Performance analysis of motor for electric vehicle convertion by power quality analyzer

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Performance Analysis of Motor for Electric Vehicle Convertion by Power Quality Analyzer

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Abstract. Electric vehicles are a manifestation of technologicaladrnnces in the transportation sectorthat are beingpromotedrecently. Meanwhile, in the process of converting a vehicleinto an electric\·ehicle, there are severalcharacteristicsthat have alsochanged, one of whichis the stability of the \·ehicle. This study touches a little on the effect of changes in the center of gravity and total mass of the vehicle on vehiclestability. The stabilitydiscussedin thisresearchis the roll radius and the vehicleskid. This researchwasconductedby collecting\·ehicle mass data and processingitinto the vehicle's center of gravity and fromthis data itwasprocessedintovehiclest ability to bediscussed. This studyanalyzes the performance of the electricmotorpowertrainelectricvehicle (EV) system as an electricvehicle motion. This studyanalyzes\·ariousfield conditions as \·ariables thatwillbeused as a reference in measuring the reliabilitylevelof \·ehicle performance, referring to specifications, center of gravity and tire radius. The threeexisting tilt variations willbeused to determine the performance of an electricvehiclebasedon the performance of the electricmotorwhichwillbeused as the basis for designing a new conversion \·ehicle. The methodused in thisresearchis to analyse the power, current and voltage consumed by the motorwhen operating an electricvehicle. The use of a Power Quality Analyzer (PQA) in monitoring the operation of an electricmoto rwhengiven a load variation of gear speed I to 3 from the measurementresults, the current tends to increase al 15-20 amperes and the voltage tends to be stable, 27 volts.

Keywords: Centre of gravity, Powertrain; Analyzer; Electric Vehicle, Perfotmance.

INTRODUCTION

The availability of fuel which tends to decrease will lead to motivation for researchers to make more environmentally friendly vehicles, one of which is electric vehicles as vehicles with electric current as a source of propulsion. Awareness of environmental protection and energy savings continues to increase, where with the presence of electric vehicles the consumption of fossil fuels will be reduced because the vehicle is zero emissions. The biggest difference between an electric vehicle (EV) and a combustion engine vehicle is located in the powertrain system where traditional vehicles with a combustion engine are driven by fossil-fueled engines to provide energy for the vehicle to be able to drive while the energy source of electric vehicles is electric energy that is the driving system includes motor system, controlsystem, andbattety system. [l].
City streets, which are congested with vehicles, will not allow cars to run at high speed. However, some people demand their cars to have the same speed before and after conversion. It is to ensure satisfaction in convertingE[2]. Target speed depends on the performance of the electric motor. The component performance of an electric motor is determined by the propulsion system used. The efficiency of the propulsion system depends on the type of electric motor used and the efficiency of the motor controller. The efficiency is also available on vehicle power transmission components, namely transmission, propeller shaft, and differential. But in EV conversion, the efficiency of power transmission components is considered ideal or constant. Work obstacles on the vehicle must be determined to find out the performance requirements. It is to achieve speed targets, including; vehicle specifications, the gravityand tire radius, calculationof vehicle friction force, final drive transmission ratio, and vehicle traction calculation[3].
The simulation resultsshowedthat the proposedcontrollerreduces fuel consumption in the real driving cycle and

additional capital of about 21% and 6% respectively. The combination of renewableenergyresourcescan beappliedto hybridelectricvehicles (HEV) for the nextgeneration transportation that exploits various aspects and techniques of HEV fromenergy management system (EMS) [I]

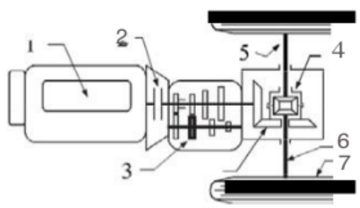

FIGURE 1. *Schematic of the power train system*

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The storage system consists of fuel cell (FC) as the main power source and solarce 1 SC) as an additionalresource. A nonlinearcontrollerbased ona nonlinear model system utilizesLyapunovstability design techniques [2].In Battery Electric Vehicles (BEV), heatthat arises from the mistake of the batterywork process needs to beanticipated, because of incorrect traction and friction can cause overheatingthat can makeddangerous [3]. The effect of strength performance on the layout of the powertrain system wasverified by using computer aided engineering (CAE) and the electricweight balancer [4].
Severalsrudiespresented an increase in energyefficiency in EV by exploitingseveralconsiderationswhichare in the spotlight as the main transportation of the future [5].They are, first, integratedmotor-transmission(IMT) withmotors and gearboxesdirecltyinstalled and the adoption of controller area network (CAN) technology. Secondly, wireless power-transfer-systems (WPTS) based on wirelesselectricvehicles (WEVs). Third, classified as roadwaypoweredelectricvehicles (RPEVs) and stationarychargingelectricvehicles (SCEVs). Fourth, the design and implementationthe onlineelectricvehicle (OLEY) syste[6].

