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Pedal Assist E-Bicycle with Motor Supply Cutoff System

[1] K. S Ramanjaneyulu, [2] A.Das, [3] K.Jitendra,

[4] M.Bhanu, [5]P.Gowthami, [6] P.Radhika

[1]Associate Professor, Dept. of EEE, NSRIT, Visakhapatnam, AP

[2,3,4,5,6] B. Tech Students, Dept. of EEE, NSRIT, Visakhapatnam, AP

NSRIT-Nadimpalli Satyanarayana Raju Institute of Technology

Abstract

The Pedal-Assist E-Bicycle with a motor supply cutoff system is designed to enhance urban mobility by providing a fully electric riding experience without the need for manual pedaling. The system incorporates a 250W BLDC hub motor powered by a 36V, 12Ah lithium phosphate battery, controlled via an advanced electronic controller and throttle mechanism. Additionally, a real-time obstacle detection and motor cutoff system is implemented using an Arduino Uno, ultrasonic sensor, buck converter, and relay. This feature ensures rider safety by detecting obstacles within a 200cm range and automatically deactivating the motor to prevent collisions. The integration of these technologies results in an efficient, eco-friendly, and intelligent e-bicycle, making it a viable alternative to conventional two-wheelers. Performance analysis includes response time measurements, power consumption efficiency, and braking distance versus speed evaluations. The proposed system contributes to the advancement of sustainable transportation solutions while enhancing user convenience and road safety.

Keywords: E-bicycle, BLDC motor, obstacle detection, ultrasonic sensor, Arduino Uno, motor cutoff, sustainable transportation.

Introduction

The growing demand for sustainable and efficient transportation has led to the widespread adoption of electric bicycles (e-bikes) as an eco-friendly alternative to conventional fuel-powered vehicles. E-bikes offer several advantages, including reduced carbon emissions, lower operational costs, and enhanced mobility, making them a preferred choice for urban commuters. However, many traditional e-bikes still require manual pedaling, which may not be feasible for all users, particularly those with physical limitations or those traveling long distances. To address this issue, a fully electric Pedal-Assist E-Bicycle with a motor supply cutoff system has been developed to provide a seamless and effortless riding experience.

This project introduces an advanced e-bicycle system that eliminates the need for manual pedalling while ensuring enhanced safety through an intelligent obstacle detection mechanism. The proposed system integrates a 250W BLDC hub motor, a 36V, 12Ah lithium phosphate battery, an electronic controller, and a throttle to provide efficient motorized propulsion. Additionally, an Arduino Uno-based motor supply cutoff system is incorporated, featuring an ultrasonic sensor, relay module, and buck converter. This system continuously monitors the surroundings and detects obstacles within a 200cm range. Upon detecting an obstacle, the Arduino triggers the relay to cut off the motor's power supply, thereby preventing potential collisions and enhancing rider safety.

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The main objective of this project is to develop an energy-efficient and user-friendly e-bicycl that operates without requiring human effort for pedalling. This feature is particularly beneficial for urban areas, where frequent starts and stops in traffic can make traditional cycling exhausting. The motor cutoff system ensures that the vehicle stops automatically when an obstruction is detected, reducing reaction time and improving braking efficiency.

By integrating automation, safety, and efficiency, the proposed Pedal-Assist E-Bicycle with a motor supply cutoff system represents a significant advancement in personal transportation. This research paper explores the system's design, working principles, circuit implementation, performance evaluation, and cost analysis. Through experimental testing, key performance parameters such as response time, power consumption efficiency, and braking distance versus speed are analysed to assess the system's effectiveness. The findings aim to contribute to the development of intelligent and sustainable mobility solutions for modern urban environments.

Methodology

The Pedal-Assist E-Bicycle with a motor supply cutoff system is designed to provide a fully electric riding experience while ensuring safety through automated obstacle detection and motor deactivation. The methodology consists of two key modules: the electric propulsion system and the obstacle detection-based motor cutoff system. The implementation follows a structured approach, including system design, component integration, circuit development, programming, and performance evaluation.

1. System Design and Components Integration

The e-bicycle is designed to operate without manual pedalling, relying entirely on a 250W BLDC hub motor powered by a 36V, 12Ah lithium phosphate battery. The controller and throttle mechanism regulate the power supplied to the motor, ensuring smooth acceleration and speed control.

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Fig-1: BLDC motor and controller Configuration

A charging display is integrated to monitor battery status, and a charger is included for recharging the battery when needed. The entire system is connected using durable connecting wires to ensure efficient power transmission and signal communication.

