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Design Optimization and Performance Study of An Electric Scooter

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ABSTRACT-

Electric vehicles (EVs) and in particular electric scooters and bikes have experienced an immense growth in India, as the cities grapple with increased traffic, pollution and reliance on imported fuel. India has one of the largest automotive manufacturing ecosystems in the world, and this leads to both local organizations and multinational brands, which can contribute to the rapid transition to electric mobility. The given paper analyses the current situation of the electric two-wheeler development, as well as the most significant opportunities and challenges the industry has. Up to now, government assistance, growing popular interest and local engineering and manufacturing progress have contributed significantly to the broader acceptance of EVs. Another significant point of the research is that the reliable charging infrastructure is necessary in order to be widely adopted. In-industry responses, policymakers, and user feedback indicate the weaknesses in the maturity of technology and testing, supply chain preparedness, and the

execution of the policies. India is also the second largest market in the world when it comes to two-wheelers, so it is well placed to spearhead the EV revolution in the country. Significant elements such as batteries, chargers, BLDC motors, controllers, and DC-DC converters have also been described in the paper as well as the identification of future opportunities of growth.

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

1.INTRODUCTION

Electric scooters are vehicles that run on electricity instead of gas or diesel. Their batteries can be charged and replaced with a standard charger. They are a clean and cheap way to get around because they don't burn fuel and don't pollute the air. As pollution and gas prices keep going up, electric cars are becoming a more popular choice for the future. They don't hurt the environment and work almost like regular fuel scooters. The battery, BLDC motor, controller, and other small electronic parts make up the main part of an electric scooter. The battery stores energy, and the motor uses that energy to move the scooter (Fig.1). The reason why BLDC hub motors have been popular is that they are small, efficient and produce minimal noise. An electrical system is also a good one that keeps the rider safe and makes the scooter operate well [1].

As electric vehicles gain popularity in all parts of the world, India continues to import a high volume of vital components, particularly those of China.

This demonstrates that India should increase its own capacity of the design and production of the electric scooters. This study will help India transition out of service economy to a nation that manufactures and develops its goods [2]. Therefore, our core Objectives to create or develop an e- scooter will be as follows: -

I. To reduce emissions
II. To counter the weaknesses of electric vehicles.
III. To enhance life and performance of the current e- scooters.
IV. To lower the operation cost of the car.

2.OBJECTIVE

I. To get familiar with the components E-Scooter
II. To Calculate the motor, battery, and charger requirements
III. To reduce the running cost of the scooter