FIGD"RE 2. *The outside size of the vehicle*

The testingof the role of renewableenergy and powertrainoptimization in order to minimizingdailycarbonemissionswereconducted for plug-in hybridelectricvehicles and electrically-poweredvehicles[4].For manual transmission, the zero-shift mechanismis an ideal arrangement to increase transmission efficiency[5]
The combination of the electric engine and the powertraindistinguishespowertrain architecture and increases the energyefficiency and reducestorsional vibration[6]. The proposedgear ratio transmissioncan beseen in **FIGURE 2.** The aim of thisstu 1 is to find out the performance of traction force when the vehiclegoes on a flat plane 0° and incline angle> 0°.[7]

THE AIM AND OBJECTIVES OF THE STUDY

This research aims to obtain the most suitable gear ratio for two-speed transmission. Then an analysis is performed to get the value of the motor's performance in moving the unit with gear change 1-5.
The following objectives are done to achieve that goal:

1. Change the ICE vehicle into an electric car.
2. Calculate the ability to motor electric vehicles on different speeds

LITERATURE REVIEW

The vehicle that will be reviewed is the city car-type vehicle with the required vehicle data can be seen in **TABLE 1** . The center of the car is the place of operation of the earth's gravitational force (gravity) on the overall mass of the vehicle. The location of this center of gravity depends on the geometry and the weight distribution of the car.

TABLE 1. *Vehicle data[8[*

Item	Value	Unit
Wheelbase	2.455	Mm
Overall length	3.600	Mm
Overall width	1.620	Mm
Overall height	1.520	Mm
Wheel track front	1.420	Mm
Wheel track rear	1.415	Mm
Vmax.	65	Kmfh
Passenger carrying capacity	320	Kg
Transport capacity	50	Kg
Curb Weight	780	Kg
GVWR	1.150	Ko

Different power and torque characters are obtained by combining the ratio of input gears and output gears. In general, the gear chain in the transmission box consists of several combinations of gears to make a vehicle move forward and a pair of gears to reverse, which are usually mediated by idle gear.Furthermore, this comparison of gear transmission ratios that follows the population transmission ratio of one city car in Indonesia aims to find out how much tractive force performance is produced when the vehicle is running on a flat plane of 0° and the tiltedslope> 00.
In **FIGURE 3** , shown modeling the normal force of the wheel. Where is the distance of the front wheel shaft toward the center of mass of the Z (center) car, and is the distance from the mass center of the car Z to the rear wheel axle, and the wheelbase or total front wheel axle distance to rear wheel axle. When a car is idle on a flat road, the normal force on each axle of the front and rear tires are called F,1 and Fz2, to calcula te the force that occurs on the front and rear tires are[2].

$$F_{z1} = \frac{1}{2} mg \frac{a_2}{l} \quad (1)$$

$$F_{z2} = \frac{1}{2} mg \frac{a_1}{l} \quad (2)$$

where F_z is the force (N), mis mass (kg), g *is gravity* (m/s^2), a_1 isdistance of the centerof gravity to the rearaxle(m), and $a_2$isdistance of the centerof gravity to the rearaxle(m) and -e is the distance of the front axle to the rearaxle(m)

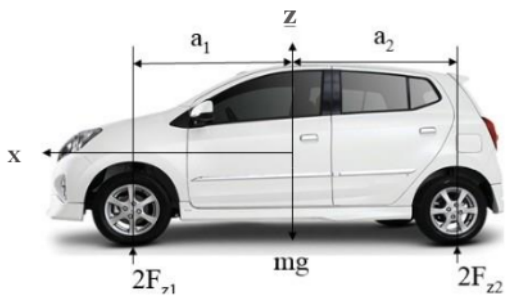


FIGURE3. *Modeling Normal Wheel Force*

Knowledge and selection of tires are essential because to determine the characteristics of traction performance, the ability to drive and control a vehicle. The tires used must pay attention to the amount of friction rolling because the wider the tire, the higher the rolling resistance. The chosen tire is radial tire type 175/65 R14. The tireshave specifications as below: wheel diameter=14 inch; tire width=l 75 mm; the ratio of tire height to width=65 %. To calculate the tire radius based on known tire specificationsin equation(3)[8].

$$Rw = \tfrac{1}{2}.\,d + t \qquad (3)$$

Where Rwistire radius (m),t is tire height (m), and d isdiameterwheel (m).

