

Design Optimization and Performance Study of An Electric Scooter

Arun Kumar Yadav^{1*}, Vinay Chauhan²

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.

Keywords: Electric vehicles (EVs), battery, brushless DC motor (BLDC), DC-DC converters, permanent magnet (PM), hub motor, miniature circuit breaker (MCB), fieldoriented control (FOC)

INTRODUCTION

Electric scooters are vehicles that run on electricity rather than gas or diesel. Their batteries can be charged and replaced using a standard charger. They are a clean and cheap way to get around because they do not burn fuel or pollute the air. As pollution and gas prices continue to increase, electric cars are becoming a more popular choice for the future. They do not harm the environment and function almost like regular fuel scooters. The battery, BLDC motor, controller, and other small electronic parts are the main components of an electric scooter. The battery stores energy, and the motor uses this energy to move the scooter (Figure 1). BLDC hub motors have become popular because they are small, efficient, and produce minimal noise. An electrical system is also a good system that keeps the rider safe and makes the scooter operate well [1].

As electric vehicles gain popularity worldwide, India continues to import a high volume of vital components, particularly from China.

This demonstrates that India should increase its capacity to design and produce electric scooters.

*Author for Correspondence

Arun Kumar Yadav
E-mail: dr.arunkumaryadavee@gmail.com

¹Associate Professor (Head), Department of Electrical Engineering, Bansal Institute of Engineering and Technology, Lucknow, Uttar Pradesh, India

²UG Scholar Department of Electrical Engineering, Bansal Institute of Engineering and Technology, Lucknow, Uttar Pradesh, India

Received Date: December 04, 2025

Accepted Date: April 08, 2026

Published Date: May 15, 2026

Citation: Arun Kumar Yadav, Vinay Chauhan. Design Optimization and Performance Study of An Electric Scooter. Journal of Automobile Engineering and Applications. 2026; 13(2): 1–7p.

This study will help India transition from a service economy to a nation that manufactures and develops its goods [2]. Therefore, our core objectives for creating or developing an e-scooter are 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.

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

SYSTEM DEVELOPMENT

Major Components of Electric Scooters. The important components of electric scooters are as follows:

- i. Battery charger
- ii. Battery
- iii. Motor controller
- iv. Motor
- v. DC-DC converter

DESIGN

Chassis

The chassis is the main structural component of cars. It serves as a sturdy foundation upon which all the important parts are built. The frame, transmission, wheels, and control systems are all supported by the chassis, except for the vehicle's external body. The primary function of the chassis 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 in motion.

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]. It is also robust and lightweight owing to its exceptional strength-to-weight ratio. The overall lifespan and efficiency of the scooter were increased by this combination.

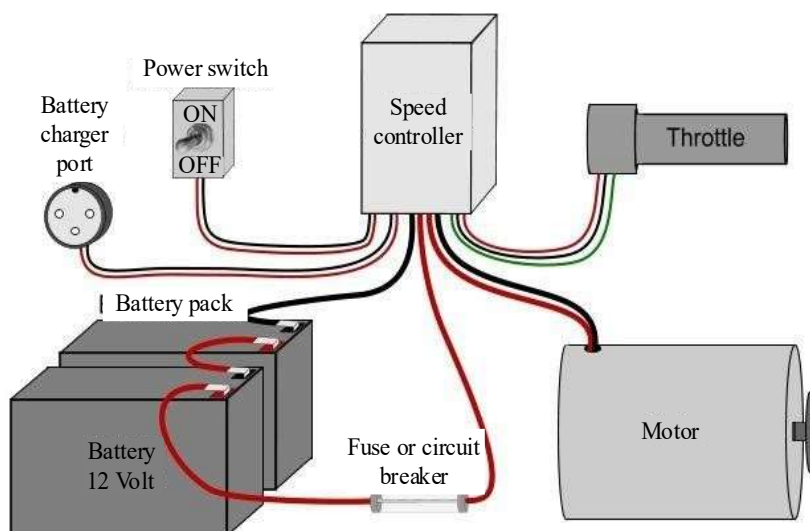


Figure 1. The key components of electric scooter.

