Jurnal
Teknologi

Full Paper

Energy Harvesting from Cooling Tower by Vertical Axis Wind Turbine (VAWT)

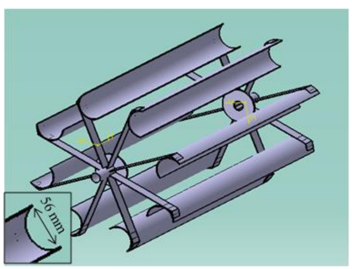
Ahmad Azizan Abd Rahman, Nor Afifah Yahaya*, Rosnadiah Bahsan, Umi Kalsom Ahmad

Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

Article history
Received
15 February 2015
Received in revised form
9 April 2015
Accepted
9 June 2015

*Corresponding author
afifah@salam.uitm.edu.my

Graphical abstract



Abstract

In general, Malaysia is not a suitable location to harvest energy from wind. This is because Malaysia's mean annual wind speed is low (less than 4 m/s) and inconsistent throughout the year. However, exhaust air systems which are usually installed in commercial buildings creates a uniform and consistent wind speed. Therefore, this provides a suitable place to harness wind energy. In this study, an innovative idea by harnessing wasted energy from the cooling tower with vertical axis wind turbine (VAWT) has been done. The VAWT was equipped with a guide-vane to increase the inlet wind speed and an enclosure to avoid the wind coming from the opposite direction. The result shows that this system was capable of generating electricity by approximately 0.0081 W.

Keywords: Exhaust air system, cooling tower, vertical axis wind turbine

1.0 INTRODUCTION

Generally, Malaysia has a low quality of wind [1] and not suitable for generating energy from wind. However, one of the alternative sources to harvest wind energy is from the exhaust air system such as cooling towers or blowers used in buildings or industrial sector. In this study, a cooling tower has been selected, since it is readily available at the Science and Technology building, Engineering Tower, Universiti Technology MARA (UiTM). Cooling towers are commonly used to dissipate heat from power generation units, water-cooled refrigeration, air conditioning and industrial processes [2], where it provides a strong and consistent wind speed at the outlet of the cooling tower.

A vertical axis wind turbine (VAWT) has been selected in this study due to the several advantages of the VAWT, such as complicated device is unnecessary to track the wind, the gearbox could be placed at ground level and quiet, thus it is perfect for installation in residential areas [3]. It also has less moving parts which requires less service and maintenance. As a first step in this study, the system has been designed and fabricated which consists of a drag type blade, guide vane and enclosure, while the belt and pulley has been implemented for the power transmission system. The fabricated VAWT has been installed at the outlet of cooling tower located at Science and Technology Engineering Tower, University Technology MARA, UiTM to measure the electricity and investigate an impact of the system to the cooling tower.

2.0 METHODOLOGY

In this project, VAWT has been designed consisting of wind turbine blade, guide-vane and the enclosure. The fabrication of each component has been done and installed at above of the cooling tower before the measurement was done.

2.1 VAWT Blade

The blades on the wind turbine act as a device to harvest energy from the wind and connected to the shaft of a generator. The generator converts the mechanical energy into electricity. Generally, there are two types of wind turbine blade, drag and lift type [3]. The drag type has an advantage of lower cut-in wind speed compared to lift type [3]. In a study conducted by W.T. Chong *et al*., H-rotor wind turbine with lift type blade were applied [4], while in this investigation, the drag blade (C-type) has been selected. The material used for the blade was polyvinyl chloride with a diameter of 56 mm as shown in Figure 1.

