Design and modification of conventional scooter into an electric scooter

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Abstract – *Electric vehicles use a motor, battery, and a controller to run instead of an engine. As the cost of fuels is increasing, there is a necessity for a substitute for IC engines. Electric vehicles are considered Green Transportation as it is environmentally friendly. The electric vehicle consists of various components like a battery, motor, and controller. We get power fa from a battery pack instead of fuel used in an IC engine. This saves money as well as the environment. One disadvantage of the current marketed EV is they are very costly and unaffordable to the common man. The modification of a conventional IC scooter into an electric scooter will provide the best alternative for the EVs currently on the market. They may be a replacement for the engine scooter but they give a drive performance approximately similar to them and is also cost-efficient. In our project, we have designed and modified a conventional IC engine scooter into an electric scooter by giving power from battery to motor to chain & sprocket then the gearbox of the vehicle, and then finally to the wheel. The concepts of reducing, reuse, and recycling were used in our project as the vehicle, as well as in it, were reused and recycled according to our requirement. The principles and components of electric vehicle systems will be shown and the process of design and modification from an internal combustion vehicle to an electric vehicle will be described in detail. This report demonstrates that creating a running EV is a financially, environmentally, and intellectually rewarding endeavor.*

Key Words: BLDC motor, EV scooter, Battery, controller

1. INTRODUCTION

To design and modify conventional IC engine scooters with an equal performance producing electric scooter to reduce air pollution produced due to conventional IC engine vehicles. The factors are responsible for the problem. **Climate**: The increase in global temperature has created the need to reduce the use of fossil fuels. India has decided to cut its GHG (Greenhouse gas) emissions by 35% by 2030. **Renewable energy**: Over the years, the easy availability of solar electricity has immensely reduced its cost and made it possible to have clean, low-cost energy for consumption. India is set to add 190 GW of renewable energy capacity by 2024 and to achieve 40% of the generation of electricity from nonfossil fuels by the same year. **Urbanization**: Economic development is creating a sense of urbanization as rural people come to urban cities in search of jobs. Urbanization also increases the energy and transport infrastructure leading to traffic and pollution. According to research by WHO, India has the most polluted cities compared to other countries which if EVs are used can decrease up to a certain amount. **Data capture**: With the increase in GPS-enabled smartphones and numerous mobility applications, mobility has gone under a digital revolution. It has created the use of existing transportation assets. For EVs, which have fewer variable costs to compensate for relatively high fixed costs, this increased utilization is an important element to achieve total costs of ownership compared to IC engine vehicles. **Battery**: Research in battery technology has led to increased energy densities, less time for charging, and increased battery life, this is combined with the development of motors with increased reliability. These improvements in batteries have reduced the costs and have improved the performance and efficiency of EVs.

In this paper, we are going to study the perception and expectations of the potential for alternative technology in automobiles such as EVs, by modifying a conventional IC engine scooter into an electric scooter by using a Li-ion battery and a BLDC motor. Also to have a study comparing characteristics of EV and IC engine scooters such as max speed, acceleration, operating cost per km, etc.

2. Literature survey

In sense with the growing innovation in EVs, it's important to define criteria that meet our requirements for the electric motor. The most used motors are induction motors and PM brushless motors. Induction motors are very cheap. While the BLDC motors are very efficient. DC motors are the most developed as an immense amount of innovation is done on them. The induction motors and the SRMs have solid advancements. The conversion of an IC engine scooter with a chain drive is explained below. The idea of converting an IC engine scooter with a positive chain drive is the first of its kind. The author explains the drawbacks faced during their project due to the poor selection of components and suggests remedies to avoid them. The first component to be selected is the electric motor. An important criterion of an electric motor is power rating based on the load required. To select a motor of required power rating, vehicle dynamics like rolling resistance, gradient resistance, aerodynamic drag, etc. are considered. Calculations for the same are given below. The steps for selecting a motor for an EV along with proper force analysis and load distribution are explained. EV has been chosen as a remedy for rising air pollution and power consumption. EVI (Electric Vehicle Initiative) is a multi-government policy that adopts and encourages the use of EVs worldwide. EVI consists of many countries from various continents. We found the current as well as market scenario all scenarios world.

