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IOT-Enabled Wireless Regenerative Braking System

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ABSTRACT: This paper presents the design and development of a IOT-enabled wireless regenerative braking system for electric two-wheelers to improve energy efficiency and battery performance. The system converts kinetic energy generated during braking into electrical energy and stores it in the vehicle's battery for later use. A breaker circuit is included to automatically stop charging when the battery is fully charged, preventing overcharging. The system is integrated with IoT technology for real-time monitoring through an onboard LCD display and the Blynk mobile application, providing updates on battery percentage, charging status, and vehicle speed.

KEYWORDS: Regenerative Braking System (RBS), Energy Recovery, IOT, Battery Management, Breaker Circuit, Sustainable Mobility.

I. INTRODUCTION

An IOT-Enabled Wireless Regenerative Braking System (RBS) converts the kinetic energy of a moving vehicle into useful electrical energy instead of dissipating it as heat during braking. This recovered energy is stored in the battery and reused, thereby enhancing the overall energy efficiency of the vehicle. In electric scooters and two-wheelers, frequent braking is common due to congested urban traffic, narrow roads, and signalized intersections. Under

such conditions, a significant amount of kinetic energy is lost during conventional mechanical braking. Regenerative braking is particularly suitable for these applications, as it captures and reutilizes a portion of this otherwise wasted energy.

The proposed system integrates an energy recovery mechanism with a battery charging unit and a breaker circuit that automatically disconnects charging when the battery reaches full capacity, ensuring safety and preventing overcharging. Additionally, IOT technology is incorporated to enable real-time monitoring of parameters such as battery percentage, charging status, and vehicle speed through an LCD display and the Blynk mobile application. The proposed system improves driving range, enhances battery life, and ensures safer energy management by combining regenerative braking with smart monitoring and wireless control for efficient and sustainable electric mobility.

II. LITERATURE REVIEW

J.M. K.C. Donev et al.(2018) discussed various braking methods, emphasizing regenerative braking as an energy-saving technique that converts kinetic energy into electrical energy to improve electric vehicle efficiency [1].

Soniya K. Malode and R. H. Adware (2016) explained regenerative braking in electric vehicles, showing how braking energy is converted into electrical energy to improve efficiency and reduce energy loss [2].

Nabila Asyifa Cabriani Lestari et al. proposed a regenerative braking system for electric scooters using a PMDC motor, showing improved battery charging efficiency and extended vehicle range[3].

Edgar Andre Manzano et. al. They proposed a regenerative braking system for the Sakura M500 motorcycle, showing that braking energy can be effectively recovered to improve battery performance and efficiency.[4].

Prof. Harsha Sarode et. al. The paper presents a battery monitoring system for electric bikes to track charging status, battery health, and enhance safety in EV usage. [5].

Akshay N. Chakole et al. studied energy generation using a dynamo based on electromagnetic induction, a principle similar to regenerative braking for converting mechanical motion into electrical energy [6].

Chunhui Liu et al. investigated regenerative braking energy recovery strategies in electric vehicles, showing that optimized control improves battery life and efficiency [7].

Kadri Mohd Ismail et al. proposed a regenerative braking system without conventional brakes, highlighting energy recovery, reduced mechanical wear, and efficient energy flow [8].

Bigaliyeva Zhanar Serykhanovna et al. introduce a method for regenerative braking in scooters using super capacitors, enhancing energy capture and battery life. The paper also discusses the theory behind rapid charge/discharge cycles in energy storage devices [9].

Alistair Teasdale et al. discussed an energy-regenerative braking model using super capacitors and DC motors to improve energy efficiency in electric vehicles. The research shows that combining super capacitors with batteries enhances performance and lifespan. Regenerative braking recovers energy during braking [10].

Nurul Muthmainnah Mohd Noor et al. demonstrated a regenerative braking system for electric motorcycles using MOSFET switches to recover braking energy. Testing under the US60 drive cycle and New European Driving Cycle showed the battery state of charge increased by up to 12.55%, improving energy efficiency and supporting IoT-enabled electric two-wheelers [11].