For safety, an obstacle detection system is incorporated, consisting of an Arduino Uno board, ultrasonic sensor, relay module, buck converter, and an on/off button. The ultrasonic sensor continuously monitors the surroundings and detects obstacles within a 200cm range. When an obstacle is detected, the Arduino Uno processes the sensor data and triggers the relay module to immediately cut off the motor supply, preventing potential collisions. The buck converter ensures stable voltage supply to the Arduino, enabling efficient operation.

2. Working Mechanism

The system operates in sequential steps to ensure a seamless and safe riding experience:

- **Activation:** The user switches on the e-bike using the on/off button, which powers the Arduino Uno, controller, and motor circuit.
- **Motor Operation:** Upon engaging the throttle, the controller regulates power from the battery to the BLDC hub motor, propelling the bicycle forward. The rider does not need to pedal, as the electric motor provides complete propulsion.
- **Obstacle Detection:** The ultrasonic sensor continuously scans the path ahead. If an obstacle is detected within a 200cm range, the sensor sends data to the Arduino Uno, which processes the information in real time.

- **Motor Cutoff for Safety:** Upon detecting an obstacle, the Arduino Uno activates the relay module, cutting off power to the motor and stopping the e-bike. This prevents collisions and enhances rider safety.
- **Resumption of Motion:** When the obstacle is cleared, the sensor detects increased distance, and the Arduino Uno restores the power supply to the motor via the relay module, allowing the bicycle to resume operation.

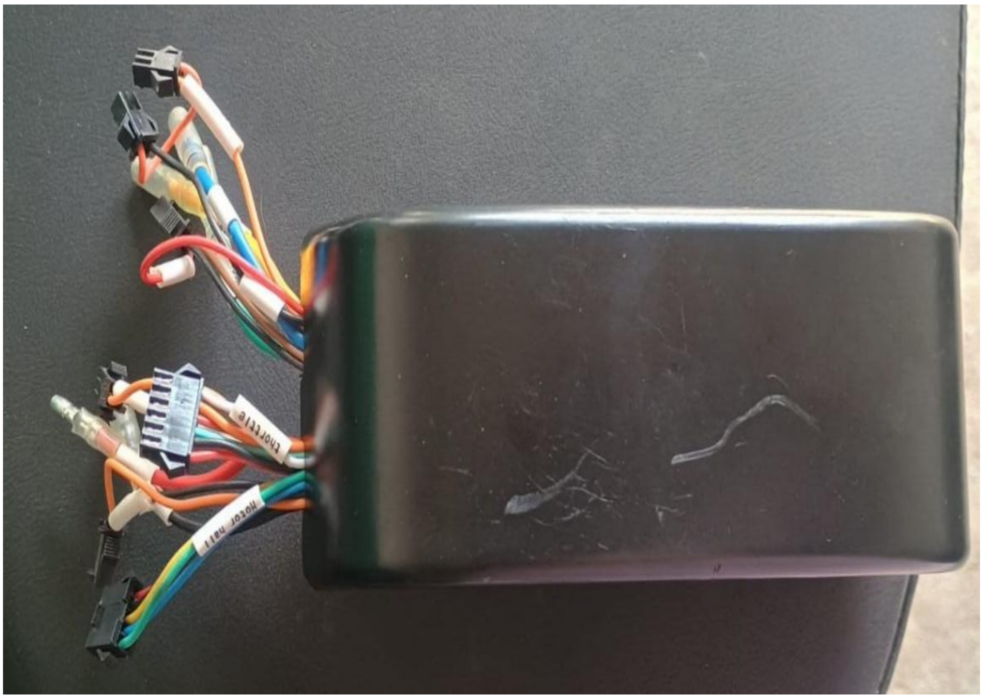

Fig-2: controller Configuration

3. Circuit Development and Programming

A detailed circuit is designed to integrate the motor, battery, controller, relay, Arduino, and safety components and its showed in fig-2 and fig-3. The Arduino Uno is programmed to read ultrasonic sensor data and control the relay for automatic motor cutoff. The programming logic includes:

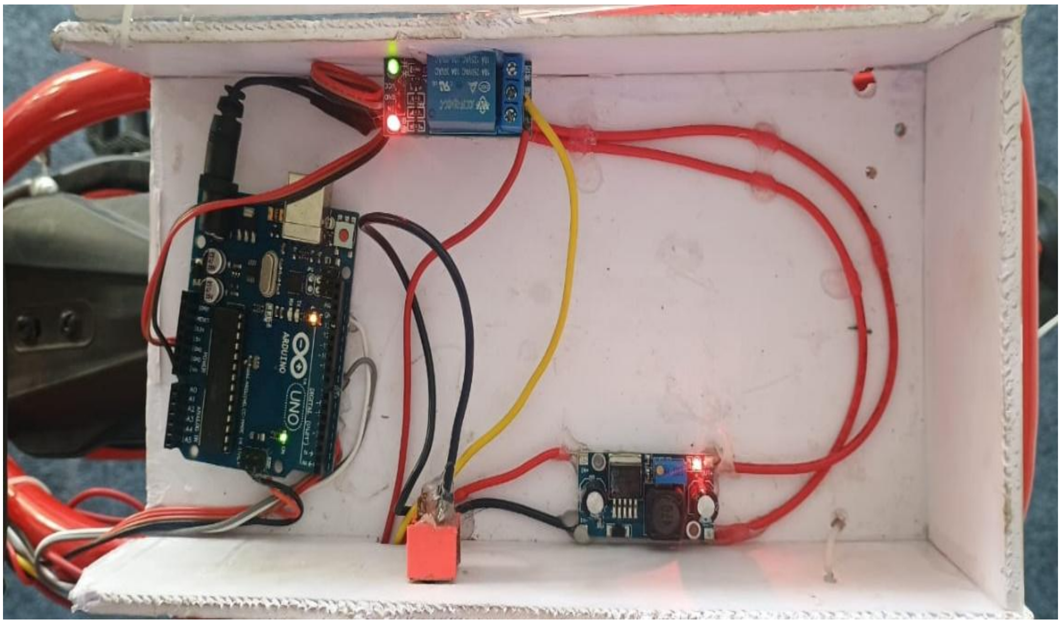

Fig-3: Motor supply cutoff system circuit

- Measuring real-time distance from obstacles using the ultrasonic sensor.
- Processing sensor data and setting a 200cm threshold for obstacle detection.
- Triggering the relay to cut motor supply when an obstacle is within range.
- Restoring power when the obstacle is no longer detected.

4. Performance Evaluation

The system is tested under real-world conditions to evaluate in Fig-5:

- **Response Time:** The delay between obstacle detection and motor cutoff.
- **Power Consumption Efficiency:** Measuring energy usage under different riding conditions.
- **Braking Distance vs Speed Analysis:** Evaluating how effectively the motor cutoff system stops the bicycle at various speeds.

Graphs and performance data are generated to analyse system efficiency and safety enhancements. The findings help validate the proposed system's effectiveness in providing a fully electric, safe, and intelligent e-bicycle solution.

1. Response Time vs. Obstacle Distance
2. Battery Consumption vs. Distance Travelled
3. Braking Distance vs. Speed

Fig-4: Pedal Assist E-Bicycle with Motor Supply Cutoff System

1. **Response Time vs. Obstacle Distance**: Shows how the motor cutoff system responds to different obstacle distances.
2. **Battery Consumption vs. Distance Traveled**: Displays how the battery depletes as the e-bike covers more distance.
3. **Braking Distance vs. Speed**: Illustrates the relationship between the bike's speed and the distance required to stop.

Table 1: Response Time vs. Obstacle Distance

Obstacle Distance (cm)	Response Time (ms)
200	50
180	48
150	45
120	42
100	40

Obstacle Distance (cm)	Response Time (ms)
80	38
60	35
40	33
20	30

Table 2: Battery Consumption vs. Distance Travelled

Distance Travelled (km)	Battery Consumption (%)
0	100
5	92
10	85
15	78
20	70
25	60
30	50
35	40
40	30

Table 3: Braking Distance vs. Speed

Speed (km/h)	Braking Distance (m)
5	0.5
10	1.2
15	2.1
20	3.0
25	4.2
30	5.5

The Pedal-Assist Electric Bicycle with Motor Supply Cutoff System operates through an intelligent integration of electronic and mechanical components to provide a seamless riding experience with enhanced safety features. The system consists of a 250W BLDC hub motor, a 36V, 12Ah lithium phosphate battery, a controller, a throttle, and a motor supply cutoff mechanism utilizing an ultrasonic sensor and Arduino Uno. The operation can be divided into different phases: starting, riding, obstacle detection, motor cutoff, and stopping.

