A Project Report on

Design and Development of Environment Friendly E-Bicycle

Submitted by,

Suryansh Ambekar	(Exam Seat No. 202201090042)
Kaustubh Mahajan	(Exam Seat No. 202201070128)
Alvin Abraham	(Exam Seat No. 202201070132)
Vipul Lavhade	(Exam Seat No. 202201060019)

Guided by,

Prof. Nikhil Sardar

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MIT | Academy of Engineering

(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

CERTIFICATE

It is hereby certified that the work which is being presented in the Third Year Major Project–1 Report entitled **"Design and Development of Environment Friendly E-Bicycle "**, in partial fulfillment of the requirements for the award of the Bachelor of Technology in Electronics & Telecommunication Engg.and submitted to the **School of Electronics & Telecommunication Engg.** of **MIT Academy of Engineering, Alandi(D), Pune, Affiliated to Savitribai Phule Pune University (SPPU), Pune**, is an authentic record of work carried out during Academic Year **2024–2025** Semester **V**, under the supervision of **Prof. Nikhil Sardar**, **School of Electronics & Telecommunication Engg.**

Suryansh Ambekar	**(Exam Seat No. 202201090042)**
Kaustubh Mahajan	**(Exam Seat No. 202201070128)**
Alvin Abraham	**(Exam Seat No. 202201070132)**
Vipul Lavhade	**(Exam Seat No. 202201060019)**

Prof. Nikhil Sardar
Project Advisor

Dr. Gayatri Ambadkar
Project Coordinator

Dr. Dipti Y. Sakhare
Dean

External Examiner

DECLARATION

We the undersigned solemnly declare that the project report is based on our own work carried out during the course of our study under the supervision of **Prof. Nikhil Sardar**.

We assert the statements made and conclusions drawn are an outcome of our project work. We further certify that

1. The work contained in the report is original and has been done by us under the general supervision of our supervisor.
2. The work has not been submitted to any other Institution for any other degree/diploma/certificate in this Institute/University or any other Institute/University of India or abroad.
3. We have followed the guidelines provided by the Institute in writing the report.
4. Whenever we have used materials (data, theoretical analysis, and text) from other sources, we have given due credit to them in the text of the report and giving their details in the references.

Suryansh Ambekar	**(Exam Seat No. 202201090042)**
Kaustubh Mahajan	**(Exam Seat No. 202201070128)**
Alvin Abraham	**(Exam Seat No. 202201070132)**
Vipul Lavhade	**(Exam Seat No. 202201060019)**

Abstract

Today, cities face issues like pollution, traffic, and the need for more eco-friendly ways to get around. Electric bicycles (e-bicycles) offer a clean and efficient option for short trips, making them ideal for urban commuting. This report covers the design and development of an environment-friendly e-bicycle that includes several key features to make it energy-efficient, durable, and safe for users. The e-bicycle aims to improve battery life using a Battery Management System (BMS), which helps control energy use and reduces battery wear. To make riding simpler, it uses an advanced control system that removes the need for a throttle, allowing for an easier, smoother ride. The design also includes supercapacitors to enable fast and easy recharging, helping users travel further on a single charge. To ensure security, the e-bicycle is equipped with an anti-theft system, giving users peace of mind when parking in public spaces. This report explains how each of these features works and how they help create a reliable, eco-friendly, and easy-to-use e-bicycle. Overall, this project aims to provide a practical green transportation option that meets the needs of today's urban commuters.

Acknowledgment

We extend our heartfelt gratitude to our esteemed project advisor/guide, Prof. Nikhil Sardar, whose unwavering encouragement and invaluable guidance have been instrumental in the successful completion of this project. His expertise and support have illuminated our path, enriching our learning experience significantly.

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Furthermore, we acknowledge and thank all the esteemed staff and faculty members whose wealth of experience, insightful advice, and unceasing cooperation have played a pivotal role in shaping this project. Their contributions have been invaluable, and we are truly grateful for their guidance and support, which have been indispensable throughout this journey.

Suryansh Ambekar

Kaustubh Mahajan

Alvin Abraham

Vipul Lavhade

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Chapter 1

Introduction

1.1 Background

In recent years, the automotive technology we use has made great progress along with people's pursuit of sustainable development and the environment. Electric bicycles are becoming a constant solution for short journeys, especially in urban environments. Electric bicycles have many benefits, such as reducing pollution, fuel consumption, and helping to prevent accidents. However, there are obstacles to their widespread adoption, including battery life and ease of charging, as well as regulatory and safety concerns. The performance of an e-bike depends on the life and performance of the battery. Yesterday's electric bike had problems: low battery and long charging process. Based on this, we are also developing new battery management systems such as battery management (BMS) technology, which not only manages power consumption better, but also improves the condition of the battery pack and minimizes damage over time. Now, in addition to the battery performance, the control system also plays an important role in keeping the car consistent. The control system is usually used to control the speed in e-bicycles, but it can be less efficient and require more battery to operate. With such a high level of control, the motorcycle can ride without needing the gas, which makes the ride emotional and also increases the battery life. Converting these systems to e-bicycles makes them easy and easy to ride, many people will switch to this type of transportation. Another worrying point is the use of electric bicycles. An additional feature for e-bicycles in urban environments is theft protection such as GPS tracking or alarm. These features are very important to users because they provide value and reliability when parking on the highway or in public areas. capability. One example of this is new technology such as supercapacitors that can be quickly charged and store excess energy from braking or pedaling to help batteries last longer. When combined with traditional battery storage, the technology can make the most of e-bicycles. Our main goal is to solve current e-bike design problems such as battery life, ease of use, low control system, fast charging with supercapacitor, and theft protection, which are solved by BMS for long battery life. In doing so, we want to pave the way for a more sustainable, realistic and safer city.(Patil et al. (2023))

1.2 Motivation

In a world where urban population is increasing and high demand for sustainable and green transportation is in trend, smart solutions such as electric bicycles (i.e., e-bicycles) provide a convenient way to travel over short distances. As transport modes are some of the key causes when it comes to pollution or congestion in cities, e-bicycles become a perfect alternative for urban commuters, which prefer to reduce their carbon footprint. Recent advancements in battery technology, control systems, and energy management have unlocked new potential for improving e-bicycle performance, comfort, and lifetime.

