ECE 445 - Senior Design Project Proposal

Electric Bicycle with Fully Electric Architecture

Spring 2023

Team 15

Ellie Urish

Jason Zou

Willard Sullivan

1 Introduction

1.1 Our Problem:

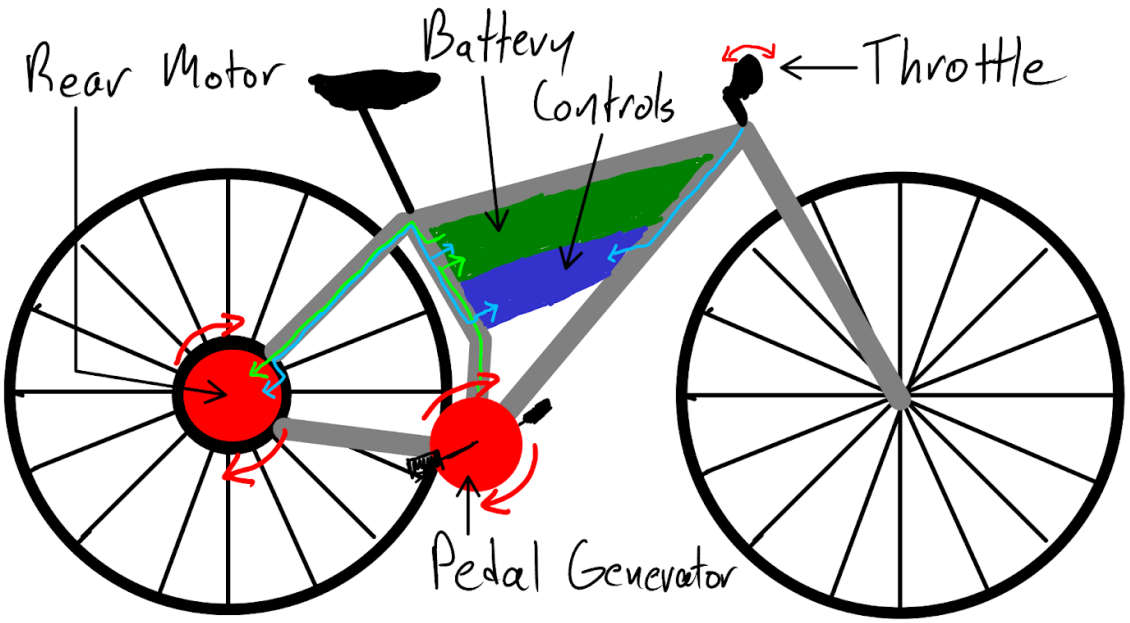
Most current electric bikes use a combination of chain and motor to provide pedal assistance. The issue with these systems is the complexity of dealing with a chain and motor simultaneously. The complexity of these systems that are constantly exposed to the elements means that durability is a concern. This problem is especially prevalent with bike sharing programs, where easy maintenance and care is essential to keeping costs down.

1.2 Our Solution:

Our idea is to construct an electric bike/moped that is fully powered by electricity, which means that instead of using a chain to transfer human power to the wheels, the pedals would instead be connected to an electric generator which would then feed a motor for the wheels.

While this configuration is not as efficient for driving the wheels as a direct chain would in terms of just human power, it allows for a very simple mechanical design with few moving parts. This could allow for very little maintenance, as there is no longer a chain or gears to take care of. Furthermore, most of the components can be sealed away from the elements by mounting them internally to the bike frame or within sealed containers that can be mounted to the bike frame. Additionally, an all electric system would also allow for regenerative braking (a reach goal) to be implemented more elegantly, allowing for energy to be recovered during braking and a better experience on hilly terrain while also reducing wear on the brakes.

