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Development of Vertical Axis Wind Turbine (VAWT) During Windy Season for the Rural Area in Langkawi

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Abstract: Wind energy is one of the clean energy sources. This project is carried out to take advantage of the windy season inland and along the coast of Langkawi. Wind energy is converted into electricity by driving a brushless generator motor to produce a Direct Current (DC) voltage of 12V. The output voltage from the DC motor will be stored in the battery before being fed to the inverter. These inverters are used to convert DC energy into Alternating Current (AC) output. The AC output can be increased by using a transformer up to 220 VAC. The voltage output from the inverter will be fed to the user to turn on electrical appliances at home. Electricity supply is very important nowadays because of the rapid development of technology. Some residents in rural areas do not get electricity from Tenaga National Berhad (TNB). This is because their place of residence is too far or isolated. To ensure they have a constant supply of electricity, a system called the Vertical Axis Wind Turbine (VAWT) has been designed. With this system, power supply troubleshooting can be improved to turn on electrical equipment such as lights, fans, ice boxes, and more. This system is developed by using wind energy which is one of the other methods to supply electricity. The results from the experiment show that as the wind speed increases, the output power from the DC motor will increase. The proposal uses specialized software and designs wind turbines that will be able to generate voltage and current.

Keywords: Vertical Axis Wind Turbine, Inverter.

1.0 INTRODUCTION

Wind energy is one of the cleanest sources of energy in the world. Langkawi is the best place to conduct this project because Langkawi has a lot of beaches where the sources of wind energy are present. VAWT is conducted to provide electrical energy to rural residents in Langkawi. Some places in Langkawi cannot reach the electrical supply provided by the TNB such as remote places and the inhabited islands in Langkawi. This project will help them get enough electrical supplies to use light during the night

VAWT system is used to change kinetic energy from the wind to electrical energy. This electrical energy is produced by the mechanical system that drives the DC motor to produce electricity in DC output. Then DC output from the DC motor will be stored in the battery storage of 12V. DC output from the battery is stepped up by using a boost converter from 12 VDC from the DC motor to 120 VDC with a 1:10 ratio. The 120 VDC will be converted to 240 VAC by the inverter to produce AC output. The AC output then will be supplied to the consumer to use electrical outlets such as lighting and fans at home.

The electrical supply is very important nowadays because of the development of technology. Some people in rural places cannot access the electrical supply from the TNB. This is because their places are too far for TNB to supply electricity and some people are living in the inhabited islands. Without electricity, they cannot experience the usefulness of electricity in their home. To supply electricity to their home, VAWT is proposed to provide enough electricity to use some minimal power appliances such as lighting and fans. To solve this problem, VAWT is developed to provide electricity to the people who live in the remote area

2.0 LITERATURE REVIEW

2.1 Design of Small-Scale Vertical Axis Wind Turbine

A paper written by Chandrashekhar PK, Sachin Managuli, and Shashank A, the project was carried out in

2016. Design of a small-scale Vertical Axis Wind Turbine (VAWT) having the combined characteristics of Savonius and Darrieus wind turbines. Remote residential areas require little energy for their home use such as lighting. This is due to the high demand for electricity supply. The reason for developing a VAWT system is because the electricity demand is increasing in remote areas and people in remote areas need little electricity for lighting. The objective of this project is to design a small-scale VAWT in a remote residential area and to combine the characteristics of Sovanius and Darrieus wind turbines to increase power generation at lower wind speeds. The results are shown in Fig.1 that when the wind speed increases, the output power also increases theoretically [1].