2.2 Guide Vane

The guide-vane is a device to guide the flow entrance of the wind through the blade. The guide vanes forms a multiple flow channels to speed up the wind as it flows through the vane and guide the wind stream to the angle of attack at the VAWT blades. Many researchers had studied and reported different design of ducted or funnelled wind turbines, which increase the on-coming wind speed and hence increased the efficiency and performance of the turbines. Dhanasekaran *et al*. has shown that the efficiency and stating characteristics of the wind turbine (horizontal axis wind turbine) improved as compared with the respective turbine without guide vanes [5]. Furthermore, S.Y Hu *et al*. estimated that the power extraction efficiency increased by about 80 % [6]. A study conducted by W. T. Chong *et al*. with shrouded features of the Omni-directional guide-vane (ODGV) enhanced the performance of wind turbine by increasing the on-coming wind speed before it interacts with the rotor blades [4]. In this project, plate mild steel has been used as a guide vane use as shown in Figure 2. The vane has been designed with different angle such as 0°, 30°, 60°, 90° and 120° to enhance the speed of wind before entering the blades.

2.3 Enclosure

The enclosure was added to avoid the wind coming from the opposite direction from surrounding and also for safety grill in the case of blade failure. Therefore, there is less possibility for the blade to fly off and cause injury and expected to improve the performance of small VAWT by preventing wind from surrounding. Figure 3 shows the design of enclosure for VAWT in this project where plate mild steel has been used.

2.4 Belt And Pulley System

Implementing belt and pulley system in a small VAWT is an alternative way to increase current produced from the generator as shown in Figure 4. This is because it allows mechanical power, torque and speed to be transmitted across axles. For power transmission between shaft, belt are the cheapest and may not to be axially aligned. Belt and pulley system generate run smoothly produced less noise compared to gears or chain. A Study by Altb. Hossain *et al*. reported that by implementing belt and pulley has increased the power from 165 W to 1000 W (at the wind velocity between 6 m/s to 12 m/s) [7].

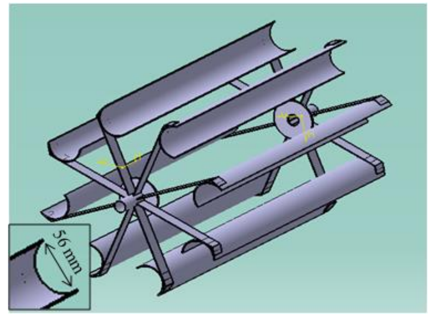


Figure 1 The VAWT blade

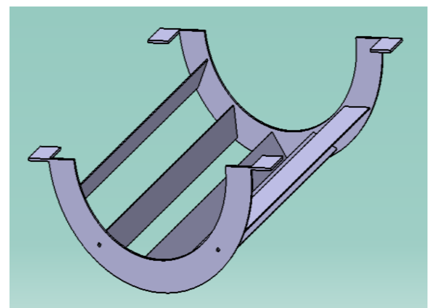


Figure 2 The guide-vane

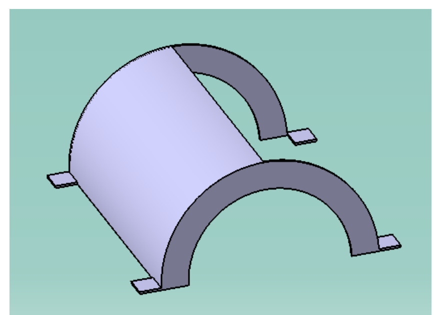


Figure 3 The VAWT enclosure

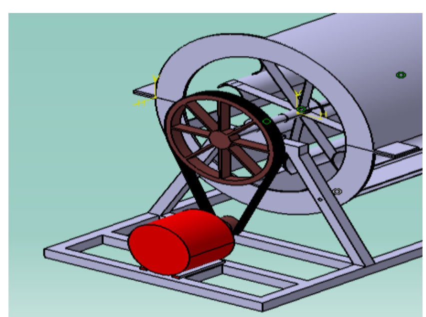


Figure 4 The belt and pulley system

2.5 Installation Of VAWT

The VAWT has been installed at the cooling tower (SQ 2500T) after the speed of wind produced by cooling tower was measured. The laser tachometer and CFM

Anemometer were employed in this study for wind speed measuerements. The diameter of cooling tower approximately 1.76 m and the data shows that highest wind speed occur from radius 0.5 m to 0.6 m from the centre of the cooling tower. Therefore, the VAWT was placed at the highest range of the wind speed as shown in Figure 5.