Despite this, there are still many challenges to overcome for e-bicycles to truly be a viable form of transport. Most e-bicycles still are based on short-lived batteries, need almost every day to be plugged in again, and have no intelligent controlling system which may constrain your experience. Further, e-bicycle cannot be the preferred choice as issues like theft to security can hold back people. Our project intends to overcome these problems using advanced functionalities of a electric bike including longer battery life, ease in handling, easy recharge process and security for the users.

We believe that our solutions address these urgent requirements and can transform e-bicycles into a more dependable, user-friendly, and secure mode of transport to encourage users to embrace this green mobility solution over traditional vehicles and create less polluted and less congested urban settings.

1.3 Project Idea

The rise in worries about pollution, traffic jams, and the need for green transport options has sparked the creation of eco-friendly choices to replace standard vehicles. An e-bicycle offers a good answer to these problems by mixing the perks of a regular bike with the strength and ease of an electric motor. This project aims to create a new, energy-saving, and green e-bicycle. This e-bicycle will have cutting-edge tech like a clever battery management system to make batteries last longer, control without a throttle for a smoother ride, and ways to gather energy to charge the battery. Also, the e-bicycle will have features like systems to stop theft and the ability to fold for easy carrying making it great for city trips and people who care about the environment.

1.4 Proposed Solution

The proposed solution involves creating an e-bicycle that uses cutting-edge tech to boost its performance, save energy, and beef up security. The design includes a Battery Management System (BMS) to make sure charging and discharging happen just right helping the battery last longer and need fewer replacements. A smart control system will take the place of the throttle letting riders manage their speed without fiddling with a manual throttle making for a smoother ride. The project also adds ways to harvest energy, like getting power back from pedaling, to charge the battery and make it last even longer. To keep the bike safe, it'll have a built-in anti-theft system to stop people from using it without permission. Plus, the e-bicycle will fold up, so users can store it or take it with them when they're not riding. All these features together make the e-bicycle a solid green way to get around that's perfect for city life.

1.5 Project Report Organization (Chapter wise summary)

This report is organized into several important sections to provide a clear understanding of the Design and Development of an Environment-Friendly E-Bicycle. The literature review section explores existing technologies in e-bicycles and recent advancements in areas like battery management, energy harvesting, and security features, establishing a foundation for the project. The problem definition and scope problem definition and scope section defines the transportation challenges that this project aims to address and outlines the scope of the e-bicycle's design and intended impact.

The system requirements and specifications section details the technical and functional requirements needed to achieve the project's objectives, including specifications for the Battery Management System (BMS), throttle-less control, energy harvesting, and anti-theft systems. The proposed methodology section describes the approach taken to integrate these features, covering the design, construction, and testing phases to ensure the e-bicycle meets sustainability and user convenience goals.

Finally, the conclusion summarizes the main points of the project, reflects on the expected environmental benefits of the e-bicycle, and suggests future improvements. Throughout the report, diagrams, figures, and references are included to support and illustrate the concepts discussed.

Chapter 2

Literature Review

2.1 Related work And State of the Art (Latest work)

Recent advancements in electric bicycle (e-bike) technology have focused on improving efficiency, sustainability, and user experience. Several studies present the integration of advanced technologies in e-bikes to address urban transportation challenges and environmental concerns.

- **Design and Fabrication of Retrofit E-Bicycle with Advanced Technologies**: This study focuses on developing an e-bicycle that incorporates a BLDC hub motor, Li-ion battery, and Battery Management System (BMS). The e-bike's cooling system and controller enhance performance and battery longevity, making it a viable solution for sustainable transportation.(Nambiar et al. (2023))
- **Design and Analysis of BLDC Motor-Based Electric Vehicle Using Fuzzy Logic Controller**: This paper introduces a fuzzy logic controller (FLC) to optimize BLDC motor speed, torque, and battery State of Charge (SOC), resulting in improved energy efficiency. The FLC minimizes energy losses, demonstrating the value of intelligent control for e-vehicles.(Lokesh et al. (2024))
- **Design and Performance Testing of an E-Bicycle**: This research outlines the design and testing of an e-bicycle with a high-speed BLDC motor, two-stage

gear system, and lithium-ion battery, focusing on achieving high torque and a long range per charge. The results validate its effectiveness as a sustainable mode of transport.(Gandhi et al. (2021))

- **A Comparative Study on the Speed Response of BLDC Motor Using Conventional PI Controller, Anti-windup PI Controller, and Fuzzy Controller**: This paper compares control strategies for BLDC motors, finding that fuzzy controllers perform best under no-load conditions, while anti-windup PI controllers are more effective under varying loads.(Shyam & Daya (2013))
- **Throttle-Less Electric Bicycle Controller Using Fuzzy Logic**: This study proposes an innovative throttle-less controller for e-bikes, integrating fuzzy logic and deep learning for power management. By removing the traditional throttle, this approach enhances rider experience, optimizes battery consumption, and adapts to different terrains and conditions.(Patil et al. (2023))

2.2 Limitation of State of the Art techniques

While current technologies bring notable improvements, several limitations remain:

- **Reliability of Power Management**: Although controllers like FLC enhance power efficiency, maintaining reliability under varied environmental conditions remains challenging.
- **Battery Longevity**: Despite advanced cooling and BMS, battery longevity can still be a limiting factor, especially under high load or continuous use.
- **Throttle-Less Control Limitations**: Throttle-less designs improve rider experience but may not be as adaptable across all types of terrain, which can limit their broad application.
- **Cost and Weight Constraints**: Advanced BLDC motors and controllers add to both the cost and weight, which may restrict widespread adoption.