Bigaliyeva Zhanar et al. investigated a regenerative braking system for electric scooters using a super capacitor in parallel with the battery. The system efficiently recovers braking energy and allows faster acceleration after stops. It reduces battery load and minimizes mechanical wear. Experimental results show around 15% energy recovery, supporting IoT-enabled energy-efficient two-wheeled vehicles [12].

III. PROPOSED METHODOLOGY

The proposed system is designed to recover kinetic energy during braking and convert it into electrical energy for battery charging, while being monitored and controlled through IOT. When the electric scooter is in motion, the motor operates normally using battery power. During braking, the motor functions as a generator and converts kinetic energy into electrical energy. This generated power is directed toward the battery for charging.

The Arduino/ESP32 continuously monitors braking conditions and system parameters. The relay then closes its contacts, connecting the generator output to the battery charging circuit. Once braking stops, the controller deactivates the relay, disconnecting the charging path to ensure safety and prevent overcharging.

Additionally, system data such as voltage, current, and charging status are transmitted wirelessly through the IOT module for real-time monitoring.

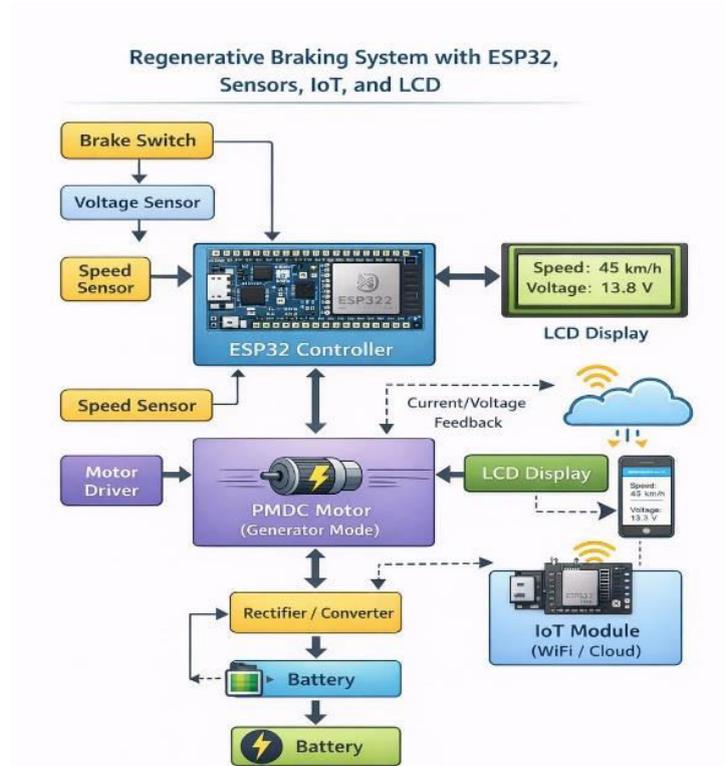


Fig .a. Block Diagram of RBS

The IOT-Enabled Wireless Regenerative Braking System with ESP32, sensors, IoT, and LCD is designed to recover energy during braking and store it in a battery instead of wasting it as heat. In conventional braking systems, the kinetic energy of the moving vehicle is lost in the form of heat due to friction between brake components.

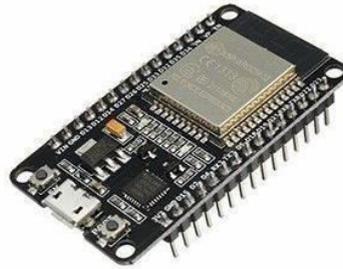
However, in regenerative braking, this energy is converted into electrical energy and reused. The main controller of the system is the ESP32 microcontroller, which processes signals from voltage sensor and speed sensor it also controls the overall operation.

When the brake switch is pressed, a signal is sent to the ESP32 controller indicating that braking has started. At the same time, the speed sensor measures the rotational speed of the wheel or motor and sends this information to the ESP32.

