

INTEGRATION OF MOTORIZED BICYCLE FOR SUSTAINABLE COMMUTING

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering in

Electrical and Electronics Engineering

by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS
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SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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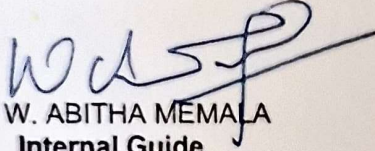
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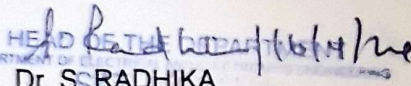
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KISHORE B** (Reg. No. 40140019) and **MOSES RAJ P** (Reg. No. 40140024) who carried out the project entitled "**INTEGRATION OF MOTORIZED BICYCLE FOR SUSTAINABLE COMMUTING** " under our supervision from November 2023 to April 2024.


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HEAD OF THE DEPARTMENT
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Submitted for Viva voce Examination held on

17/4/2024

Name

Signature

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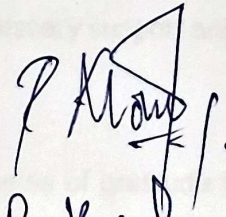
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DECLARATION

We **KISHORE B** (Reg. No. 40140019) and **MOSES RAJ P** (Reg. No. 40140024) hereby declare that the Project Report entitled "**INTEGRATION OF MOTORIZED BICYCLE FOR SUSTAINABLE COMMUTING**" done by us under the guidance of **Dr. W. ABITHA MEMALA** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

1.



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DATE:

17/4/2024

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SIGNATURE OF THE CANDIDATES

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We are pleased to acknowledge our sincere thanks to Board of Management of **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

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ABSTRACT

Speed restrictions are a common problem for electric bicycle drives, which makes it difficult for them to become widely used as effective forms of transportation. The goal of this project is to increase the speed capacity of electric bicycles in order to overcome this obstacle. In order to improve energy storage and enable efficient power transfer and control, we suggest utilizing a Lithium Ferro Phosphate (LiFePO_4) battery in conjunction with a motor controller which is integrated to act as the brains behind the bicycle system, coordinating the smooth operation of different parts. Notably, a BLDC hub motor is suggested because of its exceptional torque, which adds even more to the bicycle's enhanced performance. This study pushes the envelope of efficient and sustainable transportation by improving the technology of electric bicycles.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC- Alternate Current

DC- Direct Current

LFP- Lithium Ferro Phosphate

BLDC- Brush less DC

Ah- Ampere hour

Wh- Watt hour

Bv-Battery voltage

Bc-battery capacity

Bp- Battery power

Cc- Cell Capacity

CV- Cell voltage

Rw- Wheel radius

Nm- Motor speed

Mt- Motor torque

Nw- Wheel speed

Wt- Wheel torque

Mp- Motor power

MUP- Motor useful power

Rpm- rotation per minute

CHAPTER-1 INTRODUCTON

1.1 ELECTRIC BICYCLES-A GENERAL INTRODUCTION

Electric bicycles are becoming more and more popular because they are a practical and environmentally friendly mode of transportation. Electric bicycles are an affordable and green form of transportation, but their limited speed prevents them from reaching their full potential. The primary objective of this project is to achieve a noticeable speed increase while exploring cutting edge methods to get around this restriction and test the limits of electric bicycle drives. This study investigates the intriguing topic of enhancing electric bicycles by applying cuttingedge methods and technologies. The motor controller, which functions as the system's brain, is essential in regulating the motor's speed and direction, improving the electric bicycle's overall performance. To ensure durability and a continuous power supply, the project also makes use of lithium iron phosphate (LiFePO₄) batteries, which are renowned for their long lifespan. The project boosts the electric bicycle's speed even higher by utilising a BLDC hub motor, which is well-known for its power output and efficiency. When coupled, these technologies present a strong argument for overcoming the speed limitations inherent in electric bicycle drives. As the project progresses, it offers informative data regarding the field of electric mobility and promotes the notion of electric bicycles as quick, affordable, and ecofriendly modes of transportation. This introduction establishes the framework for a detailed analysis of the project's components, processes, and expected outcomes in addition to the motivations behind this endeavour.

1.2 HISTORY

Electric vehicles in early stages:

Although the electric vehicles have been around the early 1800s, internal combustion engine vehicles' predominance, concerns about the range, and underdeveloped battery technology have all hindered the widespread use of electric vehicles hindered the widespread use of electric vehicles.

Developments of Electric bicycles:

An important advancement occurred in the late 1990s with the introduction of e-bikes with torque sensors and power controls. One of the first e-bike models with built-in NicCd batteries was the Zike, which Vector Services displayed in 1992. Production of e-bikes increased by 35% between 1993 and 2004, while production of traditional bicycles decreased during that same period. During this time, advances in battery technology also occurred. Lighter and denser batteries were used in later models, which resulted in increased speed and range over lead acid batteries. E-bikes, also referred to as power bikes, or power-assisted bicycles, were well known by 2001. In contrast to earlier models, cogwheel gearing allows modern e-bikes to effortlessly combine motor and human inputs, which leads to effective energy conversion and utilization.

Electric bicycles in the present day:

Evolving after the advancements of the early 1900s the electric bicycles have been developed to the point where they portray some good key advancements. Various manufacturing companies have been producing E-cycles with built-in battery systems and charging ports, allowing users to easily charge the battery by inserting the charger into the designated portal. Additionally, some E-cycles come equipped with a portable charging system. This feature enables the user to eject the battery straight from the battery floor for charging and attach the battery to the floor during their ride. Portable spar parts kits have also been started to be manufactured since the past decade which allows users to customize and assemble their electric bikes, catering to individual preferences and needs very easily. These spar part kits come with either a rickshaw (which is usually attached to the crank) or the hub type motors. In recent years, e-bikes, or electric bicycles, have become increasingly popular as an eco-friendly and practical form of transportation. Modern e-bikes offer increased power, efficiency, and range thanks to developments in battery and motor technology. They offer a more environmentally responsible option to conventional cars, encouraging better lives and lowering carbon emissions. Furthermore, e-bikes are being used more and more for commuting, leisure, and last-mile transportation in cities, which is indicative of a growing trend towards sustainable mobility.

Electric bicycles in the future:

Longer ranges for E-cycles will happen in the future due to advancements in battery technology, including increased energy density, rapid charging, and the introduction of advanced battery types like lithium iron phosphate and lithium nickel- manganese-cobalt oxide. The development of more powerful, efficient, and adaptable electric bikes is being fueled by advancements in brushless motor technologies such as BLDC, lightweight construction, and simplified mechanisms. These changes promise riders improved performance, longer ride times, and increased durability. With their clever IoT integration, lightweight carbon fibre frames, environmentally friendly manufacturing methods, and safety automation features like automatic emergency braking and integrated LED lights, electric bikes are expected to become even more practical, economical, and ecologically friendly in the years to come.

1.3 MOTIVATION

The goal of this project is to improve the driving of electric bicycles by addressing one of their main limitations, which is speed. The environmental sustainability, user-friendliness, social benefits, and financial advantages of electric bicycles are highly praised. Nevertheless, their application is restricted in situations where higher velocities are necessary due to their frequent speed limitations.

Enhancement of Speed:

While electric bicycles are highly regarded for their practicality and eco- friendliness, they frequently fall short of reaching the speeds needed for specific types of transportation and commuting. The investigation of novel approaches to boost the speed potential of electric bicycle drives is a primary driving force behind this project. This acceleration is essential to extending the range of applications for electric bicycles and positioning them as a competitive option for a variety of transportation needs.

- **The rider's comfort and endurance:** With the help of axial flux motors and sophisticated power management systems, the project aims to improve rider experience by enabling passengers to travel longer distances without getting tired. This is the reason behind the project.
- **Sustainability:** This project not only meets rider comfort and speed requirements, but also sustainability guidelines. It recognizes the intricacy of sustainability.
- **Environmental Sustainability:** The project aims to mitigate the adverse environmental effects of the motorized bicycle system by promoting energy efficiency and reduced emissions. In an attempt to be ecologically friendly, it uses renewable energy sources to lower its carbon footprint.
- **Social Sustainability:** Social sustainability serves as a major driving force for this project. It ensures that the motorized bicycle system benefits people and communities by providing affordable and easily accessible transportation options. The goal is to promote health and well-being by encouraging physical activity and taking user needs and safety into account.
- **Economic Sustainability:** The project emphasises the long-term financial sustainability and economic benefits of the motorized bicycle system. It strives to be strong, affordable, and efficient so that a variety of individuals can keep using this green form of transportation.

1.4 MARKET ANALYSIS

The market for electric bicycles is expected to develop at a 15.6% compound annual growth rate (CAGR) from USD 37.47 billion in 2022 to USD 119.72 billion by 2030. Numerous reasons are contributing to this expansion, such as the COVID-19 pandemic's increased adoption of electric bikes, which decreased reliance on public transportation and increased demand for other forms of transportation. For instance, e-bike imports into the United States increased by 80% in 2021 and 76% in 2020 over pre-pandemic levels, creating substantial growth potential and income streams for major companies like VanMoof. The expansion of the industry is further aided by government measures to promote sustainable mobility, such as the USD 2 billion plan launched by the U.K. mobility Department to increase walking and cycling. Similar to this, it is anticipated that the Indian market for electric bicycles will expand at a compound annual growth rate (CAGR) of 15.7% from 2022 to 2028. The

industry will be fueled by favourable government policies and incentives as well as rising demand in Tier 1 cities. Although the Indian market is still in its infancy, industry growth is anticipated due to factors such as increasing demand for environmentally friendly transportation, fast urbanisation, and an emphasis on last-mile logistics. The absence of uniform rules across nations and expensive beginning expenses, however, continue to be major obstacles to market progress. The global market for electric bicycles is expected to increase significantly in spite of these obstacles.

1.5 IMPACT OF COVID19

The global and Indian markets for electric bicycles have been significantly impacted by the COVID-19 outbreak. Due to safety concerns, there are less options for public transportation, which has increased demand for alternative forms of transportation like electric bikes. Tube ridership in American cities such as New York fell by 90%, which resulted in a significant rise in e-bike imports and increased profits for industry players. Similar to this, during the pandemic in India, individuals started to avoid utilising public transit, which led to a rise in the use of e-bikes for private mobility. The demand for e-bikes was further stimulated by government electrification programmes and increased public knowledge of the advantages that electric vehicles provide for the environment.

The tendency of e-bike use as a personal mode of transportation increased as lockdown limitations loosened, signifying a long-term change in consumer behaviour. In general, the COVID-19 epidemic has sped up the uptake of electric bikes as a practical and environmentally friendly form of transportation, propelling market expansion both internationally and in India.

1.6 FACTORS

1.6.1 DRIVING FACTORS

The market for electric bicycles is expanding quickly due to a number of factors. Riding a bicycle to work has become more popular as a daily commute due to rising gasoline prices brought on by shortages, especially in areas heavily dependent on fossil resources. The government's measures to provide electric bicycle charging infrastructure and provide incentives have increased public interest in environmentally friendly modes of transportation.