2.3 Discussion and future direction

Future work in e-bicycle technology can focus on:

- **Enhanced Battery Life**: Research into more efficient battery types or alternative energy sources, such as solar energy integration, could further increase battery life and reduce environmental impact.
- **Improved Controller Designs**: Adaptive control methods, such as hybrid controllers combined with AI algorithms, could provide better responses under variable conditions and enhance user experience.
- **Multi-Functionality**: Integrating more features, such as GPS tracking and advanced safety mechanisms, could make e-bicycles more practical for urban commuters.

2.4 Concluding Remarks

The state-of-the-art technologies in e-bicycles present viable solutions for sustainable transportation, addressing some key challenges in urban mobility. However, ongoing research is needed to overcome current limitations, such as battery life, adaptability, and cost-effectiveness. With continued innovation, these improvements can pave the way for more accessible and eco-friendly e-bicycles, contributing to a sustainable urban future.

Chapter 3

Problem Definition and Scope

3.1 Problem statement

With rising concerns about pollution, traffic congestion, and the need for sustainable transportation, there is a growing demand for eco-friendly and efficient commuting solutions. Traditional bicycles and e-bikes address some of these issues but have limitations regarding battery management, rider safety, and adaptability to various urban terrains. This project aims to design and fabricate a retrofit e-bicycle equipped with advanced components and smart technologies, including battery health monitoring, human health sensors, and a throttle-less control system, to overcome these limitations and offer an enhanced, sustainable commuting option.

3.2 Goals and Objectives

The primary goal of this project is to design and fabricate an advanced retrofit e-bicycle that not only offers a sustainable and eco-friendly mode of transport but also integrates intelligent technologies to enhance the user experience. The e-bicycle will utilize a brushless DC (BLDC) hub motor to deliver efficient and reliable propulsion, while lithium-ion batteries and supercapacitors work in tandem within an optimized battery management system (BMS) to ensure long battery life and rapid recharge capabilities. The project also aims to incorporate a variety of sensors to monitor both the e-bicycle's operational health and the rider's physiological state, including heart rate and SPO2. Additionally, the bicycle will feature throttle-less control using fuzzy logic for smooth, adaptive motor response, creating a more intuitive riding experience. Further objectives include implementing a compact and foldable design for convenience, as well as an anti-theft mechanism for enhanced security. Through these innovations, the project strives to deliver an e-bicycle that is practical, safe, and adaptable to modern urban transport needs.

3.3 Scope and Major Constraints

Scope: This project aims to create a prototype e-bicycle that serves as a sustainable, eco-friendly alternative for urban transportation. The design will incorporate a smart battery management system using supercapacitors and lithium-ion batteries to enhance energy storage and extend battery life. Additionally, sensors will be integrated for battery health monitoring, including voltage and temperature, as well as for rider safety, with metrics such as heart rate and SPO2 to track real-time health conditions. To optimize rider experience, a throttle-less control system using fuzzy logic will be developed, managed by the C2000 microcontroller for seamless operation. The e-bicycle is also designed to be foldable for easy transportation, with an anti-theft system to ensure security. By combining these technologies, the project will deliver a versatile, efficient, and safe commuting option for urban environments.

Major Constraints: This project faces several constraints that impact its design and implementation. The high cost of advanced components, such as the C2000 microcontroller, supercapacitors, and lithium-ion batteries, presents a significant budgetary challenge. Additionally, while the battery management system aims to improve energy efficiency, the natural limitations of lithium-ion battery lifespans remain a constraint on long-term usage. The compact and foldable design further adds to the complexity, as it requires the careful integration of multiple components, including sensors and control systems, within a limited space. Another major constraint is the need for real-time data processing capabilities to efficiently handle battery and rider health monitoring, demanding high computational efficiency from the C2000 microcontroller to achieve optimal system performance. These constraints shape the development process and necessitate careful planning and design choices to meet the project's objectives within practical limits.

3.4 Hardware and Software Requirements

Hardware Requirements

- C2000 Microcontroller: For motor control, sensor data processing, and throttleless control.
- Supercapacitors: To store regenerative energy from pedaling and support battery power.
- BLDC Hub Motor: Provides reliable and efficient propulsion.
- Lithium-Ion Batteries: Primary energy source, chosen for its energy density and weight ratio.
- Sensors:
  - Battery Health: Voltage and temperature sensors to monitor battery status.
  - Human Health: Heartbeat and SPO2 sensors to ensure rider safety.

Software Requirements

- Code Composer Studio: For programming and configuring the C2000 Microcontroller.
- MATLAB/Simulink: For simulation and fuzzy logic control design.
- Embedded C Programming: To implement control algorithms and sensor interfaces.

3.5 Expected Outcomes

Enhanced E-Bicycle Prototype: A e-bicycle with advanced components and a user-friendly design, offering sustainable and safe transportation. Smarter Battery Management: Extended battery life and efficient energy use through supercapacitors and a robust BMS. Improved Rider Safety: Integrated health monitoring features for the rider, providing real-time feedback on vital health metrics. User-Friendly Throttleless Control: Smooth and responsive control via fuzzy logic and the C2000 Microcontroller, providing an effortless riding experience. Portable and Secure Design: A foldable e-bicycle with an anti-theft system, designed for convenient transport and enhanced security

Chapter 4

System Requirement Specification

4.1 Overall Description

The project focuses on designing and developing new e-bicycles with advanced features that will improve user experience, safety and efficiency. The system is designed to integrate various technologies, including smart controls, health monitoring sensors and renewable energy to increase performance and efficiency on the bicycle. Many benefits such as battery life, improved performance and autonomy. The system uses an intelligent battery management system (BMS) to monitor and optimize battery usage. A controller will also be used to provide dynamic control for better driving and better energy management. Heart rate and body temperature will provide instant feedback to users. The regenerative braking system helps extend battery life by allowing the bicycle to recover energy during braking. For added security, the system will include an anti-theft feature that allows users to lock and unlock the bicycle remotely. Software products may include data processing algorithms, user interface management, and integration with external devices such as smartphones for remote monitoring. The entire system is designed to be modular and scalable, allowing it to be adapted to different customers and bicycle models.

