Towards Building eco-friendly and emission less Electric Scooter

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Abstract. Electric vehicles are becoming more important, as not only to reduce carbon emission but also to reduce the dependency on normal combustion engine vehicles. Most of the universities have really big campuses. To make the mobility in campus easier, the harmless and power-controlled vehicle with safety technologies is introduced. Besides, it also reduces time consumption. Further, it aids differently abled persons and aged professors. This paper presents the design and development of a compact, portable and weightless electric skating scooter. The vehicle body design is inspired from the sea cartilaginous fish ‘String Ray’. It also includes mechanical features like front shock absorber, handlebar break control, portable and handle bar height adjustment. The electrical and electronic features such as obstacle detector, fingerprint and RFID (Radio-frequency identification) access, battery management system (BMS) etc., help towards building a smart vehicle. Besides, it also provides a vehicle management system for tracking the user details, location and condition of the vehicle through a server. The proposed system with addition of mechanical, electrical and electronic features will help towards enhancing the performance of an electric scooter for easy mobility. The results obtained from the on-road test, CADD software and the implementation of vehicle management system has been discussed.

1. Introduction

In the tech era, where time rises for the revolution in the field of motor vehicle, e-vehicles plays an important role in the development phase. In India, a developing nation, where several decisions and steps are being taken to reduce the usability of petrol- and diesel-powered cars by 2030 [1], the development of e-vehicles will make a rise in usability and a sustainable environment. They have fewer moving parts than conventional cars. This is greatly helpful in reducing pollution and has zero exhaust emissions. In future, the price of electric-vehicle will fall [2]. Decreased usage of petroleum and gasoline and motor oil means fewer spills and pollution in oceans, rivers and groundwater. Universities and industry campuses generally have serious mobility problems [4]. So, the mobility for disabled students and aged professors is even more a tough job. The main aim of our project is intra college mobility. To make the mobility inside campus easier, the harmless and power-controlled vehicle with safety technologies can be used which reduces time consumption and helps disabled people. Considering the problem, the work focuses on an electric skating scooter which is really compact, portable and
weightless. This electric scooter has safety electronic technologies. The maximum speed of the scooter is 25 kilometres per hour. Our electric skating scooter has a modern design which is compact and easy to carry. The scooter handlebar height can be adjusted according to the rider's need. The scooter has a front shock absorber which smoothens the ride. Electronic safety technologies like obstacle detector, fingerprint access, BMS (Battery Management System) to monitor voltage, temperature, SOC and SOH are really useful for the rider ensuring comfort and safety while riding the scooter. This technology lowers the possibility of the occurrence of accidents on campus. The main objective is to design and develop an electric scooter for short distance locomotion. Specifically, it aims to:

- Develop a light weight and easy portable scooter.
- Develop a lost cost E-vehicle.
- Propose a novelty in the basic design of the scooter unlike, normal electric scooters in the market.
- Develop the outer body resistance to environmental calamities.
- Develop an eco-friendly and low-cost fuel vehicle.

2. Literature review
In recent years, many research works and projects have been done in the field of electric vehicles especially in the field of Li-ion batteries [5] and motors [9]. In [12] a study was made to look into the power flow calculation and the design of electric vehicle model is done using MATLAB to get the best power flow response to the energy system of the vehicle. A mathematical modelling and analysis on the powertrain were done in [12] for the use of split-power system. This helps to verify the operational capabilities of the motor under varying optimal conditions. Based on wireless transfer protocol, a hybrid energy system was designed and implemented in [8] using super capacitors for high performance of the scooter. Challenges faced by electric two wheelers in mountain roads was proposed in [16]. An electric scooter simulation program was developed in [10] to enable more improvement in the driving skills of the users. A portable electric scooter was designed in [17] to make the access of the vehicle much easier and more comfortable. An integrated power module for electric scooter was designed in [13] to improve the efficiency of power board. Taking into the account conservation of energy a solarized electric scooter was developed in [14]. A different approach was taken in [15] to improve the appearance and ergonomic performance using anthropometric measurement. Motor control using PID and Fuzzy PID controller is overviewed in [6]. Vehicle performance calculations done in [18] gives a clear insight on the parameters that has to monitored during the on-road test of the electric vehicle. The graphs shown in [18] indicates the battery performance, consumption and efficiency during the real-world scenarios. A comprehensive evaluation on battery technologies in the electric vehicle market is done in [19]. This helps to analyse and compare the different types of batteries available in the market. Incentive’s knowledge is essential for consumer awareness on electric vehicles. This is explained in [20]. Several papers and literatures related to electric vehicles has been discussed.

3. Materials and Methods
In a qualitative experimental study, the practical difficulties in implementing an electric vehicle are analysed. From the study, knowledge is gained on the real parameters to be taken care of while implementing an electric vehicle. After the completion of successful design analysis in Solid works, the mechanical design is developed using aluminium sheet. Motor controller, Li-ion battery is connected and the vehicle is started by connecting the wires manually. To monitor the vehicle and battery certain modules like vehicle management and monitoring system are developed. Figure 1 explains the working flow the electric scooter. The algorithm of the work flow is given below.

