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PROPOSED DESIGN OF WIND TURBINE SYSTEMS ON A PICKUP TRUCK

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ABSTRACT

Road transportation is one of the causes to bad emission to the air. In order to solve some of the problems associated to gasoline-powered vehicles, an electric-powered vehicle has been produced but such vehicles are not widely used yet. Recently, many inventions and researches have been conducted regarding to the idea of mounting wind turbine system on electric-powered vehicles as one of the solution to decrease emissions and save energy. In the present study, proposed design of wind turbine system will be mounted on a pickup truck, Hilux. The wind turbine system was located at the roof of the pickup truck body. Based from the testing conducted, about 120 watt of the wind power (at cruising speed of 120 km/h) was converted to electrical power. The improvement of blade design and configuration, and energy conversion system would increase the produced electrical power.

Keywords: wind turbine model, prototype design, aerodynamic performance, power performance, ducting models.

INTRODUCTION

Road transportation is one of the causes to bad emission to the air. In order to solve some of the problems associated to gasoline-powered vehicles, an electric-powered vehicle has been produced but such vehicles are not widely used yet. Recently, many inventions and researches have been conducted regarding to the idea of mounting wind turbine system on electric-powered vehicles as one of the solution to decrease emissions and save energy.

Generally, battery-operated electric vehicles operation based on electricity stored in the batteries. The power of electricity originally comes from an external power source. For this project, the wind turbine system for pickup truck has been designed to provide an external power source for electric vehicle. Wind turbine mounted on the vehicle used to generate electrical power in order to charge the batteries of a vehicle when the vehicle is moving.

The capability of wind turbine system to generate electrical power should consider a few factors. First consideration is about an appropriate design of wind turbine system that consists of blade designation and turbine duct. This study will covers the process of designing the optimum wind turbine systems to harness wind power on a pickup truck followed by the design stage which involves fabricating a wind turbine in full scale size based on the design. The evaluation of power output of the wind turbine system that mounted on the moving pickup truck will be investigate.

Wind turbines can be classified into two general types: horizontal axis and vertical axis. The invention of vertical axis wind turbine (VAWT) gives new approach in wind turbine technology. VAWT can capture wind from any directions and thus eliminating the need to re-orienting towards the wind. As a result, VAWT promise new hope in simple construction and design process, reduces cost to build and to carry out maintenance, aid installation, and eliminates the problem imposed by gyroscopic forces on the rotor of a conventional machine, as a turbine track the wind. The vertical axis of rotation also permits mounting the generator and drivetrain at ground level. All of these advantages over conventional HAWT are attracting researchers and developers to improve the performance of VAWT. Darrieus lift type and Savonius drag type are two types of VAWT that is commonly used [1].

Savonius type rotor blade is a simple wind turbine that operates based on drag concept. The working principle of Savonius rotor resembles a cup anemometer. The low efficiency of VAWT limits its usage in large power production. The most apparent advantage of VAWT is that it can operate in all wind directions and thus are built without using any yaw mechanism [2].

PRELIMINARY DESIGN

Rotor selection

Savonius wind rotor is one of the vertical axis wind turbine invented by SigurdSavonius, in 1925 [2]. Savonius rotor, having the S-shaped and consists of two half cylinders called the blade. The centre has been slide symmetrical to each other and placed in between two horizontal discs. The wind hitting the Savonius wind rotor at a certain speed leads to a positive torque in the inner part of the cylinder and a negative torque in its outer part. Since the torque in its inner part is higher than the torque in the outer part, a rotation movement is secured. When the torque on the concave blade of the Savonius wind rotor is compared with the torque on the convex blade, the former appears to be higher because of the different resistance coefficients of the blade surfaces [3].

For this reason, the Savonius wind rotor rotates in the direction of the positive torque that forms on the concave blade. The running principle of the Savonius wind

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rotor facing the wind of a certain speed is simply shown in Figure-1.