1.3 Visual Aid:

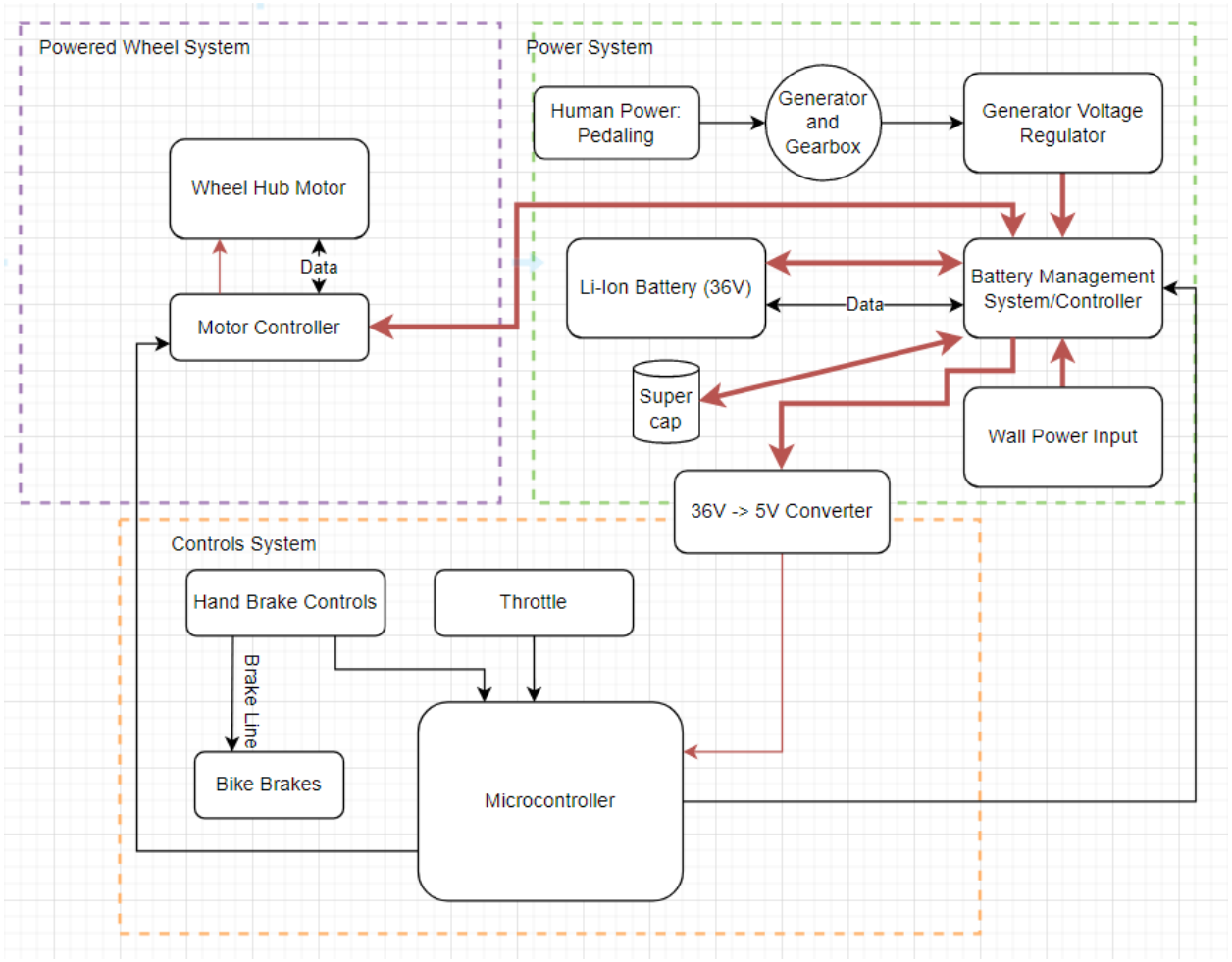


1.4 High-Level Requirements List:

- The Power System will be able to properly manage combined input power sources and effectively distribute power to the Powered Wheel and Controls Systems.
- Rear wheel motor can propel the vehicle to 5 mph on flat ground with ~180 pounds of load.
    - Note that this is a prototype, ideally this vehicle will be much more capable.
- Motor speed can be controlled through a throttle system by the user.
- Must have at least 40% efficiency of power conversion from pedaling to electricity.

2 Design

2.1 Block Diagram:



2.2 Subsystem Overview:

Subsystem 1 - Power System

The purpose of the generator is to generate electricity from the mechanical rotation of the pedals, aided with a gearbox to achieve a better mechanical advantage. We plan on using a 36V generator attached to the crank/pedals, which should be achievable due to our previous research on components. On top of this, if the user desires, they can use the onboard battery to supply additional power to the rear wheel or act as a replacement to pedaling. One of our main goals is to make this system as durable as possible, so the generator subsystem will be completely enclosed and mounted securely on the bike frame. The Power subsystem will be connected to the Controls/Electronics subsystem so power is adequately distributed and managed.

Subsystem 2 - Powered Wheel System

The Powered Wheel subsystem will be connected to the Controls/Electronics subsystem to provide power rotation to the rear wheel. The drivetrain will consist of a motor that is connected to the rear wheel's hub and is able to be controlled by a potentiometer throttle from the handlebars. We plan to use a 36V DC motor, ideally controlled with an off-the-shelf motor controller to encourage optimal efficiency.

