A PROJECT REPORT

ON

"RETROFITTING OF AUTO-RICKSHAW"

Submitted to

UNIVERSITY OF MUMBAI

In Partial Fulfilment of the Requirement for the Award of

BACHELOR'S DEGREE IN
MECHANICAL ENGINEERING

BY

SHAIKH ADNAN ABID	17DME142
ANSARI MD KALIM HASIB	17DME127
MOHAMMED TALHA SHAIKH	17DME130
CHAUHAN YEGESHWAR MANSINGH	15ME67

UNDER THE GUIDANCE OF
PROF. UBAID SHAH

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AFFILIATED TO

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A PROJECT II REPORT
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2019-2020
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CERTIFICATE

This is to certify that the project entitled

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submitted by

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is a record of bonafide work carried out by them, in the partial fulfilment of the requirement for the award of Degree of Bachelor of Engineering (Mechanical Engineering) at Anjuman-I-Islam's Kalsekar Technical Campus, Navi Mumbai under the University of MUMBAI. This work is done during year 2019-2020, under our guidance.

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Project I Approval for Bachelor of Engineering

This project entitled “Retrofitting of auto-rickshaw” by Shaikh Adnan Abid, Ansari Md Kalim Hasib, Mohammed Talha Shaikh, Chauhan Yogeshwar Mansingh is approved for the degree of Bachelor of Engineering in Department of Mechanical Engineering.

Examiners

1. ....
2. ....

Supervisors

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2. ....

Chairman

....

Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included. I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

When it comes to vehicles, one thing is sure that the future is electric. Three wheeled auto rickshaws are most popular mode of transport in India and most of the Asian countries. They play a crucial role in the Indian automotive industry. They are compact and narrow, allowing mobility on congested roads. In past we have seen the dominance of ic engine based cng auto rickshaw in automobile sector. Even though having discernible superiority in vehicle structure, auto rickshaws possesses an awful pollution problem due to use of conventional fuel supply to run the engine. And the increasing demand, increase in fuel prices, dependency on conventional source of energy, low efficiency, regular maintenances, has given a rise to battery-motor conveyance i.e. E-rickshaw.

We are focusing on making the cheapest mode of public transportation for few kilometers conventional fuel free. So the objective behind the project is to utilize the scrap/elapsed cng based auto-rickshaw, which major source of the air pollution and convert it to battery and motor driven e-rickshaw.

The electric vehicle has already gained so much popularity in market, and the upcoming regulations (electric mobility vision 2030) as governments of India has a vision of complete electric mobility by the year 2030. Considering the current and future scenario we have come up with a complete modification of cng operated auto rickshaw by replacing the engine and fuel cylinder with BLDC motor for vehicle propulsion, powered by the lithium-ion batteries. These kind of vehicles will prove to be environment friendly and have the potential to reduce the pollution significantly due to passenger transport activities. The running cost of battery powered auto rickshaw is less than the fuel based 3 wheelers and will improve the socio-economic condition.

Keywords:- Battery Motor Based Auto rickshaw, Air Pollution, BLDC Motor, Socio Economic

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CHAPTER I

1.1 Introduction

The Automotive Research Association of India (ARAI) recommended that the conversion of existing cng three-wheelers into electric is one of the supreme ways to advertise electric vehicles in India. ARAI discovered that the Indian government's goal to achieve 30 percent electric mobility by 2030,which is a bit ambitious to achieve as around millions of ic engine driven vehicles are sold in the India each year. It would be a clever option to consider e-rickshaws as last mile connectivity that means it provides door to door service. E-rickshaws are considered smart in terms of no local pollution, cheapest, safe slow speed, livable income source, affordable and flawless for urban and semi-urban areas.

This project aims to modify the present structure and mechanism of Auto-rickshaw to make it suitable for its electrification, rather than designing a complete new E-rickshaw. The old scrapped chassis and body of cng auto rickshaw has been reused in order to support the tagline “generating best from waste”. The heart of auto rickshaw ie engine has been replaced by the BLDC motor, and the fuel cylinder is replaced by the battery storage system and a controller is used for proper functioning and control of auto rickshaw. It receives input from the throttle and the controller decides the speed to be provided to the motor. The existing controller consist mainly either a pulse width modulation technique (PWM) or Variable Frequency Drive technique (VFD) based speed decider microcontroller and an inverter system to convert DC supply in 3 phase AC supply to drive the BLDC motor. As per the local requirement we have used 3.5kw bldc motor and lithium ion battery over lead acid battery which is widely preferred for e rickshaw due to its low cost, on other hand lithium ion is a premium battery with a longer lifespan and higher efficiency, but you’ll pay more money for the boost in performance. Electric vehicles have become a remarkable part of the automobile market. The reason behind their wide acceptance is nothing but the liberty they provide to control the major political issue i.e. global warming, which is greatly affected by the use of diesel and CNG in auto rickshaws. There are some issues associated with e-rickshaws like slow speed, charging issues, but these may be improved through constant developments. Even concept of battery swapping can be implemented wherein smaller capacity battery can be used by auto rickshaw and when it is discharged, it can be easily swapped with charged battery within fraction of minutes at battery swapping stations.

1.2 Problem Statement

Auto rickshaws are a most preferred means of transport in Asian countries. However, poor efficiencies and heavy maintenances are required for smooth operation of these vehicles, which results in high fossil fuel consumption, and it is major contributor in air pollution. Another question arises as what will happen to existing auto rickshaws when they won't be legal after electric mobility mission 2023.Electrification of auto-rickshaw is a potential solution to reduce pollution and dependence on non-renewable energy sources. However, this conversion is not that straightforward as it seems. It needs precise work in order to balance center weight since here we remove gas cylinder and engine. The basic configuration of e-rickshaws includes Li-Ion Batteries and brush-less DC motors (BLDC)2 which are more affordable and well-known technologies such as lead acid batteries and permanent magnet DC motors (PMDC).

As per a survey conducted in Delhi, most of the drivers in India can't afford to buy an auto-rickshaw and hence, hence they go for cycle-rickshaw. Many of them having an opinion of getting a system which should not involve much physical movement as that of cycle rickshaws. There is also a problem with obtaining a license for the auto-rickshaw. Furthermore, many of cycle-rickshaw puller doesn't know how to drive an auto-rickshaw and as per the survey they are confident of driving the e-rickshaw even in very small lanes and can live happily.

Type of rickshaws	Numbers(in Delhi)	Initial cost (rupees)	Daily earning (rupees)
Cycle-rickshaw	700000 (govt. figure)	6000-12000	350-450
Auto-rickshaw	198000	150000-300000	700-1000
e- rickshaw	100000approx	60000-110000	600-800

Table 1: Initial cost and daily earning comparison

The above table states that how economical e-rickshaws are compared to the auto rickshaws. The major advantage with e-rickshaws is that there are a lot of benefits available from government. One can see that the cost of e rickshaws is half of auto rickshaw, keep in mind that auto rickshaw comes with a heavy maintenance cost and the running costs of auto rickshaws are very high. On other hand we have e-rickshaws, having almost zero maintenance and cheaper running cost. If we compare the running cost i.e. electricity for EVs cheaper than petrol, diesel and cng. But still it requires a large charging station infrastructure to be installed throughout the country before encouraging the society for adapting it.

The idea was pretty simple to understand but much difficult as we were heading towards achieving the target. Without internal combustion engine we can use the electric motor and batteries to run the rickshaw. It is like a transition of existing scrapped auto-rickshaw to electric rickshaw which is called as ‘retrofitting of auto-rickshaw.’ Also NITI AYOG gave notice to the all three wheeler manufacturer that they should convert their internal combustion driven vehicles into electric vehicles up to 2023.

CHAPTER II

2.1 Literature Review

The concept of a hybrid electric vehicle is almost as old as the automobile itself. The primary purpose, however, was not so much to lower the fuel consumption but rather to assist the ICE to provide an acceptable level of performance. Indeed, in the early days, ICE engineering was less advanced than electric motor engineering. The first electric vehicle was built by Frenchman Gustave Trouvé in 1881. It was a tricycle powered by a 0.1 hp DC motor fed by lead–acid batteries. The whole vehicle and its driver weighed approximately 160 kg. A vehicle similar to this was built in 1883 by two British professors. These early realizations did not attract much attention from the public because the technology was not mature enough to compete with horse carriages. Speeds of 15 km/h and a range of 16 km were not exciting for potential customers. The 1864 Paris to Rouen race changed it all: the 1135 km were run in 48 h and 53 min at an average speed of 23.3 km/h. This speed was by far superior to that possible with horse-drawn carriages. The general public became interested in horseless carriages or automobiles, as these vehicles were now called. The following 20 years were an era during which electric vehicles competed with their gasoline counterparts. This was particularly true in America, where there were not many paved roads outside a few cities. The limited range of electric vehicles was not a problem. However, in Europe, the rapidly increasing number of paved roads called for extended ranges, thus favoring gasoline vehicles.

The most significant technical advance of that era was the invention of regenerative braking by Frenchman M.A. Darracq on his 1897 coupe. This method allows recuperating the vehicle's kinetic energy while braking and recharging the batteries, which greatly enhances the driving range. It is one of the most significant contributions to electric and hybrid electric vehicle technology as it contributes to energy efficiency more than anything else in urban driving. As gasoline automobiles became more powerful, more flexible, and, above all, easier to handle, electric vehicles started to disappear. Their high cost did not help, but it is their limited driving range and performance that really impaired them vs. their gasoline counterparts.

The most significant effort in the development and commercialization of hybrid electric vehicles was made by Japanese manufacturers. In 1997, Toyota released the Prius sedan in Japan. Honda also released its Insight and Civic Hybrid. These vehicles are now available throughout the world. They achieve excellent figures of fuel consumption. Toyota Prius and Honda Insight vehicles have a historical value in that they are the first hybrid vehicles commercialized in the modern era to respond to the problem of personal vehicle fuel consumption. Japanese motor vehicle industries introduced e-rickshaws in China and few other countries of Asia. The development of e-rickshaw started in India was in late 1990s with the focus on improving manual rickshaws. E-rickshaw with motor assisted pedal rickshaw (MAPRA) by Nimbkar Agricultural Research Institute were developed. ELECSHA (electric rickshaw) 2000 was also developed later on, but there were certain problems with battery performance, which made it look poor and could not make it to market.

Figure 1: E-rickshaw with motor assisted pedal rickshaw

During 1998-1999, Mahindra launched its first electric 3-wheeler rickshaw. E-rickshaws gained prominence in 2010-2012 in various rural areas of UP, Bihar, West Bengal and small town of some other states. Delhi also witnessed a sudden rise in number of e-rickshaws being in demand during Commonwealth Games 2010. Then delhi govt. launched E-rickshaws with the objective to replace cycle rickshaws; this aim was eventually failed when e-rickshaws were overlooked from NMT category and included in Motor Vehicles Act (2014) as last mile connectivity option.

Figure 2: Mahindra's electric 3-wheeler rickshaw

As per Motor Vehicles Act 2014 and Motor Vehicles (amendment) Act 2015, e-rickshaws are defined as "A special battery operated vehicle having three wheels and used to provide last mile connectivity for transport of passengers for hire or sharing, provided, such vehicle should not carry more than four passengers at a time, excluding the driver, and not more than 40kg luggage in total; and motor power having max 4kw and maximum speed of the vehicle should not exceed 25kmph.

Public transport and street infrastructure is owned and maintained by the government, while short distance connectivity is usually operated and maintained private individuals and they play significant role in case of end to end connectivity. E-rickshaw, cycle- rickshaw, autos are considered as door to door connectivity modes for commuters. These vehicles can be easily hired for personal use at affordable cost and are reliable for daily commuters, usually owned and driven by individuals while their functioning may or may not be controlled by city/ state authorities. National government schemes like Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Smart cities, National Rural Livelihood Mission (NULM), Faster Adoption and Manufacturing of Hybrid & Electric Vehicles in India (*FAME*) *Scheme*, etc. promoting e-rickshaws in cities by providing various benefits, subsidy for e-rickshaw purchase and development of charging infrastructure. As per the news 31 cities (out of 100 smart cities) who are interested in e-rickshaw operation. Already 13 smart cities have e-rickshaws integrated in their mobility system.

