Design and Development of Electric scooter

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Abstract – *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.*

Key Words: Electric vehicles (EVs), Battery, Brushless DC Motor (BLDC), DC-DC converters, Permanent Magnet (PM), Hub Motor, Miniature Circuit Breaker (MCB), Field-Oriented Control (FOC).

1. INTRODUCTION

In recent years, environmental problems caused by fuel vehicles and fuel economy become more and more serious. The vehicles of new energy, which is green, environmentally friendly and economical, is an important goal for economic and social development of many countries, but also the future development direction of the vehicle. EV is a vehicle with zero pollution emissions, mileage and fuel vehicles can be mutually comparable electric vehicles.

Being an e-scooter the electric system plays a promising role in its designing and creation. The electric system consists of battery, motor, motor controller and other electronic equipment. The most important thing that electric system does is that it gives power to the motor which helps in the running of the scooter. This energy in form of chemical or electric energy is stored in the battery which is used by a hub motor, thus the electric or chemical energy converted to mechanical energy. A proper electric system is important to ensure driver and vehicle safety in case of collision. The brushless DC (BLDC) motor is fixed to hub of rear wheel of e-scooter. The reason for choosing BLDC motor is its compactness and noiseless operation.

So our main Objectives to design or development an e-scooter are as following:-

i. To reduce running cost of vehicle

ii. To reduce the emissions

iii. To overcome the draw backs of electric vehicle

iv. To increase life period and efficiency of existing e-scooters.

2. SYSTEM DEVLOPMENT

• The Key Components in Electric Scooter

Following are the key components in Electric Scooter:-

1. Battery Charger
2. Battery
3. Motor Controller
4. Motor
5. DC-DC Converter
6. Vehicle Computer and Electronics

The electric vehicle is rather simple in structure. The key components are the propulsion parts. Fig.1 shows the configuration.

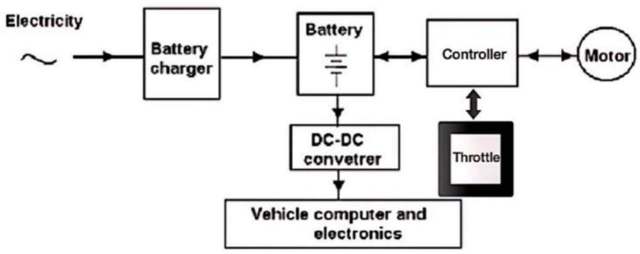

Fig 1: The key components of Electric Vehicle (Powertrain)

The battery is the main energy storage. The battery charger is to convert the electricity from mains to charge the battery. The battery voltage is DC and current (I) is inverted into switched-mode signal through power electronic controller to drive the motor.

The other electronic components in a vehicle can be supplied to the battery through DC-DC converter that step down the voltage from the battery pack to lower voltage such as 5V-20V.

1. BATTERY CHARGER

In order to utilize the battery to its maximum capacity the battery charger plays a crucial role. The remarkable features of a battery charger are efficiency and reliability, weight and cost, charging time and power density. The characteristics of the charger depend on the components, switching strategies, control algorithms. This control algorithm can be implemented digitally using microcontroller.

The charger consists of two stages. First, one is the AC-DC converter with power factor correction which converts the AC grid voltage into DC ensuring high power factor. The later stage regulates the charging current and voltage of the battery according to the charging method employed.

The charger can be unidirectional i.e. can only charge the EV battery from the grid or bidirectional i.e. can charge the battery from the grid in charging mode and can pump the surplus amount of power of the battery into the grid.

