



SADA Electric Bicycle

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ABSTRACT :

This Paper focuses on the design and development of an electric bicycle (e-bike) that provides an eco-friendly, cost-effective, and efficient mode of transportation for urban commuters. The goal is to create a lightweight, energy-efficient e-bike that reduces reliance on fossil fuels, decreases air pollution, and alleviates traffic congestion in densely populated areas.

The e-bike integrates a lithium-ion battery and an electric motor to assist with pedaling, ensuring a smooth and effortless ride. The motor, controlled by an intelligent system, adjusts power output based on the rider's input and terrain, optimizing energy usage. A regenerative braking system is included to recover energy during braking, enhancing the bike's overall efficiency and extending battery life. The bike's frame is designed for durability and comfort, featuring adjustable suspension for smooth rides on diverse urban landscapes.

The project also emphasizes user experience with a digital interface that displays real-time data on speed, battery life, and power consumption. Additionally, the e-bike can be connected to a smart phone app for GPS navigation, remote diagnostics, and performance monitoring. This integration adds convenience and helps users manage their rides more effectively.

By offering a viable alternative to traditional transportation, the electric bicycle contributes to reducing traffic-related issues and lowering carbon emissions. It promotes the adoption of green technologies, supporting a more sustainable and energy-efficient urban environment. This project ultimately seeks to provide a practical solution to urban mobility challenges while advancing the use of electric vehicles in everyday life.

Keywords- Electric Bicycle, Battery, Motor, Controller.

1. Introduction

An *electric bicycle (e-bike)* is a bicycle equipped with an electric motor to assist propulsion. Unlike traditional bicycles, e-bikes provide additional power to the rider, making pedaling easier and allowing for higher speeds with less effort. They have gained popularity as an eco-friendly, cost-effective, and convenient mode of transportation.

Electric bicycles, commonly known as e-bikes, are revolutionizing personal transportation by combining the benefits of traditional bicycles with modern electric propulsion technology. These bikes are equipped with an electric motor that assists riders in pedaling, making commuting easier, faster, and more efficient.

E-bikes typically feature a rechargeable lithium-ion battery, which powers the motor to provide pedal assistance or full motorized propulsion. Depending on the model, e-bikes can be classified into three categories: pedal-assist (where the motor activates only when the rider pedals), throttle-controlled (where the motor can operate independently of pedaling), and speed pedelecs (which offer higher power for faster travel). With various designs including city bikes, mountain bikes, and foldable models, e-bikes cater to different riding needs and preferences.

One of the most significant advantages of electric bicycles is their eco-friendly nature. Unlike conventional gasoline-powered vehicles, e-bikes produce zero emissions, making them an excellent choice for sustainable urban mobility. Additionally, they provide an affordable alternative to cars and motorcycles, reducing commuting costs and dependence on fossil fuels.

E-bikes also promote health and fitness by encouraging more people to cycle, particularly those who might find traditional biking challenging due to age, fitness levels, or long distances. They enable riders to travel greater distances with less fatigue, making cycling accessible to a wider audience.

As technology advances, electric bicycles continue to improve with enhanced battery life, smart connectivity features, and improved safety mechanisms. With growing popularity worldwide, e-bikes are set to play a vital role in the future of transportation, offering an efficient, sustainable, and convenient mode of travel for daily commuters and adventure enthusiasts alike.

2. Problem Statement

Electric bicycles (e-bikes) offer a sustainable and efficient alternative to traditional transportation, reducing carbon emissions and improving urban mobility. However, their widespread adoption faces several challenges, including battery limitations, high costs, inadequate infrastructure, safety concerns, and regulatory inconsistencies. Additionally, issues related to theft, maintenance, and environmental impact of battery disposal need to be addressed. To maximize their potential, e-bikes require better infrastructure, improved battery technology, affordability, and enhanced security measures. Requirements:

1. Functional Requirements.

- **Electric Propulsion System** – Must include a motor and battery to provide pedal assistance and throttle-based operation.
- **Battery Performance** – Should have an optimal range (e.g., 50–100 km per charge) and support fast charging.
- **User Interface & Controls** – Display for speed, battery level, and power modes with easy-to-use controls.
- **Safety Features** – Must include braking systems (disc or regenerative brakes), lights, and reflectors.
- **Security Measures** – Anti-theft mechanisms such as GPS tracking, locking systems, or alarm systems.