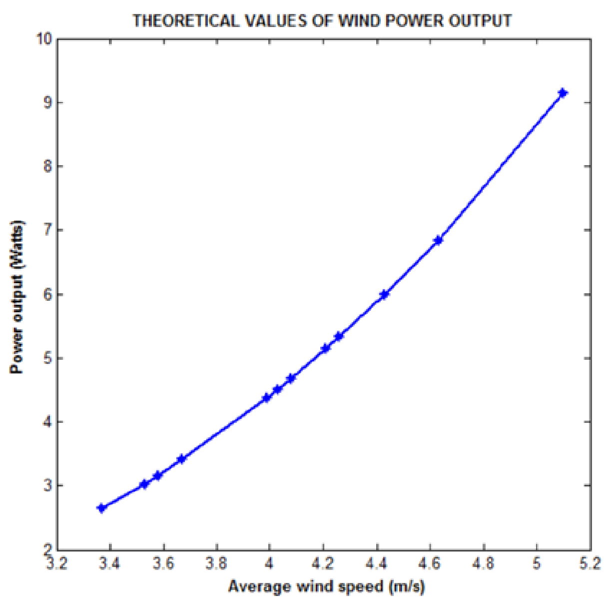


Figure 1: Graph of Theoretical Values of Wind Power Output [1]

2.2 Development of Double Rotation Vertical Ax Generator with Double Rotation of Wind Turbine

Based on the journal written by Nur Irwany Ahmad et. All in 2018, the project was carried out to use multiple rotations of VAWT in one system. The conventional operation uses a set of rotating blades of a wind turbine; therefore, it will limit the rotation of the generator stator. This project is to design and develop a twin-rotation generator with a twin-rotation vertical axis wind turbine that can produce multiple output voltages and work in both high and low wind speed conditions. Output generation is limited when using a single set of rotating blades of a conventional operating VAWT. This project is to increase the output voltage by using double rotating blades on the VAWT system and produce double output voltage and work in both high and low wind speed conditions. As a result, the output voltage based on the result is doubled as a combination of multiple rotating blades instead of using a single rotating blade set. The number of coils turns also affects the output voltage. In general, the higher the number of turns, the higher the induced voltage produced [2]. Fig. 2 shows the concept of the double rotation design in the project. This concept can double the output generated by the dual generator at the top and bottom of the VAWT design.

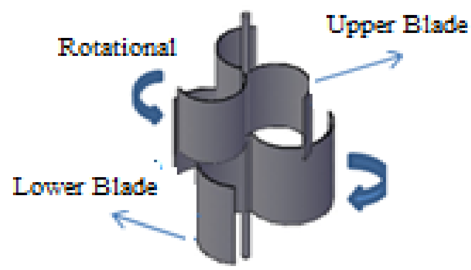


Figure 2: The Concept of Double Rotational Design [2]

2.3 Analysis of Different Blade Architectures on Small VAWT Performance

Based on L. Battisti, A Brighenti, E Benini, and M. Raciti Castelli,(2016), Vertical Axis Wind Turbines (VAWT) have a lot of advantages over Horizontal Axis Wind Turbines (HAWT) which do not require yaw system, low noise pollution, ground positioning of mechanical and electrical heavy parts. In the journal, they are using BE-M (Blade-Element Momentum) theory to analyze the load predictor model. BE-M is a computational approach adopted for rotor predesign and controller assessment. The system does not include a few factors which are ambient turbulence, field operations in the stochastic wind have an impact on turbine aerodynamic and structural behavior, and the relative forces induced by the layout and blade profile. They also use Double Disk to capture the most relevant VAWT aerodynamic behavior. The effect of the support structure (struts and shaft) is a feature that is unavoidable in the small VAWT design process. They use the most suitable choices of the airfoils database which are NACA 0012 and 0015 airfoils at Reynolds numbers of 3.5 x 105, 5.0 x 105, and 7.0 x 105.

Their results of simulations were carried out by a few VAWT architectures. They are using an H-Darrieus type of turbine where a low radius near the top and bottom of the rotor drives the blade with low tangential speed leading to a small contribution to the torque generation. They also said a strong VAWT design will keep the optimum turbine rotational velocity minimize rotor vibrations and maximize the aerodynamic efficiency. The choice of number of the blades depends on three factors which are structural, aerodynamic, and cost. Commonly Darrieus VAWT is manufactured using National Advisory Committee for Aeronautics (NACA) airfoils to make the airfoil's thickness-to-chord ratio increase as much as possible to get the best structural performance. Based on the results, the helical-bladed configuration produces a huge Tip Speed Ratio (TSR) range very close to the coefficient, and a more beneficial condition in power exchange and controller requirements. The three-bladed wind turbines produce a greater performance than the two-bladed turbine. To reduce the fatigue life of VAWT, they reduce the cyclic oscillation of the dynamic loads thus extending the turbine life and reducing vibration during operation [3].

