Performance Testing of a Proposed Design Energy Installation System for Vehicle’s Wind Turbine

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Abstract. The present study considered the performance analysis of a new proposed design of a vehicle’s wind turbine energy installation system. A test is conducted on the energy conversion and storage system that have been built to evaluate its performance and the capability. The result shows that the power that is generated by the system is directly proportional to the speed of the alternator. The time taken for charging a battery is also recorded and it is found that it takes about 2 to 3 hours to fill the 12-volt battery depending on the size and capacity of the battery used. The power generated for the system is 20.4 watt and 120.5 watt at 60 km/h and 120 km/h respectively. From the analysis that has been done, the energy from a turbine has the potential to generate power to car system. The wind energy is possible to integrate with other existing and renewable energy.

1. Introduction

Current research and studies has looked into inventing more economical and household applicable wind turbine to obtain power. Although most of the previous studies focus on harvesting wind energy are using large scale wind turbine, latest trend is looking into the idea of harvesting wind energy by mounting small scale wind turbine on a vehicle. The main concept will be similar to the conventional wind turbine but some modifications will be made to suit the usages in vehicle. Besides, an optimized storage system for the power generating will be used.

For this study, the newly proposed design of energy conversion system for vehicles will be enhanced by adding wind turbine. The wind turbine which has been developed and fabricated will be attached to the vehicle at the appropriate location. The location to place the wind turbine on a vehicle is based on the previous analysis by Sofian et.al [1].

An invention title “Wind-powered Battery Charging System” by Pena (1997) relates generally to an electrically powered vehicle and more particularly to a system for charging batteries which utilizes a wind-operated turbine and generator for charging the batteries while the vehicle is in motion and a flywheel for charging the batteries when the vehicle slows down or is stopped [3].
Kousoulis (2005) then come out with his invention title “Motor Vehicle with Wind Generator Device”. The general idea of the invention is to incorporate the wind turbine for production of electricity using the wind speed created by vehicles. The electricity generated can be connected to vehicle power accessories and to batteries so to charge them and eliminate the drainage on a main vehicle battery [4].

Jamal A. Baroudi (2007) provides a comprehensive review on detailed electrical component used for the generators [5]. All his control methods described, attempt to obtain maximum energy transfer from the wind turbine to the grid. There is a continuing effort to make converter and control schemes more efficient and cost effective in hopes of an economically viable solution to increasing environmental issues.

2. Methodology

2.1 Proposed design of energy conversion and storage system

The electrical circuit for this newly proposed energy conversion and storage system on a vehicle attached to wind turbine with 3 generators and a series of battery is shown in figure 1.

![Figure 1. Electrical circuit for energy conversion and storage system on a vehicle attached to wind turbine with 3 generators and a series of battery.](image)

The process of assembling electronic circuit must be done cautiously to make sure that the solder does not leak to ensure that in the end the circuit works properly. Figure 2 shows the overall electronic system energy conversion and storage system proposed for vehicle’s wind turbine used for this study.
2.2 Mechanical fabrication process
The newly proposed design is fabricate which also involves the installation of the alternator on the

turbine. The turbine that has been fabricated by the other party will be calibrated with an alternator.
The alternator will act as the generator to develop power to this system. Once the mechanical part is
done, then it will be combined with the electrical system that has been done. The fabrication process
also involves the installation of components into a vehicle.

2.3 Actual performance testing
A test was conducted with few factors to be considered. The first one is the capacity of the battery
pack that will be used; the second one is to make an assumption on the power generated by the
generator and also the electrical load of a vehicle.

Most battery capacity range for battery pack for Honda vehicle is about 140V to 160V as
mentioned in IMA system and up to 650 V for Toyota vehicle [2]. And yet, they are still using the
standard 12 volt battery as the ignition and the use of the loads.

