Design of Electric vehicle: A Real Time case study

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Abstract

The primary concern of the modern world is energy efficiency and environmental protection, which has speed up the designing and evolution of electric vehicles(EVs) technology. Moreover, EVs with artificial intelligence systems will enhance current road usage and traffic safety. The goal of an EV system is to provide a economical driving range, improved efficiency, both reliable and well safe operations at a feasible cost more than internal combustion counterpart. This paper presents the optimal design and development of an EVs , which includes the selection of the motor, the battery, charger, Battery Management System(BMS) and the motor control system. Battery is a significant component in the EV and its selection is mainly based on its compatibility in both charging& discharging characteristics. When safeguarding battery-operated devices, BMS are also essential for choosing the right materials for the batteries. Due to high torque, small size, brushless commutation and lower maintenance among other motors Permanent Magnet Brushless Direct Current motors (PMBLDC) are currently the preferred option among researchers and the automotive industry. The electric vehicle prototype for this study is available at the applied electronics laboratory in Thiagarajar College of Engineering. This EV prototype consists of PMBLDC motor, Li-ion battery, Battery charger, Battery management system and a Motor controller.

Key Words: Lithium-ion battery, Battery management system, Electric vehicles, Permanent magnet brushless DC Motor, Motor controller.

1. INTRODUCTION

Since 1918, there have been electric vehicles (EVs) on the road [1–5]. The use of electric vehicles for road transportation has decreased as a result of internal combustion engines' (ICE) quick development and viability. However, current issues namely air pollution, a lack of oil resources and their rapid price increment, as well as energy independence, have prompted a reorganization of electric vehicles as another mode of transportation. Variable speed drives that operate on both direct and alternating current were frequently used in applications of electric vehicle. Yet, in the twenty-first century, permanent magnet brushless direct current (PMBLDC) motors were comes into the market that are highly efficient and have a high power density. Neodymium-iron-boron (Nd-Fe-B) and Samarium-Cobalt (Sm-Co) are two examples of these materials [6–9]. unlike brushes in DC motor the PMBLDC motor mainly utilizes electronic commutation this creates complexity in the control algorithm [10–12]. As well as their increased efficiency, PMBLDC motors have excellent torque-speed characteristics, a quick random in performance, and a quiet operation. This makes them a suitable motor drive for EVs [13-16]. The primary objective design of EVs is Optimum system integration (OSI). This is essential for achieving optimal performance and economical EVs. An electric vehicle's (EV) design concept is divided into three sections: (1) Advanced technologies that can boost the EV's performance. But these technologies must be chosen from the most cutting-edge fields of automotive, electrical, electronics, mechanical, and chemical engineering. (2) Acceptance of a customized design specifically suited for EVs; and (3) Techniques from the automotive sector appropriate for EVs [17]. Currently, the automotive industry is very interested in in-wheel electric propulsion system (EPS) technology that is relevant to Modern Electric Vehicles (MEVs). MEVs' primary goals are to offer a broad range of speeds, excellent efficiency, controllability, and safety. As a result, PMBLDC motors are currently employed more frequently than other types of electric motors. The motor design and control scheme are both components of the PMBLDC motor drive system. In addition, the PMBLDC drives have improved in reliability and are now classified as IE 4 efficiency (super premium efficiency) due to the development of control systems and microelectronics. This paper explains how PMBLDC drives work for electric vehicle applications and provides information on current developments in PMBLDC drive technology and also highlights the main problems and overarching approach to EV commercialization.

The following are the primary goals for designing or developing an e-vehicle:-

i. To reduce the operating cost

ii. Conquer the vehicular out rush

iii. Rectify the short-comings of electric vehicle

iv. Enhance the over all life span and performance of conventional escooters.

The portions of the paper's format are as follows: Section 2 explains about the System Enlargement Section 3 talks about performance analysis, section 4 explains about system operation and finally section 5 represents the conclusion.