1.6.2 Restraining Factors

The electric bicycle market has a strong growth trajectory, but there are a number of obstacles that could prevent it from reaching its full potential. The high initial prices of e-bikes continue to be a major obstacle to their widespread adoption, especially in areas with low levels of disposable income. Furthermore, the lack of uniform legislation across nations exacerbates market dynamics and customer choice. The high price of e-bikes in India makes it difficult for the product to become widely adopted, which could restrict access to environmentally friendly mobility options for a larger segment of the population. Furthermore, potential purchasers of electric bicycles may be discouraged from making an investment due to worries about the longevity and replacement costs of e-bike batteries. It will be essential to address these issues if we hope to maintain the market's growth momentum and promote the widespread use of electric bicycles.

1.7 SEGMENTATION

1.7.1 PROPULSION TYPE ANALYSIS

The market for electric bicycles is divided into two segments: pedal assist and throttle propulsion kinds. Pedal assist dominates this category. Due to features like longer battery life, less maintenance needs, and the option for consumers to choose between several levels of pedal assistance, the pedal assist category has a significant share of the market. The dominance of this market is anticipated to continue because consumers who want a ride that balances manual and electric assistance are drawn to it. Throttle section Has Potential for Growth: Although the market is dominated by the pedal assist section, there is room for the throttle segment to grow significantly over the next several years. The market for throttle-operated electric bicycles is predicted to be driven by factors including instantaneous acceleration and reduced pedalling effort, particularly in difficult terrain. The faster growth rate of this segment highlights the variety of propulsion alternatives available in the electric bicycle industry, as well as the fact that consumer preferences are always changing.

1.7.2 ANALYSIS BY BATTERY TYPE

Lithium-Ion Batteries Are the Industry Leader: For electric bicycles, lithium-ion batteries are the best option since they combine weight, capacity, and efficiency. Lithium-ion batteries offer better performance and energy density than lead-acid batteries, with three times the capacity and twice the voltage, which makes them perfect for energising electric bicycles. These benefits account for its market dominance, which propels the expansion of the electric bicycle market on a global scale.

Lead-Acid Batteries Continue to Be Useful: Lead-acid batteries are still widely used in electric bicycles, even though lithium-ion batteries are more common. This is especially true in areas where cost is a more important factor than performance. Although there are certain limitations in terms of performance, lead-acid batteries are still used in electric bicycles due to their lower initial cost and simplicity of recycling. More lightweight and efficient alternatives to lead-acid batteries may arise as the market and technology develop, but consumers on a tight budget will always need lead-acid batteries due to their affordability.

Global Electric Bike Market Share, By Battery Type, 2022

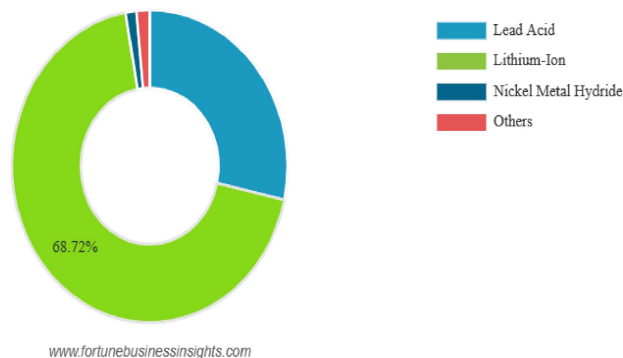


Figure 1.1 Analysis by battery type

1.8 LATEST TRENDS

The global market for electric bicycles is expected to increase at a compound annual growth rate (CAGR) of 15.6% from 2022 to 2030, or USD 119.72 billion. The reason for this rise is the rising demand, Tier 1

cities like Delhi, Mumbai, Pune, and Bangalore, for environmentally friendly transit options as well as the supportive policies and incentives offered by the government. Electric bicycles are gaining popularity among urban commuters and delivery businesses due to urbanisation and the necessity for effective last-mile connection solutions. The market is undergoing a revolution thanks to ongoing developments in battery technology, particularly with regard to lithium-ion batteries, which offer greater energy density, extended range, and quicker charging periods. Additionally, In order to improve user experience and spur market expansion, smart features and connection choices are being added to electric bicycles. Increased rivalry and product diversification brought about by the arrival of new competitors and the growth of established firms spur innovation and improve consumer options. Electric bicycles are becoming more and more popular as a clean, economical, and efficient form of transportation as environmental sustainability becomes more and more of a priority. This is especially true in India, where there are growing initiatives to promote eco-friendly transportation. Additionally, there is an increasing trend towards high-end, performance-focused electric bicycles that appeal to experts and fans looking for top-notch parts and exceptional performance. All things considered, the market for electric bicycles is expected to develop significantly due to a combination of factors including shifting customer preferences, growing environmental consciousness, and technological advancements.

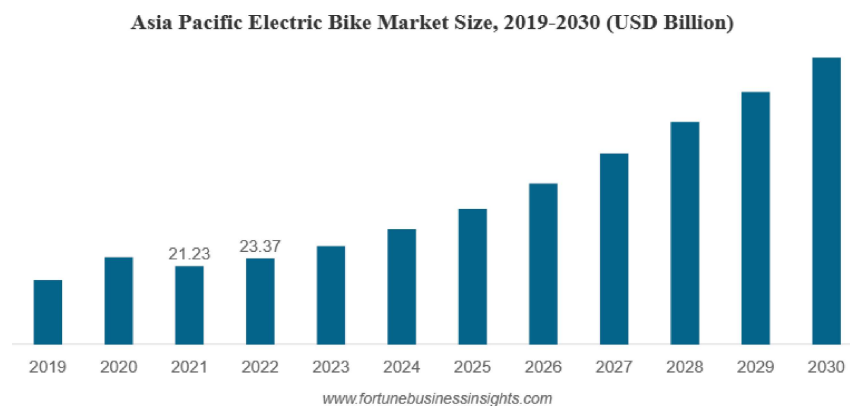


Figure 1.2 Recent trends

1.9 KEY DEVELOPERS

Giant Bicycle, Inc. (Taiwan).

Hero Cycles Ltd (India).
Accell Group
(Netherlands).
Robert Bosch GmbH (Germany).
Kalkhoff Werke GmbH (Germany).
Pedego Electric Bikes (U.S.).
Panasonic Corporation (Japan).
Mobility Holdings, Ltd. (Tern)
(Taiwan). Trek Bicycle Corporation
(U.S.).
Shimano Inc. (Japan).

1.10 DEVELOPMENTS

1. August 2021: To demonstrate the potential of electric bicycles for commercial uses, Hero Lectro Cargo (HLC) collaborated with Swiggy, an on-demand delivery platform, to test the deployment of cargo e-bikes for last-mile food delivery in Hyderabad. 2. In December 2021, Firefox motorcycles revealed intentions to increase production localization and meet the rising demand for premium entry-level motorcycles in India by broadening its e-bike lineup. 3. In January 2022, Giant Bicycles and Team Bike Exchange-layco announced their partnership to rejoin the UCI World Tour, a move that demonstrated the increasing acceptability and use of electric bicycles in professional cycling events and competitive sports. 4. In February 2022, Hero Cycles Ltd established a Lectro's experience centre to exhibit their selection of electric bicycles and give potential buyers a chance to test ride several models, assisting them in making well-informed purchase selections.

1.11 PROJECT OVERVIEW

We describe the general project structure in this section. It includes the research goals of the project, important areas of concentration, and the approach used to bring about the intended improvements. It offers a thorough understanding of the project's approach to achieving the objectives of increased speed and rider and comfort.

CHAPTER 2 LITERATURE SURVEY

2.1 MAJOR FINDINGS FROM LITERATURE SURVEY

ELECTRIC BICYCLE- a performance evaluation: Published in:
IEEE Industry Applications Magazine (Volume: 13, Issue: 4, July- Aug. 2007).
Annette Muetze, Ying C .Tan

This article looks into the performance evaluation and classification of electric bicycles. It gives an overview of the state of the art in electric bicycles, including regulatory issues in various countries and performance standards. The article identifies the key parameters, requirements, and challenges for improving the performance of electric bicycles. It also discusses the benefits of riding an electric bicycle, such as reduced energy costs, environmental friendliness, and health benefits. The article concludes with a road map for improving the performance of electric bicycles and suggests areas for future research.

Design and Performance Testing of an E-Bicycle:
Published in: 2013 International Conference on Renewable Energy Research and Applications (ICRERA).
G. Cipriani, V. Di Dio, R. Miceli IEEE Member, G. Ricco Galluzzo, M. Russo.

This document provides a thorough examination of the electric drives used in electrically assisted bicycles. It describes the construction of a test bench for measuring the output torque of electric drives and determining their efficiency. The test bench complies with Directive 2002/24/EC, ensuring that electric drives operate within legal power limits. Furthermore, the document discusses the testing of an electric rickshaw prototype at the University of Palermo's SDES Laboratory, emphasising the potential of electrically assisted bicycles in promoting sustainable urban transportation.

Methodology to Develop a Real world Driving Cycle for Electric Vehicle
Simulation Studies: Methodology to Develop a Real World Driving Cycle for
Electric Vehicle Simulation Studies

Published in: 2021 IEEE Transportation Electrification Conference (ITEC-India).

Authors: Sibi Krishnan K, Jithin T J. Prasanth Pathiyil, Vikas Gautam, Jouffroy
Michae.

This article discusses how to create a real-world driving cycle for electric vehicle simulation studies. The driving cycle has a significant impact on the performance, thermal behaviour, and lifetime of electric vehicles. The article describes a method for calculating driving cycles from road load data by compressing a large amount of data collected over multiple trips. The algorithm computes various parameters for each micro-trip, and the candidate micro-trips for the final compressed driving cycle are chosen based on the weighted sum of these variables. The driving cycles generated are tailored for city, highway, and countryside use and have a duration of 3600 to 5400 seconds. The paper also includes simulation results for the generated driving cycles using a forward-facing simulation model.

Performance Analysis and Design of 250 Watt Outer Rotor BLDC Motor for Urban
Electric Bicycles

Published in: 2022 7th International Conference on Electric Vehicular Technology (ICEVT). O. Ustun, G. Tanc, O.C. Kivanc and G. Tosun.

The paper discusses the increasing popularity of electric bicycles and the need for better technology to support them, focusing on the design of a low- power and high-efficiency BLDC motor for electric bicycles. It presents a reverse- engineering process to optimize the winding design, compares the proposed design with a reference design in terms of performance, and analyzes the magnetic flux distribution. The proposed design meets all performance criteria and shows improved efficiency, making it suitable for electric bicycles.

Modelling and Analysis of the Technical Performance of DC-Motor Electric
Bicycle Drives Based on Bicycle Road Test Data

2007 IEEE International Electric Machines & Drives Conference.

Annette Muetze, Ying Chin Tan.

The document discusses the modelling and analysis of technical performance for direct drive DC-motor electric bicycle systems using road test data. It values adjusted modelling tools and assesses both instantaneous and overall performance. The study also looks into the impact of various parameters on drive performance. The findings highlight the limitations and benefits of such drives when considering real-world riding profiles.