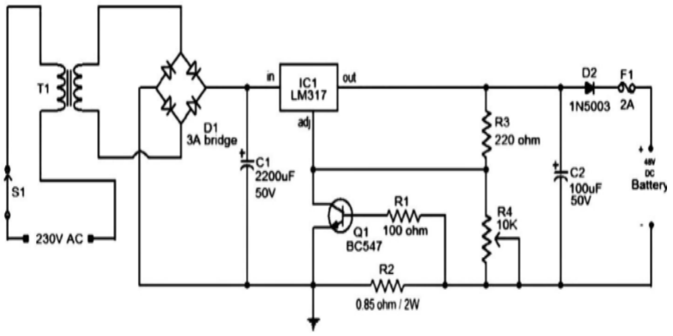

Fig.2:- Electric circuit diagram of battery charger

This is lithium ion battery charger circuit (48v 5A) for 48v 25Ah battery as shown in figure2. The circuit given here is a current limited lithium ion battery charger built around the famous variable voltage regulator IC LM 317. The charging current depends on the value of resistor R2. Resistor R3 and POT R4 determines the charging voltage. Transformer T1 steps down the mains voltage and bridge D1 does the job of rectification. C1 is the filter capacitor. Diode D1 prevents the reverse flow of current from the battery when charger is switched OFF or when mains power is not available.

2. BATTERY

Batteries are the components that store electrical energy, allowing for the motor of the vehicle in question to run. There is already an analysis between different kinds of batteries as seen in the table.1 below, The main materials that allow recharging are nickel cadmium, nickel zinc, nickel metal hydride, and lithium-ion/lithium-polymer, these are respectively listed as NiCd, NiZn, NiMH, and Li-ion/Li-Po on the battery analysis table. Specific energy is energy per unit of mass denotes a lighter battery as the value increases if the energy were to be kept constant.

Parameter	**NiCd**	**NiZn**	**NiMH**	**Li-ion/Li-Po**
Specific Energy (Wh/kg)	40-60	100	60-120	100-265
Energy Density (Wh/L)	50-150	280	140-300	250-730
Specific Power (W/kg)	150	>900	250-1000	250-340
Charge/Discharge Efficiency (%)	70-90	80	66	80-90
Self-Discharge Rate (%)	10	13	30	8-5
Cycle Durability (cycles)	2000	400-1000	500-1000	400-1200
Nominal Cell Voltage (V)	1.2	1.65	1.2	NMC 3.6/3.7, LiFePo4 3.2

Table.1: - Comparison between batteries

From this table lithium ion battery was the most efficient choice for an electric bike because it offers high energy density while remaining relatively light-weight and compact in size. Lithium ion batteries can be very dangerous; therefore it is essential to research the quality of the lithium ion cells and the protective implementations used.

➢ Battery management systems

It is also referred as BMS. The battery system is formed by a number of battery cells. They are connected in parallel or series that is according to the design. Each of the cell should be monitoring and regulated. The conditioning monitoring includes the voltage, current and temperature. The measured parameters are used to provide the decision parameter for the system control and protection.

3. MOTOR CONTROLLER

A motor controller is a device or group of devices that serves to govern in some predetermined manner of performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, limiting or regulating the torque, and protecting against overloads and fault. In this project we are using "sine wave vector controller". The battery block is interfaced with the motor controller block. The motor controller controls all the functional capabilities and is the central component of the system. The basic requirement for the control is to regulate the amount of power applied to the motor, especially for DC motors. The motor controller can be adjusted to synchronize with other brushless motors. To drive and control the BLDC motor, the use of motor controller was implemented. The motor controller is an essential device for any motor driven device. The motor controller is analogous to the human brain, processing information and feeding it back to the end user. Of course, the applications of a motor controller vary based on the task that it will be performing. One of the simplest applications is a basic switch to supply power to the motor, thus making the motor run. As one utilizes more features in the motor, the complexity of the motor controller increases. Field-Oriented Control (FOC) or sine wave vector controller is an important technology for motor systems, particularly those using permanent magnets (PM). In general, FOC provides an efficient way to control BLDC motor in adjustable speed drive applications that have quickly changing loads and can improve the power efficiency of an BLDC motor.

4. BLDC HUB MOTOR

The use of the permanent magnets(PM) in electrical machines in place of electromagnetic excitation results in many advantages such as no excitation losses, simplified construction, improved efficiency, fast dynamic performance and high torque or power per unit volume.