Subsystem 3 - Controls System

The Controls system will have the ability to route the generative power to the drivetrain or to the battery. With the assistance of a PID controller to optimize the power output of the generator (which will vary from the rider), our subsystem can be more efficient and limit the power consumption of the drivetrain subsystem. Furthermore, as an additional goal for our project, we aim to have this subsystem control the "launch control" of the bike so that the user does not have to struggle with starting at rest. The electronic system will be based on a custom PCB with a microcontroller and output pins to connect to other components. It will control charging/discharging of the battery, speed of the drive motor, and reading the potentiometer to determine desired speed. The braking system also falls under the controls system, although we are leaving it mechanical for safety reasons, we will use the normal handbrakes on the bike frame we are using. However, if the bike brakes are pressed, we will cut power to the motor to save energy.

2.3 Subsystem Requirements:

Subsystem 1 - Power System

- Supply 36V +/- 1V to the Powered Wheel System at up to 7A
- Supply 5V +/- 0.1V to the Controls System at up to 1A
- Regulate input from generator to to charge 36V Battery

The Power System, which will use the tandem pedaling generation and battery powers, will supply 36+/-1V to the Powered Wheel System and 5+/-.1V to the Control System. The Power System is essential to this project as without this subsystem, the rest of the bicycle will not function. The generator/gearbox aspect of this subsystem is also essential to maintain the scope of this project's goal - reusability and regenerability of an electric bicycle. This system has some redundancies as it has two power sources.

Subsystem 2 - Powered Wheel System

- Drive wheel motor with 36V input from Power System
- Accept speed control signal from microcontroller
- Transmit encoder signal from wheel motor to microcontroller

The Powered Wheel System will draw 36+/-1V from the Power System and will utilize data from the Control System to operate correctly. This system is essential as this system is required to propel the bicycle. Additionally, this system is especially vulnerable since it is dependent on both the Power and Control Systems to operate correctly. Failure with the motor controller or the hub motor will result in complete failure of this subsystem.

Subsystem 3 - Controls System

- Process throttle input to determine desired motor speed
- Control speed of rear wheel motor, using encoder signal to correct for error
- Send control signals to Power system to control battery charging/discharging

The Controls System will draw 5+/-.1V from the Power System to power the various electronic components, being the throttle controls and the microcontrollers, as well as send data to the motor controller in the Powered Wheel System to carefully control the hub motor. Along with the other subsystems, this one is also essential for the general operation of the bicycle; if any one of the main components fail, the bicycle will cease to operate. The Controls System will also help us obtain our goal of 40% efficiency as it can have the capability to restrict power draw to the hub motor.

2.4 Tolerance Analysis:

Currently, a main concern of our design is the overall cost and efficiency - without the ability to use high performance components, our bicycle will suffer. Due to this, we may have to scale down our project to use less powerful components with the objective of proving that our generator/battery power system with a control system will function. There is a possibility of scaling our prototype back to 12V so we can obtain quality components to achieve our efficiency goal without going over budget.

3 Ethics and Safety

With any transportation device, the user not only assumes various types of risk, but also is able to assume a level of trust with their vehicle. As outlined in Section 1.2 in the ACM Code of Ethics, the statement “ensure that all harm is minimized” [1] stands out to us. To ensure we achieve this, one of our requirements is to keep the three subsystems adequately contained so there is no risk of electrocution. Furthermore, we plan to limit the acceleration and top velocity of the bicycle to discourage reckless use. The main braking system of the bicycle will also be a standard bicycle braking system that is mechanical and separate from the main control system to ensure that the user will always be able to come to a stop safely.

Our product falls into a gray area - it is not necessarily a bicycle, nor is it a Moped. In the State of Illinois, our type of vehicle falls best in the Electric Bicycle category, which is a bicycle that has some sort of assistance by a gas or electric motor. These vehicles, in the state of Illinois, “are legally bicycles, as long as their motors are smaller than 750W (one horsepower) and their pedals are fully functional.” [2]. Electric Bicycles are subject to the same laws as bicycles, but also do not require insurance nor registration - to abide by the ACM Code of Ethics, we will encourage users to have some type of liability insurance or make sure they are well versed in the risks of using this type of vehicle, including wearing usual protective equipment such as a bicycle helmet.

4 References

1. “The code affirms an obligation of computing professionals to use their skills for the benefit of society.,” Code of Ethics. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 09-Feb-2023].
2. “Illinois laws for moped, scooter, and Electric Bikes,” Horwitz, Horwitz & Associates, Ltd., 16-Sep-2022. [Online]. Available: https://www.horwitzlaw.com/blog/illinois-moped-laws/. [Accessed: 09-Feb-2023].