Suitability of Electric Motors and Conventional Control Techniques for Electric
Vehicle Applications:

2022 International Conference of Advanced Technology in Electronic and Electrical
Engineering (ICATEEE).

Guichi Amar, Ghadbane Ismail, Bouzidi Riad.

This paper discusses the suitability of various electric motors and control techniques for electric vehicle (EV) applications. The authors focus on the use of direct torque control (DTC) technique for induction motor control in EVs, and present simulation results showing its effectiveness in achieving any speed setpoint while varying resistance torque. The authors also discuss the importance of drive cycle tests to assess speed control techniques, and provide a case study using the DTC technique on an induction motor. Overall, the paper provides valuable insights into the challenges and opportunities of using electric motors and control techniques in EVs.

Electrical Motors for Electric Vehicle – A Comparative Study

Published in: Proceedings of Recent Advances in Interdisciplinary Trends in
Engineering & Applications (RAITEA) 2019.

Pooja Naresh Bhatta, Hemant Mehar b, Manish Sahajwanib.

In this paper, the authors conduct a comparative analysis of electric motors used in electric vehicles. Motors considered include DC motors, induction motors (IM), permanent magnet synchronous (PMS) motors, permanent magnet brushless DC/AC (BLDC/BLAC) motors, and switched reluctance motors (SRM).

Cycling study of 18650 Nickel-Rich Silicon-Graphite Lithium-ion batteries under different charge current: Jorge Alonso-del-Valle, Manuela González, Juan Carlos Viera, Víctor García, David Anseán.

The study evaluates the performance of 18650 Nickel-Rich Silicon- Graphite Lithium-Ion Batteries under different charge currents. Two different cell models from different manufacturers were tested to assess their long-term cycling behavior and the impact of high charge currents. The analysis includes capacity, energy efficiency, and impedance measurements, revealing that high charge currents significantly reduce the cells' lifetime capacity. The study emphasizes the importance of proper evaluation of cycle life and degradation for the potential use of this technology in next-generation electric vehicles.

Performance Analysis of Bi-directional DC-DC
Converters for Electric Vehicles:

Published in: IEEE Transactions on Industry Applications (Volume: 51, Issue: 4, July-Aug. 2015).

Mehnaz khan, Adeeb Ahmed, Iqbal Hussain, Yilmaz Ozer, Mohamed Badawy.

The paper presents a performance analysis and comparison of two types of bidirectional DC-DC converters - Cascaded Buck-Boost-Capacitor in the middle (CBB-CIM) and Cascaded Buck-Boost-Inductor in the middle (CBB-IIM) - for use in plug-in electric and hybrid electric vehicles. The authors provide insights into their device requirements, control strategy, and efficiency analysis for specific scenarios in-vehicle applications. The simulation and experimental results for both converter types are also included, making this a comprehensive resource for anyone interested in electric and hybrid electric vehicles.

2.2 PROBLEMS IN EXISTING SYSTEM

Existing electric bicycle systems face several challenges that limit their performance and usability. One significant issue is the low speed capability of these vehicles, which limits their efficiency, especially in urban areas where higher speeds are frequently required. Furthermore, the battery and torque efficiency of current e-cycles are suboptimal, resulting in inefficient power utilization and lower overall performance. Furthermore, the batteries in these systems drain quickly, resulting in shorter operating ranges and frequent recharges. Addressing these issues is critical for improving the functionality and user experience of electric bicycles, resulting in their widespread adoption as a sustainable transportation solution.

2.3 DISADVANTAGES OF THE EXISTING SYSTEM

- **Lack of Speed:**

The electric bicycle systems that are currently in use have a noticeable speed limitation that makes them less useful and practical, particularly in urban settings where faster speeds are frequently required.

- **Lack of Power Density in Battery:**

Existing electric bicycles frequently have batteries with low power densities, which limits their ability to store energy and shortens their operating ranges. This limits the overall functionality of these vehicles.

- **Less Safety in Batteries:**

Overheating, fire hazards, and premature degradation are just a few of the safety concerns related to the batteries used in electric bicycles, which can endanger both users and the environment.

- **Lack of Motor Efficiency:**

Another major flaw in the current generation of electric bicycle systems is their inefficient motors, which result in less than ideal power consumption, a shorter range, and overall worse performance.

- **High cost:**

Many consumers may find the expense of purchasing and maintaining an electric bicycle to be prohibitive, which may hinder the device's uptake and accessibility, especially in areas where more affordable alternative transportation options are available.

2.4 IEEE STANDARDS FOLLOWED

1. IEEE 1815 - Electric Power Systems in Rail Transportation: This standard has been followed because it is pertinent to the topics of power systems and control that are essential to the effective transfer of power and management of electric bicycles.
2. IEEE 1547: Standard for Electric Power Systems and Distributed Resources Interconnection: Adherence to this standard ensures that distributed energy resources, like the lithium ferro phosphate (LiFePO₄) battery, can be safely and reliably connected to the electric bicycle system.
3. IEEE 2030: Handbook on Energy Technology and Information Technology Smart Grid Interoperability for Electric Power System (EPS), End-Use Applications, and Loads Following this standard guarantees smooth and compatible communication between various energy technologies and parts of the electric bicycle system.
4. IEEE 1185 - Standard for Electric and Hybrid Vehicle Propulsion Motor Performance and Test Procedures: By adhering to this standard, one can be certain that the recommended BLDC hub motor's performance satisfies the necessary requirements and testing procedures for electric vehicle propulsion systems.
5. IEEE 2846 - Smart Grid Data Dictionary Recommended Practice: Adherence to this standard enables smooth communication and operation amongst different parts of the electric bicycle system, especially if smart grid functionality is included.

2.5 TRADE OFF

1. Range vs. Speed: Because faster electric bicycles use more power, they may have to give up some of their range in order to achieve faster speeds. To satisfy the various demands of riders, it is crucial to strike a balance between the requirement for faster speeds and the desire for longer travel distances.
2. Power Density vs. Weight: Increasing the battery pack's power density can improve an electric bicycle's performance, but it may also make the vehicle heavier

overall. Achieving the ideal handling and efficiency without sacrificing agility requires finding a balance between weight and power density.

3. Cost vs. Performance: While high-performance parts like sophisticated motor controllers and lightweight materials can greatly enhance an electric bicycle's performance, doing so may also raise the cost of the bike. Achieving a cost-performance equilibrium is crucial for providing users with value and maintaining market competitiveness.

4. Agility vs. Safety: While adding safety features like a fuse and low potential brakes can increase rider safety, they may also make a bicycle less responsive and agile. Creating a well-rounded riding experience requires striking a balance between safety features and the requirement for agile handling.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM OF THE PROJECT

The creation of an effective and affordable motorised bicycle system for electric bicycles is the main goal of this project. A high-performance controller will be incorporated into this system to increase energy efficiency. Our objective is to improve the usability and accessibility of electric bicycles by giving priority to technological advancements, which will in turn encourage sustainable urban mobility. Another main goal of this project is to get electric bicycles faster, with an emphasis on using a BLDC hub motor to achieve better torque and performance. Through innovation and progress, this project tackles important facets of urban transport competitiveness.

3.2 RESEARCH HYPOTHESIS

The creation of an effective and affordable motorised bicycle system for electric bicycles is the main goal of this project. A high-performance controller will be incorporated into this system to increase energy efficiency. Our objective is to improve the usability and accessibility of electric bicycles by giving priority to technological advancements, which will in turn encourage sustainable urban mobility. Another main goal of this project is to get electric bicycles faster, with an emphasis on using a BLDC hub motor to achieve better torque and performance. Through innovation and progress, this project tackles important facets of urban transport competitiveness.

3.4 ADVANTAGES OF THIS PROJECT

Enhanced Energy Efficiency: By incorporating motor controller, energy efficiency is increased. This results in more efficient energy transfer between the battery and motor, extending the range of an electric bicycle on a single charge.

safety and dependability are improved, lowering the possibility of overloading and other potential problems.

- **Improved Usability and Convenience:** This project intends to make electric bicycles more competitive and useful for city commuting by concentrating on enhancing their speed.
- **Cost-Effectiveness:** One of the main objectives of this project is to maintain affordability so that a greater variety of users can continue to have access to improved electric bicycles, which will support sustainable urban mobility.
- **Sustainability:** By lowering energy consumption and environmental impact through improved energy efficiency and the capacity to recover energy during braking, the project supports efforts towards broader sustainability objectives.
- **Urban Mobility:** The ultimate goal of this project is to improve urban mobility by offering an efficient, affordable, and ecologically friendly substitute for traditional modes of transportation. This alternative can aid in easing traffic jams and lowering pollution levels in urban areas.

3.5 OPERATING MODES OF THE PROJECT

3.5.1 PEDAL MODE

During the pedal mode, the user starts off by starting to pedal the cycle. The magnets that are present in the crank produces magnetic flux which is sensed by the cadence sensor. The sensor then gives the signal to the motor controller which tells the motor to activate for a very short span of time. As a result, the user experiences a push for a second or two making it easier for riding especially for older people.

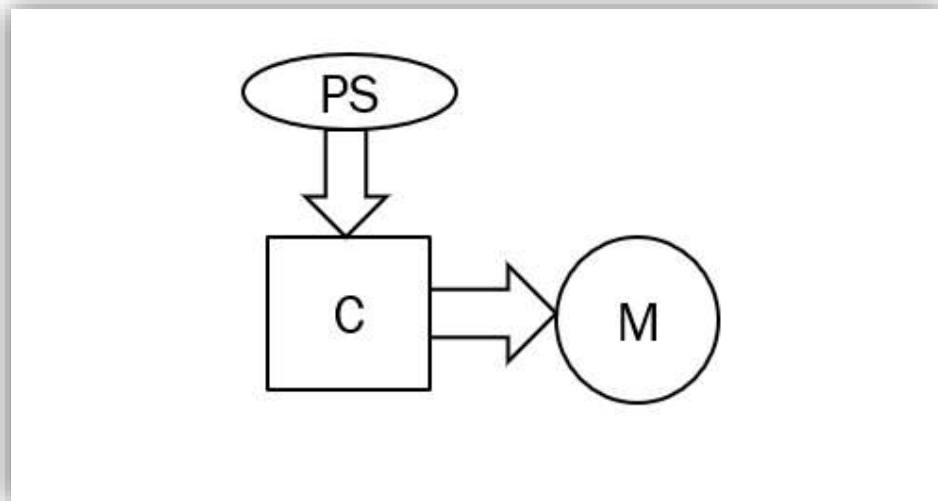
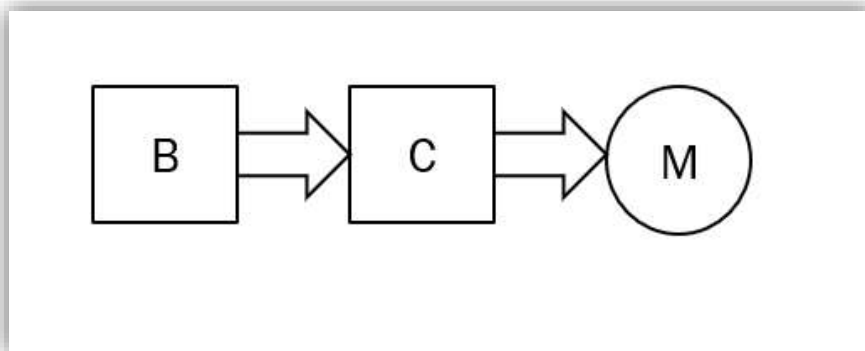


Figure 3.1 Pedal mode

3.5.2 ELECTRIC ASSIST MODE

Just like ideal bikes, electric assist modes displays the normal function of using the energy from the DC power source (battery) by using a throttle to the motor drive.



