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Conversion Kit for Three Wheeler

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Abstract: ***This study describes the conversion of an IC engine based auto rickshaw to an electric rickshaw. Conversion kits are critical to meeting the Central Government's objective of electrifying 80% of vehicles by 2030 that are both energy and cost efficient. The usage of these kits can be done for deregistered vehicles or currently used vehicles. This will be more economical for consumers than buying a new one. Therefore, for the conversion a Bajaj RE auto-rickshaw was selected. Power and torque requirements to propel the converted vehicle were calculated both using numerical method and Simulink, QSS Tool Box. In addition to these requirements, output parameters such as voltage, current and SOC were also analysed using these models. Conversion kit components such as motor, battery, controller and gearbox were selected as per the requirements. A design of all these components was made using Solidworks software. Assembly of these components on Bajaj RE chassis was made same software. All of these analyses and designs were used and all the components of conversion kit were retrofitted on Bajaj RE chassis. A wire harness was used to connect these components and controller tuning was done based on the calculated parameters.***

Keywords: Conversion, E-rickshaw, NEDC (New European Drive Cycle), $LiFePO_4$ Battery, PMSM motor, Simulation, Bajaj RE

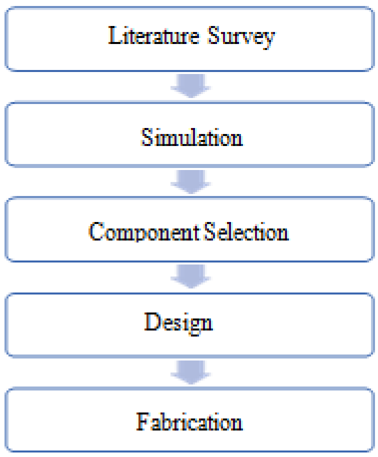
1. Introduction

An electrical auto can be propelled by one or more electric motors, using electrical energy stored in rechargeable efficient Lithium Ion batteries. This motor gives instant torque to the electrical vehicles, creating strong and smooth acceleration. They are also around three times as efficient as normal petroleum or diesel cars with an internal combustion engine. The first practical electrical car was produced in the 1880s. Electric cars were popular in the late 19th century and early 20th century, until advances in internal combustion engines but the mass production of cheaper gasoline vehicles led to a decline in the use of electric drive vehicle.

Three wheeled auto rickshaws are one of the cheapest means of private transport in India. Three wheeled goods carrier are preferred to transport small to medium loads within the city limits. According to a recent survey, there are on average 50000 auto rickshaws in tire 1 cities (cities having more than 4 million population). In the financial year 2016-2017, 402,034 passenger three Wheelers (8.83% drop from 2006-07) and 109,624 commercial three wheelers (12.75% hike from 2006-2007) were sold. The sale of these vehicle is expected to fluctuate between -5% and 5% in the upcoming years. It is thus safe to say that the three wheelers will not be out of service any time in the near future in the country. Threats of global warming and the fear of limited fossil fuel resources have forced the nations all around the globe to implement emission norms for the fuel powered vehicles in their country.

Figure 1: Bajaj RE Auto rickshaw

2. Methodology



The need for conversion kits, vehicle parameters and an approach towards selecting components are carried out in literature survey. Simulation is carried out considering vehicle parameters using both Simulink and QSS Tool Box. Numerical calculation is also done using these parameters. From the obtained results of simulation models and numerical calculations component selection is done accordingly. After selection of components, a design of the components of conversion kit is done using Solidworks software. Chassis design of auto rickshaw is also carried out using same software. Conversion kit components are assembled with this chassis using Solidworks. Fabrication is carried out by using all these components. Bajaj RE chassis is used for conversion and required components of Conversion kit such as Motor, Battery, Controller and Gear Box are mounted on Bajaj RE chassis. Connections of motor, controller and battery is carried out using wire harness and converted vehicle is made to run on campus roads.

3. Calculations

In order to propel a vehicle it must overcome certain resistances. Those resistance are:

Rolling resistance

$$F_{roll} = \mu \times mg \times \cos(\Theta) \quad (1)$$

Grade resistance

$$F_{grad} = mg \times \sin(\Theta) \quad (2)$$

Acceleration force

$$F_{ac} = m \times a \quad (4)$$

The total resistance a vehicle must overcome for the drive is the sum of above mentioned resistances which can be named as Tractive force.