CHAPTER III

3.1 Methodology

A market survey conducted by our research team revealed that most of auto-rickshaws were labeled as scrapped due to their inefficient engine performance. Several models of scrapped auto-rickshaws in RTO area of Navi Mumbai were studied, to get an insight of their condition. Based on the study it was decided that, for retrofication some unnecessary parts and components from existing rickshaw must be removed to accommodate the installation of new electrical components and to minimize the weight of the converted auto-rickshaw. Then a ground survey involving auto-rickshaw owners was conducted to check feasibility of the project. This ground survey revealed that most of the auto rickshaw runs for somewhere around 100 km daily. Table 1 summarizes detailed figures of our survey for daily auto rickshaw running of 100 km

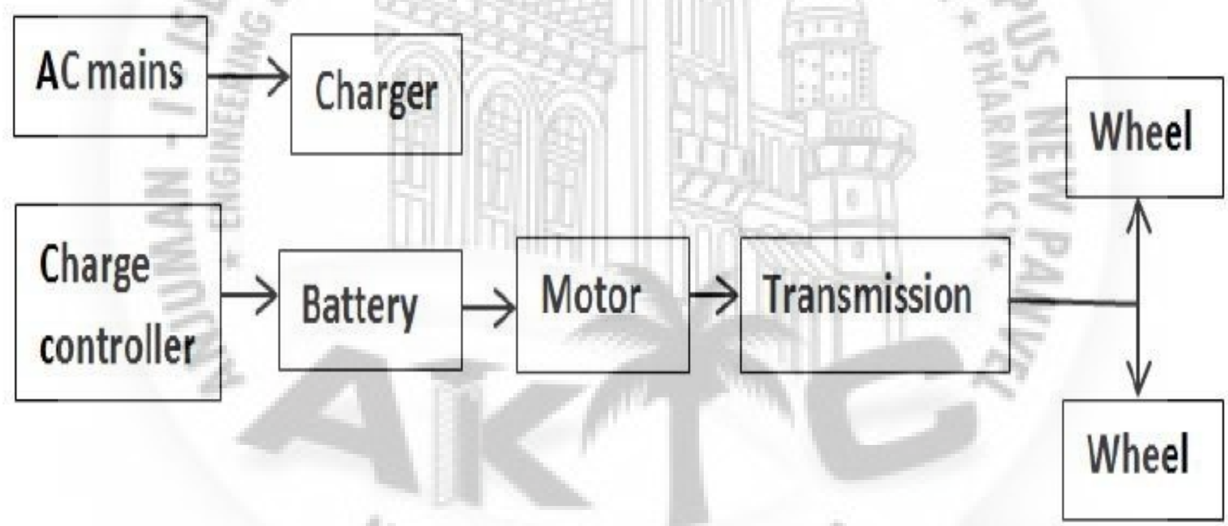

Figure 3: Schematic layout of our retrofitted rickshaw

Figure shows the schematic layout of all important components of the proposed model of retrofitted E-rickshaw in which motor and battery are most important. Selection of these two components is the bottom line of this paper.

	New petrol Auto (₹)	New CNG Auto (₹)	Retrofitted Auto (₹)
Upfront cost	1,80,000	2,20,000	1,00,000
Central subsidy (FAME 1)	-	-	30,000
State subsidy (proposed)	-	-	50,000
Net cost	-	-	20,000
Loan	1,80,000	2,20,000	0
Total cost per day			
Insurance +EMI	178	218	20
Energy	404	118	240
Maintenance	48	72	30
Total cost per day	630	408	290
Savings after retrofitting			
Per day	340	117	-
Per month	10,208	3,537	-
After 7 years	8,57,000	2,97,152	-

Table 2: Economic feasibility of retrofitted auto-rickshaw

Data of Table 2 confirmed the economic feasibility of the project, which served as green signal for further proceedings of design as shown in below flow diagram.

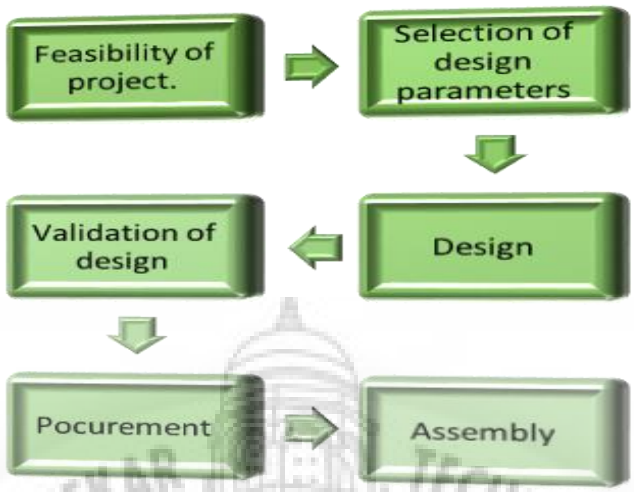

Figure 4: Design process

Based on driving conditions design parameters are selected. Design is done using vehicle dynamics and laws of mechanics. Technical feasibility is checked through mathematical simulation using MATLAB Simulink as a tool. Simulation validated the design calculations and finally specifications, which came out of simulation, were optimised and components were procured. Simplest but effective structure to support the motor and transfer power, was incorporated for assembly of the propulsion motor as can be seen in figure 3. IC engine body was modified and a custom stepped hollow shaft was designed to transmit power from one side of engine to gear box.

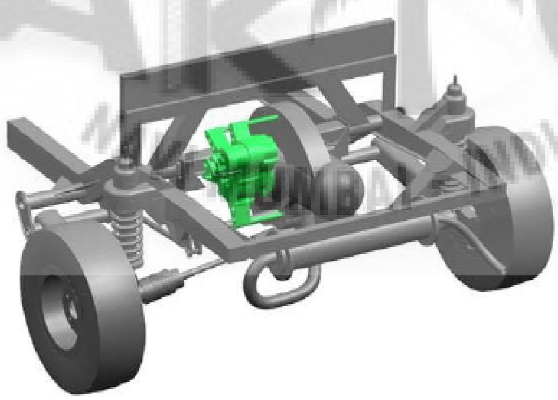

Figure 5: Assembly of traction motor

We calculated all the forces act on body in both dynamic and static condition. We calculated tractive force by calculating all other sub-forces. Also calculated the torque of motor and power. Also calculated the speed of motor, wheels etc. and according to calculation we have to select the motor and battery. By calculation of voltage and power range of battery we came to know the performance of battery. By using simulation, we can obtain several key parameters from the result so after proper simulation we got the final results in graphical forms which were so helpful for the selection of battery specially.

With the help of calculations and simulation we selected motor and battery. We selected DC brushless motor with 3.5 KW power range with 60 NM torque. We selected Lithium Phosphate battery cells and decided to make a battery pack by joining them according to cell balancing. We selected the battery on the basis of ampere rating, cell balancing, voltage, range and cost parameters. For cell balancing we also decided to use battery management system and controller circuit.

To connect and transmit the power from motor to gearbox we designed a stepped shaft with keyways on both side to align it with motor shaft perfectly. We planned to weld a plate to the frame of rickshaw on which the electric motor can be bolted. This arrangement will be used to give rigid support to electric motor to avoid shocks and vibrations. The motor shaft and the designed shaft should be locating in such a way that they should align each other to avoid any power loss and perfect power transmission. The torsional rigidity was also a factor while designing the power shaft and failure can be avoided by using high endurance limit material.

By connecting the electric motor to gear box by a shaft we can transmit the power. The controller circuit is next to the electric which is connected it by three phase wires. Number of wires goes to different places for different tasks. The controller is connected to battery pack through a battery management system. The switch is provided to start the motor by using battery and for control throttling is used.

CHAPTER IV

4.1 Battery

Battery is a primary part of any electric vehicle be it electric car, electric bus or e rickshaw. Ideally, electric-vehicle batteries should have least mass, i.e. high specific energy, and minimum volume, i.e. have high energy density. Rechargeable battery acts as the power source for propulsion of any electric vehicle. New advance battery technologies with higher specific energy, low-priced, and longer sustainability and cycle lifetimes may be required to empower a fruitful electric vehicle. different battery advances are being utilized based on their benefits, applications, and cost. Driving Range of the EVs depends mainly on the battery capacity. Cost and size of battery increases as we as we go for higher capacity. Cost of electric vehicle battery dropped thoroughly recently and it will further diminish since automobile manufacturers are concentrating on developing economical and efficient, high power battery. The most significant progression in electric vehicle battery innovation in the course of the last 5, 10, or even 20 years has been the decreased expenses of assembling them. Ten years prior they were twice what they are today, and 20 years back they were twice as much as that. In terms of carbon impression, the power used to charge the battery of the EVs would need to originate from sustainable sources so as to make up for global warming.

Some of the significant advancement in recent years include the following-

1. Increase in energy density of Lithium ion batteries
2. Development of LoPO4, Li Sulphur, LTO , Li iron varieties of batteries
3. Dry solid electrolyte Li ion battery
4. Quick charging systems
5. Battery swapping systems for fast exchange of batteries. This also lowers vehicle costs if battery is not included in price, but becomes a separate business

Types of Energy Storage Systems

The following energy storage systems are used in HEVs, PHEVs, and EVs.

There are advantages and disadvantages for every one of these batteries. There are many people having a mindset that only lithium battery can make an electric vehicle work effectively. Many established vehicle makers are reluctant to assemble electric vehicles since they aren't satisfied with any of the batteries available in the market.

There are numerous kinds of batteries are there in market for such Vehicles, making it tough to choose which one satisfies best all the most significant characteristics, from various aspects, for example, such as energy holding efficiency, pricing, safety and utilization life. Battery experts are hand crafting the cell to fortify the significant qualities required for the application. Here is a short summary of the most significant characteristics of a battery for the electric vehicles.

- **Safety**: Safety is one of the most crucial criteria and should be given high importance while picking a battery for the electric vehicles. A single accident blown out of proportion by the media could turn the society against such a vehicle. The primary concern is a thermal runaway of the battery. Deliberately structured safety circuits with strong casing should basically wipe out this, however the chance of a severe crash exists. Battery must also be safe when unveiled to misuse.
- **Life span**: Life expectancy reflects cycle tally and longevity. Most EV batteries are ensured for 8–10 years or 160,000 km (100,000 miles). Power loss through maturity is a challenge, particularly in hot atmospheres. Vehicle manufacturers need information regarding how batteries age under various client conditions and atmospheres. To make up for capacity loss, EV makers uses large batteries to allow deterioration during guaranteed period
- **Performance**: It reflects the state of the battery when driving the EV in boiling summer heat and freezing cold conditions. Batteries are sensitive to cold and warm and require some surroundings control. In vehicles powered exclusively by a battery, the energy to moderate the battery temperature, as well as heat and cool the cabin, comes from the battery.
- **Specific energy**: demonstrates how much energy a battery can hold in weight, which defines the driving range. It is sobering to understand that, a battery produces just a single percent the energy of fossil fuel in terms of output per weight. One liter of fuel (1kg)

creates generally 12kW of energy, though 1kg battery transmits around 120 watts. We must remember that the electric motor is better than 90 % efficient while the IC engine comes in at just about 30 %. Despite of this difference, the energy storing capability of a battery will need to double and quadruple before it can compete head-to-head with the IC engine.

- **Specific power:** it demonstrates acceleration, and most EV batteries react well. A moto with an equal horsepower has a superior torque proportion than an IC engine.

- **Cost:** cost presents a major disadvantage. There is no confirmation that the battery's objective cost of $250–400 for each kWh, which BCG predicts, can be met. The ordered assurance circuits for safety, battery managements for status, climate control for life span and the 8–10-year guarantee add to this challenge. The cost of the battery alone amounts to the value of an IC engine vehicle.

To get rid of pollution and save on fossil fuel, each nation is advancing the electric vehicles. This done in good faith. The thought of driving a heavy vehicle for long distances may not be transferable to battery propulsion, even with government subsidies. Ic engine is a tough contender against these batteries.