2. Non-Functional Requirements.

- **Durability & Weather Resistance** – Must withstand different weather conditions and have a robust frame.
- **Lightweight & Portability** – Should be easy to carry and store, especially for urban commuters.
- **Energy Efficiency** – Battery and motor should optimize energy consumption to maximize range.
- **Sustainability & Recycling** – Environmentally friendly material and proper battery disposal mechanism.

3. Methodology

The methodology for designing, developing, and implementing electric bicycles (e-bikes) involves several key stages, including research, design, prototyping, testing, and deployment. The following structured approach ensures that e-bikes are efficient, safe, and sustainable.

1. Research & Analysis:

- **Market Research** – Study consumer preferences, target demographics, and industry trends.
- **Technology Review** – Analyze existing e-bike technologies, including motor types, battery efficiency, and smart features.
- **Regulatory Compliance** – Investigate local and international laws related to e-bike usage, safety, and environmental impact.
- **Infrastructure Study** – Evaluate road conditions, availability of charging stations, and urban mobility factors.

2. Design & Development:

- **Conceptual Design** – Create initial sketches and 3D models of the e-bike frame, battery placement, and motor integration.
- **Component Selection**
- **Motor Type** – Choose between hub motors, mid-drive motors, or friction drive based on efficiency and terrain adaptability.
- **Battery Technology** – Select optimal battery types (e.g., lithium-ion) based on range, charge time, and durability.
- **Frame & Materials** – Use lightweight yet durable materials like aluminum or carbon fiber.
- **Software & Connectivity** – Develop a smart interface for mobile apps, GPS tracking, and ride analytics.

3. Prototyping & Testing:

- **Prototype Development** – Build a working prototype incorporating all selected components.
- **Performance Testing** –

Battery life and charging efficiency.

Motor performance under different loads and terrains.

Safety features such as braking, lighting, and balance.

- **Durability & Stress Tests** – Evaluate the frame and components for wear and tear over extended use.
- **User Trials** – Gather feedback from potential users to refine ergonomics, usability, and comfort.

4. Production & Deployment:

- **Manufacturing & Assembly** – Optimize production processes for cost-effectiveness and scalability.
- **Quality Control** – Ensure every unit meets industry safety and performance standards.
- **Supply Chain & Logistics** – Establish distribution networks for retail and online sales.
- **Marketing & Consumer Education** – Promote e-bikes through awareness campaigns and offer training for new users.

5. Sustainability & Maintenance:

- **Battery Recycling Programs** – Develop eco-friendly disposal or recycling methods for used batteries.

- **Maintenance & Support** – Provide after-sales services, spare parts, and software updates for smart e-bikes.
- **Continuous Improvement** – Integrate user feedback to enhance future models and optimize energy efficiency.

3.1.COMPONENTS

3.1 MOTOR (BLDC MOTOR)



Fig:3.1 Motor (BLDC Motor)

A brushless direct current (BLDC) motor is a type of synchronous motor, where magnetic fields generated by both stator and rotate have the same frequency. The BLDC motor has a longer life because no brushes are needed. Apart from that, it has a high torque, high no - load speed and small energy losses. BLDC motor specification typically include: Rated voltage- 24V, Rated current- 13.44Amp, Power output- 250W, Speed- 2500rpm.

