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Analysis and Optimization of Electric Vehicle Conversion Performance

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ABSTRACT: In this study, the conversion is carried out by converting conventional gasoline-fueled vehicles into electric vehicles. Replacement is done by removing the driving engine and replacing it with a motor that is automatically added to the battery as an energy source. The placement of the existing components affects the center of gravity where all the weight of the car is centered at one meeting point. From the measurement and calculation results, it is found that the change in weight of conventional vehicles to electric vehicles due to the addition of motor components in front and a battery is a total of 300 kg. The added weight resulted in a significant change in relation to the change in the center of gravity that has been measured and calculated with the change in value from 38.94% (front to back) to 54.50% and being in the middle of the car because the lower, the middle, the better. Likewise, the change from 50.34% to 50.95% (from left to right) so that the lower the car's focus, the effect will be felt when the vehicle turns or maneuvers. In addition, it also aims to determine and analyze the performance of electric motors installed in convertible electric vehicles that still use manual transmissions so that the focus of research is on transmission performance and electric motors in power and torque distribution. The 3 Phase motor is installed with a battery with a clock capacity of 150 AH and a total voltage of about 72 volts DC and is supported by a 12 VDC voltage battery to support electrical accessories and braking. Vehicle analysis focuses on the power consumption which is measured and obtained using a power analyzer that has a DAQ. The vehicle is driven in real terms with 3 passengers. GPS is also used to obtain vehicle position and altitude data during testing. The derivatives of the GPS data are the vehicle's speed, acceleration, and distance. The initial hypothesis was that the vehicle could cover a distance of 30 km under normal use. The determination of power consumption patterns of electric conversion vehicles and the reliability of their work systems. From data is obtained for further study related to how to recharge the battery and improve the work system of the conversion vehicle.

KEYWORDS: gasoline-fueled vehicles, electric vehicles, electric, motors, manual transmissions

INTRODUCTION

Based on data from the Central Bureau of Statistics (BPS) related to the increasing production and demand for the number of vehicles. The increase in the number was caused by community activities both for personal, public interest as well as increased production and distribution activities which resulted in the increasing demand for fuel as well.[1] The decreasing availability of fuel will motivate researchers to make more environmentally friendly vehicles, one of which is electric vehicles as vehicles with electric current as a power source.[2] The awareness of environmental protection and energy savings continues to increase, with the presence of electric vehicles, the consumption of fossil fuel oil will be reduced. In addition, it will have a positive impact on the environment because the vehicle is zero emissions. [3]

In fact, the awareness of the shift in the use of electric vehicles from conventional vehicles in the community already exists, it remains necessary to prepare infrastructure and the availability of vehicles at affordable prices so as to facilitate the transfer of existing technology.[4] In fact, in Indonesia, there are not many electric vehicles that are sold commercially by or there are no specialized manufacturers of electric vehicles that are compatible so that they can be used directly by the public. This is what makes the switch to electric vehicles expensive and somewhat late despite the abundant availability of electricity sources as many power plants are built. This is what interests researchers to research the conversion of conventional vehicles to become electric vehicles. [5]

Based on the description above, several things can be formulated related to the formulation, design and testing of the electric conversion car converted from a conventional vehicle (combustion motor) to an electric conversion vehicle that can show good performance on the drivetrain performance test to get the optimal gearshift combination. [6][7]

THE AIM AND OBJECTIVES OF THE STUDY

The design and research are limited by several predetermined provisions, including: 1. The test equipment uses the UI electric conversion vehicle (Molina EV) with a vehicle weight of 1011 kg 2. Tire pressure used is 40 psi, the coefficient of friction is 0.02.

The working speed of Vlimit = 0 km / hour and Vultimate = 80 km / hour 4. Electric conversion vehicles run on predetermined routes 5. The electric conversion vehicle is operated under normal operating conditions in gears 1- 5.
In this study, the main objective to be achieved is to conduct drivetrain testing on electric conversion vehicles to obtain 2 optimal gearshift combinations.[8]. To achieve the main goal, there are several additional goals that must be fulfilled, including:

1. Determine the specifications of the conversion vehicle properly.
2. Determine the ability to charge the battery properly
3. Determine the motor performance properly
4. Obtain the certainty value from the test and measurement of the Center of gravity (CoG)
5. Obtain the certainty value from the Dynotest test with a variety of gear shifts.
6. Obtain the Motor Performance Test value by measuring the Power Quality Analyzer (PQA).