2. SYSTEM ENLARGEMENT

In general, batteries are used to store energy. It is charged with the help of charger from the mains electricity. To run the electric motor, the power electronic controller converts the battery's DC voltage into a switched-mode signal. DC-DC converter, which down the voltage from the battery pack like 20V-5V, the remaining parts in a vehicle can be powered from the battery. It is simple in structure. The propulsion parts are key components. The configuration is shown in Figure.1.

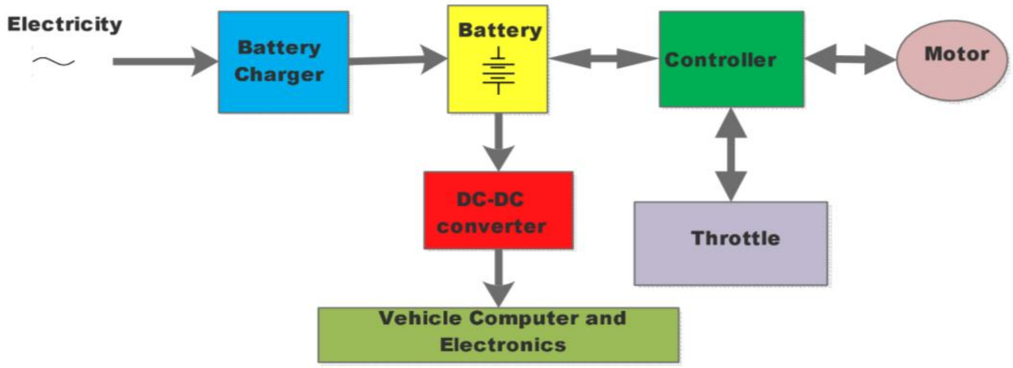

Fig 1.The Main Parts of Electric Vehicle (Power train)

2.1. CHARGER

It is important to ensure that the battery is used to its full potential. Efficiency, dependability, size and price, charging duration and energy density are the outstanding characteristics of a battery charger. The charger's properties are determined by its components, switching techniques, and control algorithms. Microcontrollers can be used to digitally implement this control method.

There are two steps to the charger. The power factor correction is first accomplished by a AC-DC converter, as it transforms the AC grid electricity into DC while maintaining a high power factor. The subsequent stage manages the battery's voltage and charging current in accordance with the charging technique used. EV batteries can either be charged uni directionally, meaning only the grid can charge the battery, or bidirectionally, so that the excess power can be returned to the grid while the battery is being charged.

Fig 2.Schematic diagram of battery charger

1. Figure 2 shows the charger circuit(48v 5Ah) for Lithium-ion batteries (48v 25Ah).The above circuit is a current-limited charger for lithium ion battery that is established on the well-known IC LM 317 variable voltage regulator.

2.2 BATTERY

Batteries are the parts of the car that store electrical energy, enabling the motor to run. The table shows that a comparison of several battery types has previously been done. According to the battery analysis table, the elementary components that enable recharging are Nickel Metal Hydride, lithium-Polymer Lithium-ion, Nickel Cadmium, Nickel Zinc, which are listed as NiMH, Li-Po/Li-ion, NiCd and NiZn respectively. if the energy were held constant, the value of specific energy, which is defined as energy per unit of mass, would rise.

Table1.Comparision between batteries

Parameter	Nickel Metal Hydride (NiMH)	Lithium-ion/Lithium Polymer(Li-ion/Li-Po)	Nickel Cadmium(NiCd)	Nickel Zinc(NiZn)
Self-Discharge	10	13	30	8-5
Charge/Discharge(%)	70-90	80	66	80-90
Power(W/kg)	150	>900	250-1000	250-340
Specific Energy Density(Wh/L)	50-150	280	140-300	250-730
Specific Energy (Wh/kg)	40-60	100	60-120	100-265
Rate(%)				
Durability of cycle (cycles)	2000	400-1200	400-1000	
Nominal Cell Voltage(V)	1.2	NMC-3.6/3.7, LiFePo4 -3.2	1.65	

From this table, it can be seen that lithium ion batteries are the most effective choice for an e- bike because they provide a maximum energy density in a small volume. Researching the calibre of the lithium ion cells and the safety measures applied is crucial since lithium ion batteries can be quite harmful.