$$F_{trac} = F_{roll} + F_{aero} + F_{\mathrm{grad}} \quad (5)$$

Table 1: Vehicle Parameter

S. no	Parameters	Value
1	Vehicle	Bajaj Re-2 Stroke
2	Length	2675mm
3	Width	1300mm
4	Radius of Wheel	0.2365m
5	Frontal Area	2.09 m^2
6	Height	1700mm
7	Gross Vehicle Weight	6 kg
8	Acceleration due to Gravity	9.81 m/s^2
9	Density of air	1.2 kg/m^3
10	Aerodynamic Drag Coefficient	0.4792
11	Radius of Wheel	0.2365 m

Required power from motor to overcome above resistances is calculated by further considering three driving scenarios

$$F_{aero} = 0.5 \times (\rho \times C_d \times A_f \times v^2) \quad (3)$$

Case 1: Top speed of 55 Kmph (15.28m/s) on a flat road (i.e. 0% gradient)

Case 2: Acceleration of 0-30 kmph (0-8.33m/s) in 6 seconds on a flat road (i.e 0% gradient)

Case 3: Grade ability of 20% at 20 Kmph (5.556m/s) (No acceleration)

The maximum tractive force among all three cases was found to be 1392.88 N in third case and maximum power required to propel the vehicle is found to be 5.8 kW.

4. Simulation

QSS Tool box

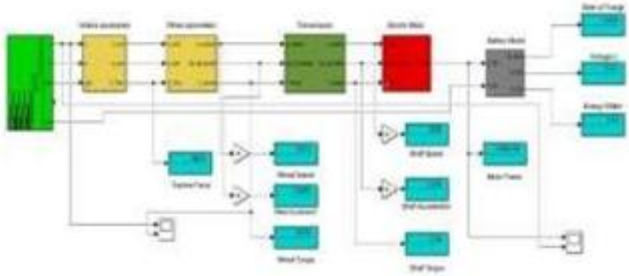


Figure 2: QSS tool box

To analyses performance parameters of Conversion kit components, a simulation model was made using QSS Tool box. Using this model, performance parameters such as Power and Torque are obtained.

Components of the QSS Toolbox:
- Vehicle block
- Simple wheel block
- Simple Transmission block
- Electric motor block
- Battery block
- Drive-cycle block

Simulink block

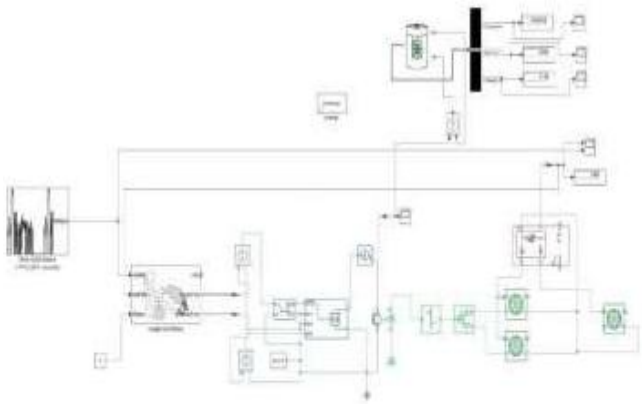


Figure 3: Electric Three wheeler Simulink Model

A Simulink model was made using Simulink where performance of parameters associated with conversion kit are obtained using this model. In this model, NEDC drive cycle is given as input to Simulink model.

Drive Cycle

A Driving cycle describes one or several trips driven by a vehicle and often it is used to analyses how the powertrain is operating and the resulting fuel consumption. It is plotted between Speed of vehicle vs Time

Input drive cycle

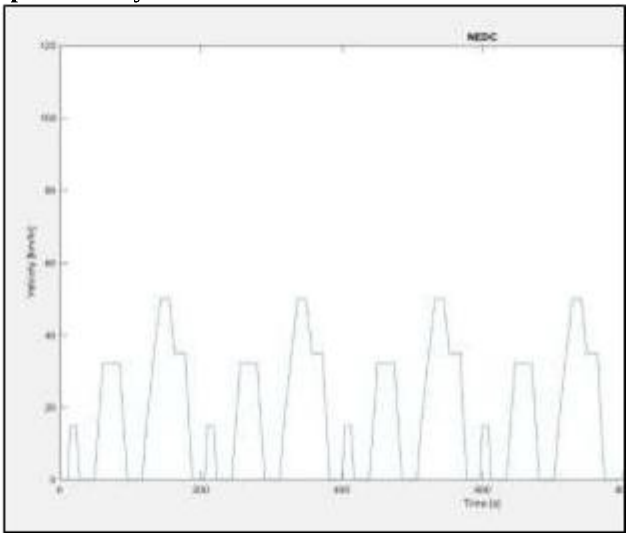


Figure 4: Velocity vs Time

5. Design

Bajaj RE auto rickshaw was selected for conversion. Dimensions of Bajaj RE dimensions were considered and a chassis design was made using Solidworks software. Dimensions of Conversion kit components were also taken into account and design of individual components was made using the same software.