4.1.1 Block diagram/ Proposed System setup

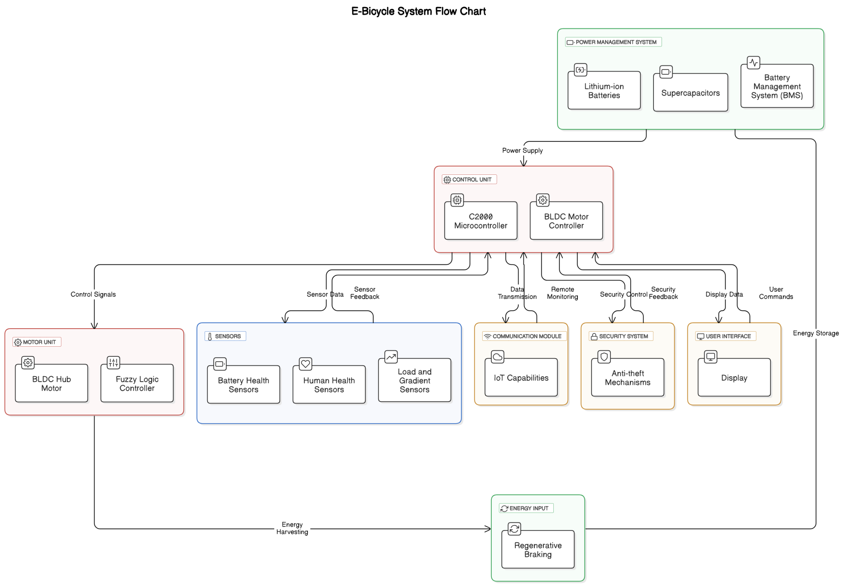

Figure 4.1: Block Diagram of system

The block diagram illustrates the design of an advanced e-bicycle system, integrating various components for efficient operation, monitoring, and safety. At the core of the system lies the Power Management System, which includes lithium-ion batteries, supercapacitors, and a Battery Management System (BMS). This section ensures proper energy storage and supply for the bicycle's functioning.

The Control Unit comprises a C2000 microcontroller and a BLDC motor controller, responsible for managing power delivery to the motor and processing signals from sensors and other modules. The Motor Unit features a BLDC hub motor and a fuzzy logic controller, working together to drive the bicycle while optimizing performance based on input signals.

The system employs a variety of Sensors to monitor critical parameters. Battery health sensors track the condition and performance of the batteries, human health sensors monitor the rider's physical state for safety, and load and gradient sensors measure the weight on the bicycle and the slope of the terrain to adjust power delivery accordingly.

For energy efficiency, the Energy Input section utilizes regenerative braking to convert mechanical energy into electrical energy, which is then stored in the power system.

The Communication Module with IoT capabilities enables remote monitoring, data transmission, and connectivity, enhancing user experience and system diagnostics.

To ensure safety, the Security System incorporates anti-theft mechanisms to protect the bicycle from unauthorized access. The User Interface provides a display that shows real-time data such as speed, battery status, and system alerts while allowing the rider to input commands.

4.1.2 Circuit Diagram and explanation

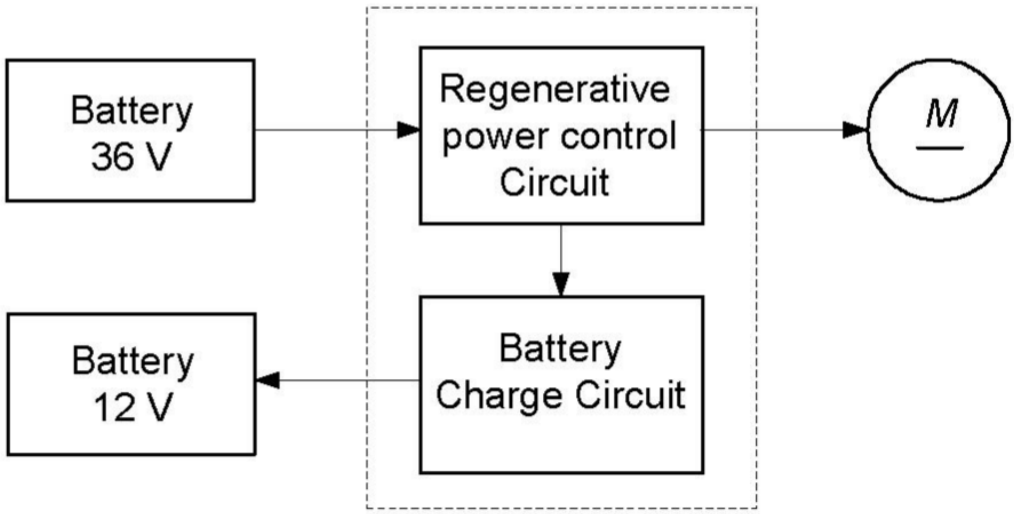

Figure 4.2: Circuit Diagram of E-Bicycle

This diagram is portraying the guideline of power control circuit operation of an Electric bicycle. The control circuit is isolating to two parts for inspection the status of regenerative control and battery charger control circuit. The guideline operation of control circuit is appear in this detail. (Cheng et al. (2010))

