E-Bike Share Model Optimization

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Group ID: 17

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I. Objectives

- Implement a DC generator that can be integrated onto e-bikes to generate electricity while the rider is cycling.
- Design a DC-DC voltage regulator to manage the electricity generated by the DC generator, ensuring a stable and controlled charging process for the existing e-bike battery.
- Develop a battery monitoring system using Arduino ATMega2560 microcontroller to accurately measure and track the charging and discharging process of the e-bike battery.
- Integrate an energy meter using Arduino LCD display to provide real-time data on the battery's state of charge, enabling a fair and transparent distance-based billing model, eliminating the shortcomings of the pay-per-minute billing model.

This project aims to design an efficient e-bike battery charging and monitoring system that promotes e-bike ridership by providing cost-saving benefits for the riders. This system will enhance the convenience and accessibility of e-bikes, improve billing accuracy and transparency, and contribute to the growth of the city's e-bike share programs.

II. Introduction

City-owned e-bike share programs typically implement a pay-per-minute billing model. In this system, riders are charged for unlocking the bike at the dock and for every minute they have possession of the bike, regardless of whether they are actively riding it. An example of such a model can be found in the e-bike share program operated by the city of Vancouver. Upon unlocking the bike, riders are charged $1.50, and subsequently billed at a rate of $0.35 per minute. While this pricing structure may suit daily commuters traveling directly from point A to point B, it may not be ideal for visitors who wish to leisurely explore the city on an e-bike.

Vancouver's downtown area, along with its beautiful parks and beaches, offers a plethora of attractions that can take hours to fully appreciate. Therefore, expecting visitors to pay $0.35 per minute, or $21 per hour for bike usage may be perceived as excessive. This pricing scheme could discourage tourists who wish to take their time exploring the downtown core and its surroundings, giving the impression that the city's e-bike share program is not particularly tourist-friendly.

The purpose of this project is to design an innovative e-bike battery charging and monitoring system that aims to offset the cost of renting out e-bikes for the city-owned e-bike share programs. With the increasing popularity of e-bikes in major cities like Vancouver and Victoria, this project seeks to leverage this trend by offering free rentals and a distance-based billing model as incentives to encourage more riders, particularly tourists, to choose e-bikes for their daily commutes and recreational activities.

The proposed system centers on the development and implementation of an e-bike battery charging and monitoring system. This system will enable riders to charge the battery while riding, thereby offsetting the cost of rental for the city. To achieve this, a DC generator and voltage regulator will be installed on the e-bikes, allowing riders to contribute to the energy supply during their ride. Although this setup may introduce additional drag, the trade-off is that riders will enjoy a free rental experience. Furthermore, riders will be entitled to utilize the same amount of energy they charged in power assist mode, enhancing their overall riding experience and further incentivizing the use of e-bikes.

The energy charging and consumption will be measured and monitored by a battery monitoring system. This system will provide real-time data on energy usage, ensuring accurate energy metering of the e-bike. This advancement also opens the door to a fairer and more transparent distance-based billing model, eliminating the shortcomings of the pay-per-minute model. Riders can now enjoy accurate and equitable billing, which reflects the actual energy usage during their rental period.