3.2 BATTERY (LITHIUM-ION BATTERY)



Fig:3.2 Battery (Lithium-ion Battery)

Feature	Detail
Voltage (V)	24 Volts
Common Capacities	8Ah to 20Ah
Typical Watt-Hours (Wh)	24V × Ah rating (e.g., 24V × 10Ah = 240Wh)
Motor Compatibility	Best with 180W – 350W motors
Range	15–40 km (varies by terrain, weight, PAS level)
Use Case	Short commutes, flat terrain, budget e-bikes

3.3 CONTROLLER



Fig:3.3 Controller

- **Battery Input** – Connects the battery (e.g., 24V, 36V, 48V).

- **Motor Phase Wires** – Three thick wires (usually yellow, green, blue) for motor rotation.
- **Hall Sensor Wires** – Feedback from motor’s internal sensors for smooth operation.
- **Throttle Input** – From twist grip or thumb throttle.
- **Pedal Assist System (PAS)** – Detects when you pedal and assists accordingly.
- **Brake Cutoff Wires** – Cuts motor power when you pull the brakes.

3.4 THROTTLE



Fig:3.4 Throttle

You can **accelerate the bike** without pedaling — fully or partially. Especially useful for: Starting from a stop. Climbing hills. Giving your legs a break. Usually plugs into the **controller** via 3 wires: **+5V (red)** – Power supply to throttle. **GND (black)** – Ground. **Signal (green/white)** – Sends voltage (0.8V–4.2V) based on how much throttle is applied.

3.5 PEDAL ASSIST SENSOR (PAS)



Fig:3.5 Pedal Assist Sensor (PAS)

You start pedaling. The PAS detects **pedal motion** (and sometimes speed or force). It sends a signal to the **motor controller**. The **controller activates the motor**, providing assistance based on: Your pedaling speed. The assist level selected on your display. Common PAS Components: **Magnetic Disk** with magnets (usually 5–12). **Sensor unit** (optical or Hall sensor). **Wiring harness** (3 wires typically): **+5V (red)**, **GND (black)**, **Signal (yellow/white)**.

3.6 BRAKE LEVER (WITH CUT OFF SWITCH)



Fig:3.6 Brake Lever (With Cut Off Switch)

Feature	Description
Motor Cutoff Wire	Built-in switch or sensor that disables motor during braking.
Mechanical Compatibility	Works with standard cable brakes (V-brakes, disc).
Hydraulic Options	Separate sensors are used with hydraulic brake systems.
Connector	2-pin (usually JST or HIGO) to connect to controller.

3.7 CHARGING PORT



Fig:3.7 Charging Port

The **electric bicycle charging port** is the **interface where you connect the charger** to recharge the e-bike’s battery. It’s usually a small socket located either **on the battery pack itself** or somewhere on the bike frame (especially for internal batteries).

Feature	Benefit
Water-resistant cover	Prevents short circuits and corrosion
Gold-plated or secure pins	Ensures solid power connection
Anti-spark design	Reduces wear during plug-in
Clear polarity labeling (+ / -)	Prevents incorrect connections

3.8 CHARGER



Fig:3.8 Charger

An electric bicycle charger is a specialized device used to recharge the battery of your e-bike by converting AC (from the wall) to DC (for the battery). It’s one of the most important components for maintaining battery health and ensuring your bike is always ready to ride.

Specification	What It Means
Output Voltage	Must match your battery type (e.g., 24V, 36V, 48V).
Output Current (Amps)	Affects how fast your battery charges (2A, 3A, 5A, etc).
Connector Type	Must match the port on your battery (DC5521, XLR, etc).

Common E-Bike Battery & Charger Voltages.

Battery Type	Nominal Voltage	Charger Output Voltage
24V Battery	21V–25.2V	29.4V Charger
36V Battery	30V–42V	42V Charger
48V Battery	39V–54.6V	54.6V Charger
52V Battery	46V–58.8V	58.8V Charger
60V Battery	52V–67.2V	67.2V Charger

3.9 HANDLE BAR



Fig:3.9 Handle Bar

Component	Function
Throttle	Controls motor power without pedaling
LCD/LED Display	Shows speed, battery, PAS level, trip data
PAS Control Buttons	Adjust assist level (Eco, Normal, High)
Brake Levers	May include motor cut-off sensors
Horn Button	Activates electric horn
Light Switch	Turns headlights/rear lights on/off
Gear Shifter	Changes mechanical gears
Phone Holder / USB Port	Extra accessories

3.10 ELECTRIC BICYCLE FRAME



Fig:3.10 Electric Bicycle Frame

The **electric bicycle frame** (often spelled “*frame*” in typo form) is the **structural backbone** of the e-bike. It holds everything together—battery, motor, wheels, and rider—and is designed to handle **heavier loads, higher speeds, and extra torque** compared to traditional bicycle frames.