3. Design and selection of components

3.1 Block diagram of power flow

The electric vehicle has many components like charging module, converters, controllers, batteries, electric motor and the block diagram of power flow in an electric vehicle is shown in Fig -1.

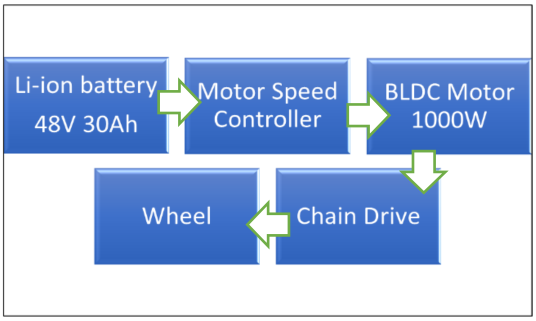

Fig -1: Block diagram of power flow

From the Fig -1, the power supply can be obtained externally by using solar panels to generate electricity or from domestic AC supply. This power is then rectified using converter and is made available to the battery through charging module. The battery supplies electric power to the motor through a motor controller, which helps in controlling the input and output parameters of the motor. The output mechanical power from the motor is given to the wheel through a drive shaft. In this way, electric power flows through various components in an electric vehicle and gets converted into mechanical power.

3.2 Selection of power rating of motor

An electric motor determines the output characteristics of vehicle as a whole in terms of power, torque, speed, etc. The electric motor selected for driving a vehicle must have the ability to provide sufficient power and torque to overcome the force due to load and other opposing forces acting on the vehicle.

For deciding the power rating of a 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 200 kg is considered.

The force required for driving a vehicle is calculated below [1]- [4]:

$$F_{total} = F_{rolling} + F_{gradient} + F_{aerodynamic\ drag} \quad ...(1)$$

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 motor must overcome, in order to move the vehicle.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 07 | July 2022 www.irjet.net p-ISSN: 2395-0072

I. Rolling Resistance

The resistance offered to the vehicle due to the contact of tires with road is called as Rolling resistance. The formula for calculating force due to rolling resistance is given by equation (2):

$F_{rolling}=C_{rr}*M*g$ ...(2)

Where, C_{rr}= coefficient of rolling resistance
M= mass in kg
g= acceleration due to gravity= 9.81 m/s 2

For the application of scooter, C_{rr}=0.012
M= 200 kg

Therefore,
Frolling= 0.012*200*9.81=23.544 N

II. Gradient Resistance

The resistance offered to the vehicle while climbing a hill or flyover or while travelling in a downward slope is called as Gradient resistance of the vehicle. The angle between the ground and slope of the path is represented as α, which is shown in Fig -2.

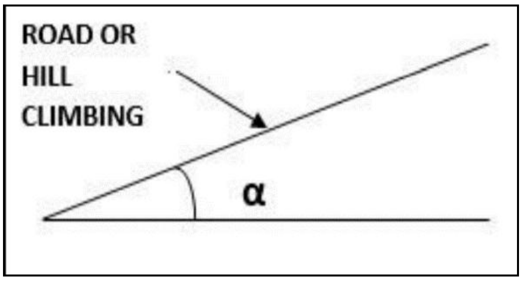

Fig -2: Angle between the ground and slope of a path

The formula for calculating the gradient resistance is given by equation (4):

Fgradient resistance=+ M*g*sin α ...(3)

In this illustration, let us consider the electric scooter runs on a flat road. Therefore, the angle α =0^0

Fgradient= 200*9.81*sin 0^0 = 0 N. ...(4)

III. Aerodynamic Drag

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

The formula for calculating the aerodynamic drag is given by equation (5):