(i) BATTERY MANAGEMENT SYSTEMS(BMS)

The battery system is composed of several battery cells. According to the design, they are linked together either in parallel or in series. Each cell needs to be controlled and monitored. Voltage, current, and temperature are among the conditioning parameters being watched. In order to determine the control and protection circuit, the above mentioned parameters to be used

Fig 3. Battery Management system

2.3 CONTROLLER CIRCUIT

It is a appliance, or combination, that controls how an electric motor performs in accordance with predetermined rules. The motor controller perform the following operation like motor starting/halting, forward/reverse rotation, controlling the Torque-Speed characteristics finally safeguarding against overloads including faults also. This work utilizing a "sine wave vector controller" in which motor controller and battery blocks are connected with each other.The system's core element, the motor controller, regulates all functional capabilities. The primary necessity for the control is to regulate the input which is given to the motor, particularly for DC motors. It is possible to synchronize the motor controller with other brushless motors. PMBLDC motor was driven and controlled using a motor controller. Any gadget that uses a motor must have a motor controller. The motor controller functions similarly to the brain in that it processes information and relays it to the user. Naturally, a motor controller's applications depend on the function it will carry out.

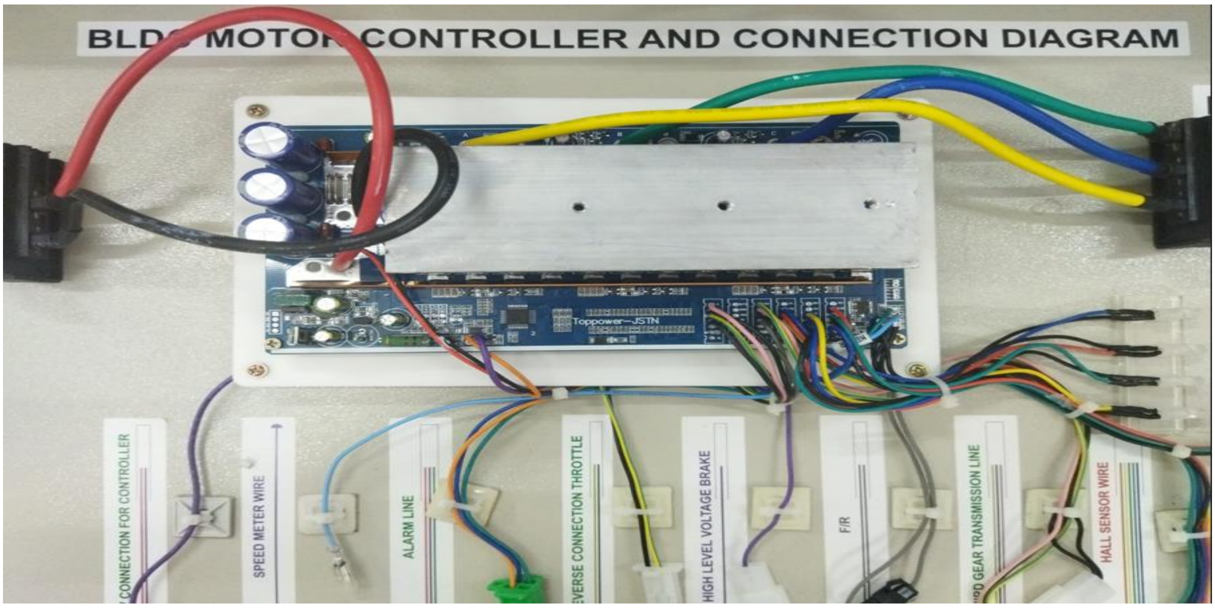

Fig 4. BLDC MOTOR CONTROLLER CIRCUIT

One of the most straightforward uses is a simple switch that powers a motor and causes it to run. The complexity of the motor controller rises as more motor features are used. An essential motor systems technology, especially those utilizing permanent magnets (PM) is frequently known as sine wave vector controller or Field Oriented Control(FOC). In adjustable speed drive applications with rapidly changing loads, FOC generally offers an effective method to control PM BLDC motors and can effectively raise the overall efficiency of the corresponding motor.