A brushless dc (BLDC) motor is a synchronous electric motor which is powered by direct current electricity (DC) and which has as electronically controlled commutation system, instead of a mechanical commutation system based on brushes. In such motors, current and torque, voltage and rpm are linearly related. In BLDC motor the electromagnets do not move, instead the permanent magnets rotate and the armature remains static. The construction of modern brushless dc motor is very similar to the ac motor, known as permanent magnet synchronous motor. Figure3 illustrates the structure of a typical three phase brushless dc motor. The stator windings are similar to those in a poly phase ac motor, and the rotor is composed of one or more permanent magnets. Brushless dc motors are different from ac synchronous motors in that the former incorporates some means to detect the rotor position or (magnetic poles) to produce signals to control the electronic switches. The most common position/pole sensor is the hall element, but some motors use optical sensors.

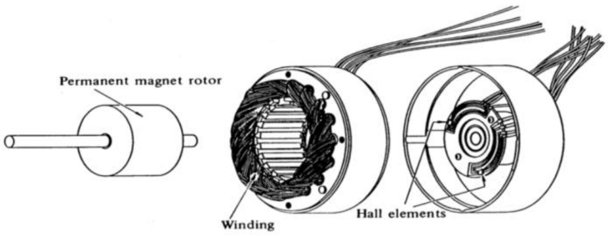

Fig.3:- Disassembled view of a brushless DC motor

Although the most outer box and efficient motors are three phases but two phases brushless dc motor are also very commonly used for simple construction and drive circuits. Figure4 shows the cross sections of a two phase motor having auxiliary salient pole.

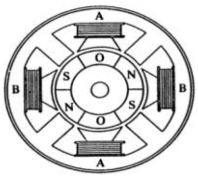

Fig.4:- Two phase brushless dc motor

5. DC-DC CONTROLLER

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. The different configurations of EV power supply show that at least one DC/DC converter is necessary to interface the FC (frequency controller), the Battery or the Supercapacitors module to the DC-link. In electric engineering, a DC to DC converter is a category of power converters and it is an electric circuit which converts a source of direct current (DC) from one voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). DC/DC converters can be designed to transfer power in only one direction, from the input to the output. However, almost all DC/DC converter topologies can be made bi-directional. A bi-directional converter can move power in either direction, which is useful in applications requiring regenerative braking. The amount of power flow between the input and the output can be controlled by adjusting the duty cycle (ratio of on/off time of the switch). Usually, this is done to control the output voltage, the input current, the output current, or to maintain a constant power. Transformer-based converters may provide isolation between the input and the output. The main drawbacks of switching converters include complexity, electronic noise and high cost for some topologies.

3. PERFORMANCE ANALYSIS

➢ Hub Motor Calculation

1. Motor Specification

   Volt (V) = 48 v, Power (P) = 1000 w

2. Power Equation

Power (P) = Current (I) × Voltage (V)

Hence, I = P ÷ V = 1000 ÷ 48 = 20.83 Amp.

3. Speed of Motor In RPM

   N = K ÷ (d × 0.001885) =35÷(25.4×0.001885)=731 RPM

Where, N = Speed In RPM, K = Speed In kmph

d = Wheel Diameter in cm

- Wheel Diameter (d) is 10 inch (Given)

1 inch = 2.54 cm, So, d = 10 inch = 25.4 cm

- Speed In kmph (K) is 35 kmph (Given)

4. Torque of the motor (T)

$T = (P\times60)\div(2\times\pi\times N)=(1000\times60)\div(2\times3.14\times731) = 13.06$ Nm

   Torque of the wheel hub motor, T = 13.06 Nm

5. Selection of Motor

For deciding the power rating of vehicle, the vehicle dynamics like rolling resistance, gradient resistance, aerodynamic drag, etc. has to be considered. For illustration procedure for selecting motor rating for an electric scooter of gross weight 170 kg is considered.