LITERATURE REVIEW

Electric Conventional Vehicles

An electric conversion vehicle is a vehicle designed from a conventional vehicle with a fossil fuel engine (internal combustion motor) replaced with an electric motor as a propulsion with a power s ource from a DC battery which is adjusted to the capacity of the motor driven. By replacing the internal combustion motor with an electric motor, many components are no longer needed, such as the entire fuel system, air filter, exhaust system and engine control unit. However, there are also some components that can still be utilized because they still perform the same function, such as the transmission, clutch, and also all drivetrain components of the vehicle. [9]

In converting a car into an electric vehicle, we must know the type of car we are converting and consider the weight of the car in order to ensure that the electric motor that replaces the combustion motor in the car is able to keep the car running as it should, therefore, the power and torque that are can be generated by an electric motor to be one of the parameters to consider in converting. The type of electric motor used in this electric conversion vehicle is an AC motor 7.5 kW. In addition, because the electric motor is powered by a battery, we also have to consider the type of battery to be used, whether the battery is able to provide the power needed for the electric motor used. There are two types of batteries commonly used in electric vehicles, namely Deep Cycle Lead Acid and Lithium. The better type to use is the lithium battery type, however, due to its very high price, the conversion of the Makara Electric Vehicle 02 is the Deep Cycle Lead Acid Battery. This research will focus on the subject of analysis on the power and torque generated by electric motors used in conversion vehicles. [10].

The option to convert vehicles has been made by several communities as well as government agencies. Electric Vehicle of America (EVA) revealed that the impact of converting electric vehicles includes lower maintenance costs. Some of the advantages of convertible electric vehicles are as follows: Recycling of used vehicles, Reducing levels of air pollution, Eliminating the need to replace lubricants, Eliminating the obligation to use a water cooling system, allowing users to perform the majority of vehicle maintenance independently. [11] The author uses power and torque as the main variables as part of the analysis and also the results of his research. the rate of work that occurs because the force applied is power. If the force does work (W), in a unit of time (t), the average power due to the force exerted on that time frame, can be made as an equation:

$$\boldsymbol{P} = \frac{W}{\Delta t} \tag{1}$$

Torque is a product of the force and distance perpendicular to the axis of rotat ion. Like the above equation, torque can be calculated by the force we get at a certain distance, where on a rotating object, the distance we use is the radius of the force to the rotating axis of the object.

Gear Ratio

Gear ratios When a series of gears are used to transmit power from the drive to the wheels, the gear connected to the drive is called the driver gear or input gear, and the gear connected to the wheel is called the driven gear or output gear. In general, the gear that is located between the driver gear and the driven g ear is called the idler gear. [12] Gear ratio (GR) is the ratio of the number of teeth in the output gear (connected to the wheel) to the number of teeth in the input gear (connected to the drive or motor) The gear ratio is the description of the ratio of the output torque to the input torque.[13] Thus, we can multiply the drive shaft torque (input) by the gear ratio to find the torque at the axle (output). We can calculate the torque at the axle as follows:

Table 1. Vehicle gear transmission ratio

Gear Ratio I	**3,417**
Gear Ratio II	1,960
Gear Ratio III	1,250
Gear Ratio IV	0,865
Gear Ratio V	0,707
Gear Ratio Reversr	3,143
Final Gear Ratio	4,643
Tires Dimention	155/80 R13

For the needs of the main electric motor (bus driving) is calculated by analyzing the vehicle traction force. The traction force needed to move a vehicle is influenced by several drag forces that work when the vehicle is moving which is illustrated by the following equation:

$$F = m\,a + R_a + R_{rl} + R_g \tag{2}$$

Where: F is the traction force, m is the mass of the vehicle, Ra is the aerodynamic drag force, Rrl is the friction force, a is the acceleration of the vehicle, Rg is the gravitational force arising from elevation.[14]

In the vehicle performance analysis, only uphill operations are considered. This grading style is usually called gradation resistance from Figure 2.5,

To simplify calculations, the street angle, α, is usually replaced with the grade value when the street corner is small. As shown in Figure 2.5, a class is defined as:

When road corners are small, roadblocks can be simplified.

$$i = \frac{H}{L} = tan\,\alpha + \quad sin\,\alpha \tag{3}$$

$$F_{rd} = F_f + F_g = M_v g(f_r\,cos\,\alpha + \quad sin\,\alpha) \tag{4}$$

Where: ρ is density of fluid, Cd is drag coefficient, Af is frontal Area, v is vehicle speed, fri is rolling coefficient, α is elevation angle