2.4 PMBLDC MOTOR

Currently accepted "workhorse" of the industry is induction motors (IM),but due to their low efficiency at light loads, they do not entirely meet the requirements of an EV propulsion system. Despite having the maximum power density, PM Brushless DC motors have a complicated control strategy. The auxiliary field winding in permanent magnet Hybrid motors (PMH) allows for maximum efficiency across a variable range of speed . Hence flux in the air gap is made up of both field winding and permanent magnet flux, each of which has a unique magnetic path. Switched Reluctance Motors (SRM) are strong due to their dependability and ease of fabrication [21–24].It delivers superior heat distribution, a wide speed range at constant power, and high beginning torque. SRM drives with sliding mode control can be used with electric vehicle propulsion systems. The provides a simple comparison of the motors based with 1 representing the poorest and 10 the best, for each parameter.

Table2. Comparision of motors specifications

Parameters	PM Brushless DC motors (PMBLDC)	Switched Reluctance Motors (SRM)	Induction Motor(IM)	permanent magnet Hybrid motors(PMH)
Torque Vs Speed	10	10	10	10
Power Density	10	6	5	8
Overall Efficiency	8	6	6	10
Robustness	8	10	8	8
Temperature	10	10	8	8
Status	8	6	10	6
Total	54	48	47	50

In electrical machines, more than electromagnetic excitation the permanent magnets (PM) has a number of benefits, including no excitation losses, a simpler design, dynamic performance, improved efficiency and maximum power or torque per unit volume. Brushless DC motors use a system of electronic commutation instead of brushes for a mechanical commutation system.it is driven by direct current energy (DC). In such motors, the relationships between current, torque, and voltage are linear. In a BLDC motor, the permanent magnets rotate in place of the electromagnets, which remain stationary. As far as their structure is concerned, modern permanent magnet synchronous motors resemble brushless dc motors.

The general layout of a three phase brushless dc motor is shown in Figure3. While the stator windings replicate those of a polyphase ac motor, the rotor is made up of a number of permanent magnets. Brushless dc motors operate electronic switches by creating signals based on the rotor position, as opposed to ac synchronous motors. Although the hall element is the most common position/pole sensor, other motors employ optical sensors.

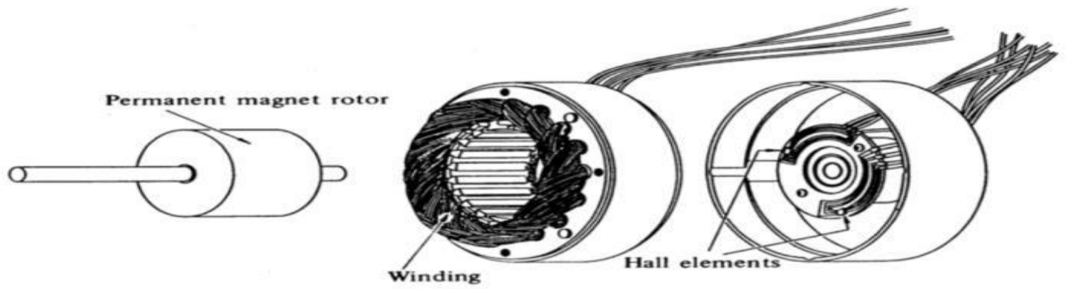

Fig 3. Cross section view of a brushless DC motor

Even though three phases motors have the biggest outer box and are more efficient, brushless dc motors can also be used for simple construction and drive circuits.