3.5.3 ELECTRIC PEDAL ASSIST MODE

This mode combines both pedal and electric assist modes. This mode is useful when there's an additional power requirement for example climbing slopes and flyovers.

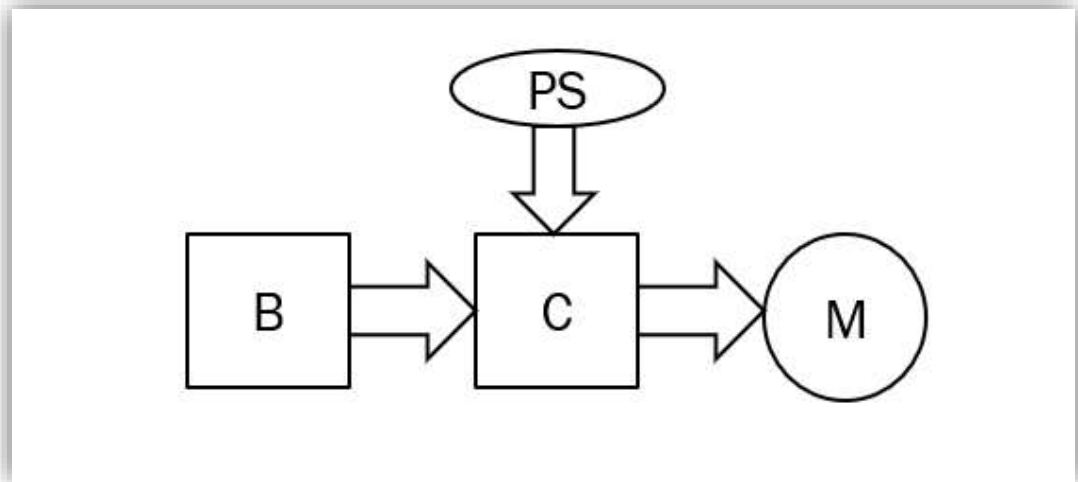
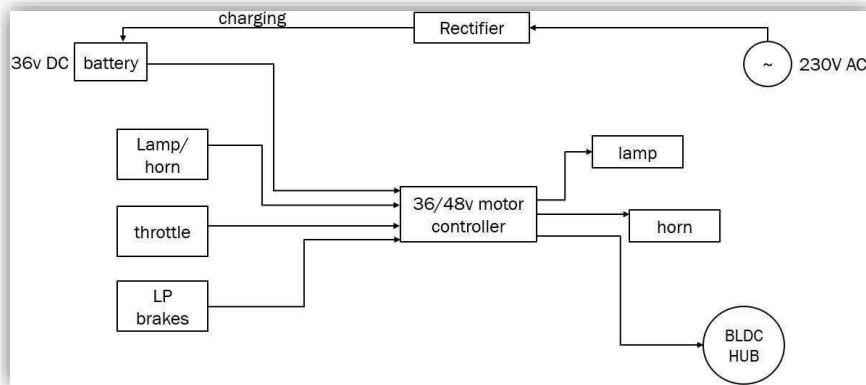


Figure 3.3 Electric pedal assist mode

3.5.4 BLOCK DIAGRAM OF THE PROPOSED SYSTEM



CHAPTER 4

DESIGN, SIMULATION AND ALGORITHMS

4.1 INTRODUCTION

This chapter describes the design that includes mathematical calculations for choosing the required parameters and software simulation for the proposed bicycle system.

4.1.1 EQUIPMENT AND SOFTWARE

Design calculations are required for this project to ensure ideal parameter selection. Engineers can calculate the specifications needed for components such as batteries, motors, and controllers to meet performance requirements. These calculations assist in determining factors such as power consumption, torque, speed, and efficiency, ensuring that the components selected are right for the intended application. Also, design calculations help to predict system behaviour, identify potential problems, and optimise the design for cost-effectiveness and performance. Overall, design calculations are critical for making informed decisions and achieving the expected functionality and efficiency of the electric bicycle system.

So after the design calculations, the required components have been chosen for the experimental setup and integration and compatibility

4.2 MOTOR LOAD CALCULATION:

$$\alpha = \tan^{-1}(\text{slope})$$

$$= \tan^{-1}(3.14/100)$$

$$= \tan^{-1}(0.0314)$$

$$\alpha = 1.8 \text{ degree}$$

So when it is 3.14/100 it means that for every 100 units there is 3.14 units of inclination or fall. this angle leads us to find the Gradient resistance (F_d).

4.2.1 TO FIND GRADIENT RESISTANCE (F_d)

Gradient resistance is defined as the resistance caused due to the inclination of a surface.

Calculating Gradient resistance (F_d):

$$\begin{aligned} F_d &= m \times g \times \sin(\theta) \\ &= 120 \times 9.81 \times \sin(1.8) \\ &= 120 \times 9.81 \times \sin(1.8) = 31.10 \text{ N} \\ &= 31.10 \text{ N} \end{aligned}$$

Assuming a total mass of 100kg and the gravitational acceleration 9.81 m/s^2 , the calculated value for Gradient resistance is 31.10N.

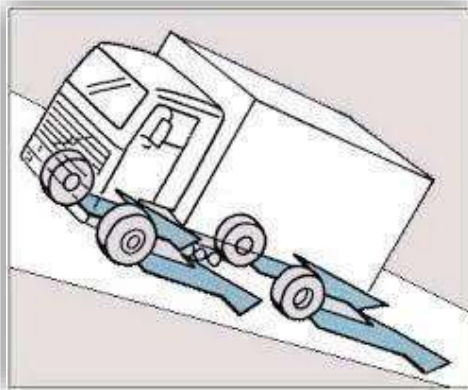


Figure 4.1 Gradient resistance

4.2.3 AERO RESISTANCE

Aero resistance or drag (F_{wf}) is defined as the force acting on an object that moves through the air. It is calculated using the following formula: $F_{wf} = \frac{1}{2} \times C_d \times \rho \times A \times V^2$.

Where C_d = coefficient of the aerodynamic area
 ρ = density
 A = frontal area of the bicycle

V = velocity

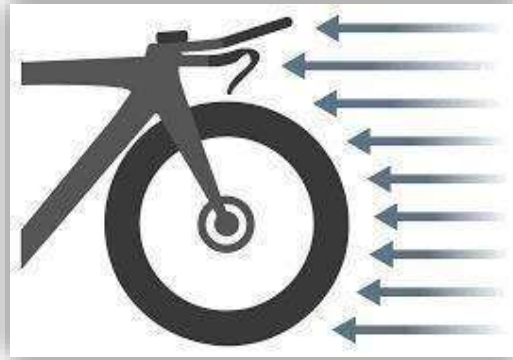


Figure 4.2 Aero resistance

Finding aero resistance (F_{wr}):

Coefficient of Aerodynamic Area (C_d) =

0.74 Density (ρ) = 1.225 kg/m^3

Frontal Area of Bicycle (A) = 0.37

m^2 Velocity of Bicycle (V) = 25 km/h

= 6.94 m/s .

Note that the parameters given above are the assumed values for a bicycle.

$$F_{wf} = \frac{1}{2} C_d \rho A V^2.$$

$$= \frac{1}{2} \times 0.74 \times 1.225 \times 0.37 \times (6.94)^2$$

$$= 8.07.$$

So with a total mass of 120 kg and an increased velocity of $25\text{--}30 \text{ km/hr}$, the calculated drag aero resistance is 8.07 N .

4.2.4 ROLLING RESISTANCE (F_r)

Rolling resistance or rolling drag is the force caused on a moving object when it rollsthrough the surface.

It is calculated using the

formula: $F_r = C_r \cdot m \cdot \cos \alpha$

Where, C_r is the rolling coefficient m is mass.

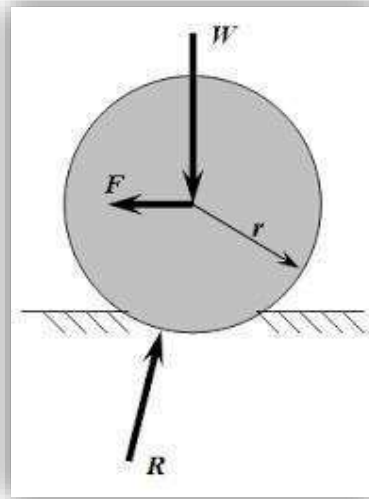


Figure 4.3 Rolling resistance

Calculating rolling resistance (F_r):

$$F_r = C_r \cdot m \cdot \cos \alpha$$

$$= 0.0041 \cdot 120 \cdot 9.81 \cdot \cos 1.8$$

$$= 4.8 \text{ N.}$$

(The value of the rolling resistance is assumed to be 0.0041 for a bicycle)

Note that the value of the rolling coefficient is assumed to be 0.0041.

Since the Rolling resistance force is parallel to the slope and not perpendicular to it, $\cos$ function is used here and the final value for F_r is calculated to be 4.8N.



Figure 4.4 Rolling resistance in a wheel

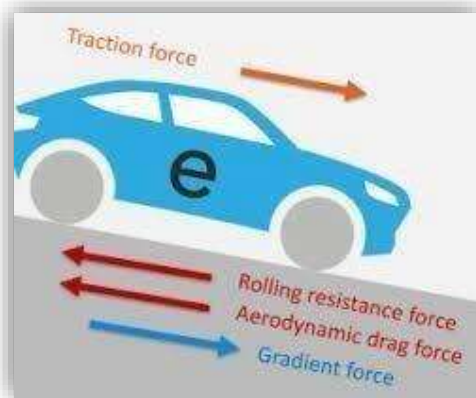


Figure 4.5 Various forces acting on a vehicle

4.2.5 TOTAL PROPULSION FORCE

Propulsion force is the generation of force by pushing or pulling to modify the translational motion of an object.

It is calculated using the

formula: $F_p = F_d + F_{wf} + F_r$

We already know that the calculated values of

Gradient resistance (F_d) =

37N Aero resistance (F_{wf})

= 8.07N Rolling resistance

So, $F_p = 37 + 8.07 + 4.8$

$= 49.8 \text{ N}$

Propulsion Power = $F_p \times \text{Velocity}$

$= 49.8 \text{ N} \times 6.94 \text{ m/s}$

$= 345.6 \text{ Watts}$ (approximately

350Watts) Thus, The Motor is to be

350 Watts.

4.3 CHOOSING A BATTERY PACK

The range required to be covered = 30km.