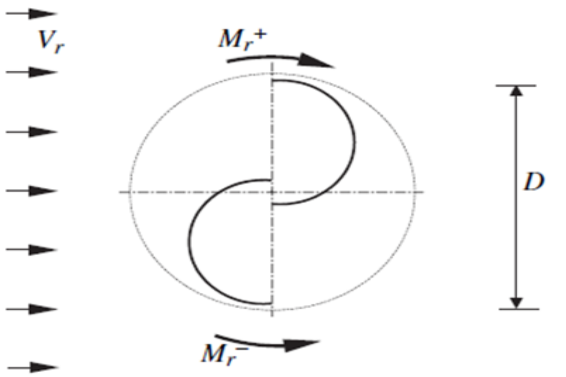

Figure-1. Direction of the torque affecting the rotor blades by the wind force [3].

Design of Savonius rotor is one of the simplest and cheapest vertical axis wind turbines. It has good starting characteristics. Its mean, it have a high starting torque, relatively low operating speeds and ability to capture wind from any direction [4]. Although there are certain number of advantages of Savonius wind rotors, but it is not widely use due to low aerodynamic performance levels factor.

Thus, various techniques were adopted by many researchers to increase the performance and improve the starting torque characteristics of Savonius turbine by using wind as working medium. Aldoss *et al.* [5] have developed a study to improve the performance of Savonius wind rotor by allowing the rotor blades to swing back with an optimum angle. It was founded that the optimum power could be increased when the blade turn against the wind. It is the one getting away from the wind, oscillated with the angles of 50° and 13.5°, respectively. Deda *et al.*[6] introduce a solution where a curtain has been placed in front of the Savonius wind rotor to prevent the torque occurs on the convex blade of the rotor in the negative direction shown in Figure-2.

Experimental measurements and numerical analysis have been conducted for the Savonius wind rotor with and without curtain. The best results have been obtained by using the rotor with curtain. Low static torque values have been obtained with the short curtain dimensions, while a considerable increase has been acquired in the static torque values with the long curtain dimensions. Golecha Kailash *et al.* [7] has carried out an experimentally study on the influence of the eight different location of the deflector plate on the performance of a modified Savonius rotor with water as the working medium at a Reynolds number of 1.32 x 10^5. It was found that deflector plate placed at its optimal position increases the coefficient of power by 50%. The maximum coefficient of power $Cp_{max}$is found to be 0.21 at the presence of deflector plate.

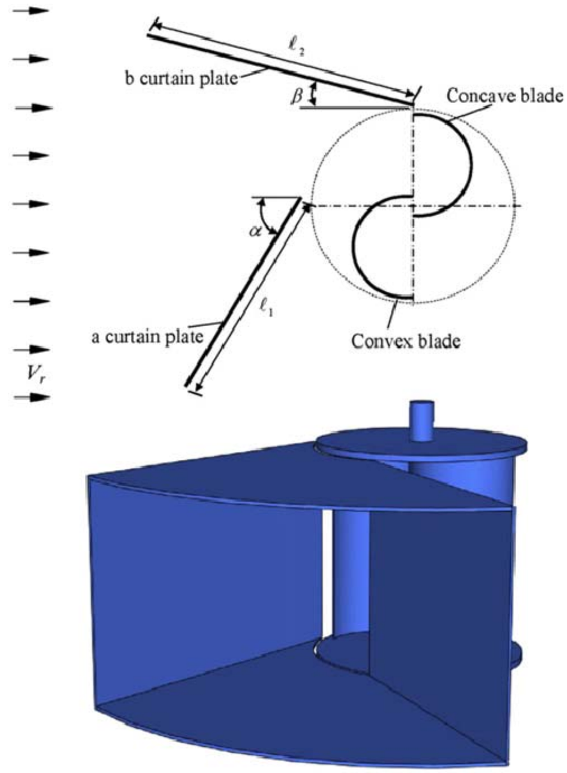

Figure-2. Curtain design parameters and arrangement [6].

