E-Bike Motor Speed Controller

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Abstract — The E-Bike Motor Speed Controller is an essential electronic unit responsible for regulating the speed and performance of an electric bike motor. It controls the power flow from the battery to the motor based on rider input through the throttle. The controller processes signals and adjusts the motor speed using techniques such as Pulse Width Modulation (PWM). This ensures smooth acceleration, efficient power usage, and protection of electrical components. The system improves safety, performance, and reliability of electric bikes. With increasing demand for eco-friendly transportation, the development of efficient motor controllers plays an important role in enhancing electric vehicle technology and promoting sustainable mobility.

Keywords: E-Bike Motor Speed Controller; Electric Vehicle Technology; Pulse Width Modulation (PWM); Motor Speed Regulation; Battery Power Management; Sustainable Mobility;

I. INTRODUCTION

Electric bikes (E-Bikes) are becoming an increasingly popular form of transportation due to their environmental benefits, lower operational costs, and convenience. The core component responsible for controlling the performance of an e-bike is the motor speed controller.The motor speed controller regulates the electrical power supplied from the battery to the motor. It receives input from the throttle and processes it to determine the desired speed of the bike. Based on this input, the controller adjusts the motor power to maintain smooth and efficient operation.The controller also monitors important parameters such as voltage, current, and motor load to ensure safe operation. It helps prevent overheating, overcurrent conditions, and battery damage. Therefore, the motor speed controller plays a critical role in improving the safety, efficiency, and reliability of electric bikes.

A. Need of Project:

The need for an automatic seed sowing robot arises from the inefficiencies and labor demands of traditional sowing methods, which often result in uneven seed distribution, improper spacing, and inconsistent depth, all of which negatively affect crop yields. As labor costs increase and shortages persist, especially in large-scale farming, automation offers a solution to these challenges. The seed sowing robot ensures precise seed placement, optimizes spacing, and improves overall efficiency, reducing both labor and seed wastage. This technology is essential for modernizing agriculture and enhancing productivity in a sustainable manner.

B. Objective:

The primary objective of this project is to design and develop an efficient and reliable motor speed controller for an electric bicycle using an STM32 microcontroller. The system aims to provide precise control of a BLDC motor by regulating speed and torque based on user input through a throttle mechanism.

The project focuses on implementing effective control algorithms, such as PWM-based speed control and PID regulation, to ensure smooth acceleration, stable operation, and optimal energy utilization. It also aims to integrate sensor feedback, including Hall sensors, to achieve accurate motor commutation and real-time speed monitoring.

Additionally, the system is designed to enhance safety by incorporating protection features such as overcurrent, undervoltage, and braking control. Overall, the objective is to develop a cost-effective and energy-efficient solution that improves the performance, reliability, and usability of electric bicycles while supporting sustainable transportation.

C. Scope of the project:

The scope of the project titled “E-Bike Motor Speed Controller” involves the design, development, and implementation of an electronic system that efficiently controls the speed of an electric bike motor. The project focuses on regulating motor speed based on user input, such as a throttle, using techniques like Pulse Width Modulation (PWM) to ensure smooth acceleration and deceleration. It includes the integration of key hardware components such as a microcontroller, motor driver circuit, battery, and control interface, along with necessary protection mechanisms like overcurrent, overvoltage, and thermal safety. On the software side, the system will use embedded programming to generate control signals, implement speed regulation algorithms, and ensure reliable operation under varying load conditions. The controller aims to enhance energy efficiency, improve battery usage, and provide stable performance. While the project is primarily intended for low to medium power e-bike applications, it can be further extended with advanced features such as regenerative braking, smart connectivity, and intelligent energy management systems.

II. SYSTEM ARCHITECTURE:

A. Block diagram:

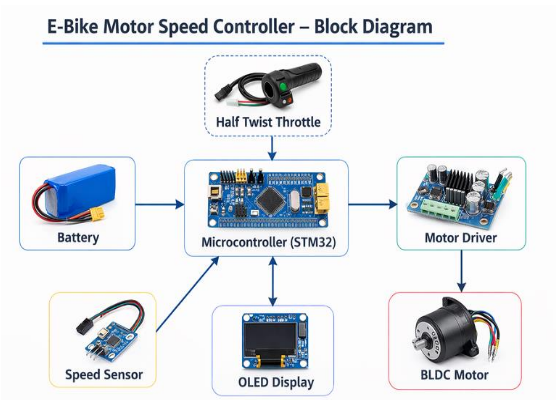

Fig. 1: Block diagram

B. Hardware used:

1) Microcontroller (STM32 Board)
2) Battery
3) Half Twist Throttle
4) OLED Display

1) Microcontroller (STM32 Board:

The e-bike motor speed controller is a key component that regulates the power flow from the battery to the motor, controlling speed, acceleration, and torque. It receives input from the throttle, pedal-assist sensors, and brakes, adjusting voltage and current for smooth and efficient operation. Typically built with a microcontroller, MOSFETs, and capacitors, controllers can support brushed or brushless DC motors, with brushless designs being more common in modern e-bikes. Beyond speed control, they protect the battery and motor from overcurrent, overvoltage, and overheating, and some advanced models support regenerative braking and programmable modes. By coordinating user input with motor response, e-bike controllers ensure safe, efficient, and responsive riding.