4.1.1 Lithium-Ion Batteries (Li-Ion)

Due to high energy per unit mass relative to other electrical energy devices, the lithium ion batteries are mostly used in free to carry devices such as cell phones, laptops etc. Other captivating properties of this battery are good high temperature, high power to weight ratio, low self-discharge and good high temperature performance. Due to all these characteristics, the most of the components of lithium ion battery can be recycled but the process cost is the new challenge for everyone. In the market most of the EVs and PHEVs are using lithium ion batteries because of its performance. They are focusing on research and development of it in terms of life, cost, performance etc. Comparatively these batteries have higher energy densities than lead acid battery or nickel cadmium battery, therefore in case of some storage problem we can reduce the size of battery.

4.1.2 Nickel-Metal Hydride Batteries

Nickel metal type batteries have specific power and specific reasonable energy, that's why these are being used in computer and medical equipment regularly. Mostly these batteries used in hybrid electric vehicles because of safe & abuse tolerance. As compare to lead acid batteries these batteries have much longer life cycle which is desirable. On the other hand, nickel metal hybrid batteries are high self-discharge, high temperature heat generations, need of hydrogen loss control and expensive.

4.1.3 Lead-Acid Batteries

Lead acid batteries are reliable, safe, high power and inexpensive can be used in automotive system widely. But due to some limitations such as poor cold temperature performance, low specific energy and short cycle life limit its usage. After research and development, advanced high power lead acid batteries are developed but they are only good for ancillary loads in commercially available electric drive vehicles.

4.1.4 Ultra capacitors

The phenomenon of energy storage between an electrode and electrolyte in presence of polarized liquid is used by ultra-capacitors. Increase in the polarized surface might increase energy storage capacity. Provides extra power during acceleration, hill climbing and helps to recover braking energy. They help electrochemical batteries level load power therefore can be used as a secondary energy storage device in electric drive vehicles.

4.2 Electric vehicles battery Characteristics

The batteries used in electric vehicles should have high energy density means high specific energy & minimum volume, for which they should have minimum mass. Following graph is showing two characteristics, energy density vs specific energy of the electric vehicle batteries. From graph the properties of lithium ion battery are apparent as compare to the lead acid battery. Lead acid battery has low energy density and specific energy while lithium polymer has high energy density and specific energy. The more specific energy, the more battery will be lighter and the more energy density, the smaller size of battery.

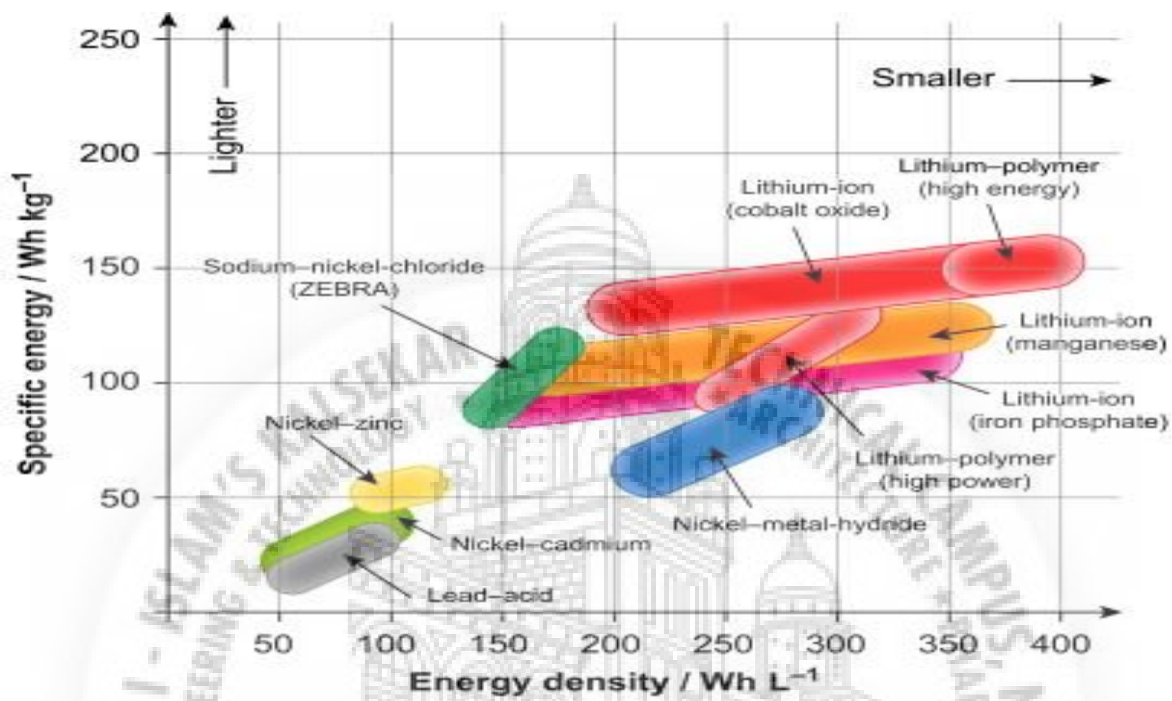

Figure 6: Specific energy vs Energy density graph

Optimization of battery design is for two purpose, to obtained high power to suit hybrid electric vehicle and to obtained high energy content suited for battery vehicle or plug in hybrid vehicle.

The table below it is observed that, specific power and power density are two most important properties for battery depend on the design of battery only. The specific energy of the lead acid battery is 1000 (W kg^{-1}) and we can bring the discharge of battery to the average by avoiding the failure of positive terminal plate. For high power applications like hybrid vehicle the nickel metal hybrid battery and lithium ion battery can be used because of their high power but the cost will increase and will be issue of talk even during mass production. In early first hybrid vehicle used a nickel metal battery and claimed to be intended to last the life of car. It can be replaced by lithium ion battery for less self-discharge rate and high power density despite high cost.

Specifications	Lead Acid	NiCd	NiMH	Li-ion[1] Cobalt	Manganese	Phosphate
Specific energy (Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80% DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	1.00V		2.50–3.00V		2.50V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 65°C (–4 to 149°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months[10] (toping chg.)	Full discharge every 90 days when in full use		Maintenance-free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		

Table 3: Comparison of batteries for power application

Lead acid battery has less self-discharge rate and available at low cost but low power density and specific power make it useless for high power application as compare to nickel metal battery and lithium ion battery. The main drawback in lead acid battery is that it can be explode and harm the people. For safety it requires battery monitoring frequently. Nickel metal hybrid battery and lithium ion battery also require module monitoring & single cell monitoring respectively for safety purpose. The operating voltage for lithium ion battery is high (3V) as compare to other two batteries and has more capacity turnovers in PSOC cycling up to 4600 comparatively. For high power application lithium ion is best suited with high cost.

Below table compares the lead acid battery with alternative batteries such as nickel metal hybrid battery, lithium ion battery and sodium metal halide (ZEBRA) battery for high energy applications. The table clearly shows the comparison between lead acid and ZEBRA battery with the help of parameters like operating temperature, cycle life, energy density etc.

The high energy application like BEV requires deep cycle life with lower weights and volume. The life cycle of lead acid battery varies from 100 to 1000 which is low as compare to other batteries. ZEBRA battery has constant deep cycle life i.e. 1300 with lower weight and volume. Nickel metal and lithium ion batteries have less self-discharge rate but expensive, while ZEBRA battery has moderate self-discharge rate which is reliable for application.

System	Lead–Acid	Nickel–Metal-Hydride	Lithium-Ion	Sodium–Metal-Halide (ZEBRA)
Standard voltage (V)	2.05	1.3	4.1	2.58
Operating voltage (V)	2.0	1.2	3.6	2.58
Specific energy (Wh kg^{-1})[a]	25–35	60	140	120
Energy density (Wh L^{-1})[a]	100	200	320	190
Cycle-life (full cycles)	100–1000	1000–2500	800–2500	1300
Self-discharge rate (% per month)	3	10	3	8% per day (thermal loss)
Operating temperature	Ambient	Ambient	Ambient	~ 300 °C
Safety precautions	Module or battery monitoring	Module monitoring	Single-cell monitoring	Battery monitoring

Table 4: Comparison of different storage strategies

The main comparative parameter is operating temperature. If we use lead acid, nickel metal and lithium ion battery despite their limitations, then it is ok up to ambient temperature. Because they couldn't operate above the ambient temperature and that's an alternative battery introduced which ZEBRA battery. ZEBRA battery can be used at 300 degrees Celsius as this is its operating temperature. ZEBRA battery simply requires battery monitoring for safety precautions and best alternative for BEV i.e. high energy application.

4.3 Energy Storage

The batteries used by electric vehicles should provide amount of mechanical work to the vehicle propulsions as compare to other storage plans and backups, not allowing the weight or area of the battery to govern the vehicle chassis. The following table is providing data of different storage systems on the basis of specific energy and volumetric energy.

Four parameters such as specific energy, energy density, storage mass and storage volume been compared for the different energy storage strategies. Gasoline and tank has highest specific energy about 30 MJ/kg with highest energy density 30 MJ/L. It has less storage mass about 16 kg as compare to lead acid battery module with 1500 kg. Also has low storage volume as compare to lead acid battery module storage volume 500L. Ethanol & tank, CNG & tank, hydrogen storage strategies have low specific energy and energy density. But they have moderate storage mass and storage volume as compare to gasoline & tank and lead acid battery module.

Energy storage strategy	Specific energy [MJ/kg]	Energy density [MJ/L]	Storage mass[1] [kg]	Storage volume[1] [L]
Gasoline and tank	30	30	16	16
Ethanol and tank	19	20	25	24
CNG and tank[2]	11	11	44	44
Hydrogen storage strategies	2.0-6.0	2.0-3.5	40-120	70-120
Advanced battery module (hypothetical)	0.5-1.0	1.0-2.0	150-300	75-150
$LiCoO_2$ cathode Li-ion battery module	0.5	1.0	300	150
NiMH battery module	0.2	0.5	750	300
Pb-Acid battery module	0.1	0.3	1500	500

Table 5: Comparison of different storage strategies

Four parameters such as specific energy, energy density, storage mass and storage volume been compared for the different energy storage strategies. Gasoline and tank has highest specific energy about 30 MJ/kg with highest energy density 30 MJ/L. It has less storage mass about 16 kg as compare to lead acid battery module with 1500 kg. Also has low storage volume as compare to lead acid battery module storage volume 500L. Ethanol & tank, CNG & tank, hydrogen storage strategies have low specific energy and energy density. But they have moderate storage mass and storage volume as compare to gasoline & tank and lead acid battery module.

The battery we have used for our project is having an Operating voltage supply of 60V and 70AH. This supply can be fulfilled by Li-Ion DC batteries, which by the way commercially exist as a cell with rating of 3.2V and 2ah/2.5ah/3ah. So to provide 60V and 70AH supply to the BLDC motor controller a general series array of 17 such cells is used and parallel configuration of 28 such arrays is required. The size of these batteries in all together is comparatively large and it is a present issue to be considered for the design of smart E-Rickshaws.

4.4 Battery Calculation:

Watt-hour Rating of Battery

Volt * ampere = power

A. For 3 Kw motor:

1. Voltage = 48v
48 * x = 3000; x = 62.5 amp
ah = 62.5

2. Voltage = 24v,
24 * x = 3000; x = 125 ah

3. Voltage = 60v,
60 * x = 3000; x = 50 ah

B. For 5 Kw motor:

1. Voltage = 48v,

48 * x = 5000; x = 104.16 ah

2. Voltage = 24v,

24 * x = 5000; x = 208.33 ah

3. Voltage = 60v,

60 * x = 5000; x = 83.33 ah

CHAPTER V

5.1 Motors

The propulsive system used in any type of electric vehicle must produce sufficient power and other characteristics that are essential for traction purpose. Based on the maximum load to be carried, an important task is to select an appropriate rating of motor. The selected motor for driving a vehicle must have the capability to provide enough power and torque to overcome the force due to load and other resisting forces acting against the movement of the vehicle. This section deals on finding the appropriate power rating required to drive an electric vehicle and the different types of motors used for traction purpose.