2.4 Performance Analysis of Novel Blade Design of Vertical Axis Wind Turbine

The blade of the turbine is the most important part which will trap the wind to drive the DC motor to generate electricity. Various designs have been invented by the researcher to get a higher rate of wind trap with the turbine. Based on Fig. 3, there are three types of blades which are the Savonius-rotor, Darrieus rotor, and H-Darrieus-rotor. The different types of rotors will produce different values of output power. This is due to the efficiency of the blade to trap the wind to drive the DC motor.

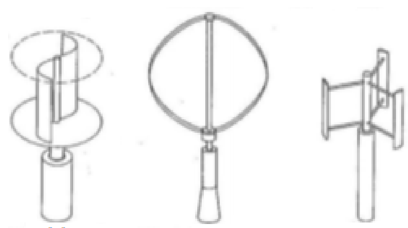


Figure 3: The Type of Blade use for VAWT: (a) Savonius-Rotor, (b) Darrieus-Rotor, (c) H- Darrieus-Rotor [4]

The purpose of their project is to improve the VAWT system by influencing the blade design and to compare the design of a new type-H rotor VAWT blade using Computational Fluid Dynamic (CFD) software. After finishing the design and calculation, the results were obtained by using CFD simulation software. The blade design consists of three types which are the upper-curve blade, upper-curve inverted blade, and upper-lower blade. Based on their results, the upper-curve blade design produces a better performance and power coefficient than the other two [4].

2.5 Comparison of Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT)

The journal is written by Muhd Khudri Johari, Mohd Azim A Jalil, and Mohammad Faizal Mohd Shariff in 2018. This journal is stated that they are carrying a research and experiment about the efficiency of the different type of wind turbine in Malaysia. Malaysia hardly has a high potential wind depending on certain seasons such as monsoon season. The project is conducted to identify which wind turbine is more efficient to use in Malaysia and to increase the efficiency and optimum output. The horizontal Axis Wind Turbine (HAWT) system works perfectly by facing the wind perpendicular to the blades and driving the motor due to the aerodynamic lift. VAWT system rotates perpendicular to the ground and rotates vertically. The results of their experiment, the results show that the VAWT system has a consistent output in low-speed wind. This is because the design of the turbine works efficiently with the random wind direction in a different environment. Table 1 shows the comparison of HAWT and VAWT [5].

Table 1: The comparison of VAWT and HAWT [5]

Parameter	**VAWT**	**HAWT**
Tower	Small	Large
Tower Mechanism	No	Yes
Location	On Ground	Not on Ground
Height	Low	High
Size of Blade	Small	Large
Wind Direction	Independent	Dependent
Bird Obstruction	Low	High

2.6 Numerical Investigation of h-Darrieus Wind Turbine Aerodynamics at Different Tip Speed Ratios

The purpose of the paper is to predict the aerodynamic performance of a complete scale model H Darrieus vertical axis wind turbine (VAWT) with end plates at different operating conditions. This paper aims at understanding the flow physics around a model VAWT for three different tip speed ratios corresponding to three different flow regimes.

This study achieves a first three-dimensional hybrid Lattice Boltzmann Method/Very Large Eddy Simulation (LBM-VLES) model for a complete scaled model VAWT with end plates and mast using the solver power flow. The power curve predicted from the numerical simulations is compared with the experimental data collected at Erlangen University. This study highlights the complexity of the turbulent flow features that are seen at three different operational regimes of the turbine using instantaneous flow structures, mean velocity, pressure iso-contours, blade loading, and skin friction plots.

The power curve predicted using the LBM-VLES approach and setup provides a good overall match with the experimental power curve, with the peak and drop after the operational point being captured. Variable turbulent flow structures are seen over the azimuthal revolution that depends on the Tip Speed Ratio (TSR). Significant dynamic stall structures are seen in the upwind phase and at the end of the downwind phase of rotation in the deep stall regime. Strong blade wake interactions and turbulent flow structures are seen inside the rotor at higher TSRs. Ok.