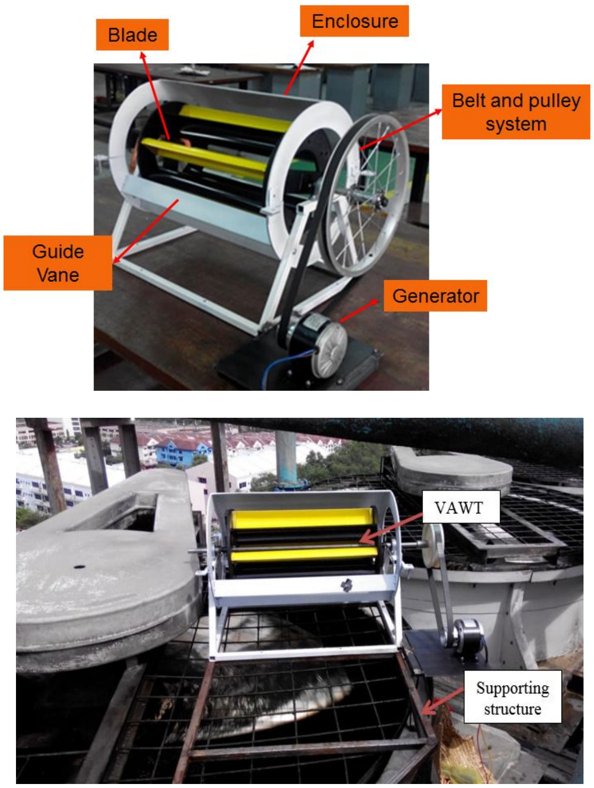


Figure 5 Protype of VAWT (top) and the location of VAWT above the cooling tower (bottom)

3.0 RESULTS AND DISCUSSION

3.1 Wind Speed Profile

The discharge air velocity was measured in six points from the centre of cooling tower as shown in Figure 6. As can be observed in the figure, the highest wind speed from the centre is between distance 0.5 m and 0.6 m and at height of 0.3 m. At the distance 0.3 m and 0.8 m from the centre, low wind speed was measured due to the belting system of the cooling tower outlet which caused an air flow resistance and a clearance between the blade tip and the inner wall duct (causing blade tip loss) as exhaust air swirled and spread out from the fan [8]. Based on the measurements of discharge air profile, VAWT was placed at between 0.5 m to 0.6 m from the centre of the cooling tower and 0.3 m height.

3.2 VAWT Field Test

The VAWT has been tested for its performance with different configurations and tabulated in Table 1. As can be seen in Table 1, the average rotational speed of small scale VAWT without any additional device was 348.94 rpm. However, as the VAWT was combined with load, the rotational speed of VAWT reduced to 122.46 rpm. The performance of VAWT increased to 28% with a guide-vane, however, it decreased to 9% after installing the enclosure. The rotational speed of the blade reduced after installing a motor as it gives a high load to the blades. The performance of VAWT incorporated with guide-vane increased higher than with enclosure because guide vane designed with different angle of attack has guide the wind flow to the blades. However, the enclosure reduced the rotational speed of the VAWT and it is expected due to the vortex produced in between enclosure and blades [9]. This also shows that the surrounding wind has a low impact to the VAWT performance.