3.SYSTEM DEVLOPMENT

- The Major Components of Electric Scooter

The important components in Electric Scooter are followed :-

I. Battery Charger
II. Battery

III. Motor Controller

IV. Motor

V. DC-DC Converter

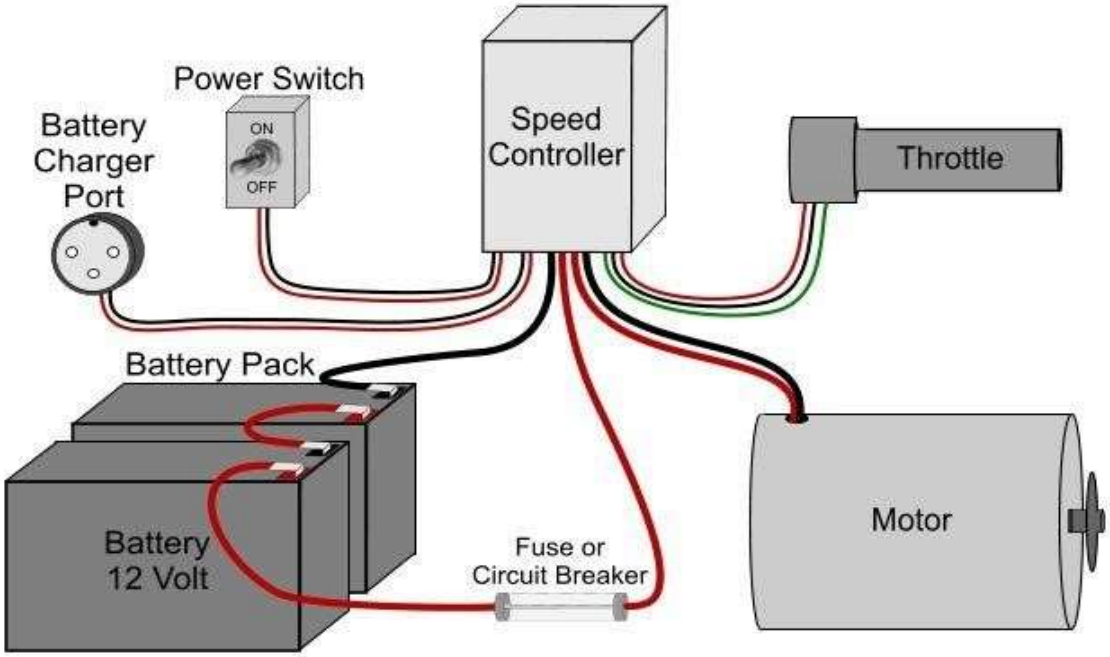

Fig 1:- The Key Components Of Electric Scooter

4.DESIGN

4.1. Chassis

The chassis is the main structural component of a car. It serves as a sturdy foundation upon which all the important parts have been built. The frame, transmission, wheels, and control systems are all supported by the chassis, with the exception of the vehicle's external body. The chassis' primary function is to provide strength and security [3]. It has the highest weight, supports every component of the car, and keeps every component in working order when the car is moving.

4.2. Material Selection

Structural steel is selected for building the frame because structural steel can withstand the stress created after an accident and is less expensive than many other materials, it is used to build the frame [4]. Because of its exceptional strength-per-weight ratio, it is also robust and lightweight. The scooter's overall lifespan and efficiency are increased by this combination.

4.3. Design Specification

Mass of the vehicle: 90 kg

Weight of the vehicle: $W = 90 \times 9.81 = 882.9$ N

Speed of vehicle: 60 km/h = $60 \times 1000/3600 = 16.67$ m/s

Angle of incline Φ = 2.5°

a. Force due to climbing hills (Fh)

Fh = W sinΦ

Fh = 882.9 × sin(2.5°)

Fh = 37.96 N

b. Rolling Resistance (Fr)

Fr = Cr W cosΦ (For street roads, Cr = 0.004)

Fr = 0.004 × 882.9 × cos(2.5°)

Fr = 3.52 N

c. Air Resistance (Fd)

Fd = 0.5 ρ Cd A V^2

(Air density ρ = 1.2 kg/m^3, Drag coefficient Cd = 0.5, Frontal area A = 0.7 m^2)

Fd = 0.5 × 1.2 × 0.5 × 0.7 × (16.67)^2

Fd = 58.36 N

Total Force on the Vehicle

F = Fh + Fr + Fd

F = 37.96 + 3.52 + 58.36 = 99.84 N

Power Required for Propulsion

P = F × V

P = 99.84 × 16.67 = 1664.33 W (≈ 1.66 kW)

5.ELECTRICAL SYSTEM

5.1. BLDC HUB-Motor

There are a number of advantages of using permanent magnets (PM) in electrical machines in place of electromagnetic excitation. Since no external excitation system is required, there are reduced losses, it is a simplified design, there is more efficiency and the machine is able to react faster to dynamic changes [5]. Machines utilizing PMs are also more likely to give a higher torque or power considering the same size. A BLDC motor is a form of synchronous motor which works with direct current and has an electronic type of commutation as opposed to the use of brushes and mechanical commutator. Current and torque, voltage and speed are in a linear relationship in these motors. But with a BLDC motor, the permanent-magnet rotor is turned instead of the armature and the windings on the stator remain stationary. The contemporary BLDC motors are built similarly to permanent-magnet synchronous AC motors

[6]. In the standard three-phase BLDC motor design, the windings are in the stator as in a polyphase AC motor, but the rotor has one or more permanent magnets. This is a major distinction between BLDC and AC synchronous motors; the former type of motor has a means of rotor position sensing to ensure the electronic switches can be used correctly (Fig.2). The most popular types of sensors used in this purpose are the hall-effect sensors, but some systems use optical sensors instead [7-8].

Fig 2:- BLDC Motor (48-72V, 2000W)

5.2. Electric scooter controller

The electronic brain of the scooter is an electric scooter controller. It takes care of the amount of power that the motor is supposed to receive and regulates the performance.

When the throttle is twisted by a rider, the controller is informed of this and determines the amount of current to be passed to the motor [9-10]. This assists in a quick acceleration and effective speeding. The controller also shields the scooter against such issues as over-current, low battery voltage, overheating, or short circuits (Fig.3). It guarantees the motor will be operated safely and harmoniously in varying conditions. Together with this, it controls the braking (in most of the models, this was regenerative braking) and battery consumption, as well as the distribution of power.