Accurate predictions of power performance for Darrieus VAWTs could help in better siting of wind turbines thus improving the return on investment and reducing the levelized cost of energy. It could promote the development of onsite electricity generation, especially for industrial sites/urban areas, and renew interest in VAWT wind farms.

The main conclusion of this paper shows that the aerodynamic performance of a complete model H-Darrieus VAWT with end plates and supporting structures was evaluated using the LBM-VLES approach. The predicted power curve provides a good overall match with the experimental power curve studied as shown in Fig. 4.

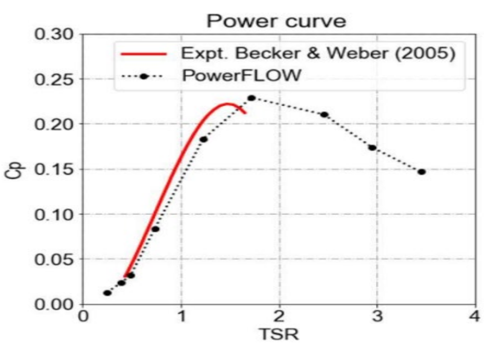


Figure 4: Power curve comparison between the experimental and present numerical prediction

3.0 METHODOLOGY

3.1 Block Diagram

The block diagram in Figure 5 is a system diagram represented with blocks to describe the relationship between the inputs, processes, and outputs of the system. The overall explanation for this block diagram will be explained in the next section.

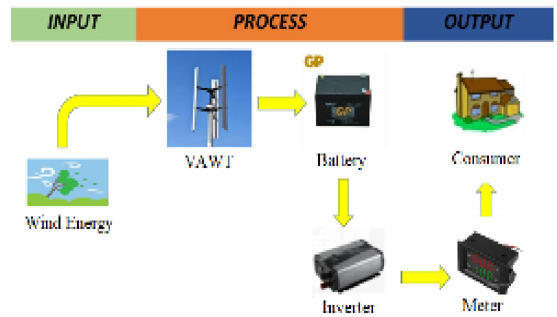


Figure 5: Block Diagram

Figure 5 contains three parts namely input, process, and output. The source of the project is wind energy. The wind energy will strike the wind turbine to create kinetic energy and then drive the DC motor of the VAWT system. The electrical energy from the VAWT will be stored in the battery and recharged through the battery charger controller. From the battery through the battery charger controller, the electricity will be fed to the inverter to convert DC to AC output before being supplied to the consumer. The meter will show the output voltage and current at the end of the system for monitoring and maintenance.

3.2 Process

Figure 6 also shows a Wind Turbine with a 3-blade Design and a DC motor. This VAWT system consists of a turbine and a DC motor. This project will use a Darrieus H-type wind turbine. The Darrieus H turbine is designed using Computer Aided Design (CAD) software. The size of the turbine with a height and width of 7000 mm and 100 mm respectively. The turbine will drive a DC motor to generate electricity. As for the DC motor, the model chosen is the 12V, 10000rpm Brushed DC Motor by Xin Da Motor to converts mechanical energy into electrical energy.

Figure 6: VAWT Configurations: (a) Wind Turbine with 3 Blades Design, (b) DC Motor

Battery Storage: GP Battery 12V/7.0AH Lead Acid Rechargeable Battery is selected for use as battery storage. The size of the battery can be represented by the length, width, and height of 150mm, 63mm, and 94mm respectively. While the weight is 2.324kg. The purpose of this battery is to store the output voltage produced by the DC motor. The output of this battery will be consistent with 12V.

Battery charge controller: A battery charger controller is used to limit the rate at which electric current is added or taken from the electric battery. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk.

Inverter: Based on Fig. 7, the purpose of the inverter in this project is to convert the DC output to AC output from the battery storage through the battery charger controller. This inverter is connected to a transformer to step up 12VAC to 240VAC before supplying to the consumer.

