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DESIGN AND PERFORMANCE ANALYSIS OF A 2 KW ELECTRIC RICKSHAW FOR URBAN COMMUTING

Sangam Prashar[1], Chirag Thakur[2]

[1]Department of Electrical Engg. HIET,Shahpur

sangamprashar3@gmail.com

[2]Department of Electrical& Electronic Engg. HIET, Shahpur

tchirag104@gmail.com

ABSTRACT

The electric rickshaw (e-rickshaw) is becoming an important mode of transportation in India, offering a sustainable alternative to traditional autorickshaws powered by fossil fuels. This paper discusses the design and optimization of an e-rickshaw, considering key factors such as motor selection, battery capacity, and control mechanisms. The vehicle complies with the Ministry of Road Transport & Highways (MoRTH) regulations, with a maximum speed of 25 km/h and a motor power of 2 kW. A 2 kW Brushless DC (BLDC) motor and a 5-kWh lithium-ion battery are chosen for optimal performance and cost-efficiency, enabling the vehicle to carry full payloads with minimal energy consumption. The motor controller, based on a microcontroller unit (MCU), integrates components such as a PWM generator and ADC for precise control over motor speed and torque. The design aims to contribute to reduced urban pollution, improve mobility, and provide an affordable solution for e-mobility in India's rapidly growing cities.

Keywords- Electric Autorickshaw, E-Rickshaw, Urban Mobility, Performance Modelling, Optimization, Sustainable Transportation**,** Battery Efficiency.

1. INTRODUCTION

The rickshaw plays a vital role in public transportation across India. The term 'rickshaw' in Japanese translates to a man-powered vehicle. A modern adaptation, the autorickshaw, operates on non-renewable fuels. Autorickshaws are crucial for urban mobility, contributing to both sustainable transportation and improved quality of life in Indian cities. By serving as a feeder mode for public transit networks, they enhance connectivity and accessibility throughout urban areas. Autorickshaws typically run on petroleum fuels such as petrol, diesel, and CNG. Although their emissions are lower compared to larger vehicles, the sheer volume of autorickshaws in cities results in significant pollution levels. Transitioning from fuel-powered to electric rickshaws could substantially mitigate urban pollution [1]. Electric rickshaws were introduced in India during the 1990s; however, high costs and limited battery life hindered their initial adoption. Today, as India shifts towards greener practices and e-mobility, rising fuel prices are driving consumers toward electric options. This shift presents a considerable opportunity and demand for electric vehicles, particularly e-rickshaws. E-rickshaws can also replace man-powered rickshaws, as they require less effort from drivers, enabling them to operate longer and cover greater distances [2]. In India, there are specific regulations governing e-rickshaws. The Ministry of Road Transport & Highways issued notification G.S.R.709(E) on October 8, 2014, classifying e-rickshaws and e-carts as distinct categories of transport vehicles. According to this notification and the Motor Vehicle (Amendment) Act of 2015, an e-rickshaw is defined as a battery-powered vehicle with a maximum output of 4000 watts, designed to carry up to four passengers (excluding the driver) and a total luggage weight of no more than 40 kilograms. These vehicles must adhere to prescribed specifications, with a maximum speed limit of 25 kilometres per hour [3]. E-rickshaws can play a significant role in reducing both air and noise pollution by effectively replacing traditional autorickshaws.

2. DESIGN OF EV

The battery is positioned under the seat in the centre, which helps to keep the vehicle's centre of gravity low and centrally located. This arrangement contributes to improved riding comfort and enhanced stability.

Figure 1 E-Rickshaw

1) The physical parameters of the vehicle are:

- Kerb weight 180 kg
- Max passenger 4 nos.
- Max payload 300kg.
- Distance between front axle and CG = 1380mm
- Distance between rear axle and CG = 1380mm

The other parameters like coefficient of drag, rolling resistance, etc are from the reference:

SR no.	Parameter	Value
1	Coefficient of drag, Cd	0.842
2	Frontal Area,Af	1.168
3	Coefficient of rolling friction, CR	0.014

According to the Ministry of Road Transport & Highways (MoRTH) notification G.S.R. 709(E) dated 08.09.2014, the maximum permissible speed for electric rickshaws (e-rickshaws) is restricted to **25 km/h**. Under this condition, the power required by the axle to sustain the vehicle's motion has been determined using a vehicle power calculator, which takes into account the vehicle's specifications and dynamics. In the scenario where the vehicle is carrying its maximum payload on a level surface (i.e., zero gradeability), the e-rickshaw is expected to reach its maximum speed of 25 km/h within 10 seconds. With gradeability set to zero, the calculated power requirement for this operation is **1.817 kW**.

