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E – Moped

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ABSTRACT

The E – Moped is experimentation for converting an engine powered vehicle to an electrically powered vehicle. In this case, a scooter is considered. It focuses on converting a readily available engine powered moped in the market and then striping the engine drive and introducing an electric drive for propulsion. The new electric drive comprises of hub motor, battery pack and ECM. The body design and framework will remain same as the manufacturer has provided. The design and implementation of electric drive is the objective. The purpose of E – Moped is to introduce an electric and affordable version of scooter which has a no adverse effect on nature and does not uses any carbon based fuel. The objective is to achieve same specification as that are observed in engine driven vehicle. The paper has a brief explanation of E – Moped with CAD design, integration procedure and testing and review.

***Keywords**: E – Moped, Electrically powered vehicle, Battery pack, Scooter, Hub motor.*

1. INTRODUCTION

As the humankind is slowly shifting from carbon based fuel powered vehicle to electrically powered vehicle, there has developed huge scope in the electric vehicle field. There has a need aroused for more research in the mentioned field. The usage of fuel has not been under controlled from the last 50 years and now the reserves of such fuel are depleted completely. Still the energy needs are not reduced on the other hand. So, the electric power can be seen as the feasible source.

The counterparts of different types of vehicles are developed like electric cars, electric bikes, electric bicycle, electric trucks, etc. Different types of electric systems are proposed by different manufacturers like some developed the whole vehicles from scratch like tesla, rivian, nikola, etc, and some proposed the idea of integrating an external electric drive to vehicles readily available in market. Some are working on battery size and life. Some are finding different way to store electric energy by using super capacitors. Also using DC or AC motor is an idea.

Many manufacturers are developing electric version of scooters. Scooters are widely preferred as a medium to travel around the world as they are cheap and can transport two people from one place to another, which is the best way to travel in the urban cities having less space. There are many products available in market. In India, the companies like Bajaj, Yamaha, Revolt and Hero are proposing new electric scooters to market. Also new manufacturers like Vihan EV, Miracle E-bike, Ampere Electric scooters, etc are coming up fast as it is the new fast growing market.

2. LITERATURE REVIEW

Several research papers were reviewed and studied for the best understanding of the technologies used in electric scooters nowadays. Using this knowledge to achieve better results in E – Moped.

Fig. 1: Laufband Zyklus [1]

Suyant Dharwarkar, Amit Jadhav [1] Laufband Zyklus a German name for treadmill cycle is designed for those people who love to walk outdoor. Treadmill belt constructed on cycle and innovation named Laufband Zyklus' is made. Electronic parts are assembled and run smoothly on walking momentum. As the person walks on the treadmill belt, the belt starts up and the rear wheel starts propelling the bike in the forward direction. Laufband Zyklus is designed for walkers as the conventional treadmill; this project is the combination of best fitness device and travelling long distance without producing any of pollution.

Ionuț Daniel Smărăndescu, Petre-Marian Nicolae [2] the paper deals with the electric scooter mobility in Europe and with the designing of a brushless dc motor for an electric scooter. In the first part of the paper, the context and the motivation of the theme are presented. In the second part of the paper, the electric scooters market is described. Then, the main parts equipping an electric scooter are exposed. The final part of the paper deals with the designing of a permanent magnet brushless dc motor for electric scooter propulsion.

Prof. Firoz khan et al. [3] this project is aimed at designing and developing of a light weight multi-utility electric scooter using hub motor transmission. The proposed vehicle is capable of doing versatile operations in various fields such as material handling in small scale industries, for carrying agricultural products and also can be used for short distance transportation purpose with much ease. Keywords: hub motor power transmission, regenerative system, transportation, material handling and goods carrier.

Fig. 2: E – Zyklus [4]

Suyant Dharwarkar, Abdulhasnain Akodiyawala [4] The E - Zyklus is experimentation for converting the manually human powered vehicle, in this case a bicycle, into an electrically powered vehicle and optimizing its performance. The concept of E - Zyklus consist a Schnell Bicycle, in which the pedal and chain drive is eliminated. A 24 V Brush less DC motor is used with a simple chain drive in case of the manual chain drive. The battery pack used is 4 piece of lead acid gel battery. Also a speed controller is introduced which is of 24 V for the speed control of the BLDC motor, with a Throttle. The objective of the experiment is to optimize the power required for the vehicle to operate, to achieve top speed of 30 kmph and also get enough torque for all operation performed by the vehicle like drive on straight road and climbing up the slope and also achieve good traction on uneven surfaces. The other objective is to see whether a hybrid vehicle is feasible or not.