Later, Golecha Kailash *et al*. [7] has foundthat the optimum position of the deflector plate on advancing blade side placed upstream to the flow which would result in increasing the power generated by the rotor. Based on results, it was found that by placing two deflector plates at their optimal positions upstream to the flow, it will increase the coefficient of power to 0.35. This is significantly higher than the coefficient of power of 0.14 observed for the rotor without deflector plates.

Wind turbine rotor

In this study, the Savonius blade model of the VAWT type will be used with respect to the air flow at the roof of the pickup truck body and axis of the wind turbine rotor. The whole body size of the system is set to be 0.1m in height and 1m width (0.1 m^2 front areas). Air velocity of turbine duct inlet for CFD simulation of flow on the turbine model will be set at 16.7 m/s, 25 m/s and 33.3 m/s which are equivalent to pick-up truck cruising speed of 60 km/h, 90 km/h and 120 km/h, respectively.

Wind turbine ducting system

One part at turbine duct called a flow guider has been introduced inside to increase the velocity of air and eliminate the moment occurring in an opposite direction of that rotation on the convex blade of the rotor without making any change in the basic structure of the conventional Savonius wind rotor. The lengths and location of the flow guider at neck region have been set

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according to a research conducted by Phillips [8] which stated that an augmentation of 1.38 on power coefficient (*Cp*) of Savonius wind rotor is achievable by a diffuser of Exit-Area-Ratio (EAR) of 2.22. An overall length to diameter meter (L/D) of 0.35. These values are used for the diffuser or duct design.

$$EAR = \frac{A_e}{A_i} \quad (1)$$

where;

Ae = diffuser/duct exit areas,
Ai = diffuser/duct inlet areas

Based on calculation above, the ducting system is having an inlet duct, inlet neck region and outlet widths of 1000 mm, 260 mm and 580 mm respectively. The length of the turbine duct is taken to be 1000 mm for it to cover the whole span of the turbine as shown in Figure-3.

PROTOTYPE OF WIND TURBINE

In this section, the selected design of wind turbine was fabricated. Mechanical fabrication process involves the production of main frame, turbine blades and turbine duct. Figure-4 shows the detail drawing of the main frame of wind turbine and Figure-5 shows model drawing of complete turbine system.

Figure-6 and Figure-7shows the installation of a wind turbine alternator. Alternator will act as a generator to generate power to the system through the pulley system. After the mechanical part is done, the system will be combined with an electrical system that has been done by the other party. The installation process also involves the installation of wind turbines and all components in to the vehicle for the test process.

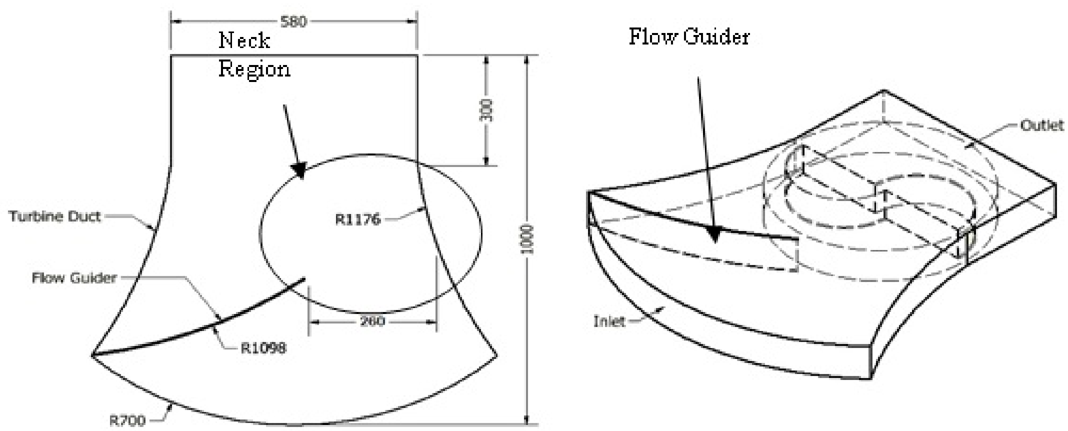

Figure-3. Turbine duct system present model.