The force required for driving a vehicle is calculated as:

$F_{total} = F_{rolling} + F_{gradient} + F_{aerodynamic\ drag}$

Where, F_{total} = Total force

$F_{rolling}$ = Force due to Rolling Resistance

$F_{gradient}$=Force due to Gradient Resistance

$F_{aerodynamic\ drag}$=Force due to Aerodynamic Drag

F_{total} is the total tractive force that the output of the motor must overcome, in order to movie vehicle.

ROLLING RESISTANCE

Rolling resistance is the resistance offered to the vehicle due to the contact of tire with road. The formula for calculating force due to rolling resistance is given by equation:

$F_{rolling} = C_{rr} \times M \times g$

Where, C_{rr} = Coefficient of Rolling Resistance,

M = mass in kg, g = acceleration due to gravity = 9.81 m/s^2

For application consider, C_{rr} = 0.004 as per below table And weight of our scooter = 170 kg

0.001-0.002	Railroad steel wheels on steel rail
0.001	Bicycle tire on wooden track
0.002	Bicycle tire on concrete
0.004	Bicycle tire on asphalt road
0.008	Bicycle tire on rough paved road
0.006-0.01	Truck tire on asphalt
0.01-0.015	Car tire on concrete, new asphalt, cobbles small new
0.02	Car tire on tar or asphalt
0.02	Car tire on gravel-rolled new
0.03	Car tire on cobbles-large worn
0.04-0.08	Car tires on solid sand, gravel loose worn, soil medium hard
0.2-0.4	Car tires on loose sand

Table.2:- Coefficient of rolling resistance

Then, $F_{rolling} = C_{rr} \times M \times g = 0.004 \times 170 \times 9.81 = 6.6708$ N (Newton)

GRADIENT RESISTANCE

Gradient resistor of the vehicle is the resistance offered to the vehicle while climbing a hill or flyover or while travelling in a downward slope. The angle between the ground and slope of the path is represented as θ which is shown in below figure

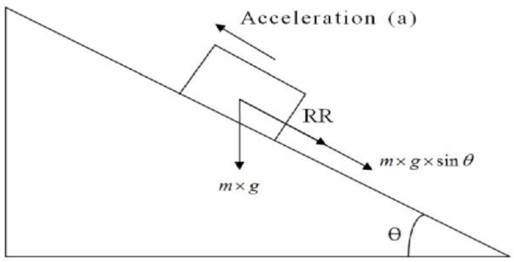

Fig.5:-Free Body Diagram of a Vehicle moving up an Inclined surface.

The formula for calculating the gradient resistor is given by equation below

$F_{gradient\ resistance} = \pm M \times g \times \sin\theta$

Where, +(positive) sign for motion up the gradient

-(negative) sign for motion down the gradient

For application consider, In this illustration, let us consider electric scooter run at an angle of θ (inclined angle)=2.5^0

$F_{gradient\ resistance} = \pm M \times g \times \sin\theta = 170 \times 9.81 \times \sin 2.5^0 = 72.7440$ N

AERODYNAMIC DRAG

Aerodynamic drag is the resistive force offered due to viscous force acting on a vehicle. It is linearly determined by the shape of vehicle.

The formula for calculating aerodynamic drag is given by below equation.

$F_{aerodynamic\ drag} = 0.5 \times C_D \times A_f \times \rho \times v^2$

Where, C_D=Drag coefficient, A_f =Frontal area

ρ = Air density in kg/m^3, v = velocity in m/s

For application consider, maximum speed of our scooter is 35 kmph (given) that is 9.72222 m/s and air density is 1.1644 kg/m^3 at 30^0 temperature and drag coefficient is 0.5 , frontal area is 0.7 as per the table shown below.