Assumed speed of the bicycle = 25km/hr, so in 1.12 hr 30km can be covered. Since the total power required to be extracted is 350W for 1.12hrs which is rounded off to 1.2hrs. Therefore, $350 \times 1.2 = 420 \text{ watt}$ battery pack is required. Since a 36-volt battery is preferred,

$36 \times \text{xah} = 420 \text{ W}$

$\text{xah} = 11.6 \text{ Ah}$.

The total ah required is rounded off from 11.6 to 12Ah.

4.4 POWERTRAIN MODELLING SIMULATION

Power train modelling is to understand the data related to the batteries motor parameters and the forces acting on the vehicle. The simulation was conducted using MATLAB, a widely used software tool for engineering simulations and analyses.

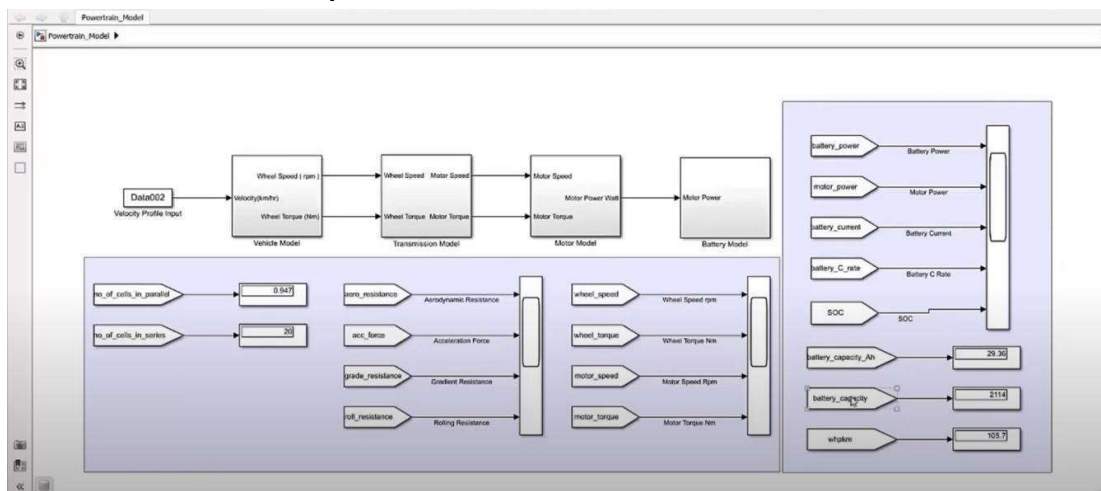


Figure 4.6 power train model

The power train consists of four models within namely: vehicle model, transmission model, motor model, and battery model.

4.4.1 MOTOR MODEL

The motor model has the velocity(km/hr) as the input and wheel speed(rpm) and wheel torque (Nm) as outputs. It also consists of Wheel speed estimation and wheel torque estimation.

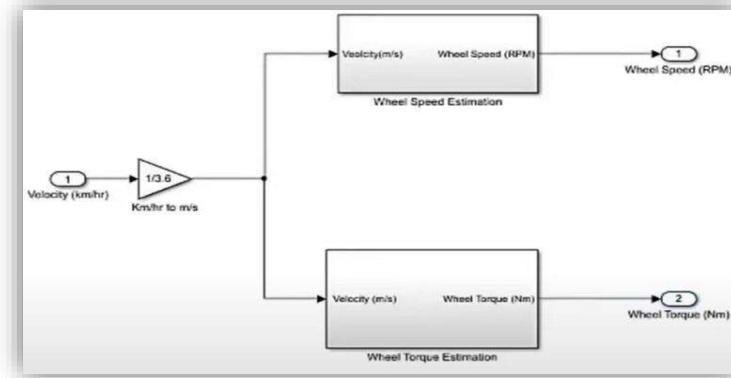


Figure 4.7 Motor model

4.4.2 WHEEL SPEED ESTIMATION

In wheel speed estimation velocity (m/s) is the input. It is calculated using the formula: $Nm = (V \cdot 60) / (2 \cdot \pi \cdot R_w)$ where,

V is velocity

NM is wheel speed,

Rw is the radius of the wheel

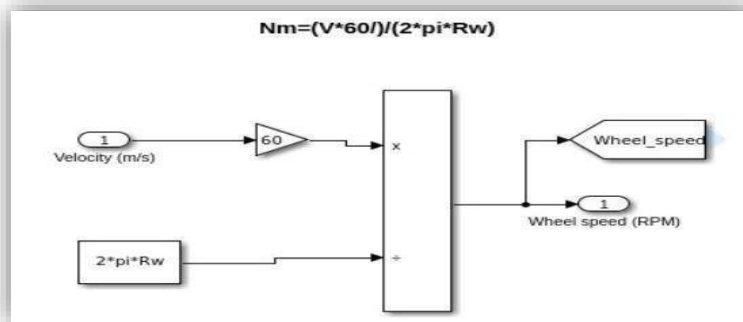


Figure 4.8 Wheel speed estimation

4.4.3 WHEEL TORQUE ESTIMATION

The wheel torque estimation consists of rolling resistance force, gradient force, aero resistance force, acceleration force.

It is calculated using the formula: $Wt = TTF \cdot R_w$

where, Wt is the wheel torque,

TTF is the total traction force,

R_w is the radius of the wheel

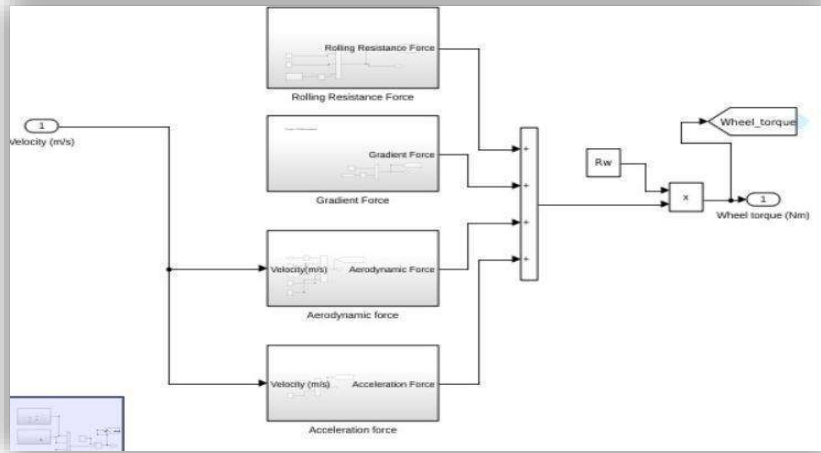


Figure 4.9 Wheel torque estimation

4.4.4 ROLLING RESISTANCE FORCE

It is calculated using the formula: $F_{roll} = GVW \cdot Crf \cdot \cos(\theta)$

where, GVW is gross vehicle weight,

Crf is coefficient of rolling resistance.

4.4.5 GRADIENT FORCE

It is calculated using the formula: $F_{grad} = GVW \cdot \sin(\theta)$

where, θ is in radians.

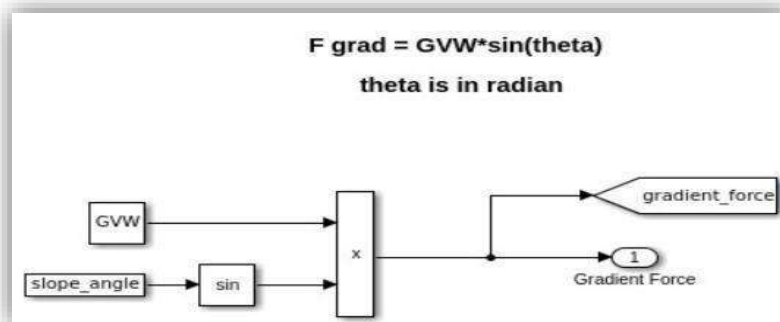


Figure 4.10 Gradient force

4.4.6 AERODYNAMIC FORCE

It is calculated using the formula: $F_{aero} = 0.5 \cdot \rho \cdot A_f \cdot C_d \cdot V^2$

where, A_f is the frontal area,

C_d is the coefficient drag,

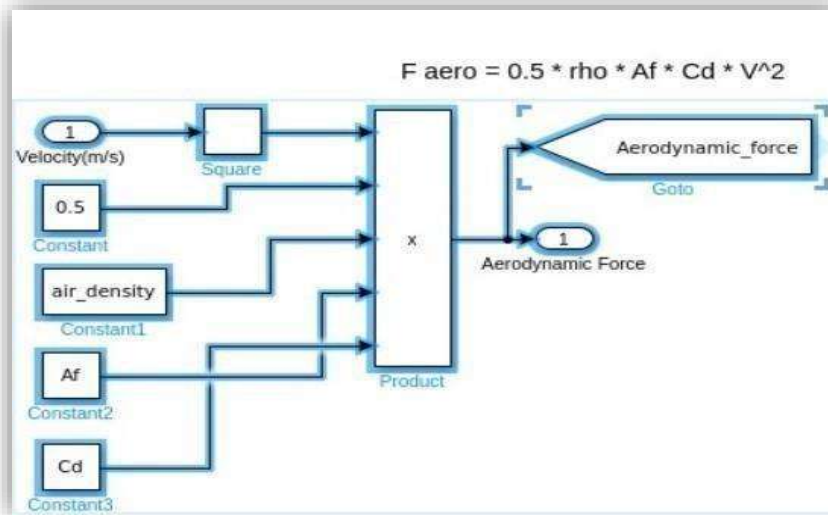


Figure 4.11 Aerodynamic force

4.4.7 ACCELERATION FORCE

It is calculated using the formula: $F_{acc} = GVM \cdot V$

where, GVM is gross vehicle mass,

V is Velocity

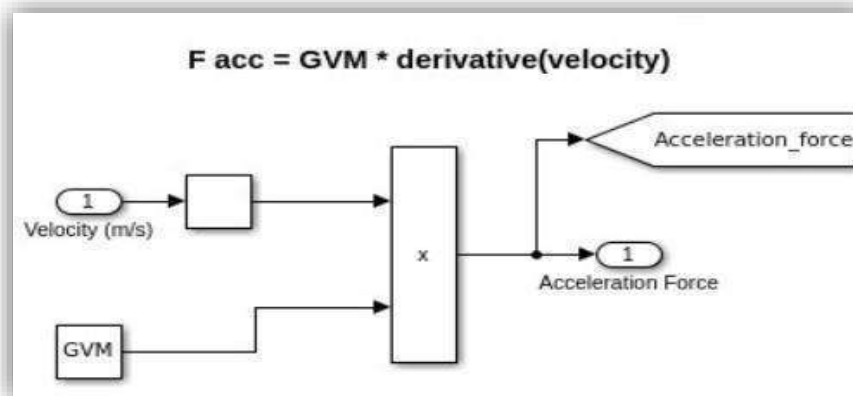


Figure 4.12 Acceleration force

4.4.8 TRANSMISSION MODEL

The transmission model in the power train system consists of the calculations of motor speed and motor torque.

Motor speed is calculated using the formula: $M_s = N_w \cdot \text{gear ratio}$
 where, M_s is the motor speed,
 N_w is the wheel speed.