Figure 5: Controller

Figure 6: PMSM Motor

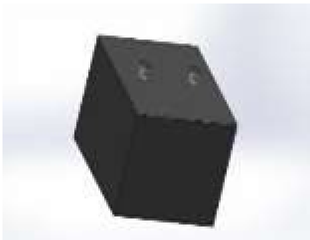


Figure 7: Battery

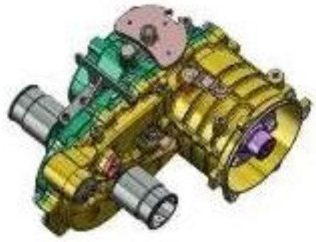


Figure 8: Gearbox

Motor, Gear box, shafts e.t.c were assembled on chassis using Solid works software.

Figure 9: Retrofitted auto-rickshaw

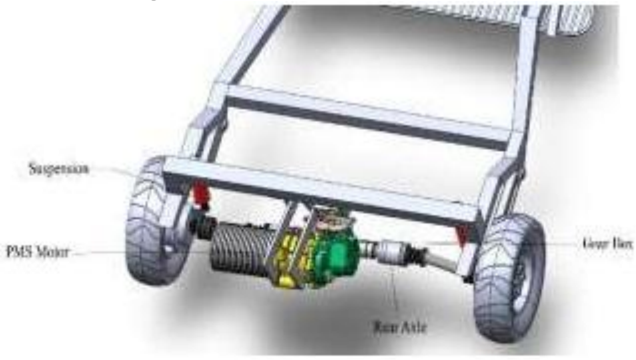


Figure 10: Assembly of components on chassis

Figure 11: Side view of auto rickshaw

6. Components

PMSM motor: Permanent Magnet Synchronous Motors (PMSMs) are brushless and have very high reliability and efficiency. Due to their permanent magnet rotor, they also have higher torque with smaller frame size and no rotor current, all of which are advantages over AC Induction Motors (AICMs). With their high power-to-size ratio, PMSMs can help make your design smaller without the loss of torque.

Controller: A speed and acceleration control system for electric vehicles that operates between the batteries and the motor. It controls the torque and power produced by the electric vehicle motors. Controllers work on a technique called pulse width modulation to control speed and acceleration. We are utilizing a Sterling G take E- Mobility Controller.

$LiFePO_4$ Battery: The high power density of lithium iron phosphate batteries ($LiFePO_4$) allows for the comparatively compact size and light weight of lithium batteries. These are a particular class of rechargeable lithium-ion battery. Increased power output, quicker charging, less weight, and longer lifetime are advantages over more conventional cobalt-based Li-Ion batteries.

Gearbox: A gearbox is used to transmit power from the electric motor to wheels through transmission shafts. This gear box is also equipped with differential. Either raise or decrease speed. A gearbox is a highly effective way to drive low speed, high torque applications from a tiny package since it can offer much more torque for a very small container. Using a smaller motor with a gearbox is more cost-effective than using a larger motor when we need to attain a specific torque level. Here, a gearbox with an 8.06 gear ratio is being employed. The gearbox rotates at a speed of 4500 RPM and generates 60 Nm of torque.

Table 2: Specifications

Motor Peak Power	8.5 kW
Motor Max Torque	57 Nm at 350 A
Max Speed of Motor	3500 RPM
Battery Voltage	48V
Battery Capacity	66Ah
Gear Ratio	8.06

7. Fabrication

In order to install conversion kit components such as motor, battery, controller and gearbox on the Bajaj RE 2-stroke auto-rickshaw chassis that was chosen for conversion, certain adjustments on the chassis were required. After these components were installed, connections were done using a wire harness.

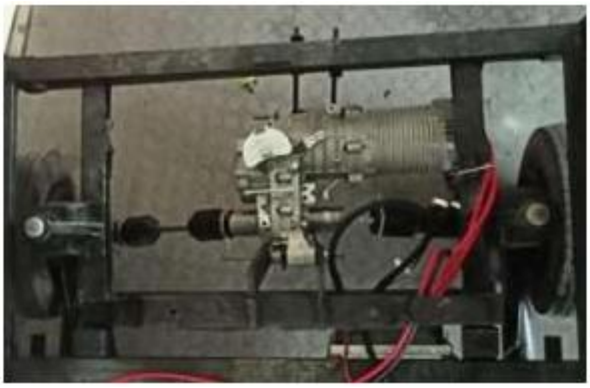
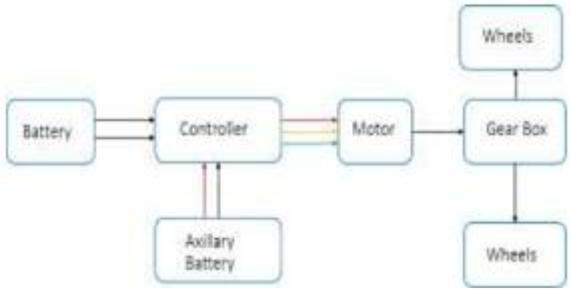