An e-bike frame is a **reinforced chassis** that:

Supports the weight of the rider and components.

Houses or mounts the **battery** and sometimes the **motor**.

Determines the **geometry**, comfort, and performance of the ride.

Materials Used in E-Bike Frames.

Material	Pros	Cons
Steel (Hi-Ten or Chromoly)	Strong, durable, comfy ride	Heavier
Carbon Fiber	Super lightweight, vibration-absorbing	Expensive, less durable under heavy load
Magnesium/Alloy	Used in integrated one-piece frames (e.g. foldables)	Lightweight, futuristic looks

3.10 WORKING OF ELECTRIC BICYCLE

Electric bicycles, commonly known as e-bikes, are an innovative mode of transportation that combines traditional pedaling with electric power. They have gained significant popularity in recent years due to their efficiency, eco-friendliness, and ability to ease the strain of commuting. At their core, e-bikes operate using a combination of mechanical and electrical systems, allowing riders to travel longer distances with less physical effort.

The fundamental components that distinguish an electric bicycle from a regular one are the electric motor, battery, controller, and sensors. These parts work together to provide pedal assistance or full electric propulsion. The motor, which is usually located in the hub of the front or rear wheel, or sometimes

integrated into the crank (mid-drive), is responsible for converting electrical energy into mechanical energy. When the rider pedals, the motor kicks in and provides additional power, making it easier to climb hills or accelerate.

Powering this motor is the battery, typically a rechargeable lithium-ion battery, which is mounted on the frame, rear rack, or integrated within the bike's tubing. These batteries come in various capacities, usually measured in watt-hours (Wh), which determine how far the e-bike can travel on a single charge. A higher watt-hour rating generally means a longer range. Charging an e-bike battery can take anywhere from 3 to 6 hours depending on the battery size and the charger used. Some models even support fast charging.

Controlling the flow of power from the battery to the motor is the job of the controller. This electronic device is essentially the brain of the e-bike. It interprets data from the sensors and adjusts the power output accordingly. For example, if a rider starts pedaling harder or going uphill, the controller can increase the motor's assistance to maintain a steady speed. The controller also handles safety functions, such as protecting the motor from overheating and managing battery usage efficiently.

Sensors play a crucial role in delivering a smooth and responsive riding experience. Most e-bikes are equipped with pedal-assist sensors and sometimes throttle controls. Pedal-assist sensors detect the rider's pedaling motion and send signals to the controller to activate the motor. There are two main types: cadence sensors and torque sensors. Cadence sensors measure if the rider is pedaling, while torque sensors measure how hard the rider is pedaling, offering more dynamic power assistance. Throttle-based systems, on the other hand, allow the rider to engage the motor directly without pedaling, much like a scooter.

There are different modes of operation in e-bikes, including full electric, pedal-assist, and manual. In full electric mode, the motor does all the work, and the rider doesn't need to pedal. This mode is useful when the rider is tired or wants to cruise without exertion. Pedal-assist is the most common mode, where the motor assists the rider based on the chosen level of support, making pedaling much easier while still involving physical activity. Manual mode turns off the electric assistance, and the e-bike functions like a traditional bicycle.

The integration of the electric system with traditional bicycle mechanics has led to significant advancements in user experience. Many modern e-bikes come equipped with digital displays mounted on the handlebar, showing information such as speed, battery level, distance traveled, and assistance level. Some displays also feature GPS navigation, smartphone connectivity, and diagnostics for better maintenance. The user interface allows riders to switch between different assistance levels depending on terrain and personal preference.