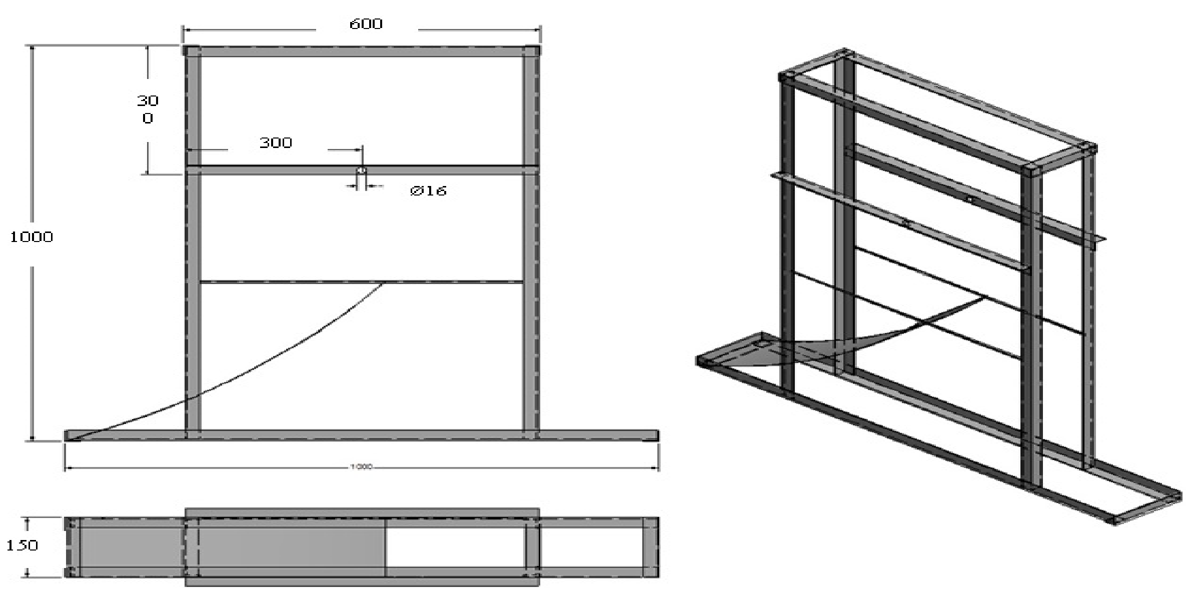

Figure-4. Main frame of wind turbine.

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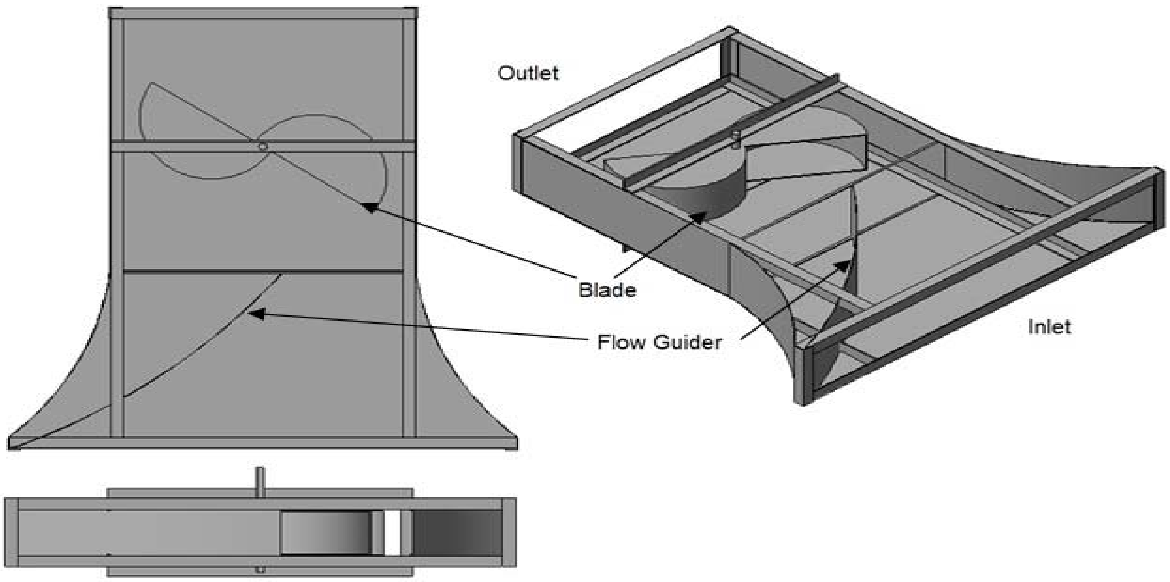