Figure 12: Mounted motor and gearbox

Figure 13: Top view of converted E-rickshaw

Drive line



The drive train system of an electric Vehicle is in responsible for transferring energy from the battery to the wheels through motor and gear box. There are numerous moving components in the drivetrain. The components of the Drive line system includes the Battery, Controller and the rotating parts transmission (gear box), drive shafts, and motor. The drivetrain system's electrification.

8. Results and Discussions

In the fabrication, the Bajaj RE chassis was utilized. Both numerical calculations and simulations are used to choose the component parameters, after which appropriate ratings of parameters like motor power are established. Use of the NEDC drive cycle was made during simulation. Using a Simulink model, output parameters like velocity, current, and voltage were calculated. QSS Tool Box was used to determine Power and SOC.

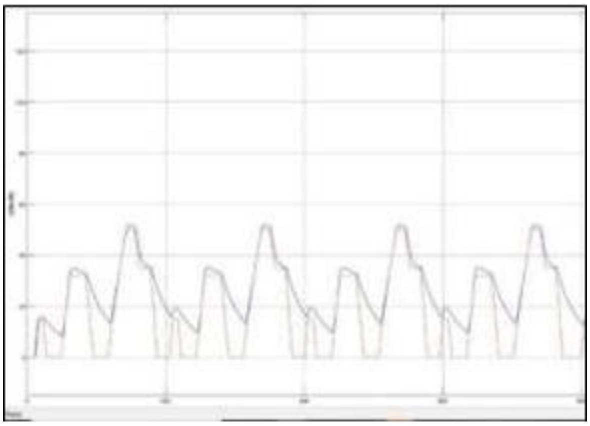


Figure 14: Resultant Velocity vs Time

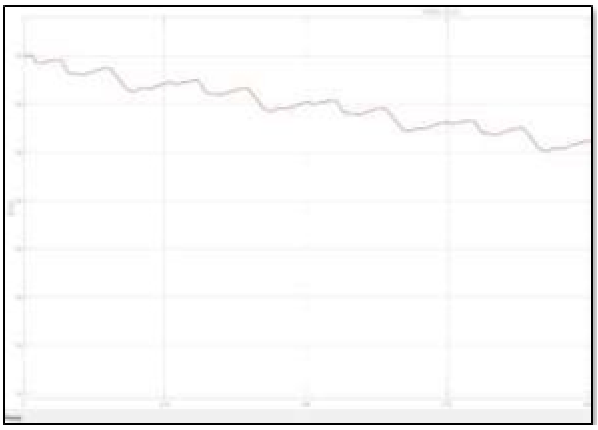


Figure 15: SOC v/s Time

In fig 15, the battery's Soc is plotted against time. The NEDC drive cycle is 11km (6miles) long and takes 1220 seconds to complete. The initial SOC of the battery is kept at 90%, and after the end of the drive cycle, the soc is found to be 78%. The motor behaves like a generator during breaking, in that it begins to supply or charge the battery. As shown in the graph above, the rising graph indicates the charging of the battery via the motor, which is known as regenerative breaking.

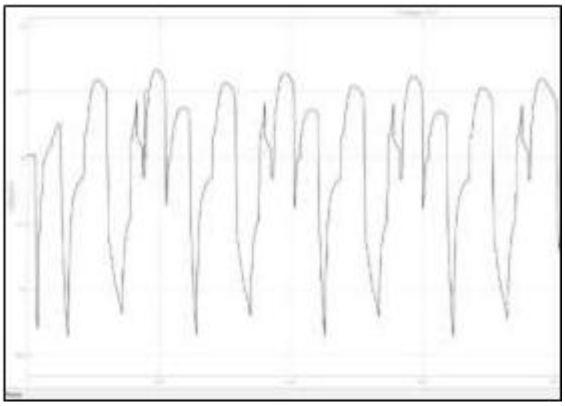


Figure 16: Voltage vs Time

In fig 16, the discharge voltage of the battery is plotted against time. Voltage levels increase where power requirements are high or during acceleration, and voltage levels decrease during de- acceleration. Voltage levels also increase during de-acceleration due to regenerative breaking, in which the motor charges the battery while breaking