J.D.K. Bishop et al. [5] this work presents the findings of a small-scale electric scooter trial in Oxford, United Kingdom. The trial scooters were instrumented with global positioning satellite data loggers and energy meters to record their time of day usage and charging regimes. The scooters were most likely driving at 09:00, 12:45 and 17:15 and charging at 10:15–10:40. The electric scooter normalized mains-to-wheel energy use was 0.10 kWh km−1. The electric scooter total operating costs (electricity and battery replacement) of £0.045 km−1 is 24% greater than the best selling equivalent petrol motorcycle and 1.7 times lower than the bestselling car. The electric scooter uses 0.45 MJ km−1, or 2.9 times and 6.1 times less than the petrol motorcycle and car, respectively. Further, the electric scooter can achieve zero carbon dioxide equivalent (greenhouse gas, GHG) emissions when electricity from renewable energy sources is used. In 2008, there were 247 000 motorcycles in the UK vehicle fleet of equivalent size to the trial scooter. Scaling up the electric vehicle fleet size accordingly would avoid 0.60 billion car or motorcycle kilometres and 54–110 kt associated GHG. The fleet would require 59 GWh, or 0.015% of total annual generation with a time-shifted, peak demand of 250 MW, or 0.44% of the 58 GW maximum national demands.

Ji-Young Lee et al. [6] the aim of this paper is to provide an optimal design of in-wheel motor for an electric scooter (E-scooter) considering economical production. The preliminary development in-wheel motor, which has a direct-driven outer rotor type attached to the E-scooters rear wheel without any gear, is introduced first. The objective of the optimal design of this in-wheel motor is to improve the output characteristics of the motor and to have a stator form to facilitate automatic winding. Response surface methodology was used for the optimal design and 2-dimensional finite element method was used for electro-magnetic field analysis. Experimental results showed that the designed and fabricated in-wheel motor could satisfy the required specifications in terms of speed, power, efficiency, and cogging torque.

Prof. Mahesh S. Khande et al. [7] India is the second largest producer and manufacturer of two-wheelers in the world. It stands next to Japan and China in terms of the number of two-wheelers produced and domestic sales. Indian two wheeler industry has got spectacular growth in the last few years. The face of auto industry that was redefined with the invention of fuel-efficient technology is all set to see dawn of a new era in two wheeler industry. It's not petrol or diesel or any other fuel, but it is electricity that has initiated a revolution in two-wheeler industry in India. Indian two-wheeler industry has embraced the new concept of Electric Bikes and Scooters that are very popular mode of personal transport in the developed countries like America, Japan and China. So the electrically charged bikes or scooters have very bright future in area of personal transportation. This Paper studies about design and development and the comparison of different part of components. Also electric two wheeler components like Battery, Charger, BLDC motor, Controller, Dc-Dc Converter explain in this paper.

Kunal D Topiwala et al. [8] we are concerning about the growing demand of energy all over the world, which motivate us to switch over renewable resource of energy. There are many different ways by which we can save energy in different sectors. Our main focus is on automobile sector where we are converting old petroleum bike to electric bike. In these electric bikes we use electrical motor (BLDC motor) instead of combustion engine as there is less pollution, low maintenance cost, reduces noise. These bikes utilize chemical energy stored in the rechargeable battery packs. This paper deals with the design and development of electric bike which make use of electric energy as primary source. There is a distribution for charging the battery emitting it from the main system.

3. PROBLEM STATEMENT

An Experimental Investigation on converting an engine powered vehicle to electrically powered vehicle with better specification.

4. METHODOLOGY

- Analysis of Problem Statement.
- Literature survey.
- Study of the system.
- Material selection.
- Computer Aided Design.
- Required calculations.
- Actual Experimental setup.
- Testing and Review.

5. OBJECTIVES

- Obtain the better efficiency from the electric drive as the engine driven vehicle could provide.
- Achieve a top speed of about 50 kmph from the electric drive.
- Achieve appropriate amount of torque for important operations like climbing a slope, movement on uneven surfaces to be performed by the vehicles.
- Obtain practical range.
- To develop the electric system as cheap and simple as possible.
- Obtaining, charging cost as less as possible.
- Reducing the weight of the vehicle as low as possible.