Figure-5. Model drawing of complete turbine system.

Figure-6. Installation of a wind turbine alternator.

Figure-7. Installation of wind turbine on roof of pickup truck.

RESULTS AND DISCUSSIONS

A series of experiments have been carried out to evaluate the performance of the wind turbine system. During the testing, wind turbine system has been installed on the top roof of moving Hilux. The effects of the travelling speed of Hilux on the voltage, the current and the power of wind turbine have been examined. Multimeter is used to measure the output voltage and current experiment to estimate generated power of wind turbine system. The experiment was conducted three times to get convincing sample data. For different speed of moving Hilux, variations of the output voltage and current of the wind turbine are shown in Figure 4.5 and Figure 4.6. The magnitudes of the maximum output voltage and current of a wind turbine are given in Table 4.1 and Table 4.2.

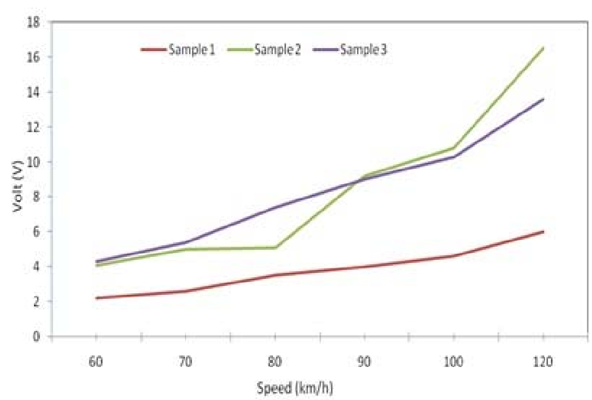

Figure-8. The output voltage of wind turbine system at various pickup truck speed.

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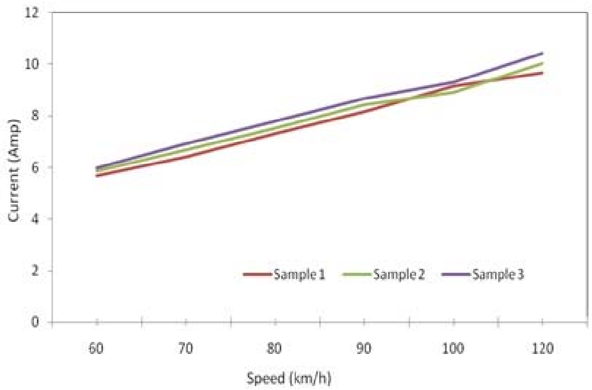

Figure-9. The output current of wind turbine system at various pickup truck speed.

As seen from the Figure-8, Table-1 and Table-2, the output voltage of wind turbine system is highest when speeds of pickup truck about 120 km/h. However, output current of wind turbine system is low compared to maximum of this system can be generated which is 55 Amp. As a result, wind turbine system is able to charge the battery of pickup truck because the minimum requirement for charging process of battery is 12 volt [9]. The time required to complete the charging process depends on the output of the current system.

Figure-10 shows relationships between the average output voltage and current of wind turbine system and pickup truck speed.

Table-1. The output voltage of wind turbine system at various pickup truck speeds.