The objectives are to convert a mechanical energy from the blade to electrical energy to generate
12V voltage and to store it in a 12 volt battery. The 12V battery voltage will then be supplied to a high
voltage system, up to 200V voltage capacity. The specification of power generator is set at 12 volt for
the voltage and 55Amp for the current and 50Hz for the frequency. The speed rotation for this
generator is 1320 rpm for the minimum cut in and up to 2700 rpm for the maximum speed. The real
energy obtained by generator will be determined by the speed of turbine. Once the speed of turbine
remains constant and achieves minimum requirement of generator speed, full voltage for the output
should be obtained.

2.4 System testing
A testing had been done to test the performance of the system. For the testing, both of mechanical and
electrical components are combined. While testing, mechanical component has been located on top of
the Toyota Hilux. Meanwhile the electrical components are placed in the passenger compartment. The
passenger takes the voltage reading using a multimeter in the seated compartment. The test has been
conducted according to the speed required by the vehicle.
3. Mathematical Modelling

There are two energy formulas that are related to this study. The formulas are related to determining the real voltage obtained from the device and the power of the system. One of the formulas is voltage formula as shown in Eq. (1). The effective output voltage obtained by voltage root mean square (V<sub>rms</sub>) is described by the equation (4.1) [36].

\[ V = V_{rms} \times \sqrt{2} \]  

(1)

Where,

\( V_{rms} \) is the voltage root mean square; \( V \) is the voltage obtained from any sources

The power of the alternator can be calculated based on the Eq. (2). The calculated value is supposed to be the output of the alternator based on the specification provided.

\[ P = V \times I \]  

(2)

So the power generated from the alternator should be 0.66kw. This theoretical value will be the reference for the next testing for the system.

\[ P = 12V \times 55A \]  

\[ P = 0.66kw \]  

(3)

So the power generated from the alternator should be 0.66kw. This theoretical value will be the reference for the next testing for the system.

3.1 Calculation of blade speed and alternator speed

There are several speeds to be calculated in this project such as the speed of the blade and the alternator speed. Based on the speedometer on the car, we can simulate the speed so called velocity to get another speed. The velocity of the car is a benchmark to calculate the speed of the blade and the speed of the alternator. Both of them are calculated in revolution per minute (RPM). From the calculation, the speed obtained for the blade at 60km/h per hour is 295rpm.

Based on the calculation, the blade speed at 70km/h, 80km/h, 90km/h, 100kmh and 120km/h has been calculated. The result for blade speed is shown in the table 1. The alternator is connected to the blade by a pulley system and driven by belting. Once the speed of blade is obtained, the speed for alternator can be calculated by calculating the ratio of the pulley size. Assuming that the speed for blade is RPM 1 and speed for alternator rotation is RPM 2. The speed for the alternator rotation is shown in table 1. The calculation ratio is shown in Eq (4). The diameters for the blade pulley and alternator pulley are 135mm and 37.5mm respectively.

\[ \frac{RPM_1}{Pulley\ diameter\ 1} = \frac{RPM_2}{Pulley\ diameter\ 2} \]  

(4)
Table 1. The blade speed and alternator rotation speed

| No. | Speed (km/h) | Blade Speed (RPM 1) | Alternator rotation speed (RPM 2) |
|-----|--------------|---------------------|----------------------------------|
| 1   | 60           | 295                 | 1062                             |
| 2   | 70           | 344                 | 1238                             |
| 3   | 80           | 393                 | 1415                             |
| 4   | 90           | 443                 | 1595                             |
| 5   | 100          | 492                 | 1771                             |
| 6   | 120          | 590                 | 2124                             |

The reason for using 60 km per hour as the initial speed in this experiment is to obtain alternator speed of more than 1000rpm because the minimum speed to generate power is 1320rpm [3]. The limitation of the speed up to 120 km per hour is to make sure that the vehicle can be controlled easily. The speed can be more than that but it is good enough to get the data with the current limitation.