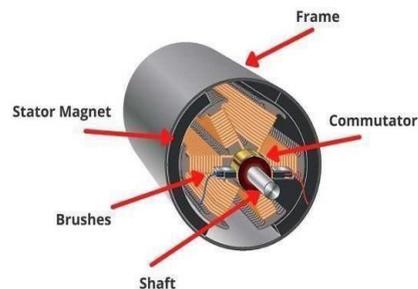
The controller analyzes the speed and braking condition and activates the regenerative braking process. The voltage sensor continuously measures the voltage generated during the process and provides feedback to the controller so that the system operates safely.

During regenerative braking, the PMDC (Permanent Magnet DC) motor works in generator mode. Instead of consuming electrical energy to rotate the wheels, it converts the mechanical energy of the rotating wheel into electrical energy.

The converted electrical energy is stored in the battery for later use, improving system efficiency and reducing energy loss. The ESP32 controller displays real-time speed and voltage on the LCD, while Wi-Fi-based IoT enables remote monitoring of parameters such as speed, voltage, and braking status, providing smart energy management.

Components:-**1. ESP32****Fig .b. Esp32 Wifi Module**

The ESP32 serves as the main control unit, collecting real-time data from voltage and speed sensors. It calculates battery percentage, speed, distance, and charging status, controls the breaker to prevent overcharging, and monitors regenerative braking. Using its built-in Wi-Fi, it updates the LCD display and sends data to the Blynk IoT app, making the system wireless and IoT-enabled.

2. PMDC motor**Fig .c. PMDC motor**

A PMDC motor acts as a generator during braking, converting the wheel's mechanical energy into electrical energy. This energy is directed through the breaker circuit to charge the battery, recovering energy that would otherwise be lost. The PMDC motor is simple, low-cost, efficient, and ideal for small electric vehicles.

3. LCD Display**Fig. d. LCD16x2**

An LCD display shows real-time parameters such as battery voltage, current, speed, and charging status. It receives data from the ESP32 and acts as a simple interface for monitoring system performance and overall status.

4. Relay



Fig. e. Relay for Interfacing

The relay acts as an automatic electronic switch in the IOT-enabled wireless regenerative braking system. When activated by the ESP32, it connects the battery to the charging circuit during braking and disconnects it when deactivated, providing safe isolation and simple ON/OFF control

5. Tyre



Fig .f. Tyre

The tyre provides road contact, stability, and traction for the scooter during acceleration, braking, and turning. In regenerative braking, good tyre grip ensures smooth and effective energy transfer, allowing maximum kinetic energy to be converted into electrical energy safely and efficiently.

6. Gear



Fig .g. Gear

The gear is used to transmit motion between the wheel and the PMDC motor. It increases the rotational speed of the motor when the wheel rotates. During regenerative braking, it helps the motor rotate faster so more electrical energy can be generated, thereby improving the efficiency of energy recovery.