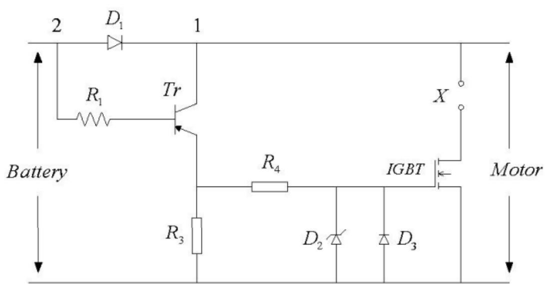

Figure 4.3: Regenerative Power Status Inspector of Battery Circuit Diagram

This circuit utilized to look at the regenerative power status by checking the greatness of voltage at the output of circuit. The strategy in arrange to inspection accomplished by interfacing a wire on a post of motor position comparison with input voltage by associated on a post of battery position. If extents on the yield voltage are greater than input voltages, a regenerative control control circuit is working by transmitting an electric flag to battery charger circuits working agreeing to this method.(Cheng et al. (2010))

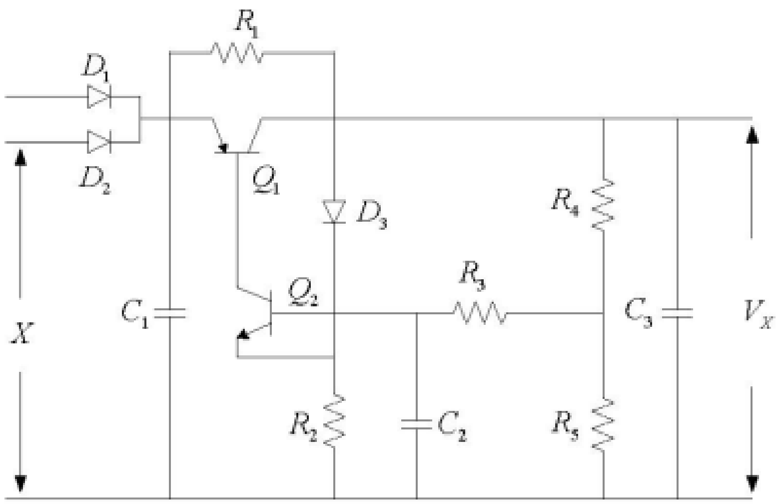

Figure 4.4: Battery Charger Circuit Diagram

The circuit illustrates the operation of a battery charger powered by a regenerative power circuit. The voltage at the "X" position of the regenerative circuit serves as the input voltage for the battery charger. The charging process is initiated when this input voltage activates the components of the circuit. Specifically, the current flows through resistors R1, R4, and R3, which sequentially activate the transistors Q2 and Q1. Once Q1 enters the ON state, the circuit produces an output voltage at point VX, which is utilized to charge the battery. This design efficiently harnesses the regenerative power, ensuring a reliable charging mechanism for the battery while maintaining the circuit's functionality.(Cheng et al. (2010))

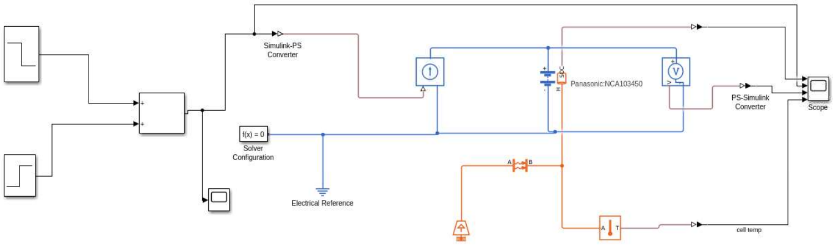

Figure 4.5: Simulink Diagram of BMS

The Simulink graph speaks to a Battery Administration Framework (BMS) outlined to screen and control the execution of a battery pack. The show coordinating different components to mimic and analyze basic angles of battery behavior. It incorporates a battery demonstrate that gives information such as cell voltage, state of charge (SOC), and current. The framework moreover joins converters to handle electrical signals, guaranteeing compatibility between distinctive pieces. Also, it highlights components to reenact and screen parameters like cell temperature, empowering security and execution examination. The visual yields shown on the scope piece encourage real-time perception of the battery's key measurements, making the show a important apparatus for understanding battery execution beneath different conditions.