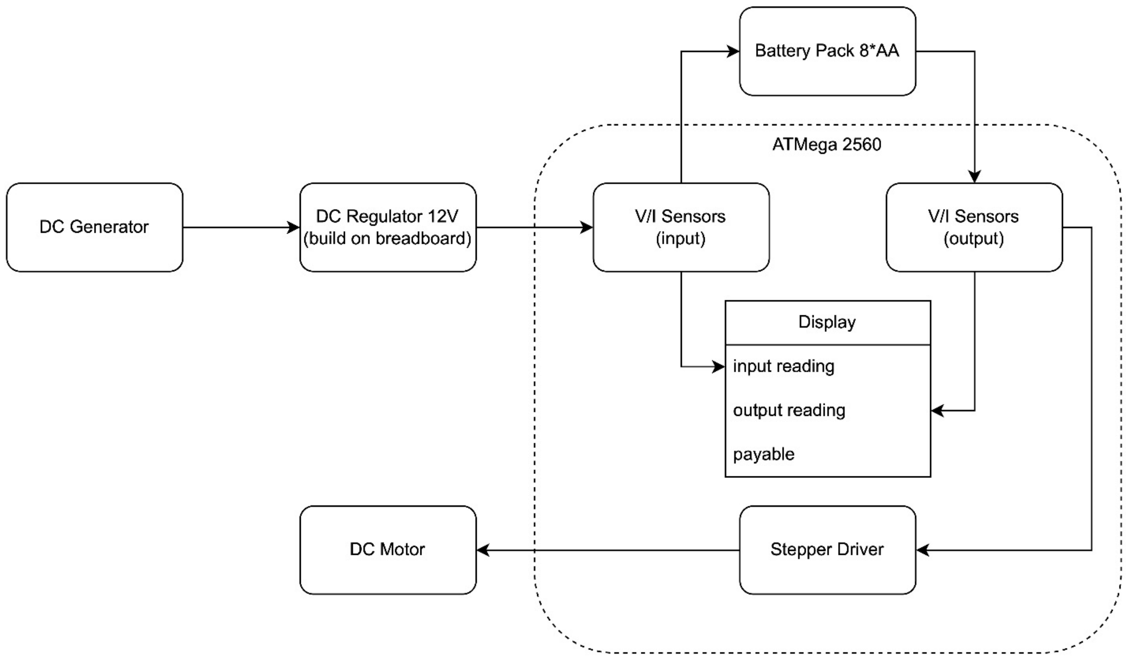


Figure 1: Design Connection Topography

III. Literature Survey & Specifications [1]

The purpose of this section is to review and examine literature focusing on different variations of modern e-bikes used for daily commutes and recreational activities. We will critically and briefly analyze previous research problems and use them for our own study. Whether you've decided to abandon your vehicle for a greener earth by cycling to work or desire an easier voyage through trails or up hills, an electric bicycle can provide numerous advantages over a traditional bicycle, with a motorized power available as needed. As of recent years, electric bike technology has grown at a rapid advanced pace as finding a bicycle with a motor is common.

What is an E-Bike?

It is a bicycle equipped with an electric motor to help you when pedaling which reduces energy required to be put forth by the rider when riding a traditional bike. They amplify your pedaling power which utilize an electric motor and battery to help you power your bike. A rechargeable battery on the bike provides the power required by the motor. The motor on the e-bike on an e-bike must help you instead of propelling you on its own. The amount of power a motor delivers is regulated, depending how hard you're pedaling. E-bikes enable riders to choose modes while considering range and battery life while balancing the power delivered through the pedals.

How does an e-bike work?

A motor is typically mounted centrally on the bike oftentimes mentioned as mid-drive motor or on the front or rear hub. A mid-drive motor works through the e-bikes gears and chain as opposed to hub motor pushes the wheel around directly. A torque sensor will calculate your effort level and compare it to the motor's power output. It is intended that the motor won't assume entire control; instead, a rider should experience steady power delivery that prevents the e-bike from lurching forward. A controller is needed for the motor, typically on the handlebar or implemented somewhere accessible on the bike. The controller lets you choose how much assistance you desire as well as an indication on the battery level.

ELECTRICAL SPECIFICATIONS & FEATURES

We'll now compare a few popular e-bike and their electrical specifications that assist riders when riding an e-bike.