6. EXPERIMENTAL LAYOUT

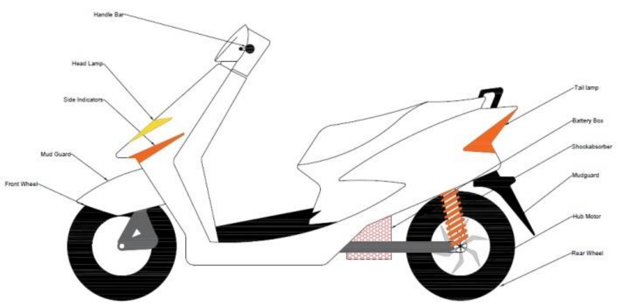

Fig. 3: CAD Diagram of E - Moped

7. WORKING PRINCIPLE

- The E – Moped work on the principle of electric energy converted into mechanical energy with a help of a DC motor.
- The motor is mounted in the hub of the rear wheel.
- There is controller present for the proper speed control of the motor.
- A throttle is used for speed control, as the throttle is engaged the controller provides the equivalent amount of electric energy to the motor and the vehicle propels itself.
- The energy storage device is a lithium-Ion battery pack, which is rechargeable.

8. COMPONENTS

8.1 Scooter

The scooter used in the experiment is Honda DIO 2010. Components like carburettor, engine, CVT, Alternator, Starter motor, fuel tank were removed from the scooter. The scooter framework was kept with the wheels, lights, seat, suspensions and front brakes. All the specific changes required for the new electric drive were made on the framework.

Fig. 4: Honda Dio (2010) [9]

Table 1: Technical specifications.

Model	DIO
Manufacturer	Honda
Year	2010
Frame	Under bone
Front Brake	Drum (130 mm)
Front Tyre	90/90-12 54 J
Rear Tyre	90/100-10 53 J
Front wheel	12 Inch
Rear wheel	10 Inch
Overall length	1808 mm
Overall width	723 mm
Overall height	1150 mm
Ground clearance	160 mm
Seat height	765 mm
Wheelbase	1260 mm
Kerb weight	105 Kg
Wheels	Alloy wheels
Front Suspension	Telescopic
Rear Suspension	3-Step Adjustable, Spring Hydraulic

8.2 Hub Motor

Fig. 5: 48V/800W BLDC Hub Motor [10]

The important component of the E – Moped is the hub motor. It is an 800 W 48 V brushless DC Gearless hub motor. The IC engine and CVT arrangement of the scooter is replaced by a single motor which does both the job. The motors give about 400 RPM on loaded condition and takes around 22.3 Ampere of current. It also does not take huge space as it is conveniently placed inside the rear wheel hub of the vehicle. It has no adverse effect on the environment, is cost efficient and the efficiency is more than any single cylinder IC engine.

Its placement is in such a way that the tyre is wound on the rim. The rim is built around the motor. In these kind of motor the armature remains stationary and the field winding and the housing rotates. The axle is connected to the armature. The drum brakes are provided in the motor assembly. Figure 5 shows the motor used in the E – Moped. This motor is manufactured by Aggarwal EV. The Specification of the Hub motor are provided in the Table 2.

Table 2: Specification of Hub motor

Manufacturer	Aggarwal EV
Rated power (W)	800 Watt
Rated voltage (V)	48 Volt
Rated speed (RPM)	1000 RPM
Rated current (A)	Less than or equal to 22.3 Ampere
Unloaded current (A)	Less than or equal to 3.3 Ampere
Size	10 Inch
Reduction ratio	Gearless
Weight (Kg)	7.9 Kilogram

8.3 Battery Pack

Fig. 6: 3.2 V 6 Ah LiFePO4 batteries [11]

The battery pack used in the experiment is combinations of several cells of LiFePO4 which are connected parallel and in series to obtain about 48 V 24 Ah of battery specification. The battery showed in Figure is a LiFePO4 single cell having the specification such as 3.2 V 6000 mAh which is manufactured by JCSSUPER. Detail specifications are provided in the Table 3 below. The battery pack is made by collectively stacking the battery together and is wrapped inside a thin plastic protective covering. A battery management system BMS is also provided for proper management of every cell and the charging display.