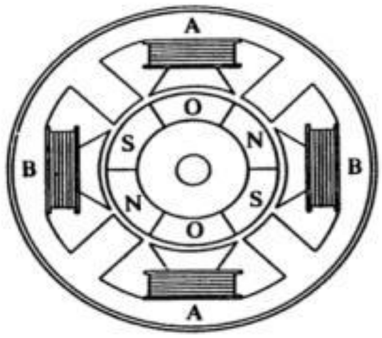

Fig.4. Brushless dc motor(Two phase)

2.5 DC-DC CONTROLLER

It is an electro mechanical device which converts a input from one level to another. EV power supply designs manifest the need for at the minimum one converter(DC/DC) to connect the Frequency Controller(FC},Super Capacitors(SC) or Battery to the DC-link. Electric field storage components (capacitors) or magnetic field storage components (inductors, transformers) may be used for the storage.

It is possible to make nearly all DC/DC converter topologies bi-directional, Nevertheless a bi-directional converter is useful in situations needing regenerative braking since it can transfer power in either direction. By altering the duty cycle (the switch's ratio of on/off time), it is possible to regulate the amount of power flowing between the two sides. Usually, this is done to maintain a steady power, manage the output voltage, or the input and output currents. Converters built on transformers could offer input and output isolation. Complexity, electrical noise, and high cost for particular topologies are the main downsides of switching converters.

3.PERFORMANCE ANALYSIS

3.1 Calculation of BLDC Motor:

P=1000W,V=48V

P=V×I

I=1000÷48=20.83Ampere.

3.2 Calculation of Motor Speed:

Speed (N)=K÷(d×0.001885)

=35÷(25.4×0.001885)

=731Revolution per Minute(RPM)

d=Wheel diameter in cm

1 inch=2.54cm

d=10 inch

Hence d=25.4 cm

3.3 Torque equation of Motor(T):

T=(1000×60)÷(2×N)

=(1000×60)÷(2×3.14×731)

=13.06 NM

3.4 Motor Selection:

For calculating the vehicle power rating the following parameters are considered

A.Rolling Resistance

B.Gradient Resistance

C.Aerodynamic Resistance

Gross weight of 170kg e-scooter is chosen for selection of motor rating

Required force for operating vehicle is

Ftotal = Frolling + Fgradient + Faerodynamic drag

A motor's output should overcome a cumulative tractive force before it can move a e-scooter

A.Rolling Resistance

An automobile's tires provide resistance to the road when they contact it.

Frolling = M × g ×Crr

Mass in kg

g-Acceleration due to gravity =9.81m/s2

Crr=0.004

Weight of e-scooter =175kg

Table 3.Co-efficient Rolling Resistance

Railroad steel wheels on steel rail	0.001to0.002
Two wheeler on	
Wooden track	0.001
Concrete	0.002
Asphalt road	0.004
Rough paved road	0.008
Truck tire on asphalt	0.006to0.01
Four wheeler on	
concrete	0.01to0.015
Tar or Asphalt	0.02
Gravel-rolled new	0.02
Gravel-large worn	0.03
solid sand, gravel loose worn and	0.04to0.08

medium hard	
loose sand	0.2to0.4

Frolling =M ×Crr×g =175×0.004×9.81=6.6708N (Newton)

B.GRADIENT RESISTANCE

In a vehicle, a gradient resistor is what provides resistance to the vehicle while climbing hills or crossing flyovers. A sloped path is represented by an angle between the ground and slope, as shown in the following figure .