	RadMission 1 [2]	Trek Verve+ 3 [3]	Aventon Pace 500 [4]
Battery	48V, 10.5 Ah (504 Wh), with Lithium NMC 18650	Bosch PowerTube 500, 36 V, 13.4 Ah, 500 Wh	Lithium-ion 48 V, 11.6 Ah (556.8Wh) with Samsung Cells
Display	Rad Power Bikes custom LED display	Bosch Purion	LCD Smart Easy Read Display with Backlight
Motor	500 w Geared Hub Motor with 5:1 Planetary Reduction	Bosch Active Plus, 250 watt, 50 Nm, 20mph or 32km/h	750W (Peak) 48V Brushless Rear Hub Motor 500 W (Sustained)
Pedal Assist	12-magnet, cadence sensing crank mounted up to 20mph	5 level pedal assist	5 levels
Range	25-45 mile range	30 -75 mile range	25-60 mile range
Throttle	Half-Grip Twist Throttle-Right side	No throttle	Lever Throttle, Up to 20mph
Picture			

Comparing these e-bikes and their electrical components, we'll use their specification to size a generator accordingly. Ampere-hour is how much amperage a battery can deliver for precisely one hour using the rating. Watt-hour is equal to one watt of energy of average power flow over an hour.

In order to size a generator, we first need to look at the output wattage the motor produces. Taking the table up above for reference, we know that the typical e-bike battery has 504Wh of capacity. In addition, the motor produces approximately 500W. Looking at the specifications, we know that a generator has to at least produce the same amount of power as the motor or more. Typically a generator only operates at 80% of its capacity, keeping that in mind, the following are the calculations for the desired generator:

Size of the generator = Output Power of Motor/0.8 *   = 500 W/0.8 = 625W[1]

From this equation, we know that the size of a generator needs to be 625W to fully offset the battery and motor.

However, incorporating a generator that is 625W or more will be extremely difficult to place on a bike. Due to that reason, we'll scale down the size of the generator, it won't be able to fully offset the battery and motor. Nevertheless, it will be enough to assist the rider while cycling for a small period of time. Moving forward, our prototype will be scaled down so our values will not be similar to the specifications of rental e-bike.

Circuit Diagram and Programming Logic

To monitor the power consumed, the current sensor (acs712) have to connect to the load (beside the motor) and the voltage sensor connect across the load, which is showed in the circuit diagram below. Similarly, to monitor the power generated, the current sensor (acs712) have to connect beside the regulator, and voltage sensor connect across the regulator. Then using Electric Power Formula P = VI to calculate the power generated and power consumption. And display the value on the 16 x 2 LCD display.

To make the ATmega2560 microcontroller detect the signal from current and voltage sensor, it is designed to use 4 ADC port.

[1] * Generators usually are 80% of its capacity

From the ATmega2560 data sheet, each ACD port have 10 bit resolution (2^10 -1 = 1023), the maximum voltage supply to the ADC from the microcontroller is 5V, to convert the reading to the voltage, the equation is:
Voltage = (reading values) * 5 / 1023.

From the acs712 data sheet, the typical sensitivity is 66 mV/A, the output voltage of the ACS712 sensor is always half value of the voltage when there is no current flowing through it (2.5V). To convert the reading to the current, the equation is:
Current = voltage - 2.5V / 0.066

When all values is measured, the LCD display is expected to show:

Power generated: 0000 W
Power consumed: 0000 W

The unit will adjust based on the readings.

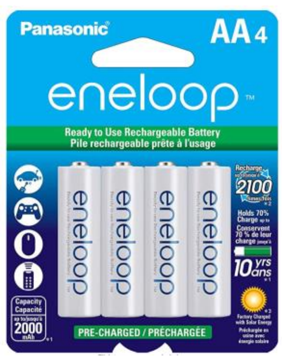
x30A PERFORMANCE CHARACTERISTICS [1]: T_A = –40°C to 85°C, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–30	–	30	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	63	66	69	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
Zero Current Output Slope	$\Delta V_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.35	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.007	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.002	–	mV/A/°C
Total Output Error [2]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2] Percentage of I_P, with I_P = 30 A. Output filtered.