$F_{aerodynamic\ drag}= 0.5*C_A*A_f*\rho*(V)^2$

Where A_F = Front surface area of vehicle including rider = 0.42 * 1.7 = 0.714 m^2

F_{aero} = 0.5 * 1.23 * 0.714 * 0.88 * $(11.11)^2$

F_{aero} = 47.696N

- Therefore, Tractive Force F_{tr} = 23.544 + 47.696

Ftr = 71.24 N

- Power = F_{tr} × V = 71.24 * 11.11

Power = 791.47 W
Efficiency = 791.47/0.85 Power = 931.14 W
But as Motor of the above power rating is not available in the market, Therefore Power = 1000W

3.3 Selection of ampere hour rating of battery

Step 1 : Find out current(in amp) consumed by motor to run
$P = V \times I$
1000=48*I
I=20.833 amp(theoretically)

Step 2 : Find out Watt hr of battery

To run 1000 Watt motor for 1hr= 1000 Watt hr
Take efficiency of battery as 80% i.e. 1000/0.8 = 1250 Watt hr
Step 3 : Convert Watt hr of battery into amp hr
$P = V \times I$
Watt hr = V × Amp hr
1250=48*amp hr
Amp hr=26.06
Hence, we take amp hr of battery as 30 Amp hr
And hence, 48V 30Amp hr will give a range of 50km for a 1000W BLDC motor.

4. BLDC motor

• For selecting the appropriate electric vehicle motors, one has to first list down the requirements of the performance that the vehicle has to meet, the operating conditions and the cost associated with it. • We have eliminated brushed DC motor because of the inconvenience caused by brushes that is they need high maintenance because of brushes and commutators. We have eliminated stepper motor because we do not need a stepped output. We have eliminated servo motor because we do not need a closed loop motor. • For high power applications like performance two-wheelers, cars, buses, trucks the ideal motor choice would be PMSM or Induction motors. Once the synchronous reluctance motor and switched reluctance motor are made cost effective as PMSM or Induction motors, then one can have more options of motor types for electric vehicle application. • For two-wheeler applications which requires less performance (mostly less than 3 kW) at a low cost, it is good to go with BLDC Hub motors or BLDC External Motors [1].

External BLDC Motor or BLDC HUB Motor? External motor would not cause any unsprung weight in the wheel as of HUB motor. Non hub motors are more efficient than Hub motors. Hub motors disrupt the balance of a bike towards the front or back. The external motors use a chain or belt to convey power to the rear wheel. This offers the opportunity to use different sized pulleys/sprockets which allows us to achieve the required RPM at the wheel. Hence we have selected the External BLDC Motor.

5. Lithium ion battery

• A lithium-ion battery or Li-ion battery is a type of rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles. • In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. • They're generally much lighter than other types of rechargeable batteries of the same size. The electrodes of a lithium-ion battery are made of lightweight lithium and carbon. • Lithium is also a highly reactive element, meaning that a lot of energy can be stored in its atomic bonds. This translates into a very high energy density for lithium-ion batteries. Here is a way to get a perspective on the energy density. A typical lithium-ion battery can store 150 watt-hours of electricity in 1 kilogram of battery. A NiMH (nickel-metal hydride) battery pack can store perhaps 100 watt-hours per kilogram, although 60 to 70 watt-hours might be more typical. A lead-acid battery can store only 25 watt-hours per kilogram. Using lead-acid technology, it takes 6 kilograms to store the same amount of energy that a 1 kilogram lithium-ion battery can handle. • Nowadays, Li-Ion batteries have the biggest market segment in equipping electric vehicles. Moderate energy consumption (14.7 kWh/100 km), continuous decline of the cost price, advanced manufacturing technology, increased cycle life, low weight and high energy storage potential make Li-Ion batteries an optimal choice in this field. Their disadvantage is represented by high functioning temperatures, which may have negative effects on their energetic performances and lifecycle. All these represent risks regarding safe exploitation of the vehicle. Hence, we have selected Lithium Ion Battery.