Design Specification

Mass of the vehicle: 90 kg

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

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

Angle of incline $\Phi = 2.5^\circ$

a. Force due to climbing hills (F_h)

$$F_h = W \sin \Phi$$

$$F_h = 882.9 \times \sin(2.5^\circ)$$

$$F_h = 37.96 \text{ N}$$

b. Rolling Resistance (F_r)

$$F_r = C_r W \cos \Phi \quad (\text{For street roads, } C_r = 0.004)$$

$$F_r = 0.004 \times 882.9 \times \cos(2.5^\circ)$$

$$F_r = 3.52 \text{ N}$$

c. Air Resistance (F_d)

$$F_d = 0.5 \rho C_d A V^2$$

(Air density $\rho = 1.2 \text{ kg/m}^3$, drag coefficient $C_d = 0.5$, frontal area $A = 0.7 \text{ m}^2$)

$$F_d = 0.5 \times 1.2 \times 0.5 \times 0.7 \times (16.67)^2$$

$$F_d = 58.36 \text{ N}$$

Total Force on the Vehicle

$$F = F_h + F_r + F_d$$

$$F = 37.96 + 3.52 + 58.36 = 99.84 \text{ N}$$

Power Required for Propulsion

$$P = F \times V$$

$$P = 99.84 \times 16.67 = 1664.33 \text{ W} (\approx 1.66 \text{ kW})$$

ELECTRICAL SYSTEM

BLDC HUB-Motor

There are several advantages of using permanent magnets (PM) in electrical machines instead of electromagnetic excitation. Since no external excitation system is required, there are reduced losses, a simplified design, higher efficiency, and the machine can react faster to dynamic changes [5]. Machines utilizing PMs are also more likely to provide a higher torque or power considering the same size. A BLDC motor is a form of synchronous motor that works with direct current and has an electronic type of commutation, as opposed to the use of brushes and mechanical commutators. The current and torque, voltage, and speed are in a linear relationship in these motors. However, with a BLDC motor, the permanent magnet rotor is turned instead of the armature, and the windings on the stator remain stationary. 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 that the electronic switches can be used correctly (Figure 2). The most popular types of sensors used for this purpose are Hall-effect sensors; however, some systems use optical sensors [7,78].

Electric Scooter Controller

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

When the throttle is twisted by a rider, the controller is informed and determines the amount of current to be passed to the motor [79]. This assists in quick acceleration and effective speeding. The controller also shields the scooter against issues such as overcurrent, low battery voltage, overheating, and short circuits (Figure 3). This guarantees that the motor will operate safely and harmoniously under varying

conditions. In addition, it controls braking (in most models, this was regenerative braking), battery consumption, and power distribution.

Battery

The key power source of an electric vehicle is its battery. It also accumulates electric energy and delivers it to the electric motor that propels the car. EVs do not use petrol or diesel but use all the energy contained in the battery pack. The battery of Electric vehicles (EVs) operates by converting chemical energy into electric energy, which provides a constant and consistent supply of power. Lithium-ion batteries are used in modern EVs because they are lightweight, can be charged quickly, and have a long life (Figure 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.

Battery Charger

A battery charger is very important because it helps the battery to work at its full potential (Figure 4 and 5). The main qualities of a good charger are high performance, dependability, low weight, low cost, short charging time, and high power output. These qualities depend on the parts used and the switching methods employed. An electric charger is a device that recharges a battery by supplying electrical energy, which the battery stores as chemical energy inside its cells.



Figure 2. BLDC Motor (48-72V, 2000W).

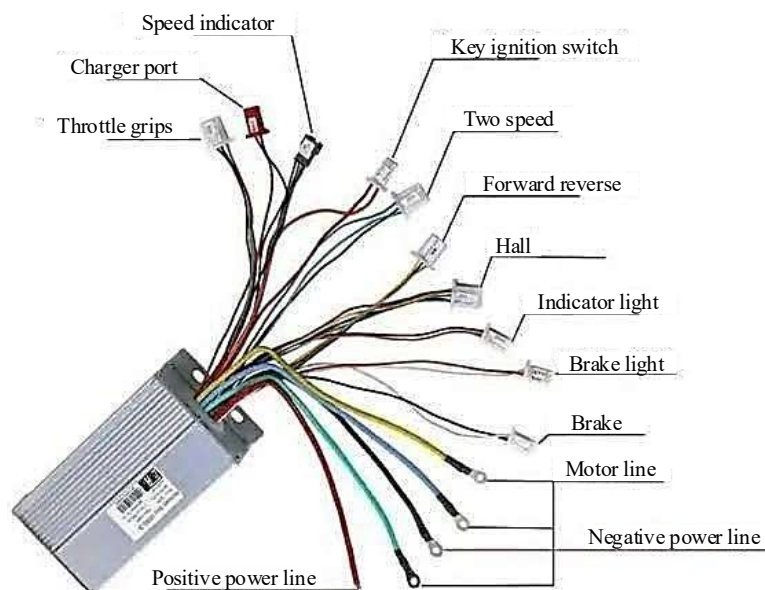


Figure 3. Electric scooter motor controller.