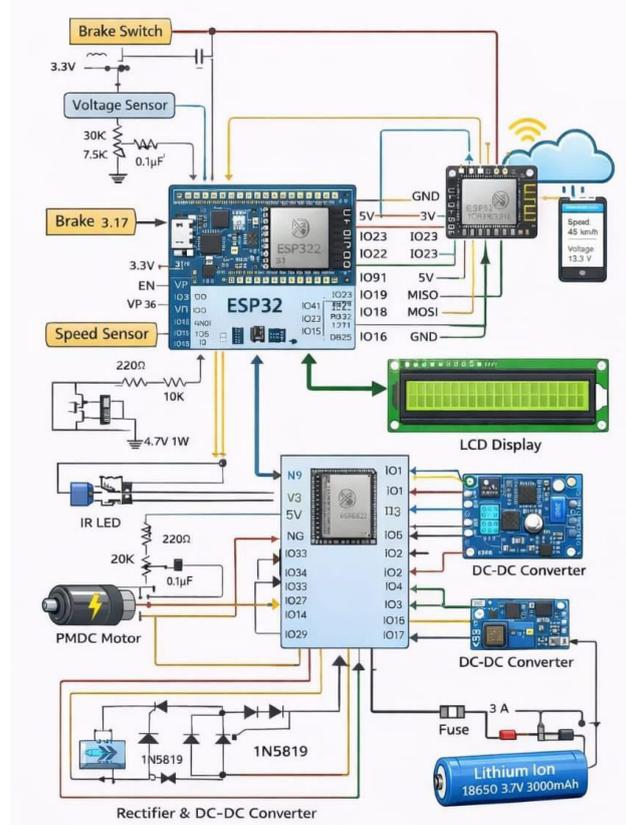


Fig .h. Circuit diagram

In this circuit, the brake switch is connected to the ESP32 input pin to detect when braking is applied. When the rider presses the brake, the signal is sent to the ESP32, which activates the regenerative braking process. The speed sensor with an IR LED is also connected to the ESP32 to measure the rotational speed of the motor or wheel. This helps the system monitor the speed in real time and determine the amount of energy that can be generated during braking. A voltage sensor is connected to the ESP32 analog pin to continuously measure the voltage produced during the energy generation process.

The PMDC motor works as a generator when the braking action is applied. During this process, the mechanical energy from the rotating wheel is converted into electrical energy. The generated electrical energy then passes through a rectifier circuit made using diodes (1N5819), which convert the generated AC or fluctuating signal into stable DC power. After rectification, the DC power is regulated using a DC-DC converter to ensure a safe and stable voltage level. This regulated energy is then stored in a 12V battery, and a fuse is included in the circuit to protect the system from overcurrent or short circuits.

The LCD display is connected to the ESP32 to show important parameters such as speed and generated voltage in real time. This allows the user to easily monitor the system performance while the vehicle is operating. Additionally, the Wi-Fi (IOT) module integrated with the ESP32 sends the system data to a mobile device or cloud platform. This enables remote monitoring of parameters like speed, voltage, and charging status, improving system control, data tracking, and overall efficiency.

VI. RESULT

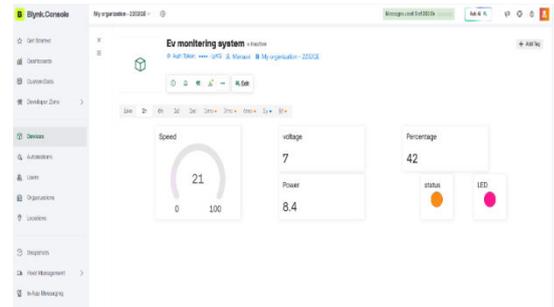


Fig .i. Result

The IOT-Enabled Wireless Regenerative Braking System was successfully implemented to demonstrate the recovery and reuse of energy during braking. The system showed that when the brake is applied, the PMDC motor operates in generator mode and converts the kinetic energy of the moving wheel into electrical energy. This generated energy is then converted into a suitable DC form and stored in the battery, reducing the loss of energy that normally occurs in conventional braking systems.

The ESP32 controller effectively monitored and controlled the entire regenerative braking process by receiving input signals from the brake switch, speed sensor, and voltage sensor. The system was able to display real-time parameters such as vehicle speed and generated voltage on the LCD display, allowing users to observe the system performance during operation. The integration of IoT technology allowed the system data to be transmitted through Wi-Fi for remote monitoring. Parameters such as speed, voltage, and braking status could be viewed on a mobile device or cloud platform. The overall results show that the system improves energy efficiency by recovering braking energy and also provides smart monitoring through IOT, making it suitable for modern electric vehicle and energy-saving applications.

VII. CONCLUSIONS

The IOT-Enabled Wireless Regenerative Braking System demonstrates an efficient method of energy recovery during braking, which helps reduce energy loss and improve overall system efficiency. By utilizing the recovered energy, the system enhances battery life and can contribute to a longer driving distance. It also supports real-time monitoring of important parameters such as speed, voltage, and the status of the regenerative mode, allowing better observation and analysis of system performance. In addition, the system promotes environmentally friendly transportation by minimizing pollution and improving energy utilization. The proposed approach is cost-effective and suitable for practical implementation. In the future, this concept can be further applied to larger transportation systems such as passenger cars, buses, and trains to improve energy efficiency and support sustainable mobility.

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