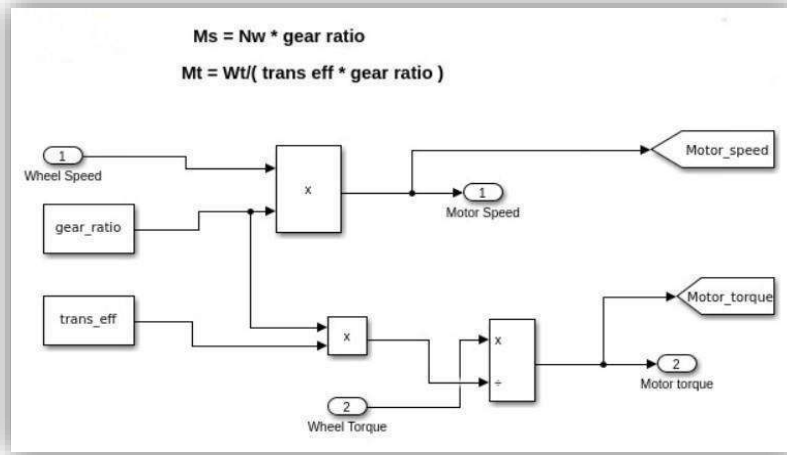


Figure 4.13 Transmission model circuit

4.4.9 MOTOR MODEL

The construction of the motor model circuit consists of the calculation of motor useful power and motor power.

Motor useful power is calculated using the formula: $MUP = (2 \cdot \pi \cdot M_s \cdot M_t) / 60$

where, MUP is the motor useful power,

M_s is the motor

speed, M_t is the

motor torque

Motor power is calculated using the formula: $M_p = W_t / (\text{trans eff} \cdot \text{gear ratio})$

where, M_p is the motor power,

W_t is the wheel torque,

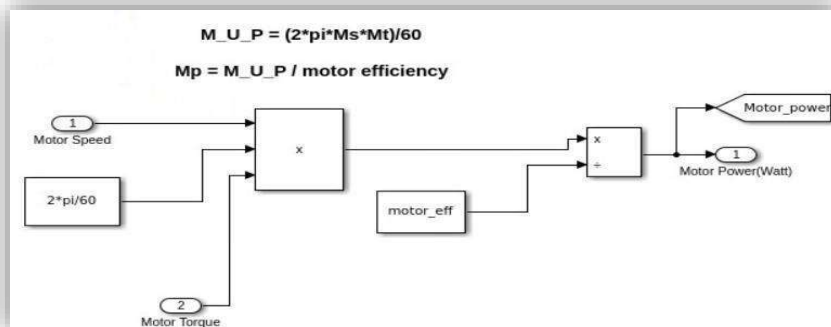


Figure 4.14 Motor model circuit

4.4.10 BATTERY MODEL

The battery model involves the calculations of battery power, Watt/hr, battery capacity (Wh) and battery capacity (Ah).

Battery power is calculated using the formula: $B_p = M_p / \text{motor controller eff}$

where, B_p is battery power,

M_p is the motor power

Watt/hr is calculated using the formula: $Wh/km = \text{int}(B_p / \text{lap distance} * 3.6 * 1000)$ where,

Wh is Watt,

B_p is battery power,

Battery capacity (Wh) is calculated using the formula:

$Wh/km * \text{range}$ Battery capacity (Ah) = $B_c (Wh) / B_v$ where,

B_c is battery

capacity, B_v is

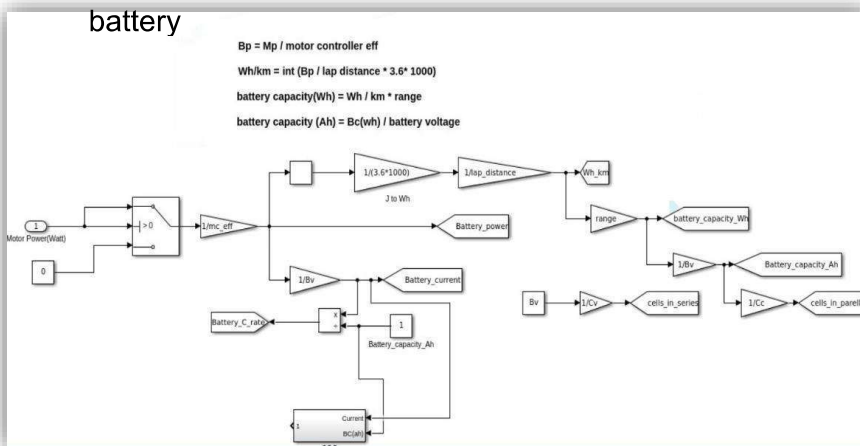


Figure 4.16 Battery model

4.5 MATLAB CODE

In the data source of the MATLAB software MATLAB has been selected. Here the vehicle parameters can be saved and modified accordingly without modifying the block so that it will be easy to change it and run it according to the required needs.

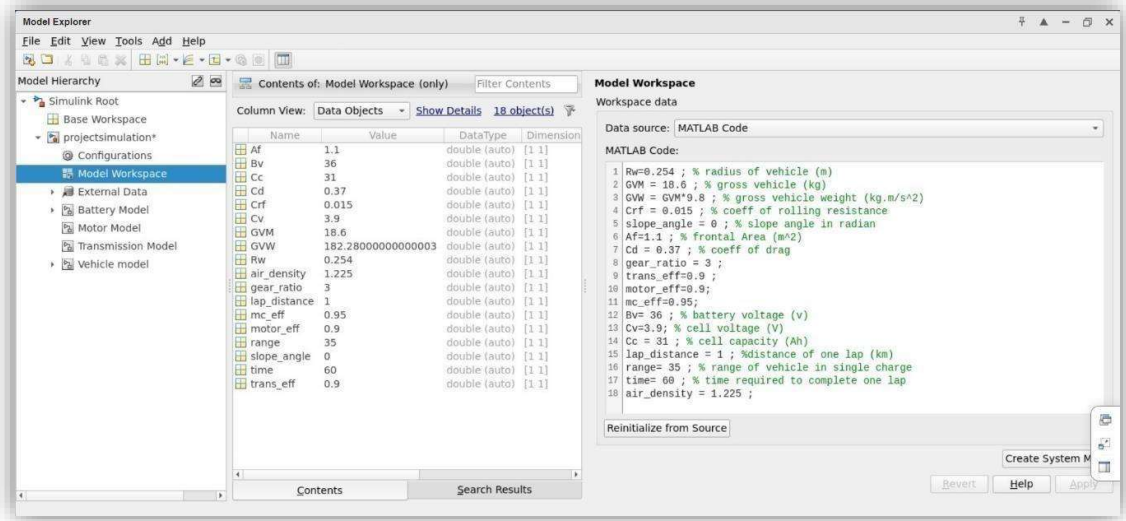


Figure 4.17 MATLAB code

4.6 CALIBRATING POINTS AND FTP DATA

When the discussion about commercial vehicle emerges, the standard profiles like FTP 75 or WTC etc. So an FTP 75 data which consists of velocity and time values have been obtained in Excel format. Also points have been calibrated using an add on called as grab it in MATLAB for the wave form simulation.



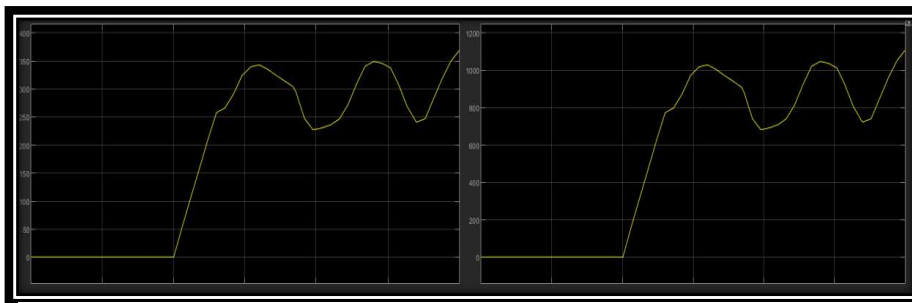
Figure 4.18 Graph for calibration

	A	B
1	Time,secs	Target speed, kmph
2	0	0
3	1	0
4	2	0
5	3	0
6	4	0
7	5	0
8	6	0
9	7	0
10	8	0
11	9	0
12	10	0
13	11	0
14	12	0
15	13	0
16	14	0
17	15	0
18	16	0
19	17	0
20	18	0
21	19	0
22	20	0

Figure 4.19 FTP values

4.7 SIMULATION RESULTS

The following are the output results obtained from powertrain modelling. The purpose of the powertrain modelling is to understand the data related to the batteries, motor parameters and forces acting on the vehicle.



From fig 4.6 it is noticed that the waveforms of the wheel speed and the motor speed are similar. This is because the motor speed directly translates to wheel speed. In other words, motor speed is directly proportional to wheel speed.

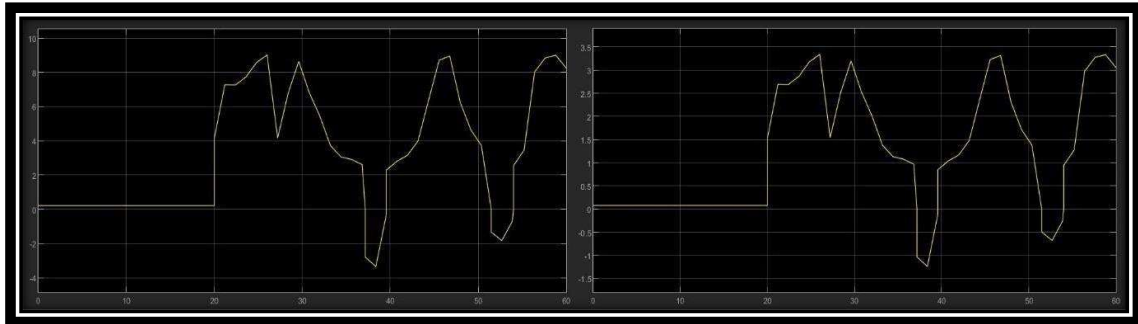


Figure 4.21 Simulation results of wheel torque (Nm) and motor torque (Nm)

From Fig 4.7 it is noticed that the wheel torque and motor torque simulation waveforms are similar, indicating a direct relationship between the two. An effective power transfer from the motor to the wheels is implied by the wheel torque, which is approximately 9 Nm, and the motor torque, which is approximately 3.5 Nm. This consistency shows that there are few mechanical losses or delays, demonstrating that the torque from the motor is effectively converted into wheel torque

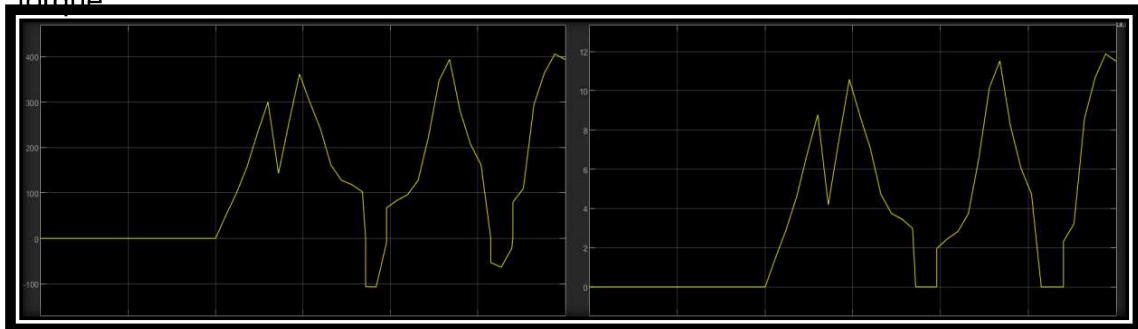


Figure 4.22 Simulation results of motor power (watt) and battery current (A)

From fig4.8 it is understood that the negative spikes in the waveforms of motor power indicate that the vehicle is decelerating. These negative spikes suggest the possibility of regenerative braking, in which the kinetic energy generated during deceleration is captured and converted back into electrical energy to recharge the

battery. Despite the fact that there are opportunities for energy recovery, this project does not use regenerative braking.