Table 3: Specification of battery

Manufacturer	JCSSUPER
Cell Voltage (V)	3.2 V
Cell Battery Capacity (Ah)	6000 mAh
Cell Weight (g)	300 gram
Cell dimension (mm)	70 x 32 x 30 mm
Pack Voltage (V)	48 V
Pack Battery Capacity (Ah)	24 Ah
Battery pack Weight (Kg)	18 kg
Battery pack dimension (mm)	75 x 200 x 320 mm

The particular battery is used in the experiment because this is the latest battery in the market having the highest battery life, which is about 12 to 15 year considering BMS. The composition of the battery is lithium-ferrous-phosphate. The battery pack is also compact which is easy to setup in compact spaces. In the E - Moped, the battery placement is provided in the place of the fuel tank. A battery pack compartment was manufactured with a help of 2 MM aluminium sheet which is mounted in the place of the fuel tank. The Figure 7 shows the battery mounting compartment.

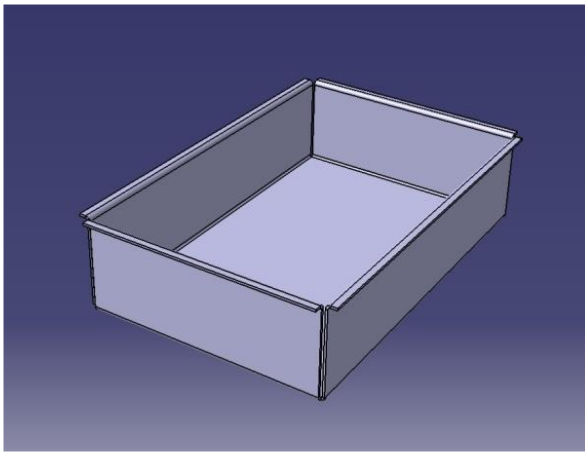

Fig. 7: Battery pack mounting compartment

8.4 Electronic Control Module [ECM]

Fig. 8: Electronic control module [10]

ECM, also called controller is the brain of the electric vehicle. The full form of ECM is electronic control module. The ECM decides the amount of power to be sent to motor and divides the power among all the accessories. The one connection from battery comes to the controller and all the connections goes out towards other components like motor, headlight, locking mechanism, tail light, cut-off brakes, Indicators, horn, etc. The ECM used in the E – Moped is 800 W controller. Using controller less than the given rating can damage controller

8.5 Throttle

Fig. 9: Throttle with horn [10]

The throttling device used is the twisting throttle. It is used to control the speed of vehicle by controlling the speed of motor. It is a very essential device. The model shown in Figure 9 is equipped with safety grip for both right and left side, horn on the right side and the throttling handle is placed at right of the handle bar.

8.6 Locking Unit

Fig. 10: Locking unit [10]

The Figure 10 shows locking unit which replaces the previous unit. It is connected directly to the controller. It is for safety of the vehicle, also to switch ON and OFF the vehicle motor.

8.7 Wire Harness

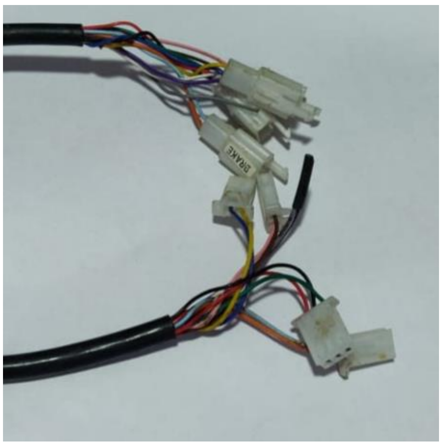

Fig. 11: Wire harness

Wire harness is the transportation line of the electric system. It transfers signal from one component to other. The different colour coded wires are bonded together in a thin plastic protective film that is how the wire harness is formed. Every wire in the harness has a specific role in the system. Some wires are for signal transfer from battery to ECM and ECM to motor. Other wires are for operation of accessories and mountings. For waterproof and secure connection the harness has connectors or plugs at both ends. The colour coding is provided for simple understanding of the connections with components.

8.8 Charger

Fig. 12: Charger [11]

The charger in the experiment is 48 V 3 A with required input of 230 V AC 50 Hz. Fast charging can also be introduced by increasing the charging current from 3 A to 5 A. The full charging of battery pack can be achieved in about 8 hours.