Figure 4. 48V/50Ah Lithium-Ion Battery.



Figure 5. 48V/15A Battery charger.

DC-DC Converter

One of the significant electronic devices utilized in electric scooters 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 so that various components of the scooter may operate correctly. A high DC voltage (48, 60, or 72 V) is commonly supplied by the battery in an electric scooter. However, all the parts do not operate at the same voltage [815, 916]. 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 [1047].

PERFORMANCE ANALYSIS

Motor Requirement

The total power required to drive the vehicle was 1665 W.; therefore, a motor rated above this value was required. A 2000 W, 48 V BLDC hub motor was selected to ensure adequate performance and reliability [1148].

Battery Requirement

The motor demands 2000 Wh of energy.

Considering a 10% reserve margin:

Total battery energy = $2000 \times 1.1 = 2200$ Wh

Rated voltage = 48 V

Required capacity = $2200 \text{ Wh} \div 48 \text{ V} = 45.83$ Ah

To meet this requirement, a 48 V, 50 Ah Lithium-ion battery was selected.

Charger Requirement

Given: Battery energy = 2200 Wh

Desired charging time = 3 hours The charger rating becomes:

Power rating = $2200 \div 3 \approx 733$ W

Voltage = 48 V

Current rating = $733 \div 48 \approx 15$ A

A 48 V / 18 A charger was selected to provide efficient and slightly faster charging.

Motor Controller Requirement

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

CONCLUSION

Today, the number of fuel-based vehicles is increasing rapidly, causing more air pollution. To address this problem, electric vehicles (EVs) are becoming a better and cleaner option. Electric scooters are good for the environment and are suitable for city travel because they do not release harmful gases. As fuel prices continue to rise, electric scooters are cheaper to use than petrol scooters.

E-scooters are helpful in rural areas, where petrol stations are few. People can easily charge them at home using electricity, making them a convenient choice in remote locations. This study provides a simple overview of EV technology by explaining the main parts and operation of an electric scooter.

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

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

REFERENCES

1. Lee JY, Woo BC, Kim JM, Oh HS. In-wheel motor design for an electric scooter. *J Electr Eng Technol.* 2017;12(6):2307-2316. doi:10.5370/JEET.2017.12.6.2307.
2. Zhai H. Modeling of lithium-ion battery for charging/discharging characteristics based on circuit model. *Int J Online Biomed Eng.* 2017;13(6):86-95. doi:10.3991/ijoe.v13i06.6799.
3. Cheng KWE. Recent development on electric vehicles. In: *Proceedings of the 2009 3rd International Conference on Power Electronics Systems and Applications (PESA)*; 2009 May 20-22; Hong Kong, China. p. 1-5.
4. Hazari MR, Jahan E, Siraj ME, Khan MTI, Saleque AM. Design of a brushless DC (BLDC) motor controller. In: *2014 International Conference on Electrical Engineering and Information Communication Technology (ICEEICT)*; 2014. doi:10.1109/ICEEICT.2014.6919048.
5. Khande MS, Patil AS, Andhale GC, Shirsat RS. Design and development of electric scooter. *Int Res J Eng Technol.* 2020;7(5):359-364.
6. Daingade P, Shirolkar A, Singh S, Tamhankar S, Shelke RD. Designing and manufacturing of electric scooter. *Int Res J Eng Technol.* 2020;7(6):1549-1553.
7. Kadam KS, Sambhar NS, Bora NM, Bhakare SR, Gaikwad SW. Design and analysis of E-scooter chassis frame. *Int Res J Eng Technol.* 2020;7(6).
8. Biswa B. Design and development of electric scooter. *Int J Acad Multidiscip Res.* 2021 Aug;5(8):63-69.
9. Matthews AM. Controller & modification of a light hub-motor propelled electric wheelchair [thesis]. Cape Town: Cape Peninsula University of Technology; 2012

10. Jape SR, Thosar A. Comparison of electric motors for electric vehicle application. international Journal of Research in Engineering and Technology. 2017 Sep;6(09):12-7
11. Reddy YK, Sanju S, Roy SK, Rubiston MM. Electric Smart Scooter. International Research Journal of Engineering and Technology. 2020, Jun;7(06):1714-23.