6. Torque vs speed characteristics

Speed and torque are inversely proportional to each other i.e. as speed increases torque decreases. Speed is a function of gear ratio and thus to select the gear ratio where optimum torque and adequate speed can be obtained, we performed analysis of characteristics of speed and torque v/s the gear ratio. As shown in the figure, the three lines represent Torque Available at wheel, minimum torque required and Speed of the vehicle. Torque available at the wheel is the actual torque delivered by the transmission to the wheel whereas minimum torque required is torque required to overcome all the forces acting on the vehicle and make it run on plain road. For gear ratio 1.92, the minimum torque required line coincides with the torque available line implying that the gear ratio cannot be further increased. For gear ratio 1.54, the Torque available is sufficiently large than the minimum torque required and speed at the that gear ratio is close to 41 kmph . Hence, gear ratio 1.54 was selected for initial testing and validation of the design and based on results further changes will be made in gear ratio.

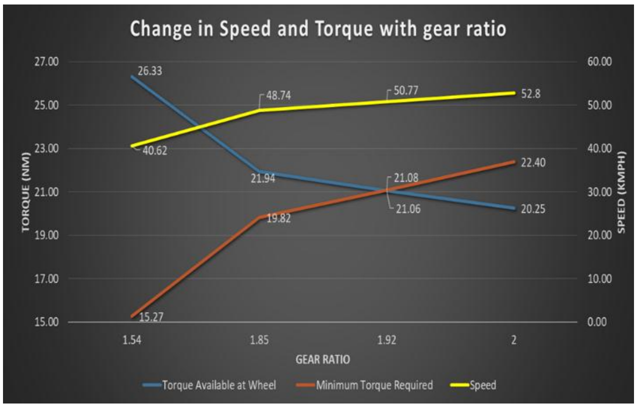

Fig -3: Graph of torque vs speed characteristics

7. Comparison of different parameters between IC engine and electric scooter

Running Cost :

The cost of operating an electric vehicle can be directly compared to the equivalent operating costs of a ICE vehicle. A liter of petrol contains about 8.9 kW·h of energy. To calculate the cost of the electrical equivalent of a liter of petrol, we multiply the utility cost per kW·h by 8.9. Because automotive internal combustion engines are only about 20% efficient, then at most 20% of the total energy in that liter of petrol is used. Now, let us consider a vehicle powered by an internal combustion engine at 20% efficiency and 2.5L/100 km [6]. To simply move the vehicle, it requires:

$$\left(8.9 \times \frac{2.5\,L}{100Km}\right) \times 20\%\, efficiency = \frac{4.45\,kWh}{100Km}$$

At a cost of ₹90/L, the mileage of 2.5 L/100 km equates to:

$$\frac{₹90}{L} \times \frac{2.5\,L}{100\,Km} = \frac{₹225}{100\,Km}$$

An electric version of the same car with a charge/discharge efficiency of 81% and charged at a cost of ₹9 per kW·h would cost:

$$\left(\frac{\frac{4.45\,kWh}{100\,Km}}{81\%\,efficiency}\right) \times \frac{₹9}{Kwh} = \frac{₹49.44}{100\,Km}$$

Therefore for 100 Km, IC engine cost : ₹225

Table -1: Comparison between IC engine scooter and electric scooter

Parameter	IC Engine Scooter	Electric Scooter
Energy stored in system	Petrol Tank	Battery Pack
Total weight in kg	110 kg	100 kg
Max Power in Kw	5.2	1
Max Torque in Nm	8Nm @ 5500rpm	18Nm @ 3000rpm
Maximum Speed	80kmph	60kmph
Charging Time	-	3-4 hours
Emission Co2 in g/km	110	0
Capacity of Battery	12v 5ah	48V 30Ah
Running Cost for 100 km	₹225	₹50
Selling price in India	₹50000	₹46000 (conversion)
Maintenance Cost per year	₹2400	₹800