Electric Motor

Based on the business concept, electric power is the amount of effort in moving the charge in units of time or the amount of electrical energy per second. The formulation is written as follows [16]

$$\mathbf{W = V.I.t} \tag{5}$$

Where: V is Voltage (Volt), I is Current (Amperes), t is Time (Second) W is Energy (Joule), t is Time (Second)

Then:

Po = V.I.Pf (6)

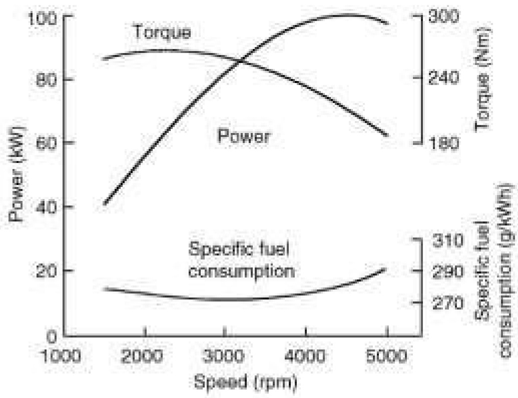

Figure 1. Types of gas engine characters [17] Internal combustion engines have a relatively flat (compared to ideal) torsio n speed profile, as shown in Figure 1.

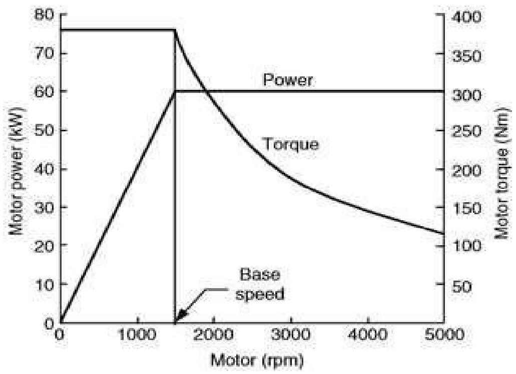

Figure 2. Types of electric motor characters [17]

As a result, multigear transmission is usually used to modify it, as shown in Figure 3.a. An electric motor, however, usually has a much closer to ideal speed-torque characteristic, as shown in Figure 3.b. In general, electric motors start at zero speed. As it increases to basic velocity, the voltage increases to its rated value while the flux remains constant.[16]

Table 2. Three-phase AC motor specifications

Tipe	*XYQ-7.5-3AHV*
Rated Power	*7,5 kW*
Rated Voltage	*51 V (A.C)*
Rated Current	*118 A*
Speed Range	*0 - 5875 r/min*
Frekuensi	*0 - 200 Hz*
Rated Speed	*3440 r/min*

RESEARCH METHOD

In this chapter, the writer will also explain how this series of data collection will have an effect in answering the problem formulation in this study by referring to the theoretical basis and existing literature studies. From the research flow diagram above, to achieve the research objectives, conduct drivetrain testing on vehicles. Electrical conversion to obtain 2 optimal gearshift combinations carried out several stages of implementation, namely: Preparation of Material Specifications, Preparation of Tool Specifications. Testing Methods, Processing Time, Testing Standards. In order to determine the efficiency of the driveline that will affect vehicle performance, the authors chose to use an experimental methodology. Experimental methodology is a methodology used to assess the theoretical understanding of this research. In its use, this motorbike functions as the main driver whose performance is seen in order to determine the performance of the conversion vehicle in general. The measured variables are the amperage and voltage at the time of operating the vehicle with the existing gear shifting variations. The electrical circuit is made to make it easier to understand the working system so that it knows and monitors how the conditions and functions of each component are to be measured according to the values and capabilities they have.

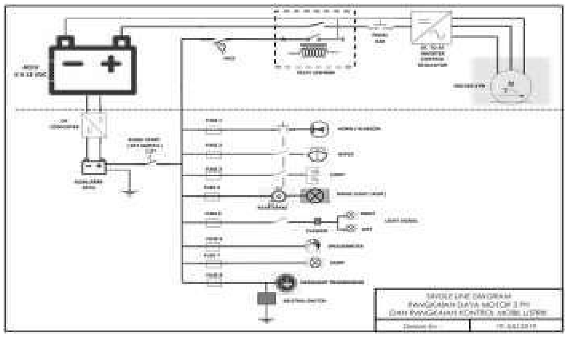

Figure 3: The single line circuit in an electric vehicle When collecting data using PQA, it can be done in the condition of the vehicle being measured in place or in running conditions so that it is more practical in operation. Make sure the circuit is installed correctly so that the validity of the data can be accounted for.