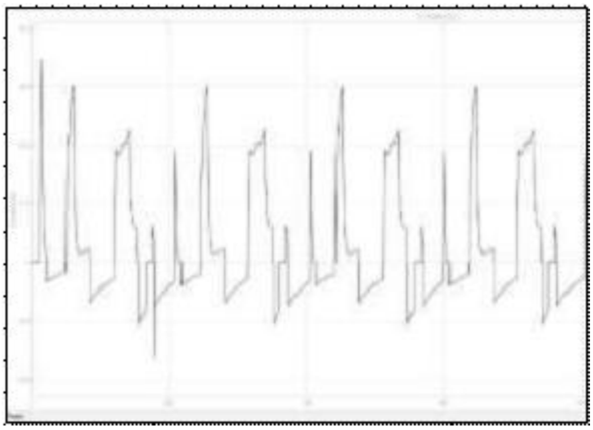


Figure 17: Current vs Time

In fig 3.17, the discharge current of the battery is plotted against time. This graph resembles to the voltage vs. time graph. The controller is designed in such a way that current is directly proportional to torque, which means that current is required whenever the torque required at the wheels is greater, i.e. during road inclination

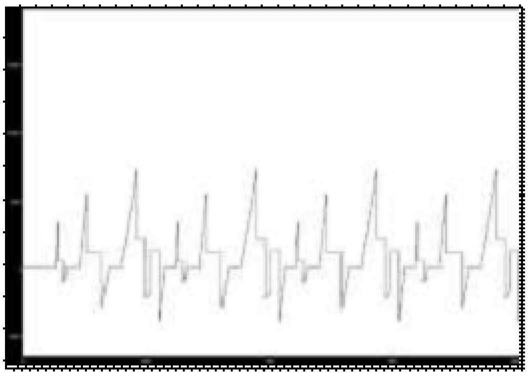


Figure 18: Power v/s Time

In fig 18, the motor's output power is plotted against time. The power value of the motor was calculated using the QSS tool box while taking into account the vehicle parameters. The power value obtained during the velocity at 60-65kmph is 8kw. The values of power increase during acceleration and decrease during de-acceleration.

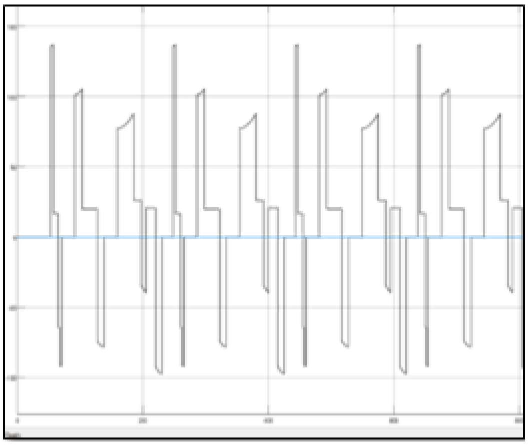


Figure 19: Torque v/s Time

In fig 19, the motor's output torque is plotted against time. When the torque required at the wheels is greater, such as when the road is inclined, the controller increases the current requirement. And the peaks in the graphs indicate that the torque required is high at that moment, therefore the controller provides additional current from the battery to the motor. The controller has been tuned in a way that the auto-rickshaw can fulfil the following conditions that were considered in calculations.

1) On a flat road, converted rickshaw can travel at a speed of 55 kmph.
2) Converted rickshaw can travel at 20 kmph on a 20% gradient.
3) Converted rickshaw can accelerate from 0 to 30 km per hour in 6 seconds.

9. Conclusion

This paper covers all of the critical steps in auto- rickshaw retrofitting. Starting with a feasibility study and on to design, simulation, and assembly. This project also includes fabrication. Sincere efforts are being made to describe a systematic approach for determining optimum specifications for the most crucial components in an electric vehicle propulsion system in the simplest possible way.

10. Future Work

Further research is expected to be carried out to check the feasibility of technologies such as fuel cell and battery swapping model for retrofitted Auto-Rickshaw. More practical aspects, such as regenerative braking can be incorporated in physical model. Detailed study on life cycle cost and recycling of battery including environmental effects can be vital areas of future studies. In this project NEDC drive cycle has been considered, use of Indian Drive Cycle would be a benefit for analysis. Thermal analysis of the battery, traction motor, and auxiliaries using simulations can significantly improve the performance and efficiency of an E-rickshaw. As a result, this could be an attractive future research topic.

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