Electric vehicle cost : ₹49.44

8. Circuit diagram of electrical connections

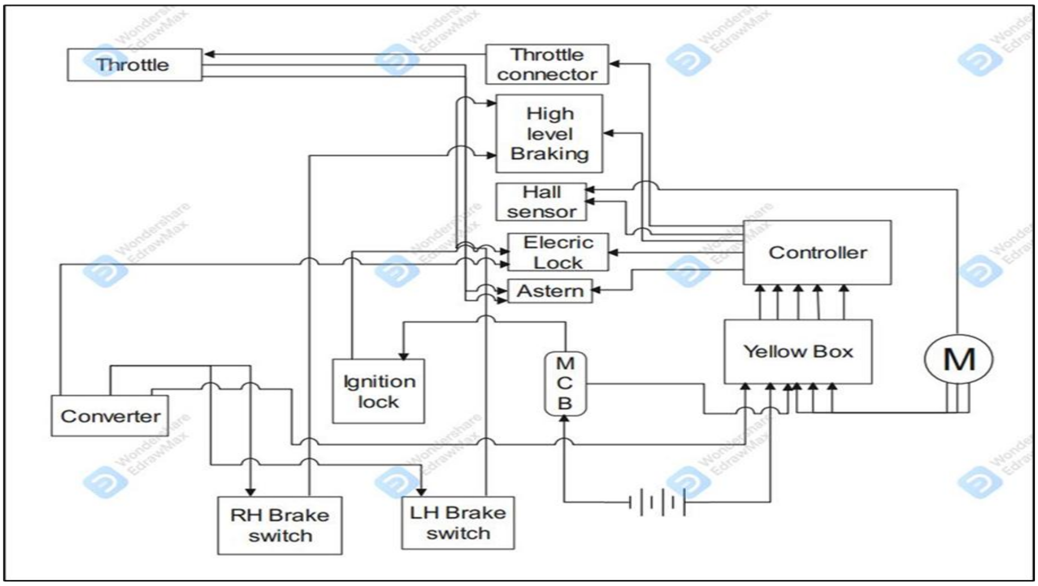

Fig -4: Electrical connections

The circuit diagram of all the electrical connections of different components is shown in figure 9. The major components shown in the circuit are Motor, Controller, Battery, Convertor, Yellow connection box, Ignition lock, Brake Switches, Brake light, Throttle, MCB, etc. All these components are connected such that all the components work properly for their respective specified purpose.

9. Conclusion

Design and Manufacturing of an electric vehicle were presented that is capable of traveling almost 35 kms in a single charge with a top speed of 60kmph. • Based on the calculations done for the power rating of an electric motor, a 1000 W Brushless DC Motor was selected for the moped scooter application. • For a 1000 W motor, a 48V 30Amp hr lithium ion battery was selected based on the calculations done. • For 100 km distance the running cost for IC Engine vehicle is Rs 225 whereas for Electric vehicle is Rs 50. • Performed comparison of various parameters between IC Engine vehicle and Electric vehicle. • Performed the evaluation of the competency of piezoelectric material in tyres. Piezoelectric materials are capable of producing significant amount of energy under certain circumstances. But, the amount of energy produced by PZT modules is not sufficient to power Electric Vehicles and neither is it efficient in increasing the range of the vehicles.

10. Future Scope

The world is quickly adopting to electric vehicles and in the next couple of decades, EVs are going to be more mainstream than internal combustion vehicles. People in US, EU would not mind spending around $35,000 on a new car. That figure is about $15,000 for people who buy a new car in China. But India, the average price of a car is less than $10,000. And therefore, people will be looking to buy an electric vehicle only when the prices of EVs will fall in that range. Converting the old IC engine vehicle to electric is cheap compared to buying a new one and as the prices fall in the range of customer, it will help them in making the transaction from IC engine to EV

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