5.2 Types of motors used in electric vehicles

5.2.1 DC Series Motor

In early 1900s the DC series motor was used majorly for the traction purpose because it has high starting torque capability which is required for traction applications. It is better used for controlling speed and could sustain if there is any increase in load. These characteristics made this motor traction friendly. The DC motor includes brushes and commutators which increase its maintenance cost and this falls in brushed motor category of DC motor. Mainly Dc series motor used in Indian railways.

5.2.1.1 Characteristics of DC series motor

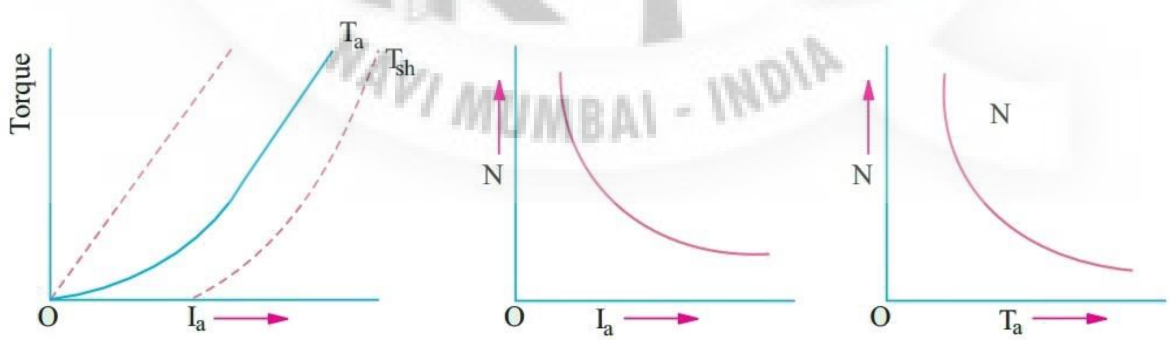

Figure 7: Performance Characteristics of DC series motor

Three characteristics curves are considered important for DC motors which are ,

i) Torque vs armature current ($T_a – I_a$)

This characteristic also called as electrical characteristic. The product of armature current and field flux is known normally. In Dc series motors, field winding is connected in series with armature. Therefore, before magnetic saturation of field flux is directly proportional to armature current. Hence the respective characteristics curve has smaller value of I_a. In DC series motor torque increases as the square of armature current, these motors are used where high starting torque is required.

ii) Speed vs armature current (N- I_a)

For small load current change in back emf is small and it may be neglected. Hence, for small currents speed is inversely proportional to flux. Flux is directly proportional to armature current therefore speed is inversely proportional to armature current.

ii) Speed vs torque (N- T_a)

This characteristic is also known as mechanical characteristic. From the above two characteristics it is found that when speed is high, torque is low and vice versa.

5.2.2 Brushless DC Motors

We can say that brushless DC motors are identical like permanent magnet DC motors. As its name it doesn't contain any brush and commutator for the operation. Therefore, it is kind maintenance free DC motor and commutation is occurred electronically. The BLDC motors have good traction properties like high starting torque, 95-98% efficiency i.e. high and used for the high power design need. Now a days maximum electric vehicle manufacturer uses BLDC motor in the vehicles because of good traction characteristics.

BLDC motors further have two types:

5.2.2.1 a) In-runner type BLDC Motor:

This is the hub type DC motor in which wheel is directly connected to the rotor. In this the rotor is outside and stator is inside. It does not require any external gearing therefore the vehicle using this motor is less bulky as absence of gears. In some special cases the motor has planetary gears inbuilt. No gear means more space and also doesn't require motor mounting space. There are certain limitations on the motor dimensions which limits the power of in-runner configuration. Hullikal, Tronx and Spero uses this motor in the electric bicycles to make it light weight. The two wheeler manufacturers like 22 motors and Eco motors uses this motor.

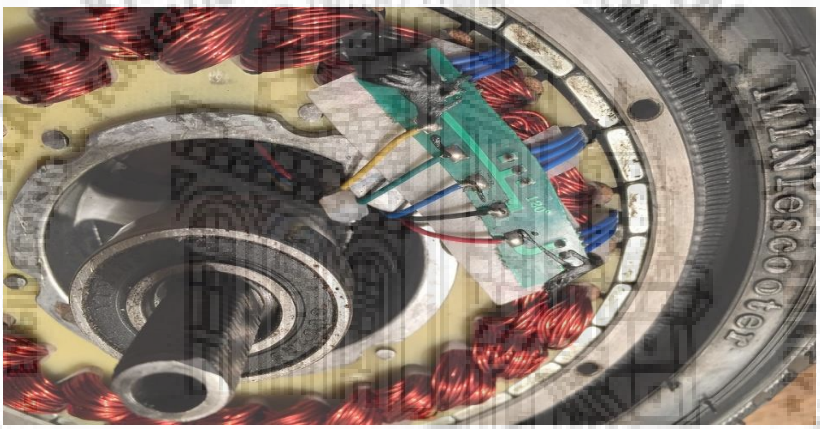

Figure 8: Hub DC motor

5.2.2.2 b) Out-runner type BLDC Motor:

This type of motor has vice versa arrangement of stator and rotor as in in-runner BLDC motor, the rotor is present inside and stator is outside. This type of motor requires external power transmission to the wheel sand gearing system, therefore it is too bulky as compare to in-runner BLDC motor. Goenka electric motors, Volta automotive, Speego vehicles, Kinetic green etc. are some three wheeler vehicle manufacturers use this configuration. It provides good propulsion to the low and medium performance scooters.

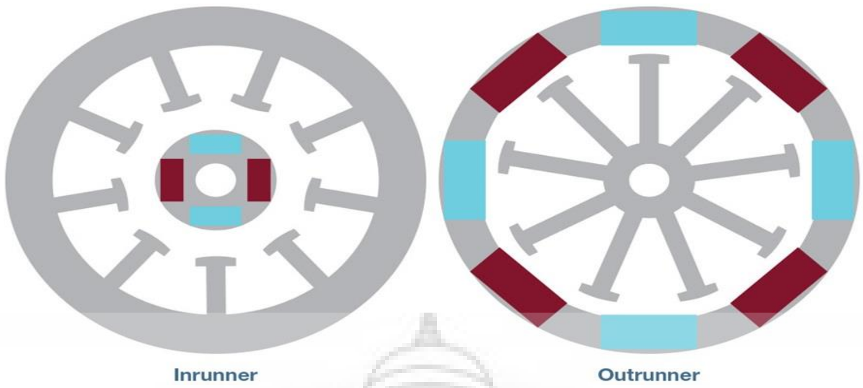

Figure 9: In-runner type BLDC motor

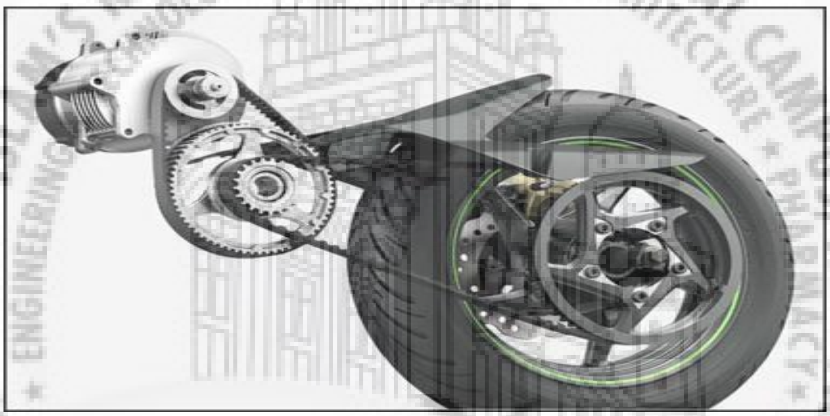

Figure 10: In-runner type BLDC motor in Ather scooter

Because of these features it is most preferable by the electric vehicle manufacturer. The main limitation is its cost due to permanent magnet but when load increase beyond the limit, permanent magnets fails to work due to thermal conditions.

5.2.3 Permanent Magnet Synchronous Motor (PMSM)

Permanent magnet synchronous motors are also identical as BLDC motors because its rotor has permanent magnets. Therefore, it has traction features like high starting torque and efficiency as of BLDC motor. The sinusoidal back EMF in the PMSM makes the difference because BLDC motor has trapezoidal back EMF. For high power ratings the permanent magnet synchronous motors are available and best option for the high performance applications like cars and busses. The PMSM is more expensive than the BLDC and induction motor but still it is in the race with these motor because of the increased efficiency. Toyota Prius, Chevrolet Bolt EV, Ford Focus Electric, zero motorcycles S/SR, Nissan Leaf, Honda Accord, BMW i3 etc. are some hybrid and electric vehicle brands use the PMSM for the purpose of propulsion.

In below graph the performance characteristics are shown with the help of torque Vs speed. There are only two modes one is constant torque mode and another is constant power mode. At minimum speed the constant torque mode does obtain in which i_{qs} is greater than zero and i_{ds} is equal to zero. As the speed increase the flux starts weakening and the constant power does obtain. In constant power mode the i_{qs} is greater than zero but i_{ds} is equal to maximum.

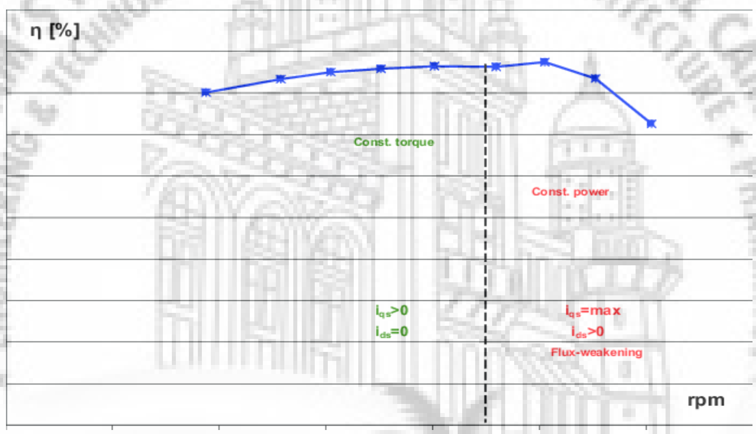

Figure 11: Performance Characteristics of PSMS

Figure 12: Permanent Magnet Synchronous motor of Toyota Prius 2004

5.2.4 Three Phase AC Induction Motors

Under fixed voltage and fixed frequency operations, the induction motors do not have high starting torque as the DC motors. By using FOC or v/f methods technics the properties of induction motor can be gain. By using these technics maximum starting torque can be obtained which is desire for traction application. It requires less maintenance therefore, the life is more of the motor, for example Squirrel cage motor which can be designed for the efficiency up to 95%. The control of the induction motor is difficult and the main limitation is that it requires complicated inverter circuit.

In permanent magnet Dc motors the flux density is contributed by magnets. In induction motor by using and varying voltage and frequency V/F parameters lead to easy adjusting of flux density on torque requirements. This reduces the losses in turn and develop the efficiency in motor.

Now a days the induction motor is used by Tesla Model S which has high performance capability against limitations. Tesla mainly avoid the dependency on the permanent magnet as selected induction motor. For purpose of propulsion Mahinda Reva e2o uses three phase induction motor. Another various leading vehicle manufacturer like TATA and TVs are planning to use induction motor in their cars and two wheelers respectively. The manufactures which are performance oriented use induction motors because they are cheap and can be used in various tough environmental conditions. That's why Indian railways going to replace Dc motor with AC induction motor.