1. System Startup

The e-bicycle system is powered by a 36V, 12Ah lithium phosphate battery, which provides energy to the BLDC motor, controller, and auxiliary circuits. When the on/off button is pressed, the Arduino Uno, controller, and motor system initialize, and the e-bike is ready for operation. The throttle control is activated, allowing the rider to accelerate without the need for pedaling. Unlike traditional bicycles, this system eliminates the requirement for manual pedaling, making it an ideal solution for urban commuting and individuals with physical limitations.

2. Riding Phase

Once the rider twists the throttle, the controller regulates power from the battery to the BLDC hub motor, enabling the wheels to rotate. The power distribution is efficiently managed by the controller, ensuring optimal energy utilization for extended battery life. The charging display provides real-time information on the battery status.

During movement, the Arduino Uno continuously processes data from the ultrasonic sensor to monitor the surroundings and detect potential obstacles in the path. This ensures that the bicycle can respond to environmental changes in real-time.

3. Obstacle Detection and Motor Cutoff System

A key safety feature of this system is the motor supply cutoff mechanism, which enhances rider safety by automatically stopping the motor upon detecting an obstacle within 200cm. The ultrasonic sensor, mounted on the front of the e-bike, continuously emits ultrasonic waves. If an object or obstacle is detected within the 200cm range, the sensor sends a signal to the Arduino Uno. The microcontroller then activates the relay, which cuts off the power supply to the motor, bringing the bicycle to a halt. This mechanism ensures that potential collisions are avoided, reducing the risk of accidents in busy or high-traffic areas