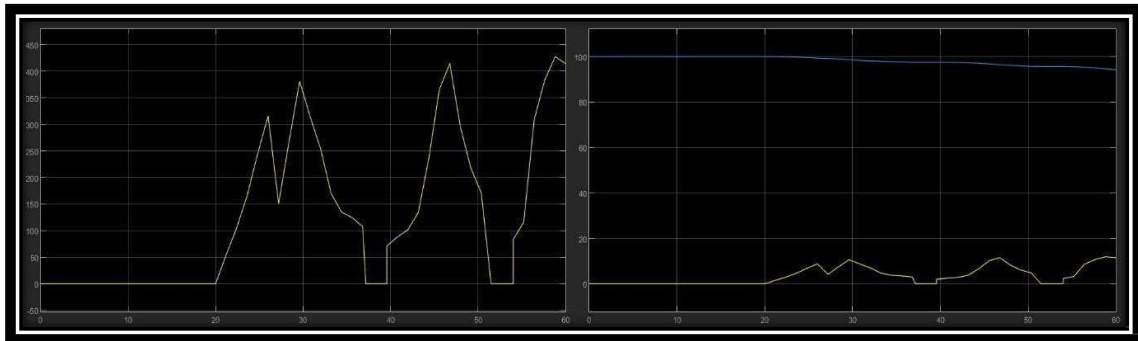


Figure 4.23 Simulation results of battery power, SOC and battery C rate

From the figures 4.8 and 4.9 it is noticed that the waveforms of battery current and battery power are similar. It is due to the fact that both of these waveforms represent different aspects of the same physical phenomenon. This means, both the battery current and power represent different ways of energy flow in and out of the battery.

In an electric circuit, power (P) is the product of current (I) and voltage (V). Since the current (I) is directly proportional to the power (P), the waveforms appear quite similar. Additionally, it is also noted in the SOC waveform that there is no upgrade in the battery percentage rather there is only decline. After completing one lap which is assumed to be one kilometer, the battery percentage is reduced for about 4%.

CHAPTER 5

EXPERIMENTAL SETUP

5.1 EQUIPMENT REQUIRED

This section describes the experimental setup and materials used to construct the proposed electric bicycle system in order to get the expected results. Following equipment and software were used:

Hardware equipment: An ideal bicycle, BLDC hub motor, motor controller, LFP battery, throttle, low potential brakes, wires, a digital multimeter, solder kit.

5.2 COMPONENTS OF THE PROPOSED SYSTEM

5.2.1 MOTOR DRIVE

A 36V 350W BLDC (Brushless Direct Current) hub motor has been chosen for the propulsion system. This option provides the perfect torque to propel the electric bicycle while keeping the energy consumption level within reason. It strikes a balance between power and efficiency.



Figure 5.1 36v 350w HUB motor

5.2.2 BATTERY PACK

A 36V 12Ah lithium-ferro phosphate (LiFePO₄) battery pack has been chosen to guarantee continuous power supply. Compared to traditional battery chemistries, this option offers a longer life expectancy, giving riders more usage cycles before needing to be recharged or replaced.

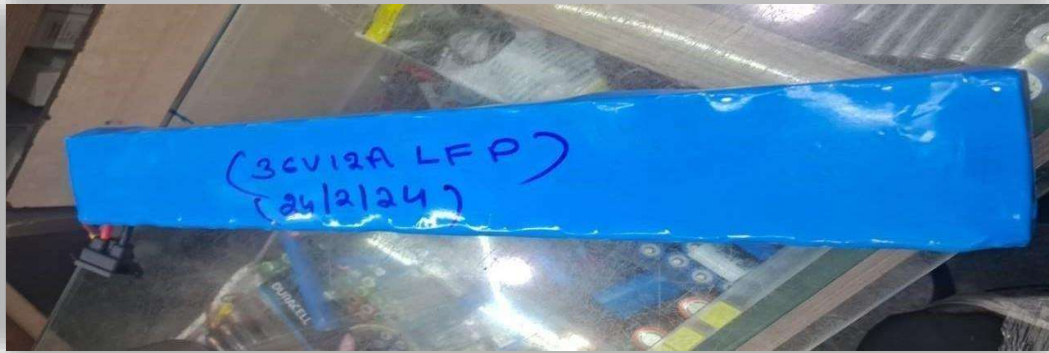


Figure 5.2 LFP battery pack



Figure 5.3 Battery voltage

5.2.3 CONTROLLER AND CONTROLLING MECHANISMS

A 36/48V motor controller, which serves as the electric bicycle's central nervous system, manages the coordination of power delivery and user commands. This controller, which is integrated with all of the system's primary parts, interprets signals from the user interface and controls the motor, battery, and other additional systems. This controller guarantees that power delivery and user commands are coordinated flawlessly. It dynamically modifies motor parameters to maximise efficiency and performance during the operation.



Figure 5.4 36/48v motor controller

5.2.4 SPEED REGULATOR

INPUT: 5V, OUTPUT 5V



Figure 5.5 Speed regulator voltage

5.2.5 LOW POTENTIAL BRAKES

Input: 5v, Output:5v



Figure 5.6 Low potential brakes

5.2.6 THREE SPEED

INPUT: 5V,

OUTPUT: 5V

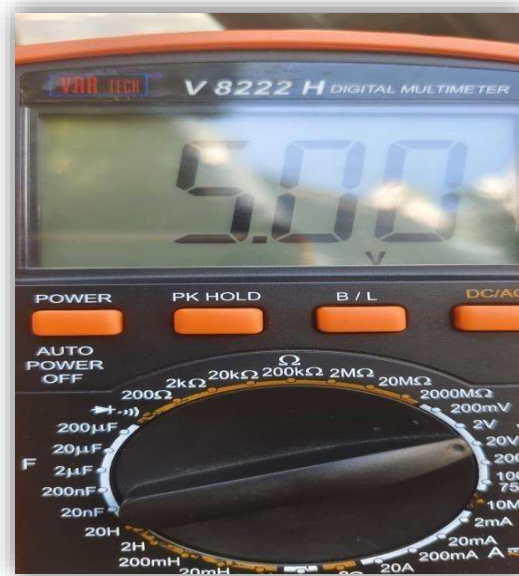


Figure 5.7 Three speed voltage

5.2.7 PEDAL SENSOR

When compared to models without this feature, electric bicycles with pedal sensors have several advantages. First off, it makes riding more enjoyable by smoothly triggering motor assistance as soon as the rider starts to pedal, guaranteeing more fluid transitions between pedalling and motor power. In addition to maximising efficiency, this synchronisation extends battery life and range by only assisting when necessary. Additionally, by encouraging a natural pedalling rhythm and lowering the possibility of unexpected speed surges, the pedal sensor encourages safer riding. Furthermore, pedal-sensor-equipped electric bicycles might qualify for regulatory advantages like being labelled as pedal-assist bicycles, which can spare them from some licencing and registration requirements. All things considered, the pedal sensor greatly improves the effectiveness, comfort, and security of riding an electric bicycle.



Figure 5.8 Cadence sensor

5.2.8 SAFETY SYSTEM

The cutting-edge braking system on our electric bike is part of an advanced safety system that enhances rider control and safety. When the brakes are applied, the brake system not only reduces speed but also automatically cuts off the motor's power supply to avoid overloading and guarantee a safe deceleration. By lowering the possibility of mishaps and system malfunctions, this preventative safety feature boosts rider confidence and peace of mind while operating.



Figure 5.9 Low potential brake

5.2.9 USER INTERFACE

Our electric bicycle's user-friendly interface offers riders simple control and individualization choices. Users can easily change the speed and direction of their ride to suit their preferences and the conditions by using a variety of input channels, such as pedal sensors and brake controls. For riders of all skill levels, integrated features like lighting and horn systems further improve safety and visibility while guaranteeing a pleasurable and comfortable ride. Convenience, safety, and ease of use are given top priority in the user interface, which makes our electric bicycle fun and accessible for a variety of riders.



Figure 5.10 Throttle with battery display

5.2.10 HEAD LIGHT

The following image is the 36v lamp



Figure 5.11 36v lamp

CHAPTER 6

INSCRIPTION OF INTEGRITY AND COMPATIBILITY

6.1 MODIFICATIONS IN THE REAR WHEEL

We start with the compatibility and integration and work towards making the assembly process go more smoothly. First, the rear wheel is fastened with new 24- gauge spokes that were carefully chosen for their strength and durability. These spokes provide the structural stability and integrity necessary for the wheel assembly's safe and efficient operation. It's interesting to note that the all the spokes are still attached to the original rim, which preserves consistency in the bicycle's functionality and appearance.

6.2 INSTALLING THE HUB MOTOR

Installing the hub motor onto the rear wheel assembly is the next step after the wheel is firmly in place. To guarantee correct alignment and fit, this procedure necessitates accuracy and close attention to detail. Carefully chosen to ensure that it works with the bicycle frame and other parts, the hub motor easily attaches to the wheel assembly and is prepared to provide dependable power for propulsion. The spokes are fixed from one hole on the right side of the hub motor to the right side of the rim, and from the next hole to the left, respectively. In contrast, the opposite is carried out on the other side of the hub to guarantee a balanced and symmetrical spoke arrangement for maximum stability and performance. The wheel's final design is similar to a traditional engine bike wheel, ensuring a comfortable and reliable riding experience.



Figure 6.1 After installing hub motor

6.3 INSTALLATION OF MOTOR CONTROLLER

The motor controller, which functions as the electric bicycle's central nervous system, is carefully installed to complete the setup process. The controller is positioned inside the seat tube, which is under the seat, in a way that maximises space utilisation and reduces interference with other components. The controller is welded to the frame precisely, providing stability and dependability all through operation. By placing the components in a strategic way, it is possible to guarantee smooth communication between the user interface and different subsystems, which improves the riding experience by enabling effective power flow and command execution.