**STEP 1:** Start
**STEP 2:** Initialize the display.
**STEP 3:** RFID reads the tag.
**STEP 4:** If the tag is valid state of the bike changes from OFF to ON.
STEP 5: User details are sent to the cloud and displayed on the server.
STEP 6: Enable and Initialize the GPS module.
STEP 7: Location is displayed on the server.
STEP 8: If the scooter starts moving speed, battery percentage are displayed on the LCD.
STEP 9: If the log out button is pressed the scooter state changes from ON to OFF.
STEP 10: User log out details are updated on the server.

Figure 1. Flow Diagram of the Proposed System.
Figure 2. Block Diagram of the Electronic module of the system.

From Figure 2 it is very clear that, the battery is the primary energy source or fuel for the vehicle. It sends switch-mode signal to the controller to drive the motor. A DC-DC converter is used to step down the voltage of the battery to 6 or 12v for the purpose of need. Hub motor is used here because of the advantage that they are independent drive system and they require little maintenance. Arduino MEGA is the main ECU to monitor the parameters like speed, battery percentage, location of the vehicle and also control the ON and OFF of the vehicle with the help of RFID. All these parameters are measured with the help of IR sensors, BMS, GPS module and RFID tag. 48v Li-ion battery is used as the fuel source of the vehicle. Battery is connected to the motor with the help of 48v motor controller. List of components used to design and develop the electric scooter is listed in table 1. The main systems involved in developing the electric scooter are battery, battery management system, motor, motor controller, vehicle monitoring system and vehicle management system. The working and functions of all these subsystems are discussed below.

Table 1. List of Hardware Components

| Name of the components       | Purpose                                           |
|------------------------------|---------------------------------------------------|
| Li-ion Battery               | Energy source for the vehicle.                    |
| Hub Motor                    | To drive the vehicle.                             |
| Motor Controller             | To drive the motor.                               |
| Arduino MEGA                 | Microcontroller unit.                             |
| IR Sensor                    | To measure speed.                                 |
| GPS Module                   | To obtain the location details of the vehicle.    |
| RFID                         | To give access for the vehicle.                   |
| Thin film Transistor LCD     | Dashboard of the vehicle.                         |

3.1. Battery

The battery acts as the main fuel source for the vehicle. At recent days, lead – acid batteries are getting replaced by Li-ion batteries because of their less running cost and less maintenance. The battery pack used in this is electric vehicle is Li-ion. The supply from the battery is controlled using a motor controller and this is given as input to the motor. The battery will be connected to the motor driver to deliver power directly to the motor.
3.2. Battery Management System
A battery management system (BMS) is a basic electronic system used to monitor the rechargeable battery pack or cell. It monitors current, voltage, State of Charge (SOC), State of Health (SOH), depth of discharge, state of power and coulomb flow. The battery management system is made up of many hardware and software functional blocks which has,
- Cut off MOSFET
- Real Time Clock
- Temperature monitoring system
- Fuel gauge monitor
- Cell voltage monitor or cell balancing circuits

All these functions blocks play a major role in monitoring each cells of the Li-ion battery pack. The battery management system should contain accurate algorithms to measure and calculate the functional status of the battery. A review on smart battery management system for Li-ion battery is described in [Ali, Zafar, et al., (2019)].

3.3. Motor
Gearless hub motor is used to drive the vehicle. It is placed in the center part of the wheel. Hub motor is actually a BLDC motor. Hall effect sensor is used to identify the position of the rotor very precisely with the help of variation in magnetic fields. The position of the rotor is identified with the help of hall sensor. The position of rotor is fed to the microprocessor unit with help of Rotor position circuitry. The microprocessor gets input from the hall sensor and based on the input fed PWM signal is sent to the switching circuit to energize the respective coils. When the permanent magnet passes through any one of the sensors, the sensor produces a positive or negative (high/low) signal which is used to determine the rotor position (N/S pole). Based on the output from the hall effect sensor, pulse width modulated signal is generated. Pulse width modulation is a technique used to control the speed of many devices. The working of PWM in motor control is discussed in [Prakosa et al., (2019)] In 555 timer IC, the actual output is a PWM signal. The duty cycle depends on the value of the resistors. Duty cycle=R1/(R1+R2). In microcontrollers and microprocessors there are dedicated output pin for the PWM signal. All these processes are involved in the working of motor and calculating the speed of the motor. To improve the torque and ripples a four-quadrant operation method of brushless motor is employed in [Gopinath et.al., (2018)].