Figure 4. Installation of tools when testing scales

Here are some steps to collect data on the torque and horse power of the conversion vehicle. The initial stage before testing the torque and horse power, the dyno test must be calibrated in the brake conditions. After we give a signal to the multitester, we can quickly find out how much power the brake is able to stop rotation. If it has been calibrated, then raise the conversion vehicle to the chassis dyno test to carry out the torque and horse power test. Because there are quite a lot of devices that have to be installed and must be integrated, and there should be no failing devices, then before the whole test (system) must be carried out partial testing. In this study, various measurements were carried out including: Battery Charging System, Center of Gravity (CG) Measurement, Torque and Power Measurement (Dynotest), Electric Motor Measurement (PQA).

RESULT

From the previous description that in order to achieve the research objectives by conducting drivetrain testing on electric conversion vehicles to obtain 2 optimal gearshift combinations, several stages of implementation were carried out, namely: Preparation of Material Specifications, Preparation of Tool Specifications, Analysis Methods, Processing Time, Testing Standards.

Charging

Based on the steps above, in this study, the engine was replaced with a 3-phase AC electric motor, plus 6 batteries as a power source, which the Charging process was carried out on 6 batteries with a capacity of 150 Ah and 12 Volt DC (the maximum voltage was 72 Volt DC.) which is installed in series is carried out at a residual voltage condition of 65 Volts (80%) carried out for 3 hours to be able to meet the capacity up to 100% of 72 Volt DC patterns and stages of charging. From Figure 4.1, we can know how the charging process that occurs in the battery, where when the charging process increases about 7 volts from 65 to 72 volts stable, it takes about 3 hours with a linear trend.

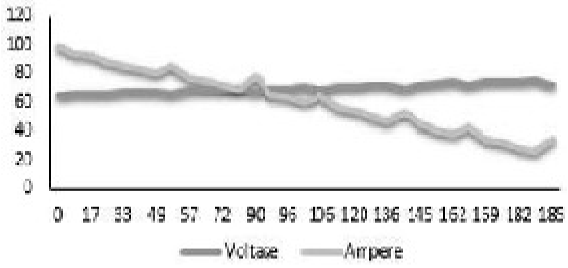

Figure 5. Comparison of Charging Voltage vs Ampere

Centre of Gravity (COG)

In the implementation of this research carried out by measuring the weight of the vehicle on each wheel as a fulcrum by comparing the various conditions of the different variables, both the vehicle variable and the additional passenger variable. 802.5 kg to 1011 kg in electric conversion vehicles (after the addition of batteries and motorbikes) means that there is an additional weight of 208.5 kg with details as the addition of the total weight of each wheel. Furthermore, in electric conversion vehicles simulated with the addition of passengers from the first passenger (78 kg), second (74kg), third (69 kg) and fourth passenger (54.5) which are respectively distributed to each part of the wheel.

Table 4. Calculation results of COG length and width

Center of Gravity (Horizontal)	Konvensional	KONVERSI (empty)	KONVERSI (1Pass.)	KONVERSI (2Pass.)	KONVERSI (3Pass.)	KONVERSI (4Pass.)
Front to Rear (cm)	95.6	133.8	132.6	131.2	135.5	137.6
Front to Rear %	38.94%	54.50%	53.99%	53.44%	55.19%	56.04%
Left to Right (cm)	70.5	71.3	73.8	71.4	73.6	72
Left to Right %	50.34%	50.94%	52.71%	50.99%	52.56%	51.42%

The following is one of the measurements with PQA when operating the vehicle in a condition without tires on the wheels

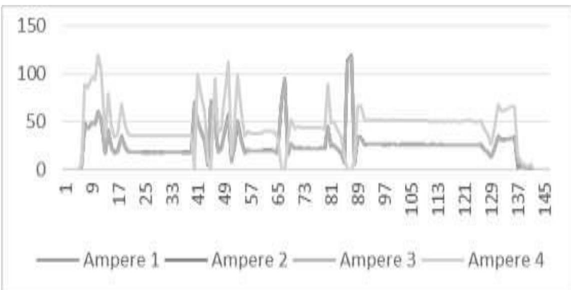

Figure 6. 3-Phase Motor RST Ampere Graph

The following are the results of measuring the voltage and amperage of a 3-phase AC motor where when the measurement uses the Power Quality Analyzer (PQA), the measurement is done by running the vehicle without a load by lifting the front wheel and varying the rotation of gear shifting 1 to 4 with maximum speed as following: • The maximum speed of 1st gear is 20 km / hr • The maximum speed of 2nd gear is 40 km / h • The maximu m speed of 3rd gear is 60 km / h • The maximu m speed of 4th gear is 80 km / h

From these results, the measurement results of the current and voltage on the 3-phase motor (attached) are obtained and when the displacement conditions occur a very high amperage spike, this if it occurs continuously will result in the ability of the battery to run out quickly.