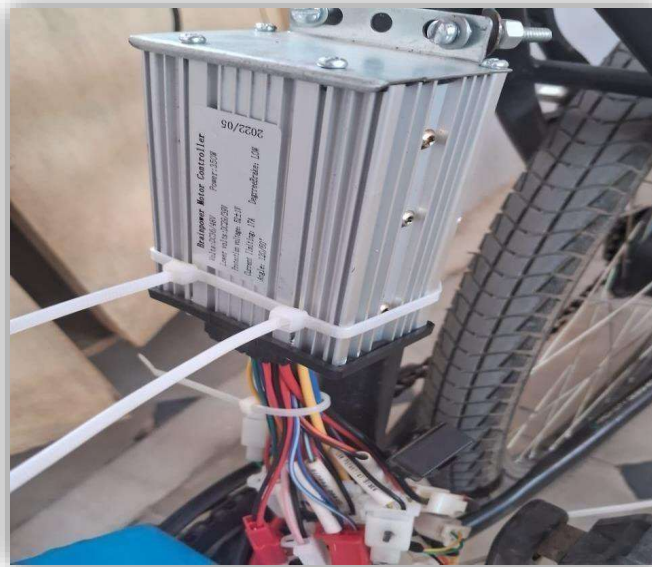


Figure 6.2 After installing motor controller

6.4 INSTALLING DC SUPPLY

Installing the DC supply: Next, the battery is installed. To ensure a tight and secure fit, the battery is carefully placed and mounted onto the welded clamps. For ideal weight distribution and balance, the backside of the battery begins three inches down the downtube from the front tube. The input and output terminals on the front side of the battery are conveniently placed about 8 inches from the crank. Easy access is made possible by this location for maintenance and charging. The sturdy clamps that are welded onto the downtube firmly clamp the battery in place,

giving it stability and avoiding any movement or shifting while it is in use. Now that the battery is precisely positioned within the weld clamps, the electric bike is prepared for dependable and effective operation.



Figure 6.3 After installing the battery

6.5 THROTTLE AND BATTERY DISPLAY

Installing the throttle is essential to turning on the bicycle's electric assist mode. The throttle can be found behind the brake lever on the right side of the handlebar for convenient access while riding. It is tightly mounted. The throttle wire is connected to the controller after installation. Nevertheless, the throttle wire and controller connectors are mismatched, necessitating exact soldering to create a good connection. The throttle is the only source of power for the system once it is connected. A key must be inserted into the throttle and turned on in order to start the electric assist mode. When the display glows green, it means that the system is powered on and prepared for use.



Figure 6.4 Throttle

6.6 COMPATIBILITY

When integration is almost finished, focus shifts to compatibility with the system, where careful testing and validation promise a higher reliability and performance. Every component is put through a rigorous evaluation process to make sure it is compatible with the overall architecture of the system and to find any potential conflicts or issues that might arise during operation. We improve the system to reach peak performance through continuous testing and refinement, providing a smooth and simple riding experience. Male XT60 connectors are soldered onto pairs of black and red wires, denoting positive and negative terminals, to bridge the electrical connections between components and guarantee compatibility and functionality throughout the system. This systematic method guarantees that every component functions in unison with the others, optimising dependability and efficiency for the rider.

6.7 FINAL TESTING

Now that the integration and compatibility issues have been settled, the electric bicycle enters the testing stage to make sure it functions as planned in practical scenarios. Simple things like power consumption are checked during testing by observing and throttling the speed, and the brakes are tested. By putting the bike through these tests, we can make sure it lives up to our high standards and surpasses rider expectations. We develop an electric bicycle that offers superior efficiency, consistency, and user satisfaction by putting integration and

compatibility first from the beginning, thereby raising the bar for urban mobility

CHAPTER 7

RESULTS AND DISSCUSSION

7.1 SKILLFULL INTEGRATION

Our electric bicycle project's results show the skillful integration of crucial elements meant to provide the best possible performance and user experience. In addition to offering a dependable power supply, the 36V 12Ah LiFePO4 battery's use has increased its lifespan, providing continued use without compromising performance. Our electric bicycle shows impressive speed and torque capabilities, easily getting speeds of up to 35 km/h when paired with a 36V 350W BLDC hub motor. The battery and motor combination has improved propulsion and allowed for smooth operation, providing riders with a seamless and comfortable riding experience.

7.2 RIDER SAFETY

Additionally, because of our focus on rider safety, security features like protective fuses between the controller and the motor and low-potential brakes attached to the controller have been added. By preventing overloading and stopping the motor's power supply as needed, these features not only protect riders' safety but also increase the system's longevity.

7.3 IMPROVED SAFETY

The integration of a 48V controller has improved safety while also offering effective control and coordination, facilitating smooth component communication and performance optimization. This has improved our electric bicycle's overall functionality and reliability even further.

7.4 FINAL CONCLUSION

To sum up, our project has effectively met its goals of producing a high-performance electric bicycle with improved safety features and effective power management for a variety of commuting scenarios. We have redefined urban mobility by utilizing innovative technologies and parts like LiFePO4 batteries, BLDC hub motors, and an

intelligent controller. This will provide users with a dependable, satisfying, and sustainable means of transportation for many years to come.



Figure 7.1 Finished

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

The development of the electric bicycle system presented in this project is an important step towards improving urban mobility through sustainable and efficient transportation solutions. A thorough understanding of the system's performance and capabilities was achieved through meticulous design, simulation, and experimentation, paving the way for future advances in electric vehicle technology. One of the primary goals of this project was to implement a suitable motor controller system capable of efficiently managing energy transfer between the battery and motor. While this particular aspect was not pursued, emphasis was instead placed on the implementation of strong safety features such as brakes linked to the controller and a protective fuse, which ensure rider safety and system integrity.

Furthermore, the combination of a 36V 12Ah LiFePO₄ battery and a 36V 350W BLDC hub motor has proven effective in meeting the electric bicycle's speed and torque requirements. The use of high-quality components, such as the lithium ferrite phosphate battery, has helped to extend battery life and increase power density, resulting in better efficiency and performance.

Simulation results have provided valuable insights into the system's behaviour, supporting the direct relationship between motor and wheel speed as well as the use of motor torque for propulsion. Furthermore, observations of battery current and power waveforms revealed the synchronous nature of power consumption and generation, indicating efficient energy utilisation.

While the project did not include regenerative braking, the presence of negative spikes in battery current and power waveforms highlights the potential for future energy recovery system implementations. Despite this, the project's emphasis on safety, efficiency, and performance resulted in a dependable and versatile electric bicycle system suitable for both urban commuting and recreational use.

To summarize, the culmination of design calculations, simulations, and experimental validation resulted in the successful development of an electric bicycle

system that embodies the principles of sustainability, efficiency, and innovation. Moving forward, continued research and development efforts will refine and optimize electric vehicle technologies, resulting in a greener and more sustainable for transportation.

8.2 FUTURE SCOPE

The project may investigate the integration of regenerative braking technology in the future to increase battery life and energy efficiency. Moreover, putting in place a safety lock system with biometric or clever authentication techniques could improve security and stop illegal use of the electric bike.

REFERENCES

- [1] Annette Muetze, Ying C. Tan. "ELECTRIC BICYCLE- a performance evaluation". Published in: IEEE Industry Applications Magazine (Volume: 13, Issue: 4, July-Aug. 2007).
- [2] Annette Muetze, Ying Chin Tan. "Modelling and Analysis of the Technical Performance of DC-Motor Electric Bicycle Drives Based on Bicycle Road Test Data". Published in: 2007 IEEE International Electric Machines & Drives Conference.
- [3] Arumugam Manthiram. "An Outlook on Lithium Ion Battery Technology". Published in: September 2017, American Chemical Society.
- [4] Brant Price, Eric Dietz, Jeff Richardson. "Life Cycle Costs of Electric and Hybrid Electric Vehicle Batteries and End-of-Life Uses". Published in: 2012 IEEE International Conference on Electro/Information Technology.
- [5] Chang-Hua Lin, Hom-Wei Liu, Chien-Ming Wang. "Design and Implementation of a Bi-directional Power Converter for Electric Bike with Charging Feature". Published in: 2010 5th IEEE Conference on Industrial Electronics and Applications.
- [6] G. Cipriani, V. Di Dio, R. Miceli (IEEE Member), G. Ricco Galluzzo, M. Russo. "Design and Performance Testing of an E-Bicycle". Published in: 2013 International Conference on Renewable Energy Research and Applications (ICRERA).

[7] Guichi Amar, Ghadbane Ismail, Bouzidi Riad. "Suitability of Electric Motors and Conventional Control Techniques for Electric Vehicle Applications". Published in: 2022 International Conference of Advanced Technology in Electronic and Electrical Engineering (ICATEEE).

[8] Hanif F. Prasetyo, Arief S. Rohman, Farkhad I. Hariadi, Hilwadi Hindersah. "Controls of BLDC Motors in Electric Vehicle Testing Simulator". Published in: 2016 IEEE 6th International Conference on System Engineering and Technology (ICSET) Oktober 3-4, 2016 Bandung – Indonesia.

[9] Huang-Jen Chiu, Li –Wei-Lin. "A Bidirectional DC–DC Converter for Fuel Cell Electric Vehicle Driving System DC-DC". Published in: IEEE Transactions on Power Electronics (Volume: 21, Issue: 4, July 2006).

[10] Jorge Alonso-del-Valle, Manuela González, Juan Carlos Viera, Víctor García, David Anseán. "Cycling Study of 18650 Nickel-Rich Silicon-Graphite Lithium-ion Batteries under Different Charge Current".

[11] Ludmila C. A. Silva, Jony J. Eckert, Fabio M. Santiciolli, Eduardo S. Costa, Franco G. Dedini, Fernanda C. Corrêa. "A Study of Battery Power for a Different Electric Vehicle Propulsion System". Published in: 2015 International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles (ESARS).

[12] Mehnaz Khan, Adeeb Ahmed, Iqbal Hussain, Yilmaz Ozer, Mohamed Badawy. "Performance Analysis of Bi-directional DC-DC Converters for Electric Vehicles". Published in: IEEE Transactions on Industry Applications (Volume: 51, Issue: 4, July-Aug. 2015).

[13] Pooja Naresh Bhatta, Hemant Mehar, Manish Sahajwani. "Electrical Motors for Electric Vehicle – A Comparative Study". Published in: Proceedings of Recent Advances in Interdisciplinary Trends in Engineering & Applications (RAITEA) 2019.

[14] S. A. Farisi, G. S. Ajie, R. B. Setyawati, K. N. R. Stulasti, Y. R. Azinuddin, D. A. P. B. Sudian, R. A. Nurfi, S. Sulistiyawan, H. K. (Kiwi) Aliwarga, W. G. Suci. "Increasing Electric Bicycle Performance using Lithium Ferro Phosphate Batteries with a Battery Management System". Published in: Esta Journal, 06-27-2022.

[15] Weidong Chen, Jun Liang, Zhaohua Yang, Gen Li. "A Review of Lithium-Ion Battery for Electric Vehicle Applications and Beyond". Published in: Elsevier, Volume 158, February 2019.

[16] Xiaojin Men, Youguang Guo, Gang Wu, Shuangwu Chen, Chun Shi. "Implementation of an Improved Motor Control for Electric Vehicles". Published in: 1 July 2022 Energies conference, Special Issue of Advanced Electrical Machine Design and Optimization.

APPENDIX