9. PROCEDURE

- An Idea in mind was put on paper, the framework design and component placement were kept in mind. Also specifications required were also defines.
- After that, market survey was done, in which the components availability, effective cost and specifications were collected and the components matching the required specifications were selected. Components like Hub motor, Controller, throttle, battery pack and charger were purchased from the market.
- A Computer aided designing software was used to design the framework, components mounting and assembly design. This was important as it provide a preview before actual experimentation is done. The CAD software used in the experiment was CATIA V5R21.
- When the experiment started the scooter was totally disassembled. The previous power providing parts were stripped from framework. The engine, CVT, carburetor, alternator, etc was disassembled. The rear wheel was also removed and the Tyre over it was removed.
- Required operation like drilling, fabrication, bending, grinding were down on the framework and mounting to achieve perfect fit between components. The battery mounting compartment and different small mounting were manufactured.
- The tyre was wound around the rim of the motor and the motor is then assembled on the hub of the rear of the vehicle.
- All the components were properly assembled and the controller was set under the storage area. The battery pack was set up in place of the fuel tank. The harness was wound

around the framework and all the connection with ECM, motor, headlight and battery pack, tail light, throttle, indicator, horn, cutoff brakes, locking unit, etc were secured.

- The battery pack was fully charged and the first test ride was conducted. The results were noted and the problems which were seen were solved and the scooter was brought to optimal operation level.
- Testing phase started were torque, speed, charging time, range and weight carrying capacity were measured with proper measurement tools.
- Coat estimation was the last step in the experiment. It showed whether the experiment was successful on the basis of comparison between available counterparts in the market.
- The opinions from riders were noted for future use.

10. DETAILED CALCULATIONS

10.1 Motor Calculation

Motor input = 48 Volt,
Motor rated output power = 800 watt,
Rated speed of motor = 1000 RPM,
Tyre size = 10 Inch (diameter).
Now, the motor is Gearless,
So, there is no gear reduction,
Therefore the RPM of motor is the RPM of tyre.
Now, Calculating circumference of the tyre,

$$\text{Circumference} = \text{Diamater of tyre} \times \pi$$

$$= 10'' \times \pi$$

$$= 31.4''$$

$$\text{Circumference of Tyre} = 31.4''$$

Calculating speed of the Cycle,

$$\text{Speed} = \frac{\text{RPM of Tyre} \times \text{Circumference of Tyre}}{39370.076}$$

[Note: 39370.076 are the inches in a kilometre]

$$= \frac{1000 \times 31.4}{39370.076}$$

$$= 0.798 \text{ Km/Min}$$

Now, converting it into km/h multiplying it with 60
We get,

$$= 0.798 \times 60$$

$$= 47.86 \text{ km/hr}$$

$$\text{Speed} = 47.86 \text{ km/hr}$$

The Calculation done here is based on the maximum outcome from the motor to the tyre. The speed may vary from 45 km/h to 50 km/h depending on various losses like total weight on cycle, road gradient quality, wind direction, uphill climb, downhill descent, tyre pressure, etc.

10.2 Battery Calculation

Required Battery pack Specification are 48V 24Ah.
The LiFePO4 battery cell specifications are 3.2 V 6000 mAh
Connecting 15 cells in series,

$$3.2 \text{ V } 6 \text{ Ah} \times 15 \text{ cells} = 48 \text{ V } 6 \text{ Ah} \text{ .... (1)}$$

As in series connection, the voltage is multiplied and the current remains constant.

Now,

Connecting 4 rows of cells in parallel

$$48 \text{ V } 6 \text{ Ah} \times 4 \text{ row cells} = 48 \text{ V } 24 \text{ Ah} \text{...................... (2)}$$

As in parallel connection, the current is multiplied and voltage remains constant.

So the total battery cells required are,

$$15 \text{ battery cells in series} \times 4 \text{ battery cells in parallel}$$

$$= 60 \text{ battery cells}$$

Now,

Total output from these 60 battery cell arrangement will give us 48 V 24 Ah.

10.3 Range Calculation

Now calculating, total output power of battery,

$$\text{Power} = \text{Voltage} \times \text{Current}$$

$$= 48 \text{ V} \times 24 \text{ Ah}$$

$$= 1152 \text{ Watt} - \text{hour}$$

$$\text{Power} = 1152 \text{ Wh.......... (1)}$$

This means battery gives power of 1152 watt per hour. That is, the battery will last for an hour if 1152 watt is consumed constantly.

Rated motor Input = 800 W
Calculating power consumption for 1 km,
Motor gives rated speed of 47 kmph at 800 W,

$$\therefore \frac{800}{47} = 17.03 \text{ Watt per kilometer}$$

$$\therefore 1 \text{ km consumes} = 17.03 \text{ W} \ldots . (2)$$

We have in total 1152 Wh of power in battery,

$$\therefore \frac{1152}{17.03} = 67.65 \text{ km.....from (1) \& (2)}$$

The scooter will travel almost 68 km once battery is fully charged.