4.1.3 Mechanical Drawing

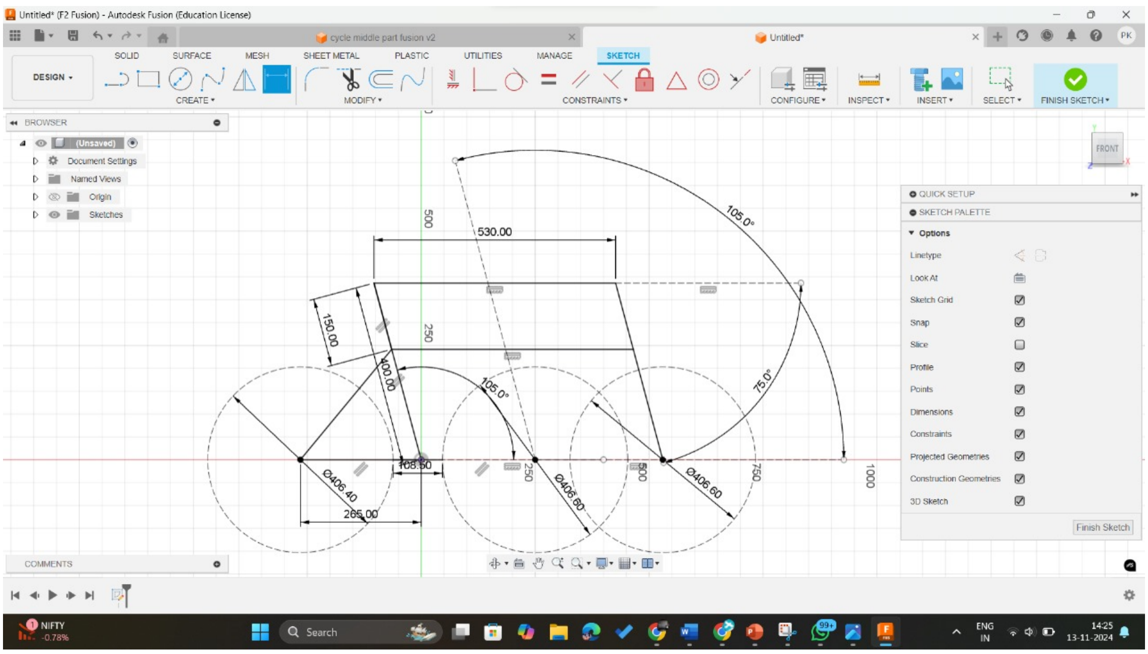

Figure 4.6: Mechanical drawing of Bicycle

Folding Mechanism in Top Tube Top Tube Design (Telescoping Mechanism):

Two-Part Design: Divide the top tube into two sections — a larger section near the seat tube and a smaller, telescoping section near the head tube and handlebars. Inner Tube Sizing: The interior of the larger section should closely match the diameter of the smaller tube, allowing it to slide smoothly inside but still fit snugly to avoid wobbling. Friction or Locking Mechanism: To keep the telescoping tube secure when extended, consider adding a friction lock, twist-lock, or a push-button latch that allows it to lock in both the extended and retracted positions. Telescoping Movement:

Slide Mechanism: When folding, the smaller tube slides into the larger tube, effectively reducing the length of the top tube by half. This also brings the front and rear wheels closer together, making it more compact.

4.1.4 Use Case Diagram

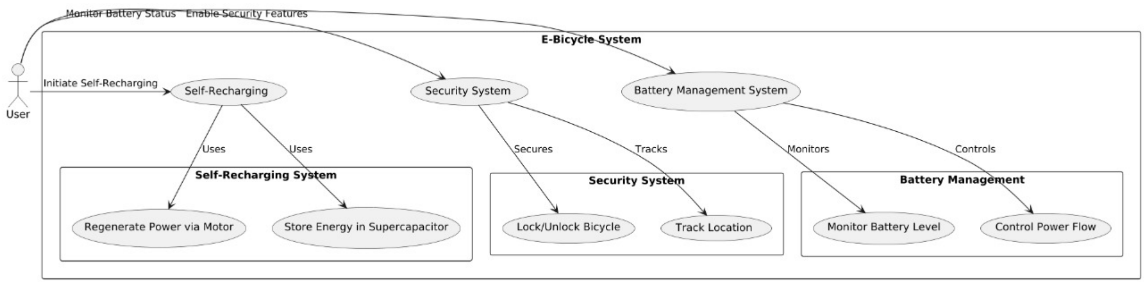

Figure 4.7: Use Case Diagram

The diagram depicts the different systems of an e-bicycle. The user can initiate the self-recharging system. The self-recharging system can regenerate power via the motor and store energy in the supercapacitor. The security system can lock and unlock the bicycle and track its location. The battery management system controls the flow of power, monitors the battery level.

4.1.5 Sequence Diagram

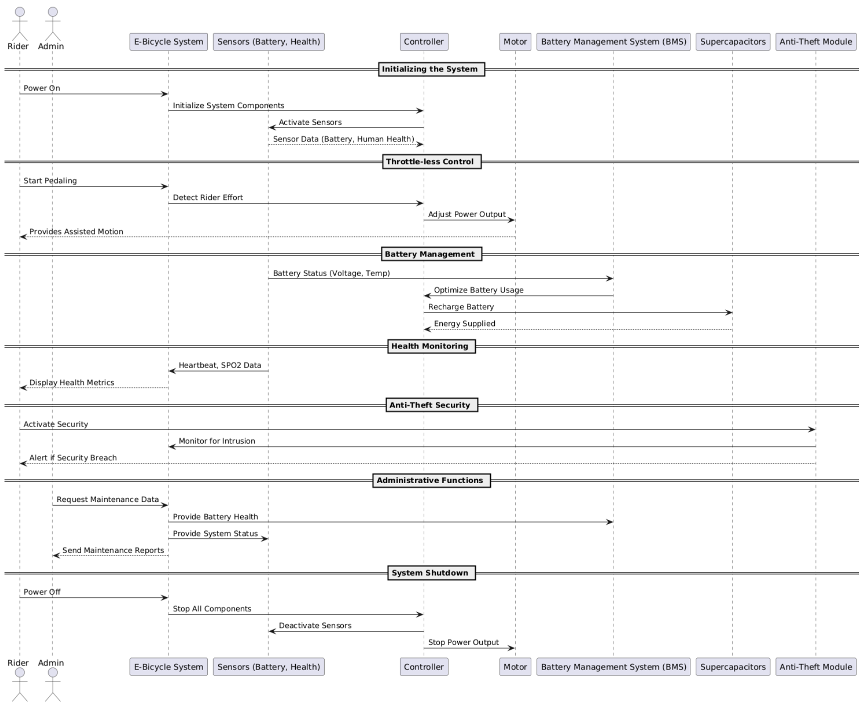

Figure 4.8: Sequence Diagram

Rider and Admin are the users of the E-Bicycle system. The system consists of E-Bicycle system, Sensors, Controller, Motor, Battery Management System, Supercapacitors and Anti-theft module. When power is turned on, the system initializes by initializing system components and activating sensors which gather sensor data from the Battery and the Human health. Then Throttle-less control adjusts the power output. Battery management optimizes battery usage, recharges battery and supplies energy to the system. Health monitoring receives Heartbeat and SPO2 data. Anti-theft security monitors for intrusions. The system can request maintenance data and provide battery health and system status as well as send maintenance reports. Finally, the system shuts down by stopping all components and deactivating sensors.