Speed (KM/H)	AC Voltage (Volt)			Average voltage (volt)
	Sample 1	Sample 2	Sample 3	
60	2.2	4.1	4.3	3.5
70	2.6	5	5.4	4.3
80	3.5	5.1	7.4	5.3
90	4	9.2	9	7.4
100	4.6	10.8	10.3	8.6
120	6	16.5	13.6	12.0

Table-2. The output current of wind turbine system at various pickup truck speeds.

Speed (KM/H)	Current (Amp)			Average current (Amp)
	Sample 1	Sample 2	Sample 3	
60	5.68	5.85	6	5.84
70	6.42	6.67	6.92	6.67
80	7.3	7.52	7.8	7.54
90	8.17	8.42	8.67	8.42
100	9.17	8.92	9.3	9.13
120	9.67	10.03	10.43	10.04

The variations of output power of a wind turbine based on different speed of pickup truck are shown in Figure-11. The magnitudes of the output power of the wind turbine are given in Table-3. From the testing conducted, the output power of the wind turbine system is low compared to results of the simulation method. The output power of testing result is 62.3 watt while simulation result about 101.3 kW when speed of pickup truck about 90 km/h.

Table-3. The relationship of speed and the power.

No.	Speed (km/h)	Average Output power (W)
1	60	20.4
2	70	28.7
3	80	40.0
4	90	62.3
4	100	78.5
6	120	120.5

The differences between magnitude of simulation and testing result are caused by several factors. The power generation of wind turbine is low because the efficiency of wind turbine is not 100 %. It has mechanical lose in the bearings, generator and transmission of energy conversion system. Compare with wind turbine power generated equation; they assume does not have any mechanical loss in wind turbine system to simplify the equation.

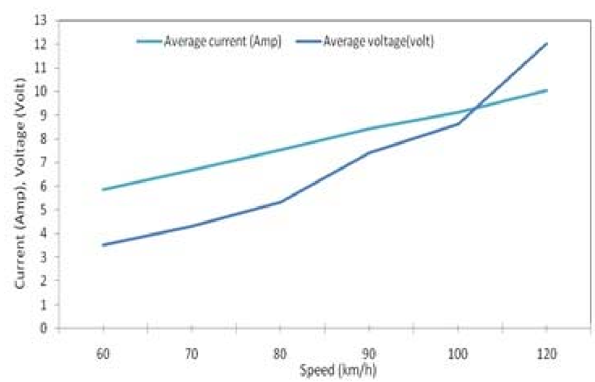

Figure-10. The output voltage and current of wind turbine system at various pickup truck speed

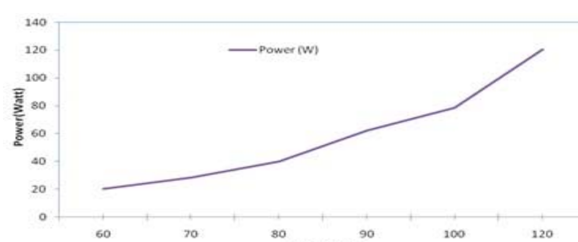

Figure-11. The output power of wind turbine at various pickup truck speed.

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Besides that, maximum air velocity at the neck region is used in wind turbine power generated equation to calculate power of wind turbine. But, the actual air velocity to turn the turbine blades was lower.

Material selection also plays important role during the designing process, as it might not be suitable especially for the wind rotor which is made from steel plate. This heavy steel plate has created high starting torque and need high velocity of air to start the rotation of wind rotor.

Output power of wind turbine system is low because of power rating of alternator used to accommodate the prototype of wind turbine system is low (0.667 kW). Power rating alternator should be higher to increase the output power generated of wind turbine system.

CONCLUSIONS

In conclusion, the wind turbine is a machine that can converts kinetic energy into electrical energy to produce electricity. Protoype model of wind turbine was fabricated to investigate the power output of wind turbines in experiments.

The location to install the prototype of wind turbine is on the top roof of the pickup truck because there is a high wind velocity in that area. But the issue is, whether the wind turbine will change the aerodynamic performance of the vehicle can be discussed in future work.

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