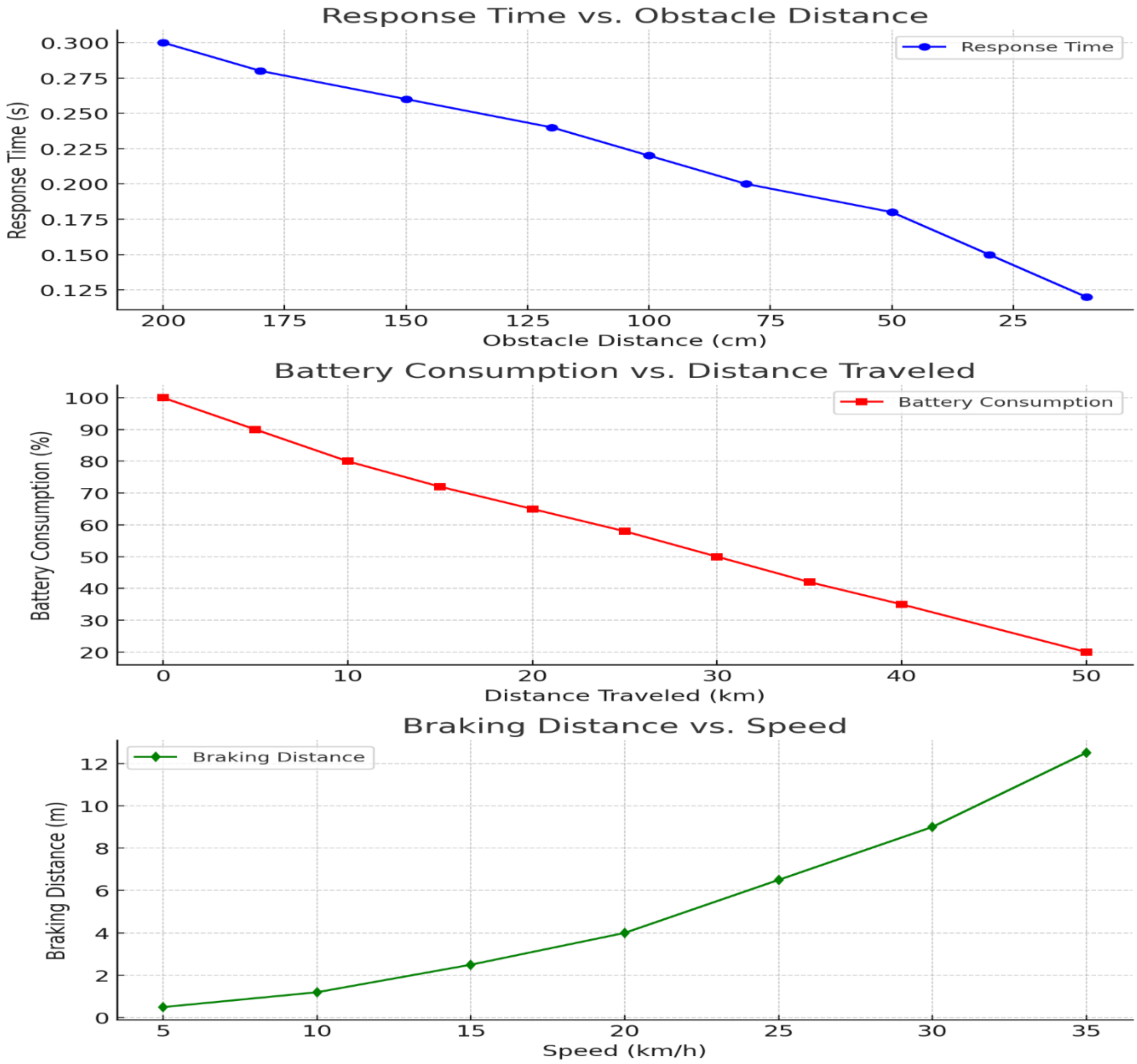

Fig-5: Response Time vs. Obstacle Distance and Battery Consumption vs. Distance Travelled and Braking Distance vs. Speed

4. Resumption of Motion

Once the obstacle is cleared and the ultrasonic sensor detects a safe distance, the Arduino deactivates the relay, restoring power to the motor. This automatic reactivation eliminates the need for manual intervention and ensures a smooth transition back to riding. The response time of this system is optimized to minimize delays and maximize rider safety.

5. Stopping the Bicycle

The e-bike can be **brought to a complete stop** in three ways:

1. **Manual Braking** – The rider can engage the manual brakes at any time to halt the bicycle.
2. **Throttle Release** – Releasing the throttle gradually reduces speed and stops the bicycle.
3. **Motor Cutoff System** – If an obstacle is detected, the motor is automatically cut off, bringing the bicycle to a stop.

At the end of the ride, pressing the **on/off button** turns off the entire system, preventing unnecessary battery drainage.

Conclusion

The Pedal-Assist Electric Bicycle with Motor Supply Cutoff System integrates advanced automation and safety features to provide an efficient and secure riding experience. The motor-assisted system eliminates the need for pedalling, making commuting effortless. Additionally, the real-time obstacle detection and motor cutoff system significantly enhance rider safety by preventing potential collisions. This innovative design makes the e-bike an ideal choice for urban transport, offering energy efficiency, environmental sustainability, and safety improvements.

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Appendix:

```
import numpy as np

import matplotlib.pyplot as plt

# Generating sample data

# 1. Response Time vs. Obstacle Distance

obstacle_distance = np.array([200, 180, 150, 120, 100, 80, 50, 30, 10])  # in cm

response_time = np.array([0.3, 0.28, 0.26, 0.24, 0.22, 0.2, 0.18, 0.15, 0.12])  # in seconds

# 2. Battery Consumption vs. Distance Traveled

distance_traveled = np.array([0, 5, 10, 15, 20, 25, 30, 35, 40, 50])  # in km
```

```
battery_consumption = np.array([100, 90, 80, 72, 65, 58, 50, 42, 35, 20])  # in %

# 3. Braking Distance vs. Speed

speed = np.array([5, 10, 15, 20, 25, 30, 35])  # in km/h

braking_distance = np.array([0.5, 1.2, 2.5, 4.0, 6.5, 9.0, 12.5])  # in meters

# Plotting the graphs

fig, axs = plt.subplots(3, 1, figsize=(8, 12))

# Graph 1: Response Time vs. Obstacle Distance

axs[0].plot(obstacle_distance, response_time, marker='o', linestyle='-', color='b', label="Response Time")

axs[0].set_xlabel("Obstacle Distance (cm)")

axs[0].set_ylabel("Response Time (s)")

axs[0].set_title("Response Time vs. Obstacle Distance")

axs[0].invert_xaxis()

axs[0].legend()

axs[0].grid(True)

# Graph 2: Battery Consumption vs. Distance Traveled

axs[1].plot(distance_traveled, battery_consumption, marker='s', linestyle='-', color='r', label="Battery Consumption")

axs[1].set_xlabel("Distance Traveled (km)")

axs[1].set_ylabel("Battery Consumption (%)")

axs[1].set_title("Battery Consumption vs. Distance Traveled")

axs[1].legend()

axs[1].grid(True)

# Graph 3: Braking Distance vs. Speed

axs[2].plot(speed, braking_distance, marker='d', linestyle='-', color='g', label="Braking Distance")

axs[2].set_xlabel("Speed (km/h)")

axs[2].set_ylabel("Braking Distance (m)")

axs[2].set_title("Braking Distance vs. Speed")

axs[2].legend()

axs[2].grid(True)

# Show plots

plt.tight_layout()

plt.show()
```