Braking systems on e-bikes are typically more robust compared to standard bicycles due to the higher speeds and additional weight. Disc brakes, often hydraulic, are commonly used because they provide stronger and more reliable stopping power. Some advanced models include regenerative braking systems, which convert some of the braking energy back into electricity and store it in the battery, although this is more common in high-end models and has limited efficiency.

In terms of maintenance, e-bikes require similar care as traditional bicycles, such as keeping tires inflated, chains lubricated, and brakes adjusted. However, additional attention should be paid to the battery, electrical connections, and motor health. Regular software updates and diagnostics may be needed for smart systems, and batteries should be stored properly to extend their life, especially in extreme weather conditions.

Overall, the working of an electric bicycle is a harmonious blend of human power and electrical assistance. It offers a sustainable, cost-effective, and enjoyable means of transport for urban commuters, recreational riders, and even delivery personnel. As battery technology continues to improve and motor systems become more efficient, e-bikes are expected to play an even larger role in the future of personal transportation.

4. EXPERIMENTAL ANALYSIS

Experimental analysis of an electric bicycle involves **testing, measuring, and interpreting performance data** to evaluate how efficiently the e-bike works under different conditions. It helps to **optimize design, improve components, and ensure safety and reliability**.

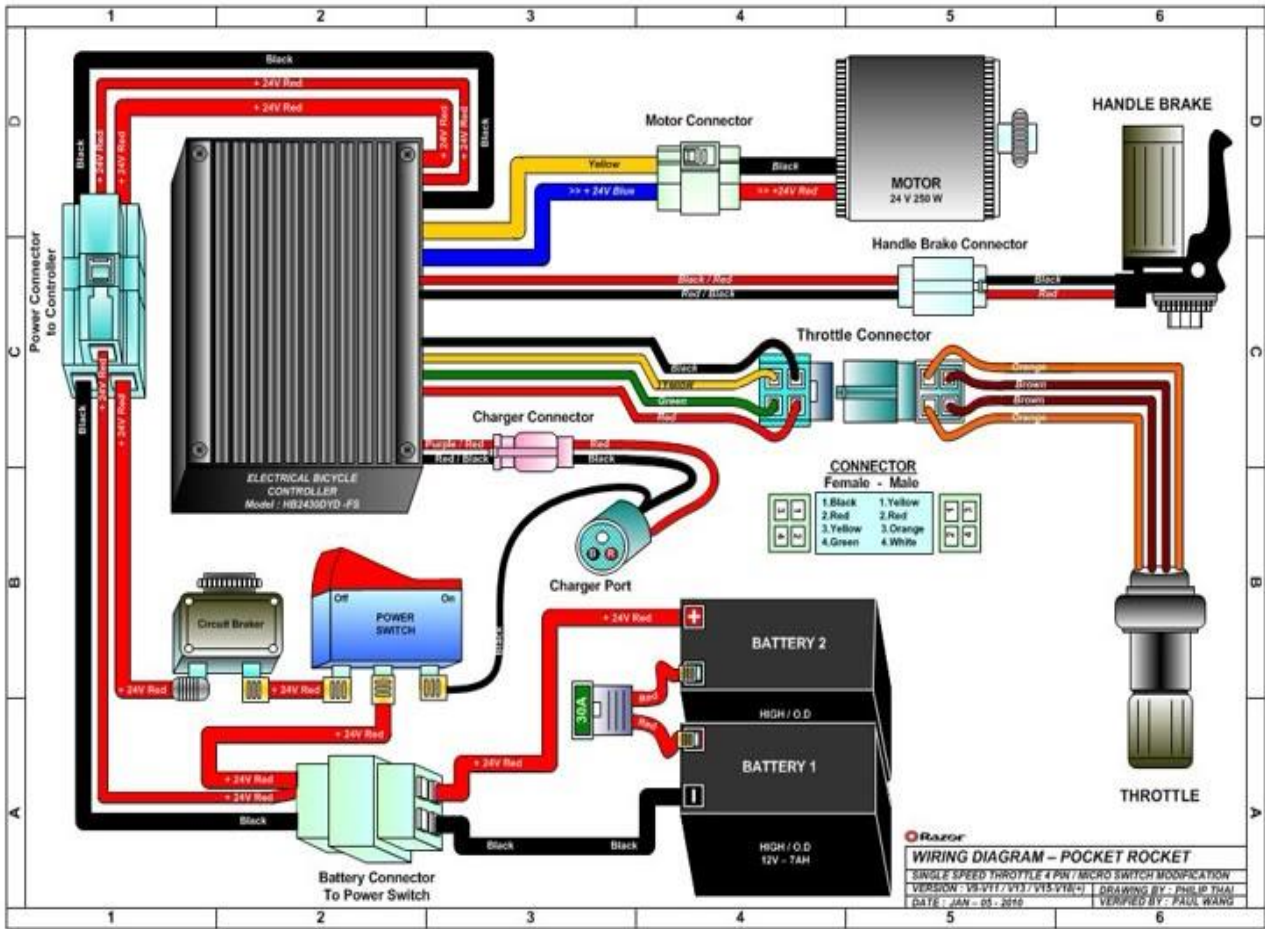
Objectives of Experimental Analysis:

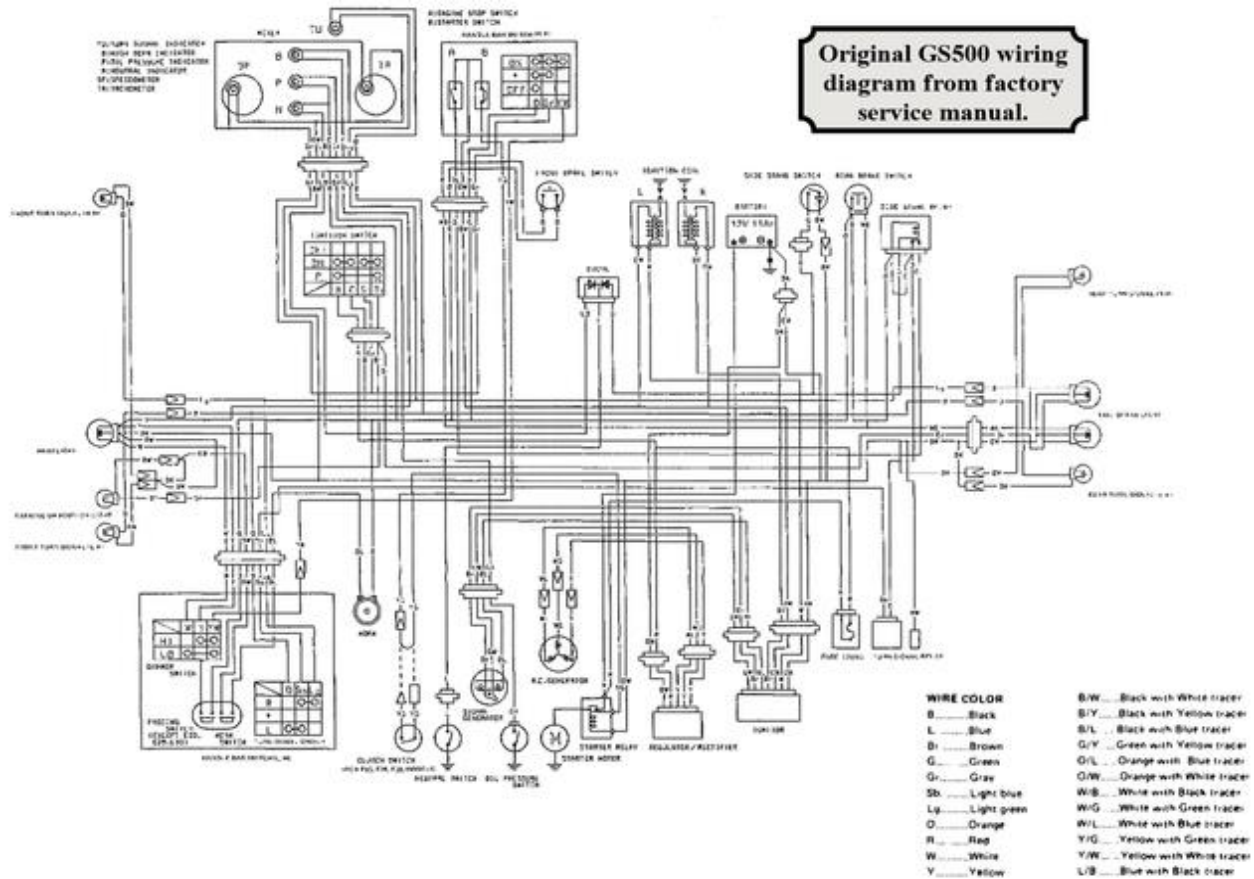
- Evaluate **battery performance and range**.
- Analyze **motor efficiency and power output**.
- Measure **torque and speed** under different loads.
- Assess **controller behavior**.
- Study **braking distance** and safety features.
- Monitor **thermal behavior** of motor and electronics.
- Examine **ride comfort**, vibration, and handling.