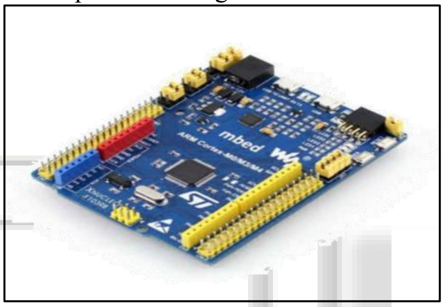

Fig. 2: Microcontroller (STM32 Board)

C. Battery:

The lithium-ion (Li-ion) battery is the most commonly used power source for modern electric bicycles due to its high energy density, long cycle life, and lightweight design. Typically configured in 36V or 48V systems with capacities ranging from 8Ah to 20Ah or more, Li-ion batteries provide sufficient energy to support extended rides and varying motor loads. They are favored over older technologies such as sealed lead-acid (SLA) batteries, which are heavier, bulkier, and less efficient. Some e-bikes also use lithium polymer (Li-Po) batteries, which offer flexible form factors and low weight but require careful handling. By efficiently storing and delivering electrical energy to the motor and speed controller, Li-ion batteries enable reliable, long-lasting, and high-performance operation for commuter, recreational, and cargo e-bikes.

Fig. 3: Lithium-Ion Battery

D. Half Twist Throttle:

The half-twist throttle is a commonly used input device for electric bicycles that allows the rider to control motor speed by rotating a portion of the handlebar grip. Unlike full-twist throttles, which require a complete rotation, the half-twist throttle moves through a smaller angle, providing more precise and responsive control over acceleration. It typically connects to the motor controller via a signal wire, sending variable voltage corresponding to the rider's twist position, which the controller interprets to adjust motor power. Half-twist throttles are valued for their ergonomic design, ease of use, and smooth modulation of speed, making them suitable for commuter, cargo, and recreational e-bikes.

Fig. 4: Half Twist Throttle

E. OLED Display:

An OLED (Organic Light Emitting Diode) display is used as a compact and efficient interface to provide real-time information to the rider. Unlike traditional LCDs, OLED displays do not require a backlight, which makes them more energy-efficient and capable of producing high contrast and clear visibility even in low-light conditions. The display can be interfaced with the microcontroller (such as Arduino) using communication protocols like I2C or SPI. In this project, the OLED screen is used to show important parameters such as current speed, battery level, motor status, and mode of operation. Its fast response time and wide viewing angle make it ideal for dynamic data display in e-bike systems. Additionally, OLED displays are lightweight and consume less power, which aligns well with the energy-efficient design goals of electric vehicles.

Fig. 5: OLED Display

III. METHODOLOGY: DESIGN AND DEVELOPMENT:

The design of the e-bike motor speed controller involves integrating electrical and electronic components to regulate motor performance. The controller receives power from the battery and processes input signals from the throttle. Using Pulse Width Modulation (PWM), the controller adjusts the voltage supplied to the motor, thereby controlling its speed. The system continuously monitors operating conditions to maintain smooth performance and prevent faults. The integration of sensors, control circuits, and display modules ensures efficient system operation and improved user experience.

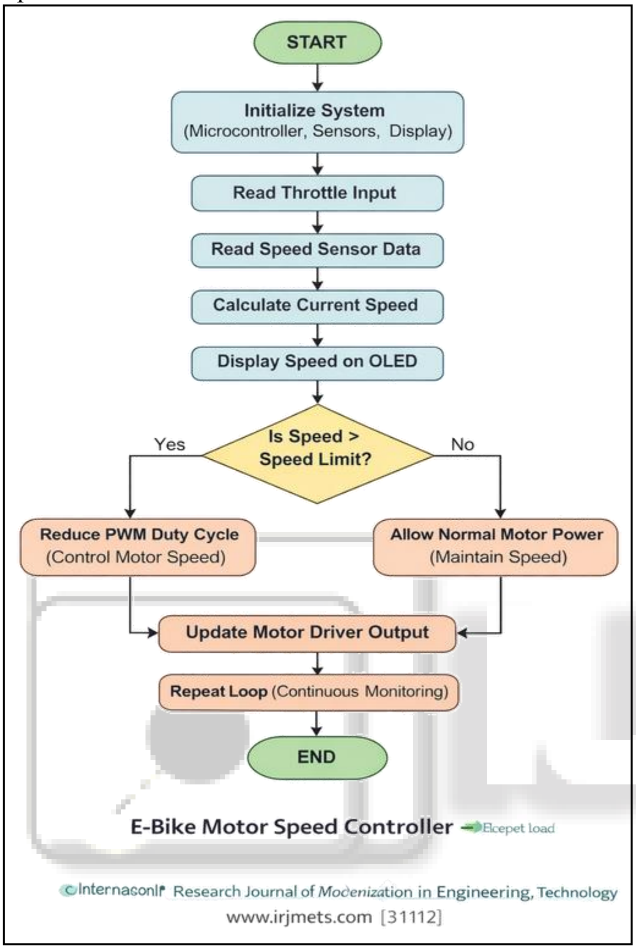

Fig. 6: Flow Chart

A. Software and Algorithm:

The software and control algorithm of an STM32-based e-bike motor controller are essential for achieving efficient, smooth, and safe motor operation. Below is a structured outline of the key components, functionalities, and algorithms used in the system.