Rolling resistance is a necessity for the vehicle to move. The value of rolling resistance is mainly dependent on the type of tire material and road material. In general, tire raw material is rubber, while road material is usually asphalt, concrete, or a combination of both.

DC motors, supply needs to be provided for the stator and rotor windings. But in an induction motor, only the stator winding is supplied with AC voltage.
Alternating flux is generated around the stator windings due to the AC power supply. This flux alternately rotates at synchronous speed. This flux field is referred to as the "Rotating Magnetic Field" (RMF)The relative velocity between the RlvlF stator and the rotor conductor causes induced electromotive force on the rotor conductors, according to Faraday's law of electromagnetic induction. The rotor conductors are connected, and hence a rotor current is generated due to the induced electromotive force. That is why this kind of motor is called an induction motor. (The same phenomenon occurs with transformers, hence an induction motor can be called a rotating transformer).Then, the rotor induced current will also produce an alternating flu," around it. This rotor flux is left behind the stator flux. The direction of the induced rotor current is, according to Lenz's law, such that it tends to be opposite to the producerAs the cause of the production of rotor current is the relative speed between the rotating stator flux and the rotor, the rotor will try to catch up with the stator Ri\1I. Thus the rotor rotates in the same direction as the stator flux to minimize relative speed. However, the rotor never manages to capture synchronous speed. This is the basic working principle of induction motorsof both types, either 1 or 3 phase.
The rotating speed of the "Rotating Magnetic Field" (RMF) isknown as the synchronous speed.

$$Ns = \frac{120 \times f}{p} \quad (RPM) \qquad (4)$$

Where, Ns is sy nchr onous rotation, fisfrequency, Pispolar number

The rotor tries to catch up to the stator fieldsynchronous speed, and thusrotates. But in practice, the rotors nevercaught up. If the rotor captures the stator speed, therewillbe no relative speed between the stator flux and the rotor, thenthereis no induced rotor current and no torque production to sustain rotation. However, thiswill not stop the motor, the rotor will slow down due to torque loss, more torque willbegiven due to relative speed. That iswhy the rotor rotates at a speed thatisalwayslesssynchronous. The differencebetweensynchronous speed (Ns) and actual speed (N) of the rotor is

$$\%slip\ s = \frac{Ns - N}{Ns} \times 100 \qquad (5)$$

'Where, s isperc entage slip, Ns issynchronous rotation and N is real rotation

Like BLDC, the induction motordoes not use a brush (brush) for the commutation of currents. Thus, the service life of an induction motorisalmostinfintie. The only limitation isbearing life.
The 3 phase induction motor circuit can beeither star or delta. This circuit has itsownadvantages and disadvantages. Withconventionalelectric circuits, the star delta circuit isused to provide large torque when first rotating..Currently, the use of an induction motorwith a certain working pattern can bedonewith an inverter. Torque, RPM, direction of rotation, ramp up, ramp down, etc. can becontrolled more easily. Inverterswith certain classes can evenbeconnectedwithothermotorinverters to getsynchronousmovementbetween 2 or more motors.

Based on the business concept, electric power is the amount of effort in moving the charge in units of time or the amount of electricalenergy per second. The formulation iswritten as follows

$$Po = \frac{W}{t} \quad (6)$$

$$W = VI.t \quad (7)$$

$$Po = VI.P \quad (8)$$

Where PoisElectrical power (Watt), WisEnergi (Joule),tisTimes(Second) VisVoltage (Volt), IisCunent (Ampere) and tisTimes (Second)

RESEARCH METHOD

The research began by designing and making a test bench for the 2-speed transmission. Then a simulation is performed to represent several conditions. This experiment is also equipped with simulations and calculations in accordance with existing theories. All results will be validated as a discussion and conclusion. A city car is used as the main comparison.

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 in the form of:

Preparation of Material Specifications, preparation of Tool Specifications, :\1ethod of Analysis, processing time and standard Testing
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 the pattern and the charging stages are as follows.