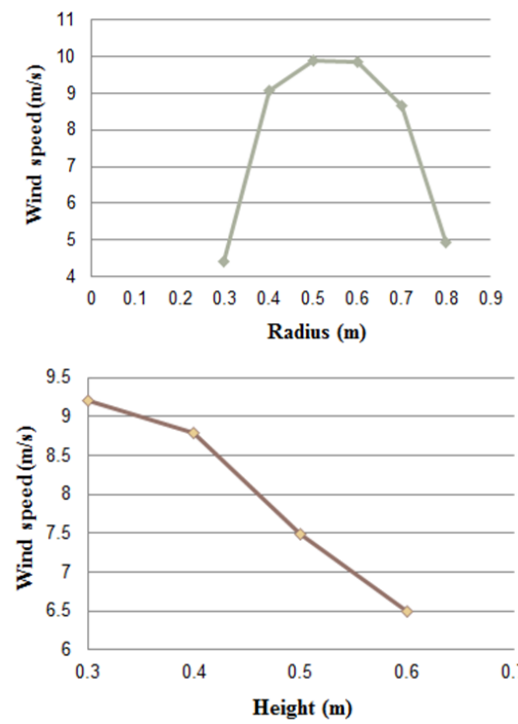


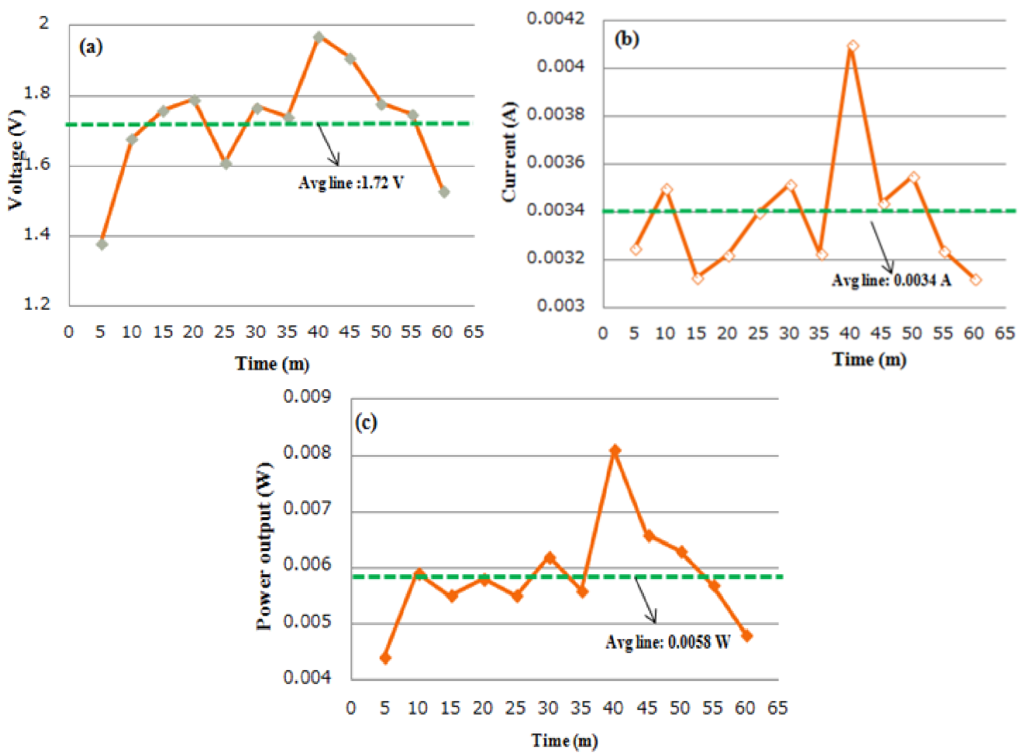
Figure 6 Discharge air profile from the cooling tower

Figure 7 shows the ability of the VAWT to produce electricity. The voltage and current were measured for 60 minutes for 5 minutes time interval. From the figure, it could be observed that maximum voltage and current produced were 1.97 V and 0.0041 A respectively, while, the average power of VAWT 0.0058W. As can be seen in the Figure 7(c), the high wind speed could be observed at minute 40, and therefore increased the voltage and current generated by VAWT. The investigation on the impact of the VAWT system to the cooling tower shows that almost no significant changes of wind speed from cooling tower before (average of 9.25 m/s) and after installation (average of 9.69 m/s) of the VAWT. Therefore, this VAWT system is expected to give no negative effect to the cooling tower and therefore is suitable to harvest the wind energy without sacrificing the efficiency of the cooling tower.