Figure 2: Performance Chart [5]

IV. Bill of Materials

Name	Photo	Price (CAD)	link
acs712 current sensor + Voltage Sensor Module DC		$14.99	https://www.amazon.ca/gp/product/B08BZKPSFY/ref=ox_sc_act_title_5?smid=A22PZZC3JNHS9L&psc=1
8-Slot 1.5V AA Battery Clip Holder Box Case with On/Off Switch		$11.2	https://www.amazon.ca/gp/product/B07H93ZWQT/ref=ox_sc_act_title_4?smid=A10F98Y09YO3EW&psc=1
Rechargeable Batteries (Pack 4) - BK3MCCA4BF		$23.98	https://www.amazon.ca/gp/product/B00JHKSN76/ref=ox_sc_act_title_3?smid=A3DWYIK6Y9EEQB&th=1
16x2 LCD		$13.99	https://www.amazon.ca/KEYESTUDIO-Display-Backlight-Arduino-Raspberry/dp/B0177XQE7K/ref=sr_1_1_sspa?crid=1FD7N89XYPG0K&keywords=lcd+display+arduino&qid=1685747267&sprefix=lcd+display+%2Caps%2C164&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFYMjZRTVBMU1FFWkUmZW5jcnlwdGVkSWQ9QTAwMTI3NDUyUkI0TVFDQlAzWFRFJmVuY3

L298N H Bridge Driver Board		$12.99	https://www.amazon.ca/gp/product/B07C4B3DL4/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&psc=1
DC motor		$22.99	https://www.amazon.ca/gp/product/B0828RRCJK/ref=ppx_yo_dt_b_asin_title_o03_s01?ie=UTF8&psc=1
ATmega2560		$29.99	https://www.amazon.ca/gp/product/B01H4ZDYCE/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1
12 Gauge Electrical Wires		$21.99	https://www.amazon.ca/Cables-Gauge-Silicone-Wire-Black/dp/B0769D5415/ref=sr_1_5?crid=13PKQ2OPJ9ZY6&keywords=12+gauge+wire&qid=1687552152&s=industrial&sprefix=12+gauge+wi%2Cindustrial%2C221&sr=1-5
DC Generator		$33.65	https://www.amazon.ca/Permanent-Reversible-Electric-Generator-3000RPM/dp/B076KMB8GM/ref=sr_1_9?crid=1KTB79RXPVT25&keywords=mini+dc+generator&qid=1687546139&sprefix=mini+dc+generator%2Caps%2C190&sr=8-9#customerReviews

Charge Controller		$17.98	https://www.amazon.ca/Controller-Intelligent-Regulator-Paremeter-Adjustable/dp/B08NFSCZ4V/ref=sr_1_5?keywords=solar%2Bcharge%2Bcontroller&qid=1687553724&sr=8-5&th=1
TOTAL		$139.59	

V. Team Duties & Project Planning

To achieve the successful completion of any project it is very important to define the roles and responsibilities of each team member and to establish clear and precise team deliverables. Our team consists of five people and their roles and responsibilities will listed below:

Dengyao Hou (Daniel):

Having initiated the project and defined its objective and scope, Dengyao has assumed the responsibility of managing the project. He will handle the project management side, which involves overseeing the team's progress and coordinating weekly team meetings. His key role in the project will be to ensure the project objectives are met, keep effective communication among team members, and manage the overall project timeline. Additionally, Dengyao will provide assistance to other team members, particularly Jacky, in the digital circuit design aspect of the project. With his pivotal role, Dengyao will keep the team on track throughout the project's execution.

CheukKi Liu (Jacky):

Jacky will be responsible for the digital circuit design and coding aspect of the project. He will work with an Arduino board (ATmega2560) and perform coding on it. Jacky will be responsible for developing the necessary algorithms for integration of the generator system on the e-bike’s existing components. His deliverable will be the working functional code.