Vehicle	C_D	A_f
Motorcycle with rider	0.5-0.7	0.7-0.9
Open convertible	0.5-0.7	1.7-0.9
Limousine	0.22-0.4	1.7-2.0
Coach	0.4-0.8	6-10
Truck without trailer	0.45-0.8	6.0-10.0
Truck with trailer	0.55-1.0	6.0-10.0
Articulated vehicle	0.5-0.9	6.0-10.0

Table.3:- Drag coefficient and frontal area of vehicle

Then, $F_{aerodynamic\ drag} = 0.5 \times C_D \times A_f \times \rho \times v^2$

$= 0.5 \times 0.5 \times 0.7 \times 1.1644 \times (9.72222)^2 = 19.2606$ N

Then, The force required for driving a vehicle is,

$F_{total} = F_{rolling} + F_{gradient} + F_{aerodynamic\ drag}$

= 6.6708 + 72.7440 + 19.2606

= 98.6754 N

Then, The power required for driving a vehicle is,

Power = Force × Velocity × (1000 ÷ 3600)

= 98.6754 × 35 × (1000 ÷ 3600) = 959.344 watt.

Where, Power in watt, Force in newton, Velocity in kmph

Hence, the power required to propel the vehicle is 959.344 W, Which is just below our motor specification 1000 W. and the design is safe.

➢ Battery Calculation

From motor calculation we get, Wattage=1000w,Voltage=48v

So, To find watt.hr = 1000w × 1hr = 1000 w.hr

- Out of the full battery 80% should in use and 20% should remaining in this case

To find the battery watt.hr = 1000w.hr × 1.20 = 1200w.hr

Hence, Current (Ah) in battery =1200w.hr ÷ 48v = 25Ah

- **Selection of battery charger**

Suppose we have to charge a battery in 5 hr. So our required wattage is 1200w.hr. According to above condition, Wattage of charger = 1200w.hr ÷ 5 hr = 240 w

Hence, current rating of charger = 240w ÷ 48v = 5A

As per the above calculation to charge 48v ,25Ah battery in 5 hour we require 48v, 5A charger.

- **Battery specification**

Voltage Rating = 48 v, Current Rating = 25 Ah

So, Wattage of battery = Voltage Rating × Current Rating

= 48 × 25 = 1200 wh (watt.hr.)

4. SYSTEM OPERATION

Basically, electric motor drive circuit has DC brushless controller of 48V which is powered by the battery of capacity 48V through MCB (miniature circuit breaker). The function of MCB is protect the circuit under over current/over voltage condition. The controller supply in a specified sequence is given to motor by controller. The hall effect sensor connected at the shaft of BLDC motor which gives signal to the controller and thus respective windings get energized as per position of motor shaft. The throttle or speed changer handle bar is connected electrically to the controller. Hence, variable speed can be obtained by accelerating the bar. Also, the braking system is connected electrically to controller. As soon as brakes are applied, it will open the circuit and then battery is disconnected from motor causes motor speed reduction and in a specified time, motor will stop.

5. CONCLUSION

Now a days, utilization of fuel vehicles are increased rapidly which result into more air pollution. To control this, utilization of EV is must because it's several advantages like electric scooter is an eco-friendly product, It is more suitable for city as it can avoid the emission of harmful gases and thereby it can reduce the atmospheric pollution. Due to frequent increase in fuel prices, the electrically charged vehicle seen to be the cheapest one compared to the traditional vehicle. E-scooters are more suitable for rural areas where the numbers of petrol bunks are not adequate, so that the rural people can charge the vehicle with the help of electricity. To understanding the EV technology, this study helps to provide outline of EV (Scooter) and there various components.

6. RESULT

Fig.6:- Designed Electric Scooter

Now a days, Most of the vehicles used are based of fuel ignition principle for long as well as short run work. Hence, this have been resulting into greater air pollution which is harmful to human being. Thus, proposed paper researched on design and development of EV two wheeler. This given EV contained a lithium ion battery of capacity 48v, 25Ah and will charge within 5 hour using charger having capacity 48v, 5A. Thus EV can be charge up to 1150 to 1200wh using this charger, which will run up to 50 km in single charge with a appropriate speed of 35 to 40 kmph.

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