3.4. Motor Controller
Motor controller is the brain of EV which basically controls the motor. The parameters monitored by the motor-controller are Motor speed, expected battery range, acceleration, direction, torque, overload protection, start and stop of the vehicle and regenerative braking. Motor controller controls the current and voltage of the battery to be supplied to the motor. Based on this, desired output power and the speed and torque are controlled. A microprocessor inside the motor-controller will take care all of these calculations. So, the processing speed of the processor should be very high.

3.5. Vehicle Monitoring System
ATmega328P Arduino Mega serves as a microcontroller unit among the battery, sensors and vehicle tracking system. In the vehicle, an IR sensor is placed near the back wheel. Whenever the sensor detects white colour on the wheel, the count is made as 1. By this method, the rpm of the wheel is calculated using RPM: diameter of the wheel*rpm*0.001885. With the help of rpm speed can be calculated which is displayed on the display mounted on the handle bar. Here the RFID tag and reader acts as transmitter and receiver. Global Positioning System is a satellite-based system used for tracking the location with time and range. The controller then sends the information the cloud to display the location in the webpage. Thin Film Transistor Liquid Crystal Display is used as a dashboard in this vehicle.

3.6. Vehicle management system
The main purpose of this project is to serve intra-campus locomotion. Therefore, maintaining and monitoring all the vehicle inside the campus is not an easy task. For this purpose, a vehicle tracking system has been developed, under which the campus management can monitor the location, user details and temperature of the electric vehicle.

4. Results and Discussion

In order to achieve better performance and reduce real-time difficulties in the making of vehicle, the estimation of the performance is done using CADD software. The mechanical design of the proposed system is shown in the Figure 3,4,5,6. In the electric scooter, AISI 4130 is selected as the roll cage material due to its high strength to weight ratio of 72 to 130 kNm/kg. The proposed design provides up to 25.5 percentage of elongation. The wheel base is 548 mm so that it provides a minimum turning radius of 1.3 m. The scooter is designed for a load carrying capacity of 120 kg. Results obtained from the on-road test is listed in the table 2. Based on the results obtained from the speed test, the battery used in the electric scooter has a discharging rate of 4.3 hrs. The range that can be covered at the economy mode is 43 km. The RFID system used in the scooter unlocks the vehicle within 3 seconds when the tag is placed near the reader. Once the user unlocks the scooter, user information is sent to the server and the vehicle is monitored.

Since, lithium-ion battery pack is used in this scooter, all safety parameters like temperature, voltage and current discharge, SOC have monitored under all circumstances. The functions of the scooter like throttle performance, rolling resistance (35.316 N), gradient resistance (153.3 N), aerodynamic drag (8.47 N) and braking system have been checked thoroughly.

| Distance (km) | Battery SoC (%) | Power consumption (wh/km) |
|--------------|----------------|--------------------------|
| 35           | Decreases 27   | 132                      |
| 42           | Decreases 33   | 148                      |
| 47           | Decreases 46   | 154                      |

Figure 3. Design of the E-Scooter done in CADD software (a) depicts the overall design, (b) main frame, (c) isometric view and (d) rack and pinion of the vehicle.
As shown in the Figure 4(a), Fascia or dashboard which is used to display the information like speed, battery percentage, remaining distance of ride, mode of the vehicle user details. The RFID tag is tested with a person’s id, the information in the respective id will be displayed on the dashboard within 5 secs of the unlock of the vehicle. The information of the vehicle which is linked to the database displays data of the user accessing the scooter. And it is also linked to the microcontroller and google maps for sensor data & tracking. Figure 4(b). shows the front-end of the webpage. Parameter displayed on the server:

- Log in and Log out credentials.
- Battery Percentage.
- Temperature of the vehicle.
- Location of the vehicle with pick up and park information.

During the on-road test of the vehicle, the maximum speed obtained at the economy mode is 15kmph, cruise mode is 20 kmph and sport mode is 27kmph. And the battery last for about 4.5 hours, 3.5 hours and 2 hours respectively for the economic, cruise and sport mode.

5. Conclusion

Electric vehicles play an important role to maintain a pollution free environment. The Electric Vehicles Market is projected to reach 26,951,318 units by 2030 all over the world. A survey says that by 2030, the government aims to make India a 100-per cent electric-vehicle nation. To achieve this many innovative electric vehicles designing ideas are required. In this paper, design and development of electric scooter is studied. Each and every part included in the development has been described in detail. In order to ensure the safety of the vehicle, vehicle tracking system has been implied. Experimental results show the stability and ease access of the vehicle. In addition, further experimental results show the charging and discharging of the battery. The overall design helps in decreasing pollution and increasing the speed of intra-campus locomotion. It has an advantage of much lower running costs. The maximum speed of the scooter is 25 kmph and the gradeability is 200. Thus, the working of the system has been tested thoroughly and it is said to function properly and successfully. In future the following things can be improved in the electric scooter,

- Design Optimization
- Weight Reductions
- Improving Ergonomics
- Manufacturing Cost Reduction
- Vehicle Tracking System
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