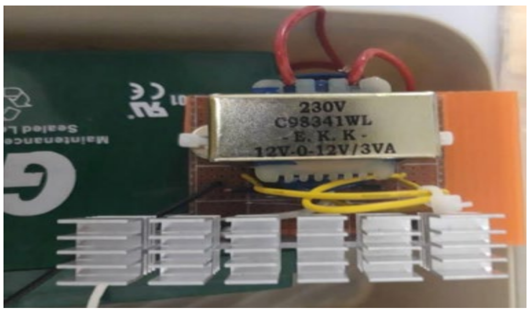


Figure 7: Inverter

3.3 Output

The result can be shown by electrical equipment that works like lights and fans in the house. The main purpose of this project is to supply electricity to people in remote areas.

Meters will be connected to the end of the system to collect and record data for monitoring and maintenance processes. The meter model used is the MT-1508 Pocket Auto Range Multimeter by Pro'Skit. Anemometer is used to measure wind speed in collecting wind speed data.

4.0 RESULTS AND DISCUSSION

4.1 Results Output from the DC Motor

Table 2 shows the data results for the voltage output from the DC motor according to the wind speed.

Table 2: The Output of the DC motor

Wind Speed (m/s)	0	2.2	3.4	3.9	4.4	5	5.4
Output Current (mA)	0	0.84	2.51	3.48	4.3	5.74	6.67
Output Voltage	0	1.3	1.8	2.41	2.53	3	3.58
Output Power (mW)	0	1.092	4.518	8.387	10.879	17.22	23.879

Figure 8 shows the output voltage from a DC motor. The DC motor is connected directly to a multimeter to get the output voltage. The graph shows that the output voltage increases gradually as the wind speed increases. When at a wind speed of 2.2m/s, the generated output voltage is 1.3 V. At a wind speed of 5.4m/s, the generated output current is 3.58 V.

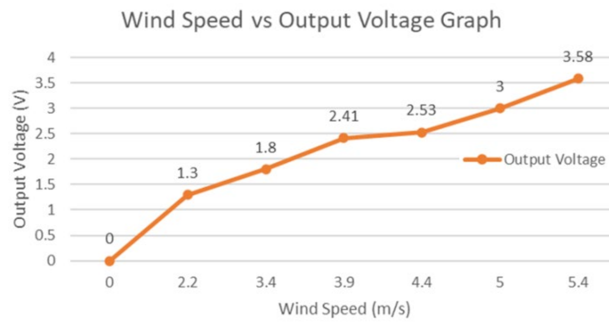


Figure 8: Output Voltage of the DC Motor

Figure 9 shows the output current from a DC motor. DC motors are connected in series with the load with a multimeter as an output current measurer. The graph shows that the output current will gradually increase as the wind speed increases. It can be shown that at speeds of 2.2m/s and 5.4m/s, the output current of the generator is 0.84 mA and 6.67 mA respectively.

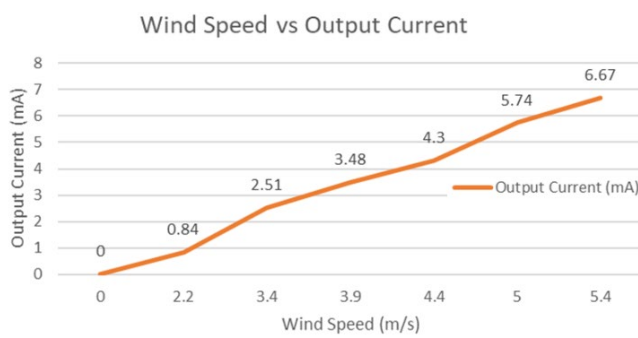


Figure 9: Output Current of the DC Motor

Figure 10 shows the output power from a DC motor. The graph shows that power output is directly proportional to wind speed. During the wind speed at 2.2m/s and 5.4m/s, the output power produced is 1.092mW and 23.879mW respectively. Therefore, the higher the wind speed, the greater the power produced by the generator.

The output power produced is small because the value of the current at the output is small. Therefore, this will cause a longer time to fully charge the battery, indirectly the durability of the battery does not last long. Other factors to consider in choosing a DC motor are the type, motor specifications, and voltage per rpm ratio to produce more significant output power.