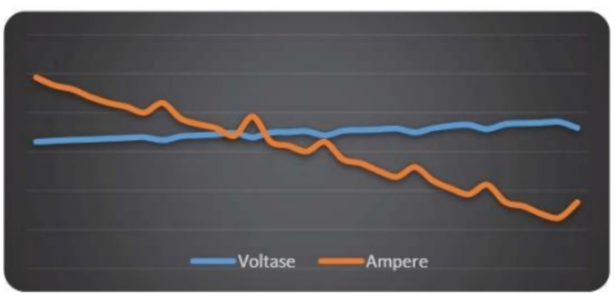


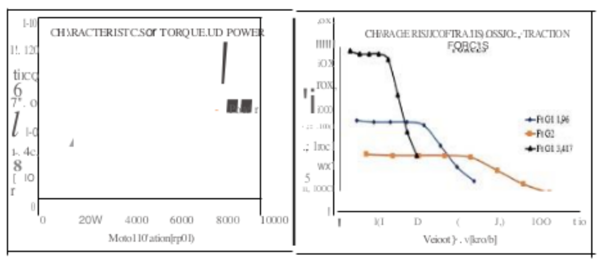
FIGURE 4. Charging Voltage vs Ampere Comparison

From the picture above we can know how the charging process that occurs in the battery, where when the charging process to increase about 7 volts charging from 65-72 volts stable it takes about 3 hours with a linear trend. Likewise the amperage value follows the ups and downs of conditions filling as a balancingprocess from the increase in volts, the amperage value decreases to the range of 20 Ampere in the condition until the condition is full of charging capacity, this happens so that there is no over current so that it is not dangerous from heat and can cause an explosion. To achieve a stable value of charging, the voltage that must be set exceeds about 3 volts because it can be seen that when the charging takes place, it is stopped for 1 minute, what happens is a decrease in voltage and amperage as shown in the following **FI GURE** 4 It is informed about the termination of the charging process in the 49th minute - 50,105-106,136-137,162-163,184-185, all of which occur when the charging voltage adjustment condition occurs until the value is stable in the voltage change range of 2 volts to 3 volts. The discharging process itself is the process when the battery is used, in this case in a conversion vehicle, the main use is on the motor, namely the 3 Phase induction motor with the following capacities:

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 has to be adjusted both straight up and down turns and braking due to speed bumps and so on, this condition forces the real ability to be obtained about 4 hoursof operation.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 has to be adjusted both straight up and down turns and braking due to speed bumps and so on, this condition forces the real ability to be obtained about 4 hours of operation.

RESULT AND DISCUSSION

Based on the calculation of the power and torque produced by the motor in Eq. (10), the maximum power of the electric motor is obtained at 61.13 kW at 5,000 rpm, and the torque produced is 116.75. Nm In



(a) (b)

FIGURE 5.(a) *Characterization of Motor (b) Performance Traccion*

According tothe analysis of the transmission traction force characteristics, it can be concluded that the transmission ratio suitable for three slope conditions is the transmission with a ratio of 1.96 for first gear and 1.25 for second gear. Thechart above shows that the traction force required by the motor to do gearshift is not too large. It is smoother compared to the transmission ratio of 3,417 to the ratio of 1.25. The transfer is less efficient, and the traction force required will be massive.

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

(a) (b)

FIGURE 6.(a) Conector and (b) *Power Quality Analyzer Hioki PW3J98*

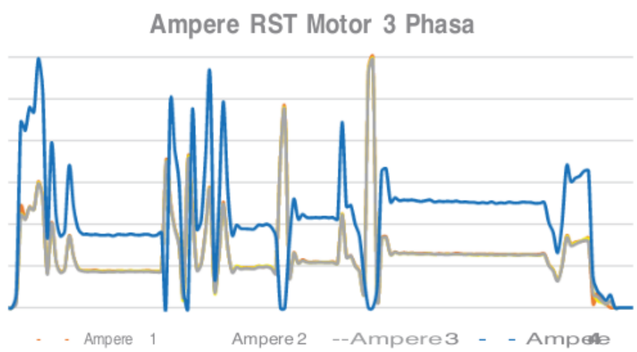


FIGURE 7. Characteristics current motor by PQA

The following are the results of measuring the voltage and ampere of a 3-phase AC motorwhere the measurement uses the Power Quality Analyzer (PQA), the measurementisdone by running the vehiclewithout a load by lifting the front wheel and varying the rotation of gearshifting 1 to 4 with maximum speed as following:

- The maximum speed of 1st gear 20 km / h
- The maximum speed of 2nd gear 40 km / h
- The maximum speed of 3rd gearis 60 km / h
- The maximum speed of 4th gearis 80 km/ h

Fromtheseresult,s the measurementresults of current and voltage in the 3-phase motor (attached) are obtained and when the displacement condition occurs a ve1y high amperage spike, this if itoccurscontinuouslywillresult in the ability of the battery to run out quickly