4.1.6 Activity Diagram

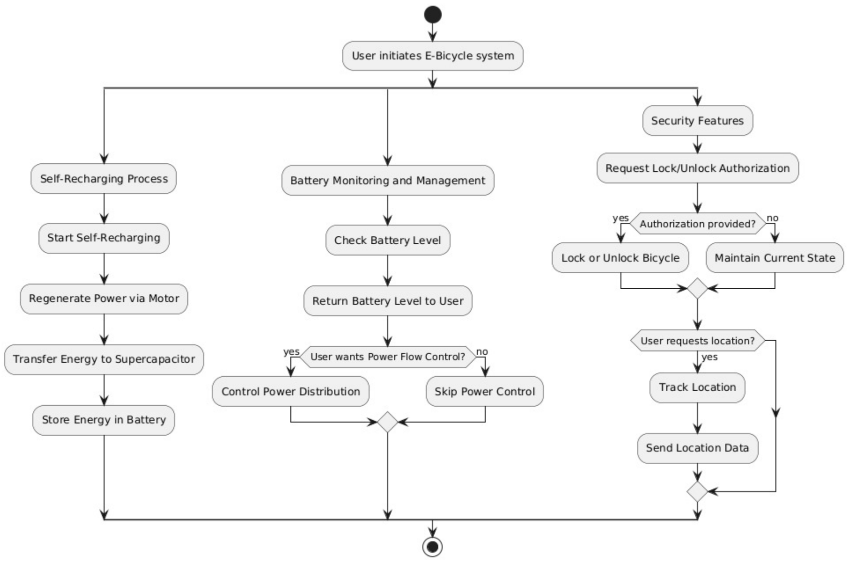

Figure 4.9: Activity Diagram

The activity diagram depicts the flow of a user interacting with an E-Bicycle system. The user begins by initiating the system, which then prompts the system for security features and authorization. Once authorized, the user can lock or unlock the bicycle. Depending on the user's input, the system will either control the power flow or skip power control. If the user requests the location, the system will track the location and send it to the user. The system also has a self-charging process, which regenerates power through the motor and stores it in the battery. The battery level is monitored and managed throughout the process.

4.1.7 Hardware and Software Requirements

Hardware Requirements:

- C2000 Microcontroller: For motor control, sensor data processing, and throttleless control.
- Supercapacitors: To store regenerative energy from pedaling and support battery power.
- BLDC Hub Motor: Provides reliable and efficient propulsion.

- Lithium-Ion Batteries: Primary energy source, chosen for its energy density and weight ratio.
- Sensors:
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Software Requirements:

- Code Composer Studio: For programming and configuring the C2000 Microcontroller.
- MATLAB/Simulink: For simulation and fuzzy logic control design.
- Embedded C Programming: To implement control algorithms and sensor interfaces.

4.2 Project Planning

The "Smarter Electric Bicycle" project has been carefully planned to ensure smooth progress and successful completion. The first step was to study and understand the work already done in this field by looking at research papers and other sources. This helped us find new ideas and gaps that we could focus on, like making the bicycle throttle-free, improving energy usage, and adding features like health monitoring and anti-theft systems. These studies gave us a clear direction for building our project.

After the research, we worked on designing models and diagrams to explain how the system would work. We created a block diagram to show the key parts of the bicycle, such as the power system, batteries, sensors, and security features. A use-case diagram was made to show how users will interact with the bicycle, focusing on features like safety, health monitoring, and energy efficiency. A sequence diagram was also prepared to map out the step-by-step flow of actions between the parts of the system, helping us understand how everything fits together.

We then outlined the methods we will use to build the project. This includes deciding on the system's structure, using mathematical models to predict performance, and setting specific goals, like saving power and improving the user experience. We also planned the circuit design to connect the sensors, batteries, and motor, ensuring that all parts will work together properly.

The project plan is divided into stages. First, we will choose the right hardware, like sensors, a controller, and the motor. Then, we will test each part separately to make sure they work as expected. After that, we will combine everything and check if the whole system works smoothly. Features like energy regeneration, IoT connectivity, and health monitoring will be added step by step to meet our goals.

Chapter 5

Proposed Methodology

The proposed methodology for the Smarter Electric Bicycle project outlines the systematic approach taken to design, develop, and refine an innovative e-bicycle that is efficient, user-friendly, and sustainable. This chapter details the key components, objectives, and processes that drive the project forward.

5.1 System Architecture

The framework design of the proposed e-bicycle integrates advanced components and technologies to create an efficient, intelligent, and user-friendly system. At the core of the system is the C2000 microcontroller, which acts as the brain of the e-bicycle. It manages motor control, processes sensor data, and ensures smooth communication between various subsystems. The propulsion system uses a BLDC hub motor, selected for its ability to provide smooth and efficient movement while using minimal energy.

The e-bicycle's energy is stored and managed through a combination of lithium-ion batteries and supercapacitors, which ensure consistent power delivery and support regenerative braking. A Battery Management System (BMS) continuously monitors key factors like voltage, current, and temperature to maintain battery health and prevent damage caused by overcharging or overheating.

Several sensors are included in the design to monitor both the performance of the e-bicycle and the rider's safety. Battery health sensors monitor the condition of the batteries, while load and gradient sensors measure the terrain and the rider's weight to adjust motor power accordingly. Additionally, health sensors track metrics such as heart rate and oxygen levels (SPO2), providing real-time feedback to ensure the rider's safety during use.

The control system uses fuzzy logic to enable throttle-free operation. This system processes data from sensors to automatically adjust motor power based on factors such as terrain, speed needs, and rider input. This removes the need for manual throttling, making the e-bicycle easier and more comfortable to use.