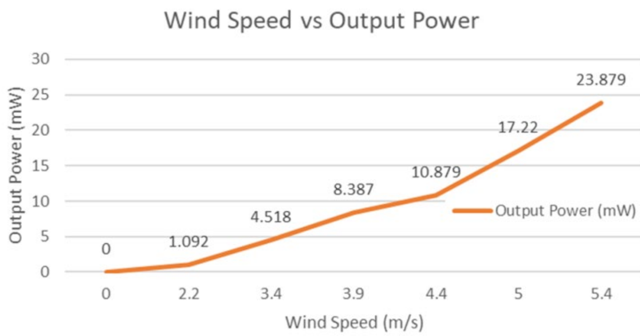


Figure 10: Output Power of the DC Motor

4.2 Output Voltage Inverter

Figure 11 shows the DC voltage from the battery fed to the inverter. DC voltage data is shown on the battery charger controller. The value for the input voltage to the inverter is 12.6VDC.


Figure 11: Voltage DC 12.6V to the Inverter

Table 3 shows the output voltage AC from the inverter. The output voltage inverter fluctuated from 233.3 to 240 AC. Fig. 12 shows that the lamp rated 20W is lit up.

Table 3: Output Voltage Inverter

No.	DC(V) (Battery)	AC(V) (Output Voltage Inverter)	
1	12.6	238.3	
2	12.1	233.3	
3	12.9	228.3	

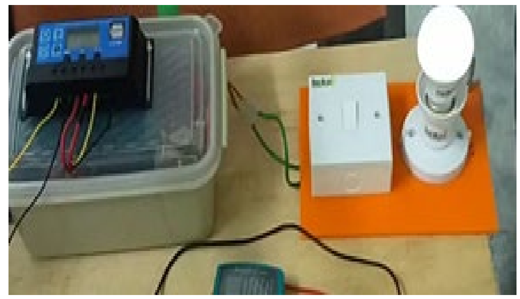
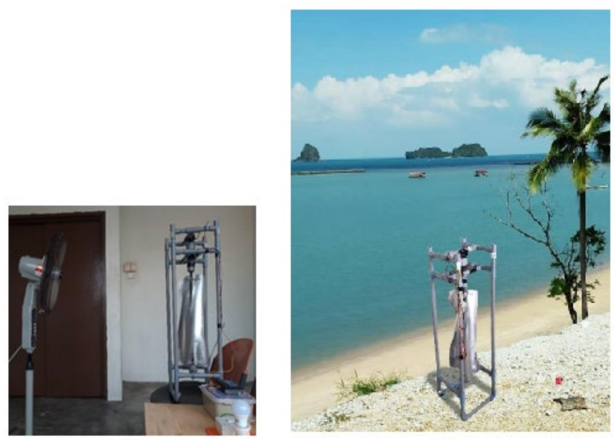


Figure 12: Bulb light up

A completed prototype project for a VAWT hybrid cycle system to generate electricity is shown in Fig. 13. A test was conducted both indoors and at Pantai Lagenda, Kuah, Langkawi.


(a) (b)
Figure 13: Prototype Project: (a) Indoor (b) Outdoor

5.0 CONCLUSION

The main objective of the prototype and the experiment that has been carried out has been achieved based on some results obtained showing that the wind turbine that has been developed has successfully produced electricity as much as 233VAC to 240VAC. Thus, the VAWT system can create another alternative way of producing electricity. It is recommended that this VAWT system can be adopted for small industries. It is also found that the cost to develop it is not expensive.

6.0 RECOMMENDATIONS

In this project, there are several improvements that can be made to improve the efficiency and performance of the vertical-axis wind turbine. There is some recommendation. to improve to make the project run at its best. The type of generator is one of the factors to generate higher voltage and current. Based on the calculation in the results and discussion section, the DC motor with a higher rating voltage and lower rpm is one of the solutions to improve the power output based on this project. Using specific software to design the wind turbine. This software helps to design the best shape of the wind turbine to catch more wind energy. The software uses simulation and calculation to find the spot where the turbulence occurs which causes dragged to the wind turbine to spin faster to drive the generator. Finally, analysis of the output voltage when affected by the monsoon season in November, December, and January every year.

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