4. Result and Discussions

4.1 Result for voltage and current generate by alternator

An actual testing is conducted to get the reading of the components in the system. The first reading is on the alternator generating power. In order to get the actual power generated by the system, readings for voltage and current must be obtained. The test is conducted three times to get reliable data. Figure 3(a) shows the average voltage, figure 3(b) shows the average current for the system and figure 3(c) shows the average power generated during the testing.

![Graphs showing voltage, current, and power generation](image-url)
4.2 The relationship between power and speed

The power generated is based on the speed of the vehicle. The power increases when the speed increases. From the test conducted, the power generated at speed 60 km/h is 20.4 watt while at speed 120 km/h the power generated is 120.5 watt. According to the study by Jianhu Yan [4] and Jamal A. Baroudi [5], the pattern for the result is similar where both of them gain the same sequence for the speed and power. Figure 4 shows the relationship between the speed and the output power.
4.3 Battery charging

The 12 volt battery charged is recorded at full voltage load running in the system at 12 volt. From the observation, the battery is charging about 0.03 volt in three minutes. It is hard to maintain the value because in order to obtain 12 volt voltage, the vehicle must run at 120 km/h. From the other observation, the battery charged for ten minute is 0.55 volt. Based on the samples, an assumption for the charging can be calculated based on Eq (5).

\[
\begin{align*}
0.03 \text{ volt} &= 3 \text{ min} \\
0.55 \text{ volt} &= 10 \text{ min}
\end{align*}
\]

Thus, 
\[
12 \text{ volt} = 3 \text{ hour} 23 \text{ min}
\] (5)

Based on the calculation, the time for charging 12 volt empty battery is 202.5 minutes which is equal to 3 hours and 23 minutes. Since the battery is in good condition, there must be voltage already stored in the battery. Usually the battery stores about 2.3 to 3 volt [6]. So in average, the minimum voltage remains in the battery is 2.7. From 2.7 to full charge 12 volt, the battery needs about 9.3 volt. So the time taken to charge 9.3 volt is estimated around 128 minutes which is equal to 2 hours and 8 minute. This calculation is done as simulation result due to the constrained condition on the actual testing. To run a vehicle at the constant high speeds about two to three hours is quite difficult and risky. That’s why the interaction equation is used to estimate the time for storing the power.

5. Conclusions

From the study it can be concluded that the energy from a turbine has the potential to generate power to car system. The wind energy is possible to integrate with other existing and renewable energy. At this stage, the energy gained does not replace the existing one but it can be considered as a new energy source in the future energy development. In a hybrid system, the wind turbine can be an alternative for electrical source but not to replace the petrol engine. Wind turbine can minimize the usage of power generation from the engine as a source of electricity in hybrid system. The combination of wind turbine and petrol engine becomes more efficient and provides continuous electricity to the vehicle all the time.

The output power which is measured by the voltage in the system depends on a few factors such as;

a) The speed of the vehicle which is directly proportional to the blade speed and the power obtained, as mentioned by Jianhu Yan [4].

b) The rotation of the turbine blade. It can be concluded that the higher speed of the vehicle, the more revolution gained on the blade. Once the blade produces higher revolution on the rotation, then more power will be generated to the system. Since this system needs to be tested on the road, speed of vehicle is set to 120 km/h to ensure the safety on the road.

c) The material used for the turbine blade. The material of turbine blade can affect the turbine rotation. In this project, the material used is mild steel with the thickness of 2mm. The weight of mild steel is heavier compared to the other advance material. This situation causes the rotation of turbine blade at the beginning to be slower than expected. The friction of the steels also affects the rotation even though ball bearings are already installed. The connection between the steels somehow reduces the rotation efficiency.

d) The electrical circuit. For the electronic circuit there is classified into three sections which are inverter circuit to step-up the voltage from Dc to Ac, rectifier circuit is to convert Ac to Dc and regulator stabilizer is to stabilize the flow of voltage to 12vdc. The regulator will regulate the overload source to the required source.
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