The gear ratio of the vehicle is in accordance with the following table 5.

Table 5. Vehicle gear transmission ratio

Gear Ratio I	**3,417**
Gear Ratio II	1,960
Gear Ratio III	1,250
Gear Ratio IV	0,865
Gear Ratio V	0,707
Gear Ratio Reverse	3,143
Gear Ratio Final	4,643
Tire Dimention	155/80 R13

Specification of electric motor as Drivetrain

Table 6. Specifications of motor vehicles

Spesifikasi Inverter:

Rated Power	Rated Voltage	Rated Speed	Rated Torque	Peak Power
7.5KW	72V	3000rpm	22.3NM	16KW

$$Po = \left(m\,a + \frac{1}{2}\rho\, C_d\, A_f\, v^2 + f_{rl}\, m\, g + m\, g \sin\alpha\right).v$$

Haversin formula:

$$d = 2r\sin^{-1}\left(\sqrt{\sin^2\left(\frac{\Phi_2-\Phi_1}{2}\right) + \cos(\Phi_1)\cos(\Phi_2)\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right)$$

The electric vehicle test route (real experiment) in the UI environment with a distance of about 5 km.

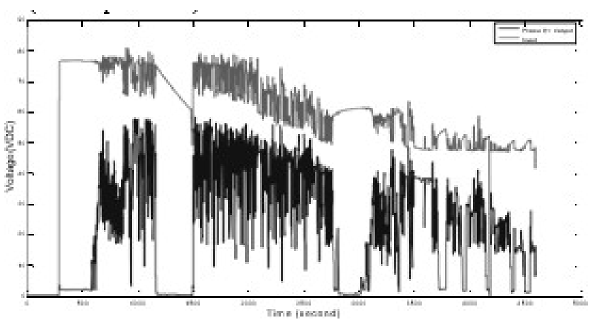

Figure 7. Comparison between input voltage and output phase 1 voltage on an electric motor.

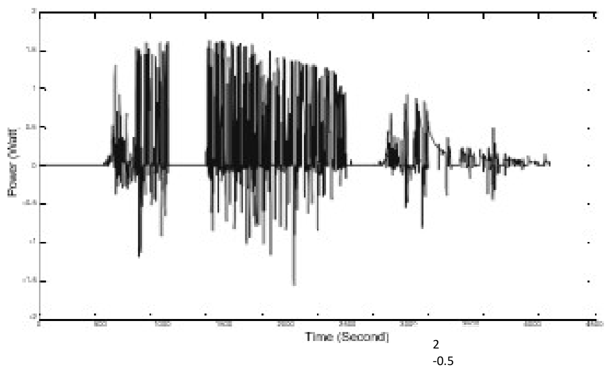

Figure 8. Graph of the power used by the electric vehicle during the test

DISCUSSION

Based on the steps above, in this study, the engine was replaced with a 3-phase AC electric motor, plus 6 batteries as a power source, which the Charging process was carried out on 6 batteries with a capacity of 150 Ah and 12 Volt DC (the maximum voltage was 72 Volt DC.) which is installed in series is carried out at a residual voltage condition of 65 Volts (80%) carried out for 3 hours to be able to meet the capacity up to 100% of 72 Volt DC patterns and stages of charging. From Figure 4.1, we can know how the charging process that occurs in the battery, where when the charging process increases about 7 volts from 65 to 72 volts stable, it takes about 3 hours with a linear trend. When viewed from the capacity of the battery 150 AH times 6 pieces and the capacity of its use with a motor load of 118 A, it can be calculated that its use is capable of rotating the motor up to 7 hours of operation with stable conditions, but because there are several factors that make this capability not fulfilled, including: vehicle load, the route of the vehicle so that it must be adjusted both straight up and down and braking due to speed bumps and so on, this condition forces the real ability to be obtained about 4 hours of operation. DC- DC Converter installed on the conversion vehicle as shown in Figure 37 is a tool that functions to charge the battery support system by reducing the voltage from 72 volts to 12 volts. This supporting battery functions to supply power to the vehicle's implement both wipers, horns and even the most important thing is the supply to the braking system.

