide valuable information on the wind characteristics of Malaysia. For example, a 20-year (1993-2013) offshore wind speed around Penang area is subjected to a maximum wind speed of 10.3 m/s and a minimum wind speed of 0.5 m/s (Nor et al. 2014). While the annual offshore wind speed along the Malaysian coast ranged from 1.2 m/s to 4.1 m/s only (Chiang et al. 2003). Another study was also conducted to measure wind speed in Kudat and Labuan, where the average maximum speeds were found to be 5.55 m/s and 4.75 m/s respectively (Islam et al. 2011).

DESIGN CONSIDERATION

Considering the low wind speed characteristics, a small wind turbine generator is considerably more suitable to be deployed especially in remote locations such as on islands that are not connected to the national power grid. However, although the wind turbine is intended to capture slow wind, in order for the turbine to withstand the occasionally very strong wind on these islands, we opted for the bladeless turbine which makes use of the Magnus Effect.

Magnus effect is a phenomenon in which a force (lift) is generated in the direction perpendicular to the flow direction when a rotating cylinder or a sphere is placed in the air flow (wind).

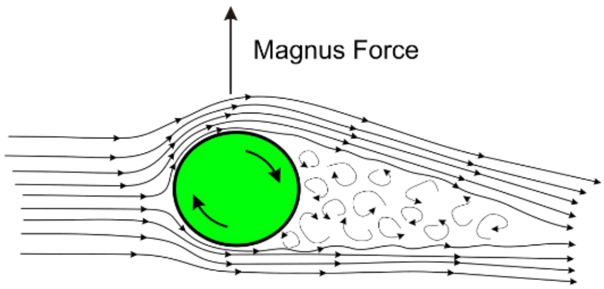

FIGURE 1. Magnus force phenomena

Figure 1 shows how the Magnus effect works on a cylinder. The lift force created by the cylinder is perpendicular to the laminar flow direction. The different pressure created between the lower surface and upper surface will produce the force. Airflow is moving from left to right, and the cylinder is rotating clockwise. The friction from the cylinder is pushing the motion of the air on top of the cylinder to go faster and deflecting air more towards the top. In the meantime, the friction slows down the air movement below the cylinder and therefore creating a higher static pressure there than on top of the cylinder. Besides, smooth surface will create less turbulence, therefore less drag. Below is the formula to find the lift force produce by Magnus effect (Asrokin et al. 2013).

$$L = \rho G V \text{ (lbs/ft)} \tag{1}$$

with

ρ = gas density (slug/(cu ft))
$G = 2 * \pi * b * Vr$
$Vr = 2 * \pi * b * s$
G = Vortex strength ((sq ft)/sec)
s = spin (rev/sec)
b = radius of cylinder (ft)
Vr = rotational speed (ft/sec)

The following formula is used to find the power that the turbine can produce. (Decoste et al. 2011).

$$\mathrm{Pw} = \frac{1}{2}\rho \mathrm{AV}^3 \text{ (Watt)} \quad (2)$$

with

A = Diameter of rotor * Length of blades (ft^2)

$$\mathrm{Cp} = \frac{\left(8/_{27}\right)\mathrm{Pw}}{\left(1/_{2}\right)\rho \mathrm{AV}^3} \quad (3)$$

$$\mathrm{Pt} = \mathrm{Cp} * \mathrm{Pw} \text{ (Watt)} \quad (4)$$

with

Pw = Power of wind (W)
ρ = air density (lbm/ft³)
A = swept area of urbine blades (ft^2)
V = wind speed (mph)

Next is the formula to find rotational speed of the turbine rotor. (Decoste et al, 2011).

$$\omega = \frac{\lambda V}{r} \text{ (rpm)}$$

with

ω = speed of the turbine's rotor (rpm)
λ = tip speed ratio
r = radius of turbine's
V = speed of wind (m/min)

Based on the formulas, when the lift force is high, the rotation of wind turbine will be also high and produce more power.

FABRICATION AND TESTING

The conceptual design of the wind turbine was achieved using SolidWorks. Then, the components of the designed wind turbine were fabricated using a 3D printer. Figure 2 shows the design of Magnus Wind Power Generator using the Solid Work Software. The distance from cylinder to the central rod is adjustable. It has three distances which are 6 cm, 7 cm, and 8 cm. This different of distances are tested in finding the best distance to produce output voltage. Figure 3 shows the normal cylinder that is used in the wind turbine. It has smooth surface and has no spiral. Figure 4 shows the second design which has a spiral on the cylinder. Figure 5 shows the third design which has three black card boards between the cylinders and central rod. This design is similar to the Savonius rotor. Figure 6 shows the Magnus wind turbine being tested under the wind of an industrial fan.