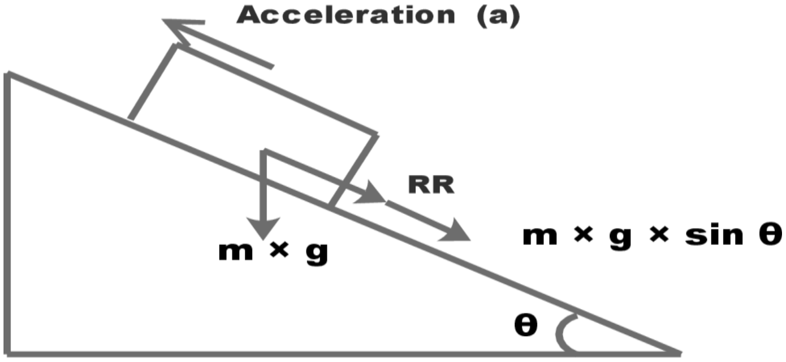

Fig 5.Diagram of a moving vehicle Inclined surface.

Fgradient resistance = ±M × g × sin θ

The gradient is denoted by a positive polarity sign for movement upward and a – negative polarity for downward. Regarding applicability, Let's use an electric scooter operating at an inclined angle of =3.50 as an example.

Gradient Force (Fgradient)=170×9.81×sin2.5 =72.7440N

C.AERODYNAMIC DRAG

Viscose forces provide a vehicle's aerodynamic drag, which is a resistive force. It linearly influences by its shape

Faerodynamic drag = 0.5×CD×Af×ρ×v2

Af=Frontal area, CD=Drag coefficient

V=Velocity in m/s

ρ=Air density in kg/m3

For example scooter maximum speed is 35kmph which is 12.5m/s and density of air is 1.1644kg/m3 at around 40° temperature and coefficient of drag is 0.5, frontal area is 0.7 which is available in the below table.

Table 4.vehicle Drag coefficient and frontal area

Vehicle	**C_D**	**A_f**
Two wheeker with rider	0.5 to 0.7	0.7 to 0.9
Carriage	0.4 to 0.8	6 to10
Truck		
without trailer	0.45 to 0.8	6.0 to10.00
with trailer	0.55 to 1.0	6.0 to10.0
Articulated vehicle	0.5 to 0.9	6.0 to10.0

Faerodynamic drag=$1/2\times CD\times Af\times\rho\times v^2$

$=0.5\times0.5\times0.7\times1.1644\times[9.72222]2=19.2606$N

Total driving force for operating EV is,

Ftotal = Frolling + Fgradient + Faerodynamic drag

=6.6708+72.7440+19.2606

=98.6754N

$P_{(Total)}$=Velocity×Force×(1000÷3600)=98.6754×40×0.277

=959.344 watt

To propel the vehicle the total power requirement is 959.344 W,which is safe design because the rating and it is below motor specification 1000 W.

3.5 Battery Design

W=1000 W,Voltage=24V

In battery 80% charge is utilized and the remaining is 20%.

Hence 1200w.hr=1000 w.hr×1.20

Battery current (Ah)=1200w.hr÷48v=25Ah

3.6 Battery charger Selection

Sometime the battery takes 5 hr for optimum charging.

Hence charger wattage =1200w.hr÷5hr=240w

Ampere rating of charger =240w÷48=5A

48v, 5A charger is need for charging 48v,25Ah battery in 5 hour.

Electric vehicle prototype is depicted in the below figure.