In the implementation of this research carried out by measuring the weight of the vehicle on each wheel as a fulcrum by comparing the various conditions of the different variables, both the vehicle variable and the additional passenger variable. 802.5 kg to 1011 kg in electric conversion vehicles (after the addition of batteries and motorbikes) means that there is an additional weight of 208.5 kg with details as the addition of the total weight of each wheel. Furthermore, in electric conversion vehicles simulated with the addition of passengers from the first passenger (78 kg), second (74kg), third (69 kg) and fourth passenger (54.5) which are respectively distributed to each part of the wheel. The additional weight resulted in a significant change in relation to changes in the center of gravity which resulted in the measured and calculated center of gravity in good condition because the value had changed from 38.94% (front to back) to 54.50% and was in the middle of the car because it was getting lower, the middle, the better. Likewise, the change from 50.34% to 50.95% (from left to right) so that the lower the focus of the car, the effect will be felt when the car is bent at a turn or maneuver. A car with a low focus of gravity will be more stable and have less symptoms of dizziness, making it easier to con trol. The weight shifting when turning and braking is also less and easier to read, making the car very easy to control by the rider.

The following are the results of measuring the voltage and amperage of a 3-phase AC motor where when the measurement uses the Power Quality Analyzer (PQA), the measurement is done by running the vehicle without a load by lifting the front wheel and varying the rotation of gear shifting 1 to 4 with maximum speed as following: • The maximum speed of 1st gear is 20 km / hr • The maximum speed of 2nd gear is 40 km / h • The maximum speed of 3rd gear is 60 km / h • The maximum speed of 4th gear is 80 km / h . From these results, the measurement results of the current and voltage on the 3- phase motor (attached) are obtained and when the displacement conditions occur a very high amperage spike, this if it occurs continuously will result in the ability of the battery to run out quickly. The following are the results of measuring the voltage of a 3-phase AC motor where when the measurement uses a Power Quality Analyzer (PQA) which is measured by running the vehicle. Measurement of voltage and average current shows conditions that are not much different where at each gear shift there is a surge in both the increase and the voltage, even though the two currents have a higher number than the change in voltage. Large changes in current due to each displacement require a large amount of power to accelerate the rotation and load which in the context of electric motor loads is dominated by changes in current while the voltage is relatively more stable.

The research was conducted by testing the torque conversion vehicle. Experimental data on torque and horse power with the results of the rpm rotation before. From the measurement results of horse power (HP) to the speed of each gear shift condition (1-5) where the value of the 1st gear HP has a low resistance to speed with a relatively higher HP than 5th gear and the highest is the gear. 4th because it has the longest resistance with the relatively high HP value. Likewise, in the Torque measurement results against the speed of each gear shift condition (1-5) where the 1st gear Torque value has low resistance to speed with. The torque is relatively higher than the 5th gear and the highest is 4th gear because it has the longest resistance with the highest relatively high Torque value. Describing the various possibilities to get optimal results, in this case there are 2 possibilities by using 2 gear combinations are used to get the optimum value between hors e power, torque and rpm.

CONCLUSIONS

From the results of the research and analysis presented, the following conclusions can be drawn:

1. Conventional vehicle conversion (power 65 HP / 6000 RPM and torque of 86 Nm / 3600 RPM) is one solution considering the large population of conventional vehicles and the possibility of expensive electric vehicles being the background for the research on the conversion of these vehicles into electric vehicles.
2. Charging the battery is done with a fast process with a duration of about 3 hours for a charge of 5-7 volts (65-72 volts) with a battery capacity of 150 AH times 6 pieces and the capacity of its use with a motor load of 118 A real capability obtained about 4 hours operation.
3. The results of the calculation of the power and torque generated by the motor, the maximum power of the motor is 61.13 kW at 5000 rpm motor rotation and the resulting torque is 116.75.
4. Selection of the transmission ratio that is very suitable for use in two-speed transmissions is the transmission ratio 1.96 for 2nd gear and 1.25 transmission ratio for 3rd gear based on calculations and from the results of analysis and calculations, the optimal value is the combination. Between 2nd and 3rd gears, the value of torque and power to speed optimization has the highest value so that the vehicle is only capable of traveling at 65.30 km / h at two speeds and the vehicle is also capable of traveling at 49.98 km / h in second gear.

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