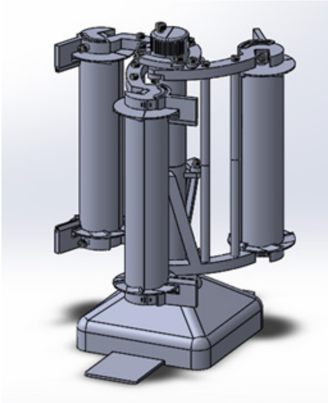

FIGURE 2. Design of wind turbine generator

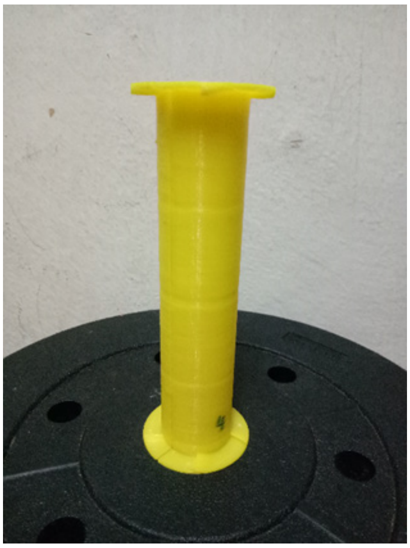

FIGURE 3. Design 1

FIGURE 4. Design 2

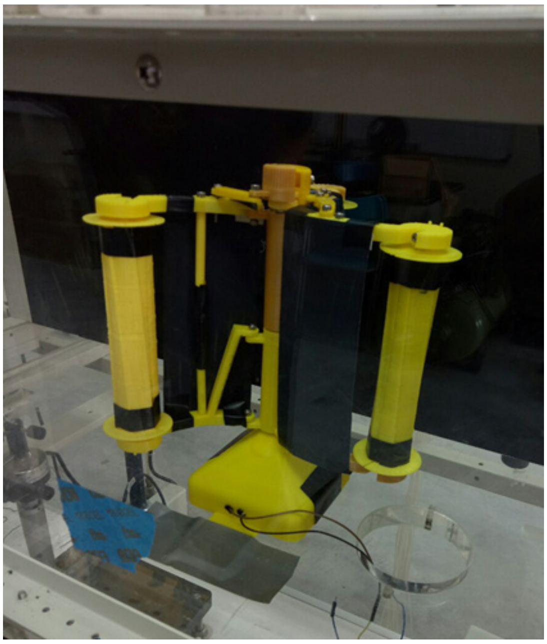

FIGURE 5. Design 3

FIGURE 6. Test set up for the Magnus wind turbine

RESULT AND DISCUSSIONS

Table 1 below shows the relationship between distance of cylinder from central rod and voltage output of wind turbine. The output voltage increases as the cylinder distance increases.

TABLE 1. Output voltage from various wind speed

Wind speed (m/s)	Voltage output (mV)		
	6 cm	7 cm	8 cm
5.11	31	34	37
5.20	34	38	40
5.33	40	44	47
5.90	46	48	50

Table 2 shows the voltage output of wind turbine for the 3 designs. Design 3 produced the highest output voltage for the various wind speeds.

TABLE 2. Output voltage comparison based on design

Wind speed (m/s)	Voltage output (mV)		
	Design 1	Design 2	Design 3
5.11	31	37	52
5.20	36	40	55
5.33	41	47	60
5.90	45	50	70

Finally, as summarized by Figure 7 below, it can be seen how the distance of cylinder from central rod affect the output voltage. 8 cm, which is the largest distance, is the best distance that produces more output voltage than other distances. Also, design 3 has performed relatively better than the other two designs in term of the rpm hence translated to better output voltage.

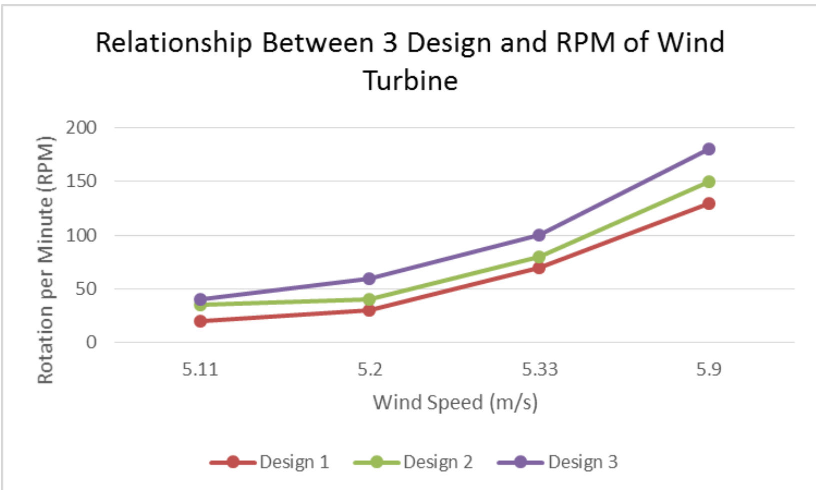

FIGURE 7. Comparison of the turbines RPM in relation to the wind speed

CONCLUSION

In this work, a proof of concept Magnus vertical wind turbine was designed with the aim of having the ability to capture slow wind but has strong enough design to withstand forceful wind. While the proof of concept demonstrates its ability to function in slow wind, further improvement is needed to improve its performance.

DECLARATION OF COMPETING INTEREST

None

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