From this study, it could be shown that the proposed VAWT have an ability to harvest wind energy at exhaust air system such as cooling tower. However, there is a lot of room for improvements for future work such as changing the motor with generator, optimizing the blade design, changing the material to the lighter materials. There also a need to investigate the effect of high humidity of the cooling tower to the VAWT system before it could be implemented.

Table 1 Rotation speed of VAWT for a different configuration

Configuration	Rotation speed (rpm)			
	Reading 1	**Reading 2**	**Reading 3**	**Average**
Blade	332.05	348.54	366.24	348.94
Blade + Motor	122.34	124.62	119.41	122.46
Blade + Motor + Guide vane	156.02	157.32	160.54	157.96
Blade + Motor + Guide vane + Enclosure	136.05	132.76	129.52	132.78



FFigure 7 The voltage (a), current (b) and power output (c) of VAWT system

4.0 CONCLUSION

Harvesting energy from the exhaust air system, cooling tower by VAWT has been tested and the impact of the system to the cooling tower has been investigated. The fabricated VAWT consist of drag type blade, guide vane, enclosure, belt and pulley, and has been installed at Science and Technology Engineering Tower, University Technology MARA, UiTM. The VAWT, has generated average current and voltage 0.0034 A and 1.72 V respectively. It also has been shown that proposed VAWT do not give any negative impact to the cooling tower system. Although there is a lot of improvement must be done before implementing this system to the exhaust air system, however, it has been proved that this system is applicable to generate electricity at low wind speed countries especially at urban areas to harness wind energy from the exhaust air system such as cooling towers which are consistent and predictable.

References

[1] Chong, W. T., Naghavi, M. S., Poh, S. C, Mahlia, T. M. I. and Pan, K. C. 2011. Techno-economic Analysis of a Wind-Solar Hybrid Renewable Energy System With Rainwater Collection Feature For Urban High Rise Application. *Applied Energy*. 88: 4067-4077.

[2] Lucas, M., Martínez, P.J. and Viedma, A. 2009. Experimental Study on the Thermal Performance of a Mechanical Cooling Tower with Different Drift Eliminators. *Energy Conversion and Management*. 50: 490-497.

[3] Sanghyeon, K. and Cheolung, C. 2015. Development of Low-noise Drag-type Vertical Wind Turbines. *Renewable Energy*. 79: 199-208.

[4] Chong. W. T., Fazlizan, A., Poh, S. C., Pan, K. C. and Ping, H. W. 2012. Early Development of an Innovative Building Integrated Wind, Solar and Rain Water Harvester for Urban High Rise Application. *Energy and Buildings.* 47: 201-207.

[5] Dhanasekaran, T. S. and Govardhan, M. 2005. Computational Analysis of Performance and Flow Investigation on Wells Turbine for Wave Energy Conversion. *Renewable Energy*. 30(14): 2129-2147.

[6] HU, S. Y. and Cheng, J. H. 2008. Innovatory Designs for Ducted Wind Turbines. *Renewable Energy*. 33(7): 1491-1498.

[7] Hossain, A., Iqbal, A. K. M. P, Rahman, A., Arifin, M. and Mazian, M. 2007. Design and Development of 1/3 Scale Vertical Axis Wind Turbine for Electrical Power Generation. *Urban and Environment Engineering*. 53-60.

[8] Bleier, F. P. 1998. *Fan handbook: Selection, Application and Design.* New York: McGaw Hill.

[9] Michea, G. and Richard, B. 2013. Green Vortex formation on Squared and Rounded Tip. *Aerospace Science and Technology*. 29: 191-199.