10.4 Torque Calculation of Motor

Motor rated output power = 0.8 kilowatt,
RPM at driving sprocket = 1000 RPM,
Formula for Torque is given by,

$$\text{Torque} = \frac{60 \times \text{power (kW)}}{2\pi \times \text{Speed (RPM)}}$$

$$\tau = \frac{9.5488 \times 0.8}{1000}$$

$$\tau = 7.64 \times 10^{-3}$$

$$\tau = 7.64 \text{ N} - \text{mm}$$

10.5 Charging Time Calculation

The charger used is of 48 V 3 A.
Input given is 230 V AC 50 Hz.

$$battery\ capacity = 48\ V\ 24\ Ah$$

$$P = 48 \times 24$$

$$P = 1152\ Wh \ldots\ldots\ldots (1)$$

$$charger\ output = 48\ V\ 3\ A$$

$$P = 48 \times 3$$

$$P = 144\ W \ldots\ldots\ldots\ldots (2)$$

From (1) & (2),

$$Time = \frac{battery\ capacity}{charger\ output}$$

$$T = \frac{1152}{144}$$

$$T = 8\ h$$

So, charging time for battery pack is about 8 Hours.
A fast charger of 5 A can be used,

$$charger\ output = 48\ V\ 5\ A$$

$$= 240\ W \ldots\ldots\ldots\ldots (3)$$

From (1) & (3),

$$Time = \frac{battery\ capacity}{charger\ output}$$

$$T = \frac{1152}{240}$$

$$T = 4.8\ h$$

The total charging time becomes 4.8 hours.

10.6 Cost of battery charging

The cost of 1 unit is 8.57 rupees.

$$\text{Cost of electricity} = \frac{\text{Battery capacity } \times \text{Unit cost}}{1000}$$

$$= \frac{1152 \text{ Wh } \times 8.57 \text{ rupees per unit}}{1000}$$

$$= \frac{1152 \times 8.57}{1000}$$

$$\therefore \text{cost of electricity } = 9.88 \text{ rupees}$$

Battery charging cost is about 9.88 rupees.

11. RESULT AND SPECIFICATION

Table 3: Details.

SR NO.	Detail	Desired [Calculated]	Actual [Measured]
1.	Top Speed	47 kmph	45 kmph
2.	Wheel size	Front - 12 / Rear - 10 Inch	
3.	Weight capacity	165 kg	150 kg
4.	Range	67 km	60 km
5.	Charging time	8 hours	10 hours
6.	Comfort	Good	Satisfactory
7.	Cost of charging	9.88 per full charge	
8.	Motor	48 V /800 W	
9.	Battery pack	48 V / 24 Ah	

[Note: the values in the table are approximated.]

The table 3 above shows the detailed specification of E – Moped. As table indicates clearly that the desired or calculated parameters are not as same as the actual or measured parameters. This difference is because of the losses that were not taken in account. It was estimated that the overall reading would be less at the start.

12. APPLICATION

- E – Moped has many applications from the field of day to day transportation to being an emerging new stylish technology.
- It is a perfect mode of transportation to people living in urban area having problem of parking and space management.
- It will cause enough influence on the studying class as it is inexpensive, Eco-friendly, easy to use.
- It can be a part of different government movement to encourage the use of electric class vehicles.

13. FUTURE SCOPE

The battery life of the vehicle can be increased with providing better battery solution in near future.
The speed of the vehicle can also be increased by providing a much high power motor for propulsion.
Different secondary electric accessories can be integrated to provide a more advance and high end model of the vehicle.
Regenerative braking is a way of charging that can also be the field of expansion.
The battery pack can be made into small stack and that stakes can be made swappable for faster and convenient use of vehicle.

14. CONCLUSION

The purpose of the paper is to provide an effective way of integrating an electric drive in a vehicle, which was previously engine driven. It shows the products which are already available in the market and the way to convert the vehicle on your own. The components to be used and the manufacturing and assembly to be done are shown in the paper clearly. The results, in which the E – Moped specifications are shown. It is and environment friendly solution to mode of transportation. It is gearless, which makes it easy to drive. It makes no direct pollution and has very low carbon foot print. The charging price is very less as compared to the rate of fuel which makes it very efficient cost vice.

15. ACKNOWLEDGEMENT

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