As the gradeability increases, the power demand will correspondingly increase due to the added resistance from the incline. However, according to MoRTH regulations, the motor power should not exceed **4 kW**. If a higher-rated motor is selected, the battery capacity must also be increased to support the additional power demand. This increase in battery capacity subsequently raises both the size and cost of the vehicle. Therefore, to balance performance, cost, and vehicle weight, an **optimal motor power rating** is chosen that provides the necessary performance without unnecessarily increasing costs [4-6].

To Find the Power of the Vehicle	
Vehicle Details	**E-Rickshaw**
Kreb Weight in kg	1800
Payload weight in kg	300
Total Weight in kg	480
Vehicle frontal height in m	1.77
Vehicle frontal width in m	0.660
Total frontal area of vehicle in m2	1.168
Vehicle Runing Details	
Speed of vehicle in kmph	25
Speed of vehicle in mps	6.94
Top speed from Kmph	25
Top speed from mps	6.94
Time required for top speed	10
Acceleration of vehicle mps	0.69
Terrain Details	
Road inclination in degree	0
Drag Coefficient	0.64
Air Density	1.2
Coefficient of rolling friction	0.014
Power	

Rolling Resistance power	0.456
Air Drag power	0.202
Hill climb power	0
Acceleration Power	1.15
Total Power	**1.8**

2) Selection of Motor

Based on the previously discussed optimal constraints, the rated power of the motor has been selected as **2 kW**. With this 2-kW motor, the vehicle is capable of carrying its full payload and achieving a maximum speed of **25 km/h** within **10 seconds**, demonstrating strong performance characteristics. The motor chosen for this project is a **2 kW Brushless DC (BLDC) motor**, and the relevant motor parameters are provided below [7].

Parameter	Rating/Type
Type	PMDC
Voltage (V)	48 V
No load Current (A)	5
Rated Current (A)	45
Rated Speed (RPM)	4000
Rated Torque (Nm)	7.6
Max. Output Torque (Nm)	22
Rated Power (W)	2000
Max. Rated Power (W)	3000
Efficiency	>83%
No. of Poles	8
Motor diameter (mm)	145
Insulation Class	Class B

3) Selection of Battery

The selection of the battery is based on the required operational duration of the vehicle. If the vehicle is expected to run at its rated power of **2 kW** for **4 hours**, the battery capacity required would be **4 x 2 kW = 8 kWh**. However, an 8 kWh battery would incur a significant cost, which may not be economically viable. To optimize the cost while ensuring sufficient operational range, a battery with a capacity of approximately **5 kWh** has been selected. This battery capacity strikes a balance between performance and cost, offering a practical solution for the vehicle's operational requirements [7].

Parameter	Rating/Type
Type	Li-ion
Capacity	4.8kWh
Nominal Voltage (V)	48
Ampere-hour (Ah)	100
Cycle life	>2000

4) Controlling Design

The motor controller is a crucial component in an electric vehicle (EV) that manages the power flow from the battery to the motor. It ensures that the motor operates in a controlled manner, according to predefined performance characteristics. A motor controller typically serves several essential functions, including the initiation and cessation of motor operation, selection of forward or reverse rotation, regulation of speed, adjustment of torque, and protection against overloads or electrical faults. These controllers can either employ electromechanical switches or, more commonly in modern applications, power electronic devices to regulate the motor's speed and directions [8-9]. In the case of EVs, the motor controller is typically based on a **microcontroller unit (MCU)**. The MCU-based controller integrates various components that work together to manage motor operation efficiently. These components include:

a) **Microcontroller (MCU)**: The central processing unit responsible for coordinating all motor control tasks.
b) **Microprocessor**: Executes the control algorithms and performs computation tasks.
c) **Pulse Width Modulation (PWM) Generator**: Modulates the motor's power supply to control the speed and torque.
d) **Analog-to-Digital Converter (ADC)**: Converts analog signals, such as motor current or voltage, into digital values for processing.
e) **Transmitter/Receiver (Tx/Rx)**: Facilitates communication with other vehicle systems or external devices for monitoring or diagnostics.

3. CONCLUSION

The design of the electric rickshaw (e-rickshaw) presented in this paper successfully integrates various technical components to provide an optimal solution for urban transportation in India. The vehicle meets the regulatory standards set by the Ministry of Road Transport & Highways (MoRTH), with a focus on minimizing pollution while maintaining high performance. The selection of a 2 kW Brushless DC (BLDC) motor and a 5-kWh lithium-ion battery ensures that the vehicle can carry its full payload and reach the maximum speed of 25 km/h within the required time frame, offering both efficiency and practicality. The motor controller, based on a microcontroller unit (MCU), plays a key role in regulating motor functions, enhancing performance, and ensuring the vehicle operates smoothly. With the growing shift towards greener alternatives and e-mobility, this e-rickshaw design can contribute significantly to reducing urban pollution and improving the quality of life in Indian cities. Moreover, the design balances performance, cost, and weight, making it a viable and sustainable transportation option for the future.

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