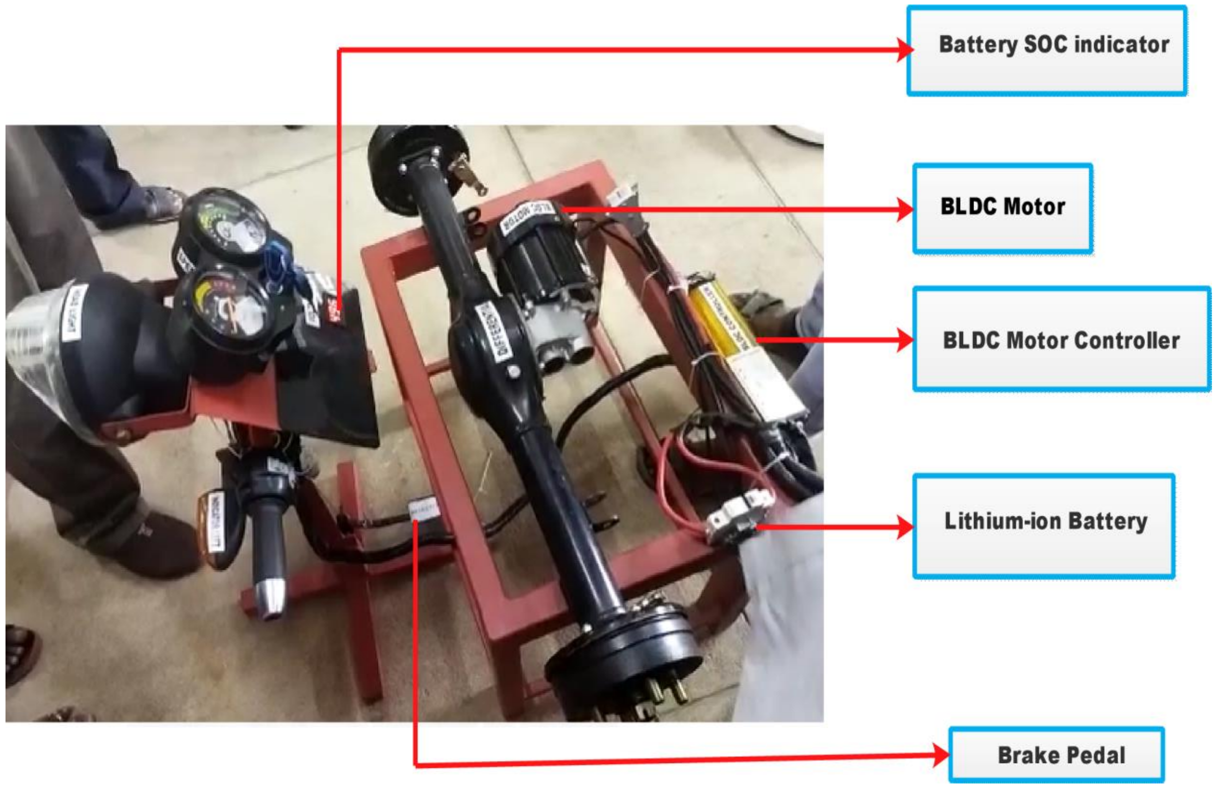

Fig 6. Designed Electric Scooter

4. SYSTEM OPERATION

Electric motor driving circuits often have 48V DC brushless controllers that are powered by 48V batteries via MCBs (miniature circuit breakers). The purpose of an MCB is to safeguard a circuit from over current and over voltage situations. The controller supplies the motor with power in a predetermined order. The BLDC motor's hall effect sensor, which is attached to the motor shaft, sends signals to the controller, causing the controller to energise the appropriate windings according to the position of the motor shaft. The controller is electrically attached to the handle bar for the throttle or speed changer. Consequently, accelerating the bar can be used to create a variable speed. The controller is electrically coupled to the braking system as well. upon applying the brake, it will disconnect the circuit, and when the motor's battery is unplugged, the motor's speed will decrease and eventually halt.

5.CONCLUSION

The use of fuel-powered vehicles increases rapidly today, which leads to more air pollution. Electric vehicles are pollution free product, which makes them more adaptable for city use due to their ability to reduce air pollution by not emitting harmful gases. Compared to a traditional vehicle, the electrically charged vehicle has been seen as the most economical because fuel prices have been increasing frequently. Therefore, this paper focused on EV two-wheeler design including overview of Electric Vehicle technology and its enormous components and the prototype is available at

Thiagarajar College of Engineering. This electric vehicle has a lithium ion battery with a 48V, 25Ah capacity that could be fully charged in 5 hours using a 48V, 5A charger. Hence it can be charged from1150 to 1200wh using this charger, and at an optimum speed of 35 to 45 kmph, it can go up to 50 km on a single charge.

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