Haris Khattana and Magai Magai:

Haris and Magai will share responsibilities related to the research for the project and gathering materials and information for the report. Their main responsibility is to conduct comprehensive research on existing generator systems-bikes components and any related technologies helping this project. Their deliverable includes compiling their findings into a well-structured report. They will also assist Kenneth with hardware aspects of the project.

Kenneth Jueves:

The primary responsibility for Kenneth will be to work on the analog circuit side of the project. The focus will be dealing with the DC generator and voltage regulator. He will be assisted by Haris and Magai to select the appropriate generator for the project and to design an efficient power generating system. His tasks will include wiring the generator and voltage regulator and ensuring proper connections.

Projects like these always involve some kind of bottlenecks that may arise while working on it. Some of those bottlenecks may include availability of parts/components, technical challenges and any unforeseen obstacles. In case any of these challenges arrive, the team will tackle them by informing our supervisor and asking for advice, exploring different software and hardware solutions or by changing the project scope to adjust our timeline. As a team we are pretty confident and ready to tackle all the problems, we'll achieve our goal by communicating with each other, collaborating effectively and supporting each other.

VI Milestone & Progress Made

The following will be the overview of the key milestones and progress made so far.

On May 19th, our team was formed with our project and a supervisor was assigned. Our team then sat down and started discussing the project's scope and objectives.

From May 20th to June1st, our team dedicated time to focus on early stage research, keeping our scope and objectives in mind the team started looking at existing technology. The research was needed to understand a deeper understanding of our project and highlighting key components, consideration and challenges that may be associated with this project that the team may encounter.

From June 2nd to June 24th, our team is focusing on two main tasks, one is to write the bill of materials (BOM) and second is the design the project. BOM will consist of necessary tools and components that will be vital for the hardware implementation. Secondly, the team has also focused on designing the project which includes the flowchart, hardware and software aspects of the project and how to integrate it.

AS of June 24th, our team has successfully completed the BOM and the flow chart explaining the functionality of the project along with vital research needed for the completion of the project.

Moving forward from June 25th to July 15th, our team's main focus will be to fully engage in the hardware and software implementation of the project. This period will involve working full time on generator wiring and building a voltage regulator and other hardware components of the project. Similarly, the software side will also be worked on which includes coding, integrating sensors and implementing LEDs to show power generated and calories burnt.This time period is a very critical stage where our team will bring the design to life.

By writing down these milestones, the team demonstrates a structured approach to project management. This helps the team to track the progress and ensuring every task is going smoothly.

VII Summary & Future Work

The goal of this project is to provide a working prototype of a scaled down e-bike that incorporates a DC generator and voltage regulator that enables riders to contribute to the energy supply during their ride.

This project will be accomplished on the hardware side by implementing a DC generator that will be mounted on a bike that generates electricity while the rider is cycling. Sizing of the generator is crucial as it will provide the battery power required to assist pedaling.

Incorporation of a voltage regulator will be mandatory in this system. The generation of electricity while the rider is cycling will not be constant, therefore a voltage regulator will generate a fixed output that remains constant regardless of changes of the load conditions for the steady charging process of the battery.

The software aspects of the project will include integrating a Arduino ATMega 2560 microcontroller. The microcontroller programming will involve writing code that controls and executes tasks of accurately measuring and tracking the charging and discharging process of the e-bike battery.

An Arduino LCD display will be implemented as an energy meter that will be programmed to display real-time data. It will ensure accurate energy metering of the e-bike. For this scope of this project, a 16 x 2 LCD will be focused on as it is effective and inexpensive for our prototype of a scaled down e-bike. In the future, we would aim to implement a touchscreen interface.

By the end of this project, our prototype should be able to assist riders while cycling and offset the cost of renting an e-bike. Our innovative technology of monitoring and charging e-bikes battery is intended to reduce the cost of renting out e-bikes for city-owned share programs. In addition, the right to use the same amount of energy that they charge in power assist mode will improve riders' overall riding experiences and encourage more people to use e-bikes.

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