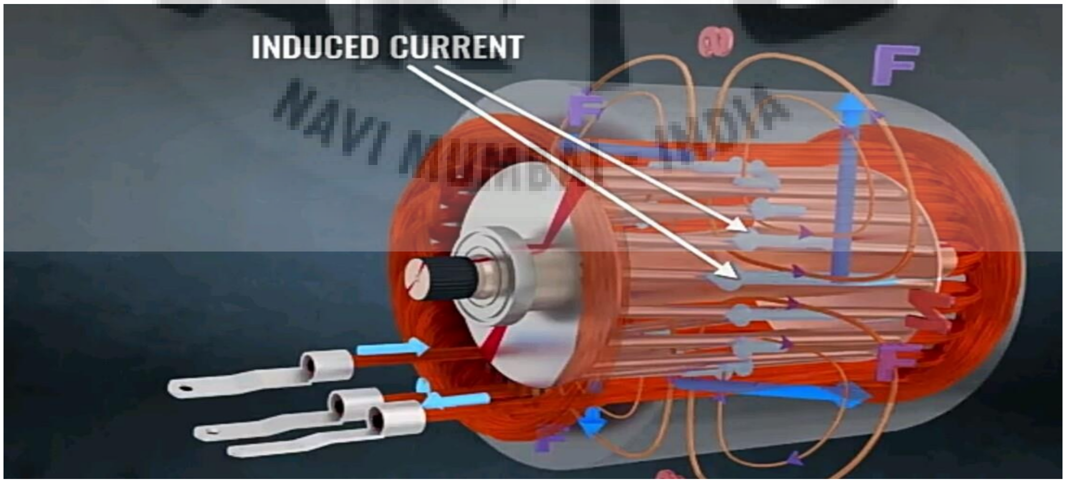

Figure 13: 3 Phase AC induction motor

5.2.5 Switched Reluctance Motors (SRM)

Switched Reluctance Motors is a category of variable reluctance motor with double saliency. The construction of switched reluctance motor is simple and used robustly. The piece of laminated steel is used as a rotor without any windings and permanent magnet on it, this makes the inertia of the rotor less which helps in high acceleration. The SRM provides high power density and used for high speed applications because of robustness. In this the stator gets heated but it is easier to cool the motor. Increased switching circuit and complicated control of the motor make it limited to some applications. It also has some noise issues but when it will enter into the market, will replace to PMSM and induction motors.

Following graph shows the characteristics of switched reluctance motor in which torque is plotted speed on y and x-axis respectively. The maximum torque and power capabilities are provided. At maximum constant torque mode, the speed is minimum which is ω_{mb}. While the torque fluctuates and decreases, the speed increases gradually up to ω_{mp} as shown in below figure; this constant power mode. At the minimum torque θ_c is constant and speed increases naturally.

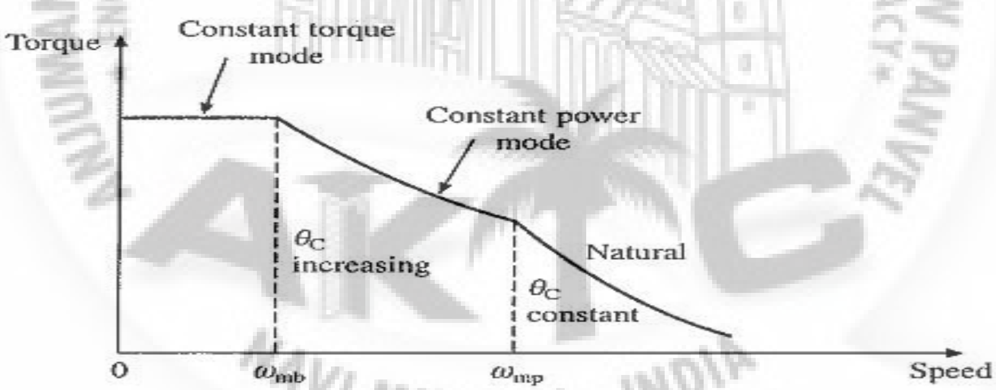

Figure 14: Characteristics of SRM

CHAPTER VI

6.1 Design Calculations and MATLAB

First step in our design process is calculation of the tractive effort . Design parameters are selected based on Indian urban drive cycle. Following Table 6 shows selected design parameters.

Parameter	Value
μ_{rr} – Coefficient of rolling resistance	0.0109
m = mass of vehicle + mass of passengers	350+350=700kg
g – Gravitational acceleration constant	9.81 m/s^2
θ – Grade (slope)	5% - 10%
ρ – Air density	1.2 kg/m^3
C_d – Aerodynamic drag coefficient	0.4792
V_a – Velocity of air	2 m/s
Auto Rickshaw (Bajaj RE) body parameters	
V-velocity of vehicle	50 Km/hr = 13.8 m/s
A – Frontal area	2.09 m^2
r – Radius of tyre	0.2365 m
G – Gear ratio	10
η_G – Gearing Efficiency	85%

Table 6: Design parameters

Tractive Effort:

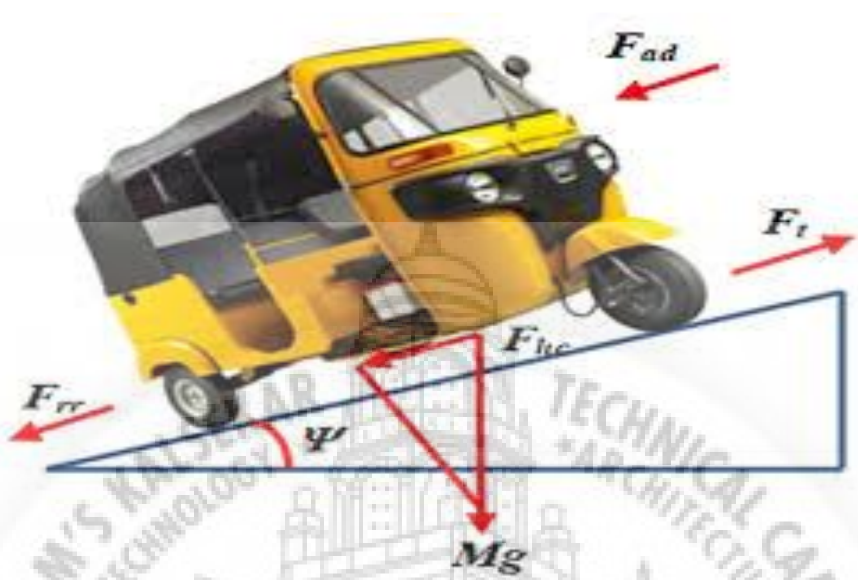

Figure 15: Auto rickshaw dynamics

1. Aerodynamic Drag,

Aerodynamic is a force which the oncoming air applies on a moving body. It is the resistance offered by the air to the movement of the body. So, when a car is moving; it displaces the air. However, it affects the car's speed and performance.

$F_{AD} = 1/2\ \rho\ C_D\ A\ (V + V_a)^2$

$= 1/2 * 1.2 * 0.1492 * 2.09 * (13.8+2)^2$

$= 150.01$

2. Rolling Resistance,

Rolling resistance is the force per unit vehicle weight required to move the vehicle on level ground at a constant slow speed where aerodynamic drag is insignificant and also where there are no traction forces or brakes applied.

$F_{RR} = \mu_{rr}\ m\ g \cos\theta$ Initially $\theta = 0$

$= 0.0109 * 700 * 9.81 * \cos(0)$

$= 74.85\ N = 75\ N$

3. Linear Acceleration Force,

Linear acceleration force is the force when applied to the mass of vehicle m which causes the linear acceleration.

$F_{LA} = m * a$

Where, a – Acceleration of 2.08 m/s^2 is required {For reaching 0-60 in 8 seconds}

$a = [(60 * 5/18) – 0] / 14$

$= 1.19\ m/s^2$

$F_{LA} = 700 * 1.2 = 840$ N

4. Angular Acceleration Force,

$F_{AA} = (I_{axle} / r^2) * a$

$I_{axle} = mr^2$ {Where, m– 5% of total mass}

$= 0.05 * 700 * 0.236$

$= 1.957\ kg.m^2$

$F_{AA} = (1.957/0.2365^2) * 1.2$

$= 41.98$ N

Therefore,

$F_{TE} = F_{AD} + F_G + F_{RR} + F_{LA} + F_{AA}$ Assume $F_G = 0$

$= 150.01 + 0 + 75 + 840 + 41.98$

$= 1106.99\ N = 1107\ N$

Speed, Torque and Power Calculations:

1. Linear Distance Travelled in One Revolution of Tyre

$= 2\pi r$

$= 2 * \pi * 0.2365 = 1.4859m$

Revolution Per Minute

N_{wheel} = Total distance covered/hr / linear distance

$= 50000 / (1.4859 * 60)$

$= 560.82$ rpm

2. Angular velocity of wheel,

$\omega_{wheel} = 2\pi N / 60 = 58.72/s$

3. Torque on Wheel

$T_{wheel} = F_{TE} * r$

$= 1107 * 0.2365 = 261.8$ Nm

4. Torque On Motor

$T_{motor} = 1 / (G * \eta_G) * T_{wheel}$

$= 1 / (10 * 0.85) * 261.8$

$= 30.8$ Nm

5. Power of Motor

$\omega_{motor} = G * \omega_{wheel}$

$= 10 * 58.7 = 587.2$ rad/sec

$N_{motor} = (\omega_{motor} * 60) / 2\pi$

$= (587.2 * 60) / 2\pi$

$= 5607.34$ rpm

6. Power Input

$P_{ip} = (m * a * V * \mu_{rr}) + (\rho * C_d * AV^3)$

$= (700 * 2.08 * 13.8 * 0.0109) + (1.2 * 0.4792 * 2.09 * 13.8^3)$

$= 3377.51$ w Peak Power

Final Results

Torque = 30 – 50 Nm

N_{wheel} = 5607 = 5000 – 6000 rpm

Power= 3.5 Kw

Concluding remarks: All results of above design calculations are based on theoretical assumptions & empirical relations and serves a basis to create mathematical models for simulations.

6.2 Drive cycle simulation and design validation

Simulation was carried out for validation of design parameters and to select propulsion system especially battery and traction motor. MATLAB 2019a was used to carry out simulation. Simulink model was created and all selected design data was verified, whether it confirms the need of the Indian urban driving cycle. All simulations were run for 2474 seconds (0.69 hours) and x-axis represents the time in seconds.

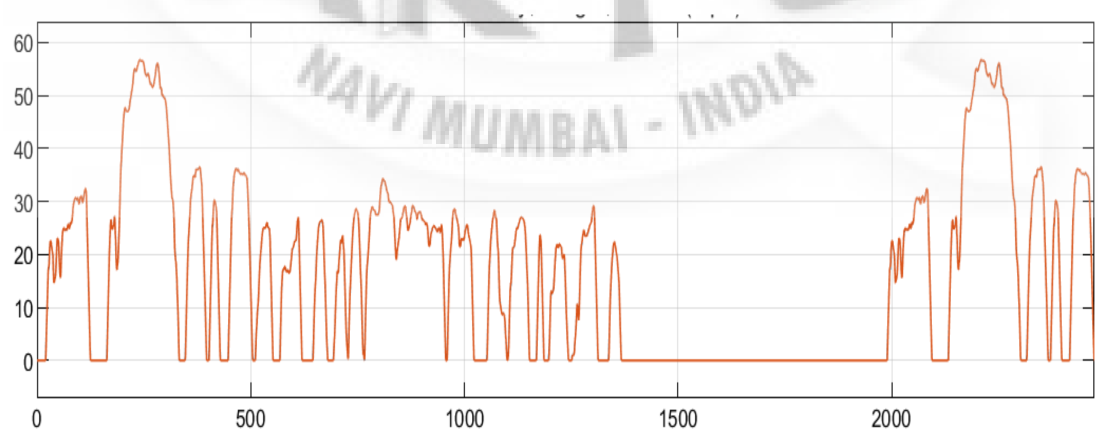

Figure 16: Vehicle speed trace in kmph

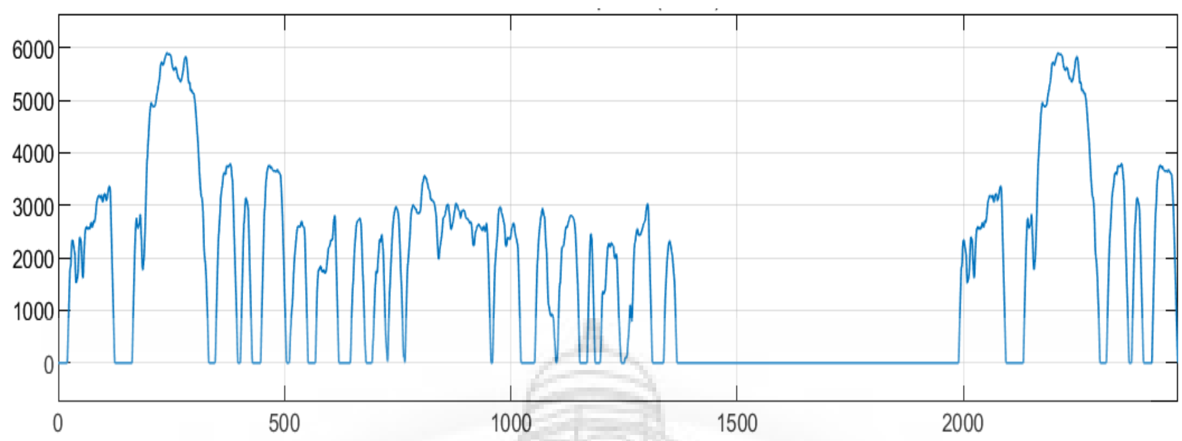

Figure 17: Motor speed trace in kmph

Figure 16 & 17 depicts that the average driving speed is 30 kmph and maximum speed is 55 kmph. Therefore, proposed system's maximum target speed of 50 kmph fulfils the purpose. As per design calculations corresponding motor speed (N_{motor}) for 50 kmph vehicle speed (N) is 5607.34 rpm and Figure 6 portrays that the maximum motor speed is 6000 rpm. Therefore, It can be concluded that motor with speed of 5000-6000 rpm will fulfil the purpose.