Software Components

1) Microcontroller Programming:

- Typically written in C/C++ using STM32CubeIDE / HAL libraries
- Code structure includes:
  - main() function
  - Initialization functions (GPIO, ADC, TIM, UART)
  - Infinite control loop

2) Sensor Integration:

- Throttle Sensor (Analog Input)
  - Read using ADC
  - Converts rider input into speed/torque demand
- Hall Sensors (Digital Input)
  - Detect rotor position
  - Used for commutation and speed calculation
- Current/Voltage Sensors (Optional)
  - Used for protection and efficiency control

3) Motor Control:

- PWM generation using STM32 timers (TIM1/TIM8)
- Control of MOSFET driver (3-phase inverter)
- Implements:
  - 6-step commutation logic
  - Duty cycle control for speed regulation

4) User Interface (optional):

- PID controller for speed regulation
- Commutation logic based on Hall sensor feedback
- Speed calculation algorithms

B. Algorithm

Here's a basic algorithm outline for the E-Bike Motor Speed Controller:

1) Initialization

- Configure GPIO pins (Hall sensors, brake, driver outputs)
- Initialize ADC for throttle input
- Initialize timers for PWM generation
- Start interrupts for Hall sensors and control loop

2) Pre-Operation Check

- Read battery voltage
- Check for fault conditions (overvoltage, low voltage)
- Ensure brake is not applied
- Initialize motor state

3) Speed Control Process

Step 1: Read Inputs

- Read throttle value using ADC
- Read Hall sensor states
- Check brake signal

Step 2: Determine Target Speed

Target Speed = (Throttle Input / Max Value) × Max Speed

Step 3: Measure Actual Speed

- Calculate speed using time between Hall sensor transitions

Speed ∝ 1 / Time between Hall pulses

Step 4: Apply Control Algorithm (PID)

Error = Target Speed – Actual Speed

Output = Kp×Error + Ki×Integral + Kd×Derivative

- Output controls PWM duty cycle

Step 5: Commutation Control

- Read Hall sensor combination
- Select appropriate switching pattern
- Apply PWM to correct motor phase

Step 6: Update Motor Drive

- Adjust PWM duty cycle
- Update MOSFET switching signals

4) Continuous Monitoring

- Check for:
  - Overcurrent
  - Low battery
  - Brake activation

If fault detected:

Stop PWM

Disable motor
Set fault flag

5) *Braking Operation*
   - If brake is applied:
   - Immediately cut off PWM
   - Optionally apply regenerative braking
6) *Post-Operation*
   - Gradually reduce speed (soft stop)
   - Disable motor driver
   - Save system state (if required)
7) *End of Operation*
   - Stop all PWM signals
   - Enter low-power or standby mode
   - Display status (if UI available)
   - Stop all PWM signals
   - Enter low-power or standby mode
   - Display status (if UI available)

IV. Impact on Users and Society:

The e-bike motor speed controller project has a significant impact on both users and society by improving the efficiency, safety, and performance of electric transportation systems. For users, it provides smooth and precise speed control, enhancing riding comfort while reducing energy consumption and extending battery life. It also improves safety through features such as controlled acceleration, braking response, and fault protection mechanisms.

From a societal perspective, this technology promotes the adoption of eco-friendly transportation by making electric bicycles more reliable and efficient, thereby reducing dependence on fossil fuels and lowering carbon emissions. It contributes to sustainable urban mobility and helps in minimizing traffic congestion and air pollution, especially in densely populated areas.

Additionally, the development and implementation of such controllers support innovation in the electric vehicle industry, creating opportunities for economic growth and technological advancement. Overall, the project plays a crucial role in advancing clean transportation solutions, benefiting individual users while contributing to environmental conservation and sustainable development.

V. Conclusion:

The e-bike motor speed controller project represents a significant advancement in electric vehicle technology, addressing key challenges related to efficiency, control, and energy management in modern transportation systems. By enabling precise regulation of motor speed and torque, the controller enhances overall performance, improves riding comfort, and optimizes battery usage, ultimately leading to extended range and reliability. The integration of advanced control algorithms and embedded systems empowers the development of smarter and more efficient electric mobility solutions. It also promotes environmental sustainability by supporting the widespread adoption of eco-friendly transportation, reducing carbon emissions, and decreasing dependence on conventional fuel-based vehicles. As the demand for clean and efficient transportation continues to grow, the implementation of such intelligent control systems will play a crucial role in shaping the future of mobility. Furthermore, this project lays the foundation for future innovations in electric vehicle technology, contributing to a more sustainable, energy-efficient, and technologically advanced society.

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