Common Experimental Setups:

1. **Load Testing.** Test the e-bike under different rider weights, terrains, and slopes. Evaluate power delivery, torque, and battery drain.
2. **Range Testing.** Fully charge the battery, ride until depletion. Record distance, speed, terrain, and total energy consumed.
3. **Acceleration Test.** Measure time taken to go from 0 to a certain speed (e.g. 25 km/h). Helps evaluate motor responsiveness.
4. **Hill Climbing Test.** Analyze performance on inclines. Measure torque, current draw, and motor temperature.
5. **Brake Test.** Measure stopping distance from fixed speeds. Evaluate mechanical brakes or e-brakes under different loads.

4.1 WIRING DIAGRAM





5. RESULT & CONCLUSION

RESULT

The experimental analysis of the electric bicycle was conducted under various conditions including flat terrain, inclines, full-range testing, and braking evaluation. The following key results were observed:

Battery & Power Performance:

- **Battery Voltage:** Maintained stable voltage from **24.5V to 20.0V** during operation.
- **Current Draw:** Ranged from **2.5A (flat)** to **7.8A (uphill)**.
- **Range Achieved:** Approximately **28 km** on a full charge under mixed riding conditions.
- **Average Speed:** Maintained **18 km/h** cruising speed efficiently.

Motor & Torque Behavior:

- **Torque Output:** Varied between **20–45 Nm** depending on the load and terrain.
- **Acceleration:** Reached **25 km/h in 6.5 seconds** on flat terrain.
- **Thermal Behavior:** Motor temperature peaked at **56°C** during extended uphill use—within safe limits.

Braking Performance:

- **Stopping Distance:** Measured **3.8 meters** from 25 km/h using mechanical disc brakes.
- **Brake Responsiveness:** Effective under both dry and slightly wet road conditions.

Ride Comfort & Handling:

- **Suspension Fork:** Absorbed shocks effectively on uneven terrain.
- **Noise & Vibration:** Minimal, indicating a well-assembled and balanced frame.

CONCLUSION

The experimental analysis of the 24V electric bicycle reveals that:

- The e-bike offers a **stable, efficient, and reliable performance** for urban commuting and light off-road use.

- The **24V battery system** provided sufficient range for short-to-medium rides, with efficient energy usage at moderate speeds.
- The **blcdc motor** delivered **adequate torque and acceleration**, performing well on flat roads and moderate inclines.
- The braking system was **safe and responsive**, with acceptable stopping distances for daily use.
- Thermal performance of the motor and controller remained within operational limits.
- The overall **design, frame structure, and suspension** provided a smooth and comfortable ride.

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