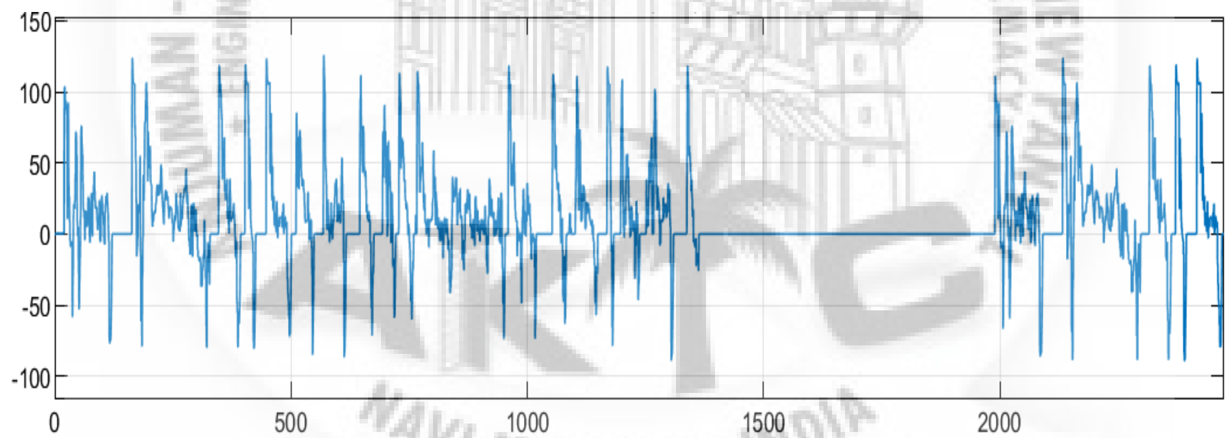

Figure 18: Vehicle torque in N-m

In Figure 18 maximum torque is 120 N-m and average torque is 50 N-m. With gear ratio (G) of 10, motor with rated nominal torque of at least 12 N-m is most suitable for economical operations.

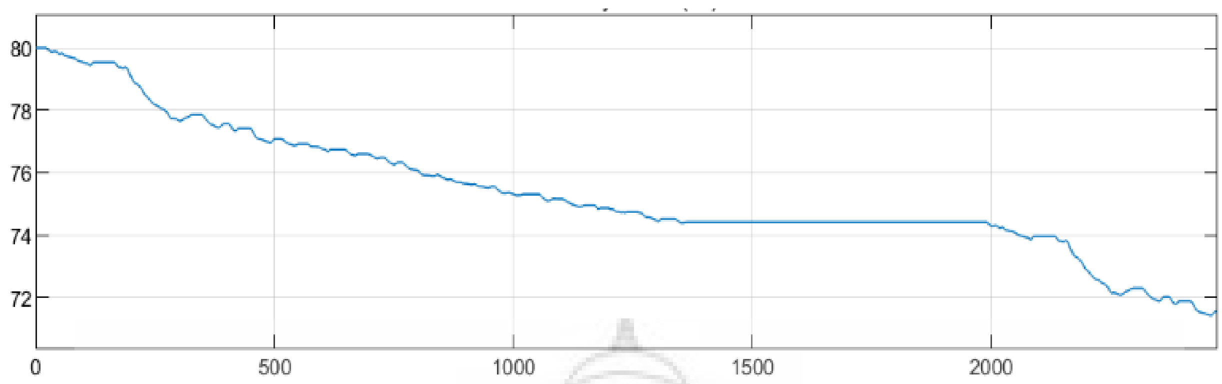

Figure 19: Battery SOC (%)

Figure 19 reveals that for 0.69 hours of vehicle operation in Indian drive cycle with battery of 100 Ah, SOC (%) is depleted from 80% to 70 %. SOC is the state of charge of the battery, which determines available electric charge in the battery.

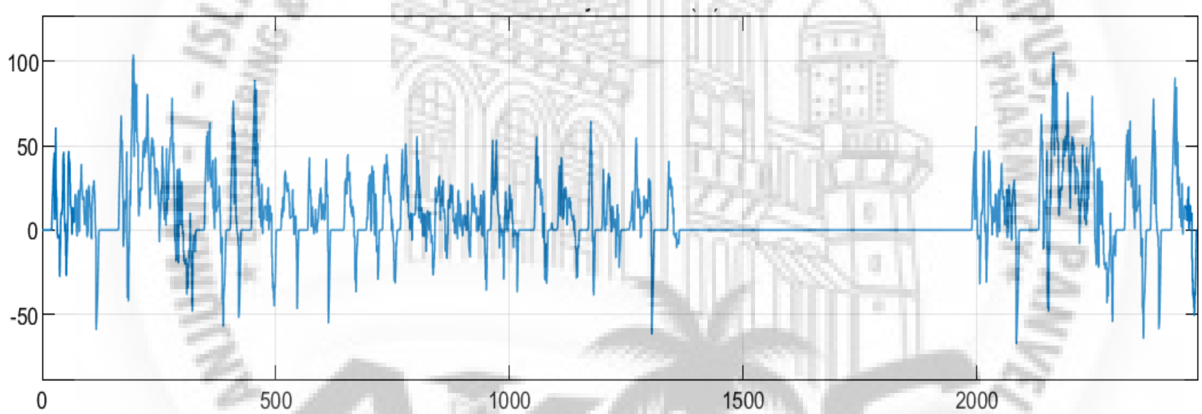

Figure 20: Battery current (A)

Figure 20 illustrates that average current demand from battery is of 50 amperes and battery with 50 A nominal rating and 3C discharge rating to handle peak demand of 100A will fulfill the purpose.

6.3 Selection of components of propulsion system

Figure 3 shows the schematic layout of all major components of propulsion system but we will focus on Battery and Traction motor.

DC brushless motor was selected with 3.5 KW nominal rated power with 12.5 Nm rated nominal torque based on our rigorous comparative study of DC Hub motor, PMSM (permanent magnet synchronous motor), induction motor and BLDC motor. Following are specification of our procured motor.

- Type: Permanent Magnet BLDC
- Voltage (Volts): 48/60
- No load Current (Amperes):- 7
- Rated Current (Amperes): 78
- Peak Current (Amperes): 100
- Rated Speed (RPM): 2500±100 / 3000±100
- Rated Torque (Nm): 12.9
- Max Output Torque (Nm): 400% of rated value
- Rated Power (W): 3500
- Max Output Power (W): 4500
- Efficiency (η): >87% on full load and full rpm
- Protection class: IP 67
- Motor weight (kg): 14
- Insulation class: B

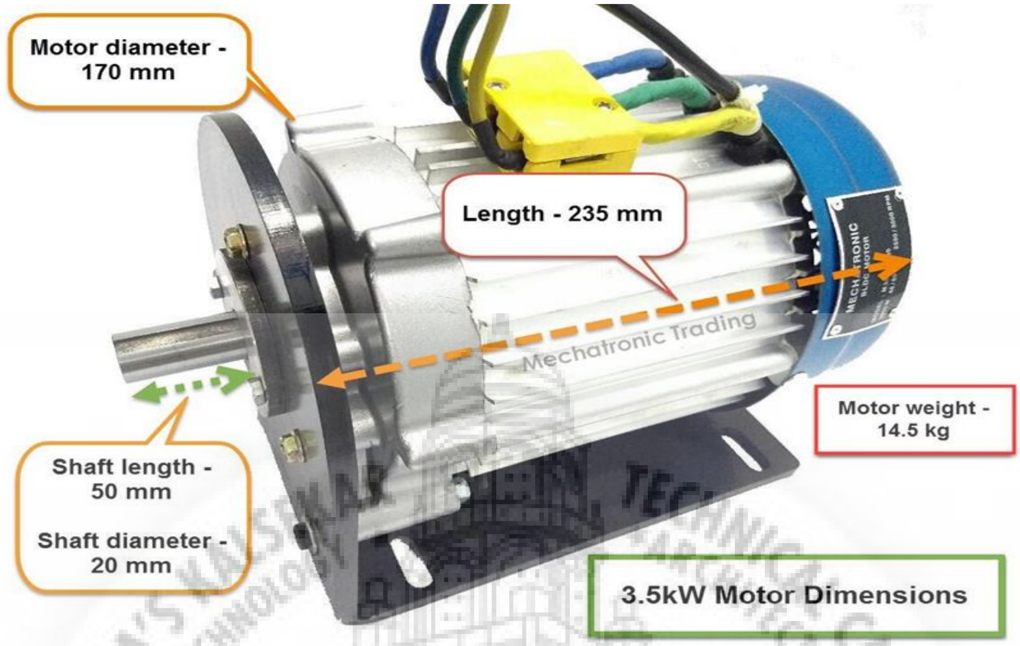

Figure 21: BLDC motor

6.4 Motor test

Motor load test was performed at testing apparatus. Purpose of motor test was to check actual performance of procured traction motor. Figure 22 represents graphical results of motor test.

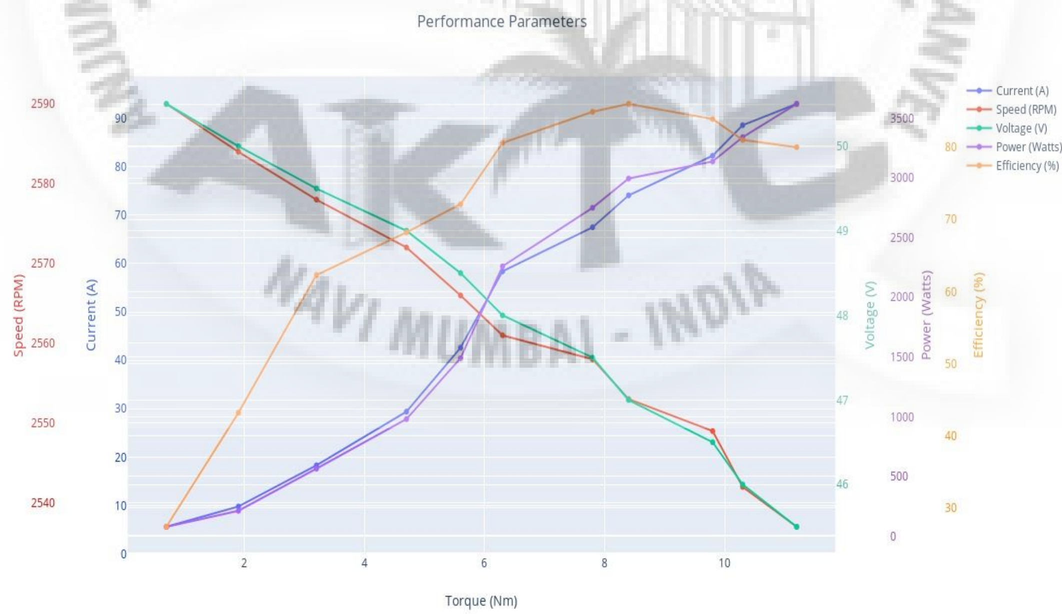

Figure 22: Motor test

Few highlight points of motor test:

1. There is approximately a linear relationship between all the performance parameters of the motor, which is desirable because linear characteristics ensure long life of the traction motor.
2. There is a directly proportional relationship between voltage & current and speed & torque respectively.
3. Motor shows higher efficiency at higher speed and at top speed efficiency reached more than 90%.
4. At lower speed power, consumption is high.
5. Motor performance is as per desired output.