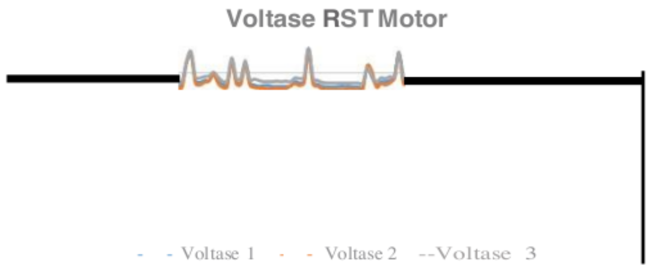


FIGURE 8. Characteristic of Voltage motor by PQA

The following are the results of measuring the voltage of a 3-phase AC motorwherewhen the measurement uses the Power Quality Analyzer (PQA) tool, the measurementisdone by running the vehicle.This research analyzes various terrain conditions as variables used as a reference when measuring the unit performance level of reliability. Charging the batteryis a fast process with a duration of about 3 hours for 5 volts (65-72 volts). The capacity of the batteryis 150 *AH* times 6 pieces and its use capacitywith a motorload of 118 A becausethere are severalfactorsthatmakethiscapability not fulfilled, includingvehicleload, vehicle route, these conditions force the real capability to beobtained about 4 hours of operation.

Addition of tools for data acquisition, especially those needed for analysis and data collection of electric vehicle performance, for example the PQA (Power Quality Analyzer) Produces motor performance conditions in Ampere and voltage measurements showing different conditions Motor performance in voltage measurements occurs voltage spikes at each displacement gear and the trend that occurs is increasing, on the other hand, the measurement of the ampere condition tends to be stable.

CONCLUSIONS

The conclusions of this research can beexplainedas follows:

1. Battery charging is a fast process with a duration of about 3 hours for 5 volts (65-72 volts). The capacity of the batte1y is 150 *AH* times 6 pieces and the capacity to use it with a motor load of 118 A because there are several factors that make this capability not fulfilled, including vehicle load, vehicle route, these conditions force the real ability to be obtained about 4 hours of operation.
2. Addition of tools for data acquisition, especially those needed for analysis and data collection of electric vehicle performance, for example the PQA (Power Quality Analyzer). Generating motor performance conditions on the Ampere and voltage measurements show different conditions.
3. Motor performancein the voltage measuremen,t there is a voltage spike at each gear shift and the trend that occurs is an increase, on the other hand, the measurement of the ampere condition tends to be stable.

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REFERENCES

I. F. Zainuri, D. A. Sumarsono, M. Adhitya, R Siregar,S. Prasetya, G. Heryana, Nazaruddin, R. Subatkah," Performance Analysis of PowerTrainElecttic Vehicle Transmission Two Speed with Reverse Engineering Meihode," JMERD Vol04 No.40ISSN:1024-1752*Publishing TSP* 2020

2. M.Rozman *et aL,*"Smart Wireless PowerTransmission System for Autonomous EV Charo,Jng",*IEEE Access,*vol. 7, pp. 112240--112248,2019, doi: IO.I109/access.2019.2912931.

3. P. Spanoudakis, N. C. Tsourveloudis, L. Doitsidis, and E. S. Karapidakis, "Experimental research of transmissions on electric vehicles' energy consumption," *Energies,* vol. 12, no. 3, pp. 1-15, 2019, doi: 10.3390/en12030388.

4. Y. Lei *ei al.,* "Control strategy of automated manual transmission based on active synchronisation of driving motor in electric bus," *Adv. Mech. Eng.,* vol. 11, no. 4, pp. 1- 17, 2019, doi: 10.1177/1687814019846734.

5. M. R. Ahssan, M. M. Ektesabi, and S. A. Gorji, "Electric Vehicle with Multi-Speed Transmission: A Review on Performances and Complexities," *SAE Int. J. A/tern. Powertrains,* vol. 7, no. 2, 2018, doi: 10.4271/08-07-02-0011.

6. J. Michaelis, T. Gnann, and A. L. Klingler, "Load shifting potentials of plug-in electric vehicles-A case study for Germany," *World Electr. Veh. J.,* vol. 9, no. 2, 2018, doi: 10.3390/wevj9020021.

7. T. Shi, F. Zhao, H. Hao, and Z. Liu, " Development Trends of Transmissions for Hybrid Electric Vehicles Using an Optimized Energy Management Strategy," *Automot. Innov.,* vol. 1, no. 4, pp. 291- 299, 2018, doi: 10.1007/s42154-018-0037-5.

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