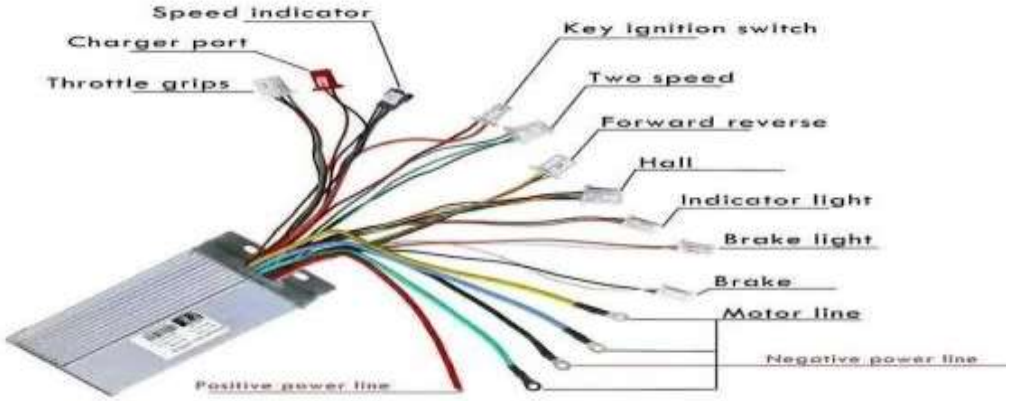

Fig 3:- Electric Scooter Motor Controller

5.3. Battery

The key power source in an electric vehicle is the battery. It also accumulates electric energy and delivers it to the electric motor which propels the car. EVs do not use petrol or diesel, but

instead, they use all the energy contained in the battery pack. The battery of EVs operates by converting the chemical energy into electric energy, which gives it a constant and consistent supply of power [11]. Lithium-ion batteries are being used in modern EVs since they are lightweight, they are able to charge more quickly, and they have longer life (Fig.3). Other systems such as lights, sensors and control units are also powered by the EV battery. It has a direct impact on its performance which in turn influences the range, speed and general efficiency of the vehicle [12].

Fig 4:- 48V/50Ah Lithium-Ion Battery

5.4. Battery Charger

A battery charger is very important because it helps the battery work at its full potential (Fig.5). The main qualities of a good charger are high performance, dependability, low weight, low cost, short charging time, and good power output. These qualities depend on the parts used and the switching methods [13-14]. An electric charger is a device that recharges the battery by supplying electrical energy, which the battery stores as chemical energy inside its cells.

Fig 5:- 48V/15A Battery Charger

5.6. DC-DC Converter

One of the significant electronics devices utilized in an electric scooter is a DC-to-DC converter. Its primary task is to transform the DC voltage on the battery to some other necessary level of DC voltage in order that various components of the scooter may operate correctly. High

DC voltage (say 48 V, 60 V or 72 V) is commonly supplied by the battery in an electric scooter. All parts do not operate on the same voltage [15-16]. Certain components such as the controller, lights, horn, dash, and USB charger require less voltage such as 12 V or 5 V. The DC converter transformer does not waste energy as it converts the high battery voltage to a safe level [17].

6.PERFORMANCE ANALYSIS

6.1. Motor Requirement

The total power necessary to drive the vehicle is 1665 W. Therefore, a motor rated above this value is required. A 2000 W, 48 V BLDC hub motor is selected to ensure adequate performance and reliability [18].

6.2. Battery Requirement

The motor demands 2000 Wh of energy.

Considering a 10% reserve margin:

Total battery energy = 2000 × 1.1 = 2200 Wh

Rated voltage = 48 V

Required capacity = 2200 Wh ÷ 48 V = 45.83 Ah

To meet this requirement, a 48 V, 50 Ah Lithium-ion battery is chosen.

6.3. Charger Requirement

Given: Battery energy = 2200 Wh

Desired charging time = 3 hours The

charger rating becomes:

Power rating = 2200 ÷ 3 ≈ 733 W

Voltage = 48 V

Current rating = 733 ÷ 48 ≈ 15 A

A 48 V / 18 A charger is selected to provide efficient and slightly quicker charging.

6.4. Motor Controller Requirement

A 48 V, 2000 W BLDC motor controller is used to regulate and control motor performance, ensuring smooth and stable operation.

7.CONCLUSION

Today, the number of fuel-based vehicles is increasing quickly, which is causing more air pollution. To reduce this problem, electric vehicles (EVs) are becoming a better and cleaner option. Electric scooters are good for the environment and fit well for city travel because they do not release harmful gases. As fuel prices keep rising, electric scooters are also cheaper to use than normal petrol scooters.

E-scooters are helpful in rural areas too, where petrol stations are few. People can easily charge them at home using electricity, which makes them a convenient choice in remote places. This study gives a simple idea of EV technology by explaining the main parts and working of an electric scooter.

When the number of petrol and diesel vehicles grows, pollution also increases. Electric scooters help reduce this because they run quietly and do not produce smoke. The scooter discussed uses a 48V, 50Ah lithium-ion battery that charges in about 3 hours and can reach around 60 km/h.

Electric scooters also require very low maintenance since they have fewer moving parts compared to fuel vehicles. They offer smooth acceleration, easy handling, and reliable performance for daily use, making them suitable for students, office workers, and families.

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