Sr.no	Voltage (v)	Current (A)	Speed (RPM)	Torque (NM)	Power (W)
1	50.5	5.6	2590	0.7	77.7
2	50	9.8	2584	1.9	212
3	49.5	18.3	2578	3.2	565
4	49	29.4	2572	4.7	980
5	48.5	42.6	2566	5.6	1490
6	48	58.4	2561	6.3	2260
7	47.5	67.5	2558	7.8	2725
8	47	74.1	2553	8.4	2995
9	46.5	82.3	2549	9.8	3138
10	46	88.6	2542	10.3	3341
11	46.5	93	2537	11.2	3620

Table 7: Results of motor test

CHAPTER VII

Costing

Sr.no	Components	Cost in rupees
1	Bldc motor (35kw)	22500
2	Motor controller	11450
3	Motor accessories	850
4	Cable wires	900
5	Harsens wire	800
6	Li-ion Battery	47000
7	Battery charger	7000
8	Rickshaw model (frame)	15000
9	Rickshaw accessories	5000
10	Paint	800
11	Oils and Greece	400
12	Transmission shaft	1100
13	Machinery & Accessories	3000
	Total	**1,15,800**

Table 8: cost of components

*The cost of electrical components is higher than the usual price in market due to corona virus

* If we cut off that factor in price list we can see a straight deduction about 20% in cost .

* For the components in bulk the price will reduce to 25-30%

*The range obtained on the system is about 60-70 km per charge

CHAPTER VIII

8.1 Advantages and Limitations

8.1.1 Advantages

1. Eco – friendly – E-rickshaws are the best option in contrast to petroleum or diesel run vehicles as they work on battery. These rickshaws don't emit any exhaust gas, hence it will help in reduction to the increasing air pollution. The batteries which will be utilized for the working of these rickshaws can be successfully recycled and hence, will take care of the issue of battery disposal.

2. Economical – E-rickshaws are cheaper than cng rickshaw. Passengers will have to pay a less. It is economical not only for the passengers but also for the owners. poor people who has to travel on daily basis can easily afford to travel by such vehicles

3. Free from noise pollution – E-rickshaws are free from creating noise pollution as they do not emit any sound. Passengers can have a smooth and comfortable ride.

4. Livelihood – E-rickshaws provide a means of livelihood for the common as well as illiterate people. Without investing much of money, poor people who have no skills can at least earn their livelihood by at least running an e rickshaw.

5. Safety – E-rickshaws involve less risk when compared to the other fuel operating vehicles. They can cause less accident as they are slower and lighter than an auto rickshaw. Highly safe when it comes to catching fire.

6. Easy maintenance – E-rickshaws don't contain engine and gear box and thus, the burden of maintenance is almost eliminated. The motor used in e rickshaws are small and the battery is easily accessible foe replacement or swapping. Hence, maintaining them is quite easier.

7. Construction– Lightweight frame with same performance and space availability.

8.1.2 Limitations

1. Less speed – E-rickshaws are usually slow in speed and it runs around 30-35 kmph and thus, it is unable to meet the speed of other vehicles. It is not a preferred mode of transportation during an emergency period.

2. Less weight These e-rickshaws are comparatively lighter in weight and hence cannot cope with larger weight. There will be always a chance of the rickshaw being toppled over if it exceeds the permissible weight. In India, one can imagine how the drivers would ride an overloaded e-rickshaw.

3. Harmful batteries – One of the major disadvantage is the issue of batteries. Today, most of the batteries used are lead acid batteries. The deep discharge of lead acid batteries are presently imported in India and these can be very harmful.

4. No proper guidelines – There are no proper rules and guidelines fixed for the functioning of e-rickshaws. The drivers are not fully trained to drive the e-rickshaws. This is a matter of serious concern in the society.

5. Rise in pollution and cost due to alternative energy sources - Even though the e-rickshaws would not consume diesel or petrol, it would be difficult to contain the cost and pollution. The electricity required to charge these vehicles would be produced from some or the other source. Burning more coal or making more dams or nuclear reactors would still contribute to environment pollution.

Still, we cannot consider the battery vehicles to be a replacement for the fuel combusting ones, as the battery vehicles cannot give a zooming efficiency to match the efficacy of the current vehicle forms. The speed of the E-rickshaws can be better over the manual vehicles, but that could be no option for a long distance travel. Again the light weight of these E-Rickshaws is another drawback with the fear of getting upside down due to over-loading. The cost-efficient E-rickshaws could be boon for the poor people who cannot afford to own an auto-rickshaw to run their livelihood. But, we need to have certain checks on the driving of these rickshaws. As these are battery operated, so definitely the speed is more as compared to the manual vehicles, which require certain restrictions and a defined route for their travel. Permitting them within the residential colonies might be a bit risky.

8.2 Law on e-rickshaw and proposed guidelines

Central Government has drafted certain proposals and guidelines for smooth operation of e-rickshaws

- Nitin Gadkari (transport minister delhi) said that all e-rickshaws should be regularized through a nominal registration fee of Rs. 100 at MCD.
- A different driving license will be issued to the drivers.
- The MCD along with Delhi traffic police will work out a challan system for not following traffic norms.
- An insurance corpus of Rs 10 lakh has to be made by e-rickshaw associations. This has to cover compensation for any grievous hurt (Rs 25,000) or fatal incident (Rs 1 lakh) caused by an e-rickshaw.
- These battery vehicles will come under the rules of the Motor Vehicles Act.
- The maximum permissible speed of an e-rickshaw should not exceed 25 km/hr with four passengers limit.
- The proposal also stated that identity marks and stickers will be issued for e-rickshaws.

8.3 Thoughts On Converting Three-Wheelers To Electric

In India, electric rickshaws do not have enough supporting infrastructure or public acceptance in order to grow at an enormous pace. Although government has proposed many subsidies but it is yet to come into effect. Many automobile manufacturers are still not getting a clear road map for such vehicles from government. The conversion of existing three-wheelers to electric can be revolutionary at least for next 7-8 years, since there are more than 2.5millions auto rickshaws are running on road.

CHAPTER IX

9.1 EV Market India

E-rickshaws have been in use since 2008 as a replacement for auto rickshaws in Asian countries like China, Bangladesh, Japan, and Nepal, and in low numbers in European countries like Switzerland, France, Germany. In India, the concept has started just 4 years back and Delhi was the first state to launch this. It is yet to be launched officially in other states, though you see a few of them here and there in other states as well.

9.1.1 MAHINDRA AND MAHINDRA was working on electric rickshaws from years and got success in it. They bring an e-rickshaw in the market named Alpha Mini, which is available at 1.12 lakh in the market of Delhi. Mahindra is now thinking to launch e-rickshaw in rest of the metro cities and parts of the India. The E-rickshaw is developed to last mile connectivity which offers the transportation to intercity people. It provides a range of 85 km if we charge it one time and gives the maximum speed of 25kmph. Alpha Mini uses 1000w motor which is powerful within controller and 120Ah battery. Before launching Mahindra tested and analyzed their product by running one lakh kilometers in the real streets of India with all conditions. Mahindra claims that their product is the need of current e-rickshaw market. As their name established because good service connections and not difficult finance schemes, it will be easy for the customers. Also they are providing attractive offers like low down payment, two years of warranty, reliable EMI and the free battery swapping.

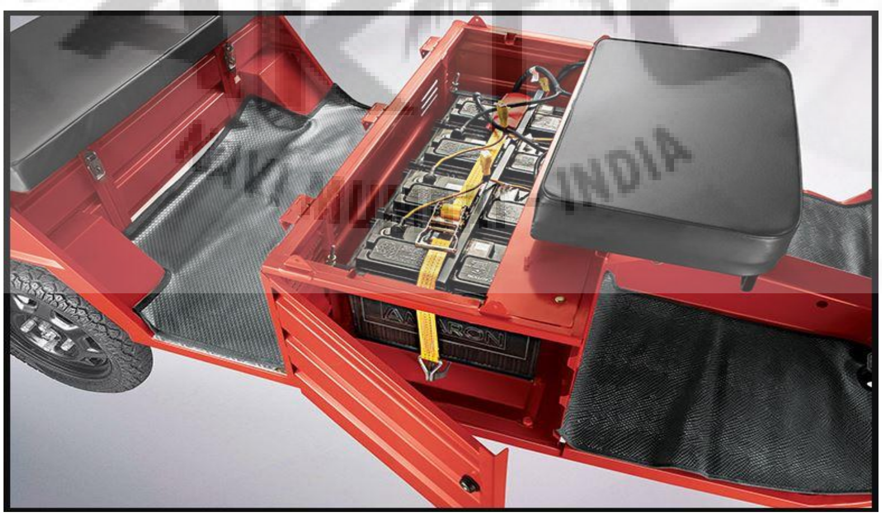

Figure 23: Mahindra Alpha Mini

Mahindra always try to fulfill the needs of customer based in rural as well as urban region. They provide cozy four vehicles to field tractors. Therefore, the e-rickshaw will also help the customers from both the region because in rickshaw is the end connectivity resource at every place. Now in some part of the country the e-rickshaw is running on the road and it is emerging product to be launched in all over the India soon. For the establishment of these rickshaws one has to face technical, political and social challenges.

9.1.2 OLA is the best auto-rickshaw ride service provider in India has added the numbers of E-rickshaw for the best experience of customer. Ola named this program "Mission Electric", to achieve the e-mobility goal of India up to 2030. They are now running their E—rickshaws for the testing in various part of country but in 2021 around one million Ola e-rickshaws will run on the roads. Ola is providing ease to the auto rickshaw drivers to switch to e-rickshaw. They are providing training and educating them. They also providing solar panels on the roof of the rickshaws and several Ola charging stations are going to build. But now a days Ola took a back step in this mission because of not that much interesting policies of government on E-rickshaw.

Ola also installed the small charging and battery swapping units in the house of drivers because of which their time can be reduced. Ola stated that they have run their e-rickshaws for four million kilometers and understood the pros and cons of e-rickshaws. Capability, applications, real world problems and conditions, charging cost and battery etc. are some important factors on which one should focus while working on electric vehicle or e-rickshaw.

Figure 24: Ola E-rickshaw

9.1.3 COMPAGE AUTOMATION SYSTEM PVT.LTD is a Pune based start up company which generally provide automotive parts and electric systems. They built an electric rickshaw and claimed to be fastest e-rickshaw of that time as compare to existing e-rickshaws. They provided specifications of their E-rickshaw at a glans like 1350gvw, 82w-h/km, 7-10 degree gradeablity and maximum speed is up to 55km/hr. They used brushless DC motor (BLDC) with their own electric conversion kit. The performance of the e-rickshaw is really optimum as compare to various brand e-rickshaws. The cost of the e-rickshaw is around 1.3 to 1.5 lakh because of the expensive lithium phosphate battery pack and powerful BLDC motor. They are now testing their e-rickshaw in the streets with real world conditions. Also they are collaborating with another startup companies and working on hybrid vehicles.