For added safety, the design includes an anti-theft system with locking features and location tracking. An IoT-enabled communication module allows real-time data sharing, enabling remote monitoring of the e-bicycle's status and condition. A user interface is also included, displaying essential information such as speed, battery level, and alerts in a simple and easy-to-understand manner. To enhance portability, the e-bicycle has a foldable frame for easy transport.

This robust design ensures the e-bicycle delivers high performance, energy efficiency, and safety, making it an excellent solution for modern urban transportation.

5.2 Objective Function

The objective of this project is to improve the efficiency, reliability, and ease of use of the e-bicycle while reducing energy consumption and increasing battery life. Achieving this involves balancing several factors, including motor performance, battery usage, and rider comfort.

One main goal is to ensure an effective balance between power output and energy savings. The motor's torque and speed are adjusted automatically based on the rider's needs. The use of regenerative braking captures energy during deceleration, converting it into electrical energy that is stored in the supercapacitors. This process reduces overall battery usage and extends the e-bicycle's range.

Another important aspect is ensuring rider safety and comfort. The fuzzy logic controller adapts to different terrains and riding conditions in real time. For example, the system reduces power output during downhill rides and provides additional assistance during uphill climbs, offering smooth and consistent performance across various environments.

Battery life is extended by using a Battery Management System (BMS), which monitors and maintains proper charging and discharging cycles. This prevents overloading and overheating, helping to improve the overall lifespan of the battery system.

Rider health is also a priority. Sensors that track real-time data, such as heart rate and oxygen levels (SPO2), alert the system or the rider to any potential health risks. This feature ensures a safer and more enjoyable riding experience.

In summary, the objective of this project is to design an e-bicycle that is energy-efficient, reliable, safe, and tailored to the needs of urban commuters. It focuses on providing a practical and sustainable solution for modern transportation.

5.3 Approach

1. Component Selection and Integration The first step involved selecting the right components to meet performance and functionality requirements. The C2000 microcontroller was chosen for its ability to handle real-time control and data processing efficiently. The BLDC hub motor and lithium-ion batteries, supplemented by supercapacitors, were selected for their high performance and energy efficiency.

2. Throttle-less Control Design A fuzzy logic control system was developed to enable throttle-less operation. The system uses input from sensors, such as gradient, load, and human health data, to dynamically adjust motor speed and torque. This eliminates the need for manual throttle control, enhancing rider convenience and safety.

3. Regenerative Braking The energy regeneration feature was incorporated to capture and store mechanical energy during braking. This energy is then

stored in supercapacitors and used to power the motor, reducing overall energy consumption and increasing battery longevity.

4. Battery Management System (BMS) The BMS was implemented to monitor battery health, manage energy usage, and ensure safety. Parameters such as temperature, voltage, and state of charge (SOC) are continuously monitored, with real-time adjustments made to optimize performance.

5. Health Monitoring and Safety The integration of human health sensors allows the system to monitor the rider's heart rate and oxygen levels, providing alerts in case of abnormalities. The anti-theft system ensures security, while a foldable design adds portability for urban users.

6. IoT and Communication Module To enhance connectivity, the system includes IoT capabilities for remote monitoring and diagnostics. The communication module allows data exchange between the bicycle and external devices, enabling features like location tracking and maintenance alerts.

7. Testing and Iteration Each component was tested individually before being integrated into the complete system. Iterative testing ensured that the system met performance expectations, with adjustments made to improve efficiency and user experience. Special attention was given to fine-tuning the fuzzy logic control and BMS functionality.

System Features and Benefits: The proposed methodology results in a highly efficient, intelligent, and safe e-bicycle with the following features:

Adaptive Performance: Real-time adjustments to power delivery based on terrain and rider input ensure a smooth and responsive riding experience.

Energy Efficiency: The combination of regenerative braking, supercapacitors, and optimized battery management significantly reduces energy consumption.

User-Centric Design: Health monitoring, anti-theft mechanisms, and a user-friendly interface prioritize rider safety and convenience.

Sustainability: The use of renewable energy through regenerative braking and efficient power management aligns with eco-friendly goals.

This structured and methodical approach ensures that the e-bicycle is not only functional and reliable but also meets the demands of modern urban commuters seeking sustainable transportation solutions.

Chapter 6

Conclusion

6.1 Conclusion

This project establishes the foundation for creating a smart, sustainable, and technologically advanced electric bicycle that overcomes the shortcomings of traditional bicycles and existing e-bikes. Through a thorough literature review, we recognized the necessity for better efficiency, improved safety features, and greater environmental sustainability in urban transportation. The proposed design features a BLDC hub motor for effective power transmission, lithium-ion batteries complemented by supercapacitors for enhanced range and longevity, and advanced sensors to track battery health and rider well-being. Furthermore, we have envisioned intelligent control systems that employ fuzzy logic for throttle-less operation and dynamic power management. The addition of health monitoring systems, including heartbeat and SpO2 sensors, highlights the potential of this project to offer not only transportation but also a health-focused integrated solution. While the implementation phase is still pending, the detailed system architecture, use case analysis, and methodology developed during this stage lay a strong groundwork for future progress. This project aims to transform urban mobility by providing an eco-friendly, efficient, and user-centered option for short to medium-distance travel.

6.2 Future Scope

As we enter the implementation phase, numerous opportunities for improvement and innovation arise. We can develop advanced control systems by integrating real-time machine learning algorithms for dynamic power management and predictive maintenance. Expanding connectivity through IoT capabilities will allow for remote monitoring, data analysis, and smooth integration with smart city infrastructure. We should also consider energy harvesting methods, like regenerative braking and solar energy integration, to boost energy efficiency. The precision of health monitoring sensors can be further enhanced, using the data to offer personalized feedback to users. Scalability can be achieved by creating modular components that can adapt to different bicycle designs and meet various user needs. Furthermore, a strong anti-theft system can be designed and incorporated into the overall framework, improving security and user trust in the system.

Appendices

Appendix A

Sponsorship Certificate

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