9.1.4 GOGOA1 basically is a supplier of automotive parts, components, electric motors, electric kits and other e-vehicle equipment. This company brings the products or components from China (YongKang Shinde Electric Vehicle Company Ltd.). GoGoA1 is located in Navi Mumbai but has its own facility in China. Except of supplying e-vehicle parts now they are focusing on the production of electric vehicles. Now this company is focusing on R&D department to deliver quality product to the consumer. GoGoA1 did not disclose anything about their products like e-rickshaw because of the patent and copyright issue. It will launch it in forthcoming days after patent. It does provide electric vehicle conversion kit, electric scooter CKD, electric vehicle parts, HUB motors, PMDC motors, controllers, batteries, wheels, throttles, chargers, display etc.

9.1.5 E-TRIO is the startup company known for the retrofitting of two wheelers, three wheelers and four wheelers. Retrofitting is the simple way of adopting electric vehicle technic just by using conversion kit with low cost. It has all started from the Hyderabad and became the first startup to obtain green flag from ARAI (Automobiles Research Association of India) for retrofitting the vehicles. E-trio has built two kits named EV-150 and EV-180 which can convert the vehicles into the suitable electric vehicle with ease and low maintenance. Also the second phase of the government has announced FAME (Faster Adoption & Manufacturing Hybrid and E-vehicles) policy, which provides incentives to EV startups. Therefore, E-trio also has come in form and collaborating with local manufacturers to increase procurement of parts/ equipment.

9.2 Perception related to e-rickshaws

E-rickshaws related perception were mapped based on sample survey conducted in areas of Delhi. The perception of owners/operators, commuters, dealers/manufacturers and authorities differ to a large extent and has been summarized as under.

	Owner/operator	Commuter	Dealers/ manufacturers	Authorities
Manufact-uring related	Design of some model of e-rickshaw are not water resilience and face difficulty in operating during rainy season and some models does not work efficiently on sloped terrain.	Not applicable.	Safety compliance is mandatory for e-rickshaw models to be approved and getting registered for plying on roads.	Many illegal manufacturers exist in market which manufactures e-rickshaws not complying to safety standards leading to accidents.
Safety related	94% operators feel that e-rickshaws are safe for drivers and commuters	63% commuters feel that e-rickshaws are safe, rest 37% feel it is unsafe.	70% dealers consider e-rickshaws safe if manufactured with safety compliance.	Unregulated operation is considered unsafe and may lead to accidents.
Operation related	Difficulty in operating in rainy season (in some models).	-	-	Challenge to manage unregistered e-rickshaws
Fares	Fare price depends on demand and time.	Unregulated fare and should be regulated.	Should be regulated.	
Charging	High cost of commercial charging if the operator charges their vehicles in private charging stations.	No applicable	Charging domestically is promoted by sellers.	Unauthorised charging stations are a menace.

Figure 25: The perception of owners/operators, commuters, dealers/manufacturers and authorities

9.3 Is E-rickshaw a smart choice for urban mobility?

It would be a great option to consider e-rickshaws replacement for end to end connectivity mode. E-rickshaws are considered elegant in terms of no pollution, economical, safe & slow speed, decent income, reasonable and ideal for urban areas. There are few concerns linked with e-rickshaws which may be connected to some smart features but these may be tackled through continuous developments. Detail of interrelation of features, issues and development may be summarized as follows:

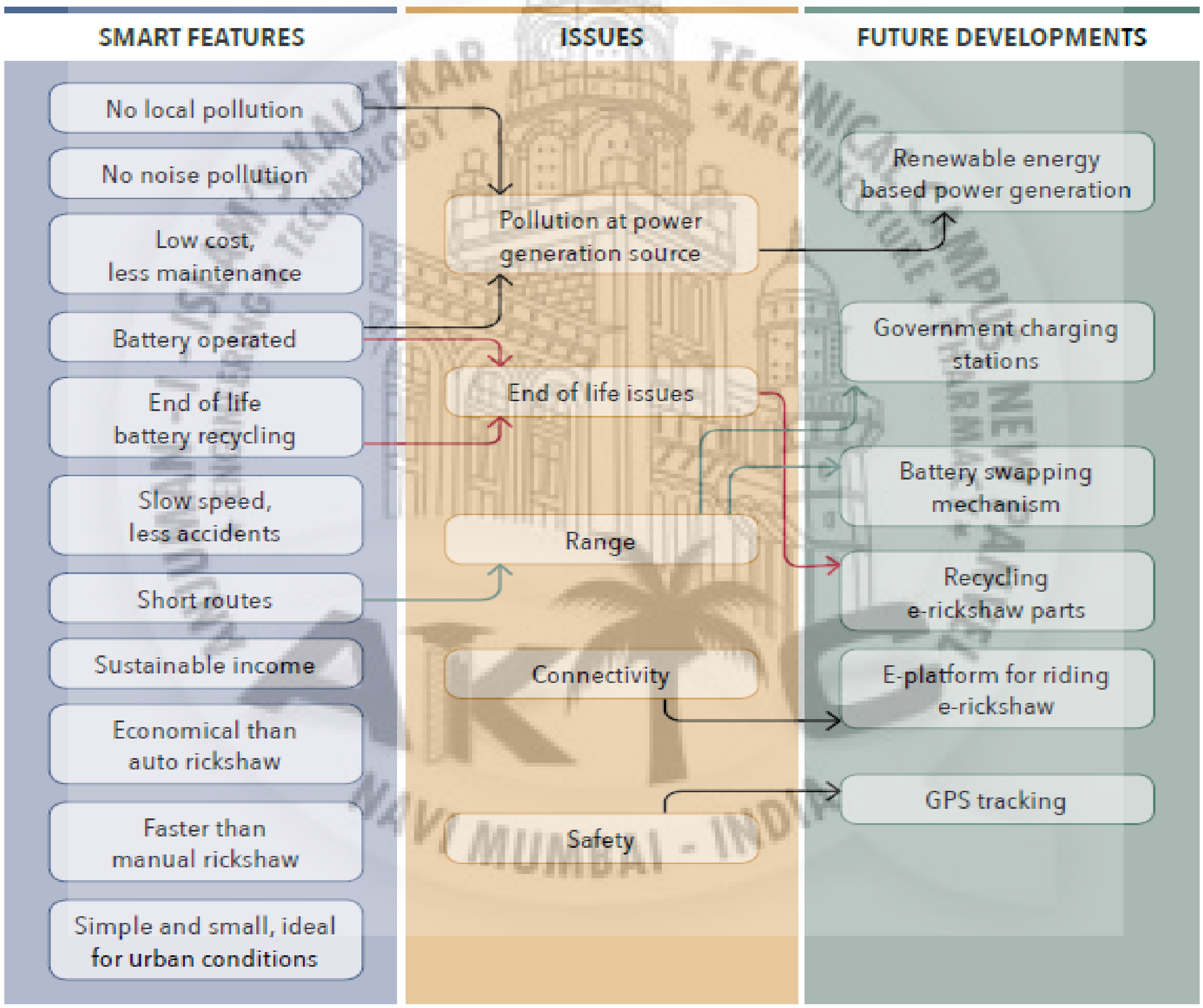

Figure 26: Interrelation between issues related to e-rickshaws, its smart feature and future development

CHAPTER X

10.1 Results

In design calculations vehicle dynamics parameters were calculated and they formed the basis for creating mathematical model in MATLAB Simulink. Results of MATLAB Simulink simulations helped in selecting powertrain components with the best-suited specifications. Thus, reducing the risk of unsatisfactory performance of retrofitted auto-rickshaw. Simulations also helped in safeguarding ourselves from economical loss and risk of accident due to inappropriate selections of the propulsion components. Improper selection of components can result in hazardous fire in battery and can endanger life of passengers.

CHAPTER XI

11.1 Future scope

Simulation results are valid under specified assumptions; perhaps it would be beneficial to check consequences after increasing the level of detail in some assumptions. Thermal investigation of battery, traction motor and auxiliaries using CFD simulation can considerably effect in improving the performance and efficiency of E-rickshaw. Thus, can be an interesting future research topic.

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 mathematical as well as physical model. Detailed study on life cycle cost and recycling of battery including environmental effects can be vital areas of future studies.

With ceaseless development in EV-technology, possibilities are infinite for research and innovation.

11.2 Future prospectus/scope

11.2.1 Opportunities

The electric vehicle is the emerging field in which one can find the scope and opportunities to become success. The government allowed to install the charging stations as like petrol pumps for ease of battery charging in E-vehicle or E-rickshaw. Vendors are also investing in this, Reliance and Tata has taken the step to install the charging stations in the Mumbai city. One can install his own charging station according to the norms and regulations.

OPPORTUNITIES	THREATS
• Introduction of charging spots by government/vendors at various locations	• High cost of replacing battery and toxic waste generated due to disposal • Unnecessary fines and confiscation of

• Introduction of e-rickshaw stands to make parking easier • Providing first and last mile connectivity to a large section of the population to decrease the share of private vehicles on the roads • Safety measures for female drivers	vehicles by regulators/govt./police. • Attempts at formalizing e-rickshaws, by making registration and vehicle standards mandatory increases costs of operation • Longer down-time for drivers compared to conventional vehicles

11.2.2 Challenges and measures to be taken

- Developing suitable charging infrastructure: Electric vehicles all around the world have caught the eye of influencer and automotive industries globally. There are many cities which have taken initiatives for electric vehicles use. The Ministry of Heavy Industries has already prepared a detailed blue print for electric vehicles future. The major concern with Indian customers regarding Electric vehicles are its charging time, driving range, battery life ,battery replacement costs, top speed and acceleration. Few of these concerns can be addressed by vehicle variants based on Li-ion batteries; however, their high initial cost becomes an obstacle in such cases.
- Charging time, speed and range are related to technology and charging infrastructure. Faster charging speed can be achieved through special charging points and similarly the driving range can be tackled by opting for batteries with higher specific energy, or through a well-planned infrastructure for charging and supply of replacement batteries distributed all over the city. However it will take few years' time to develop this infrastructure, until then battery swapping system is highly beneficial. In Battery swapping system discharged battery can be replaced by charged battery within few seconds just like LPG cylinder. User necessarily does not have to own battery but can pay initial security deposit and pay charges while refilling. This it bring down overall cost of the vehicle and instead of large infrastructure single or few swapped battery charging station can be installed. However initial system setup charges are pretty high.

- Currently 90% of e-rickshaws use lead acid batteries as it is the cheapest way to store energy. After number of cycle life, handling of lead acid batteries becomes a concern due to presence of lead in batteries which may prove dangerous for human health and hazardous to environment.
- The development of competent charging stations along with advanced fast charging options needs to be developed hand to hand with growth of Electric Vehicles. Another major issue here in India is unnecessary fines and confiscation of vehicles by regulators/govt./police due complex and fuzzy government policies.
- Accessibility of e-rickshaws in some areas is limited and commuters have to wait for it. Merging with mobile application to ride an e-rickshaw may be helpful in improving their access in unserved areas. Giants like OLA/UBER/Smart E are already working towards this issue.

11.3 Recommendations based on our study

- Charging stations and e-rickshaw parking stands need to be set up all across the city
- The routes for e-rickshaws should be increased and the drivers should be given proper knowledge about these routes
- Registration of the vehicles should be properly enforced to avoid underage driving and to take care of issues such as rash driving. The cost of registration should be reduced
- Safety measures for the lady drivers should be provided by the police
- The loans given by the bank for purchasing e-rickshaws should increase and the down payment for purchasing the e-rickshaws should be decreased
- The cost of operations must be brought down by reducing or delinking the cost of batteries. This can either be done by the introduction of battery swapping or through cost reduction of longer lasting lithium-ion batteries

Conclusion

The report discusses all the important steps of retrofication of auto-rickshaw. Starting from feasibility study to design, simulation and assembly, authors have tried to discuss every major aspect of the project. This paper can be helpful not only in auto-rickshaw retrofication but also for any other retrofication project. This paper has made sincere efforts to describe systematic process in simplest way possible for selection of optimum specifications for most important components in electric vehicle propulsion system.

Retrofitted E-rickshaws can be an effective and feasible way to promote electric mobility in India, as it is affordable when complimented with government promotional schemes, and beneficial for owners of faulty ICE driven auto-rickshaw.

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