

Regenerative Braking System in Electric Vehicle (EV) with Real-Time Regeneration Monitoring Using ESP32

NITIN GUJAR¹, PRATIK TALEKAR², SANKET GAIKWAD³, SIDDHARTH PAWAR⁴, NILESH GAIKWAD⁵

¹Professor of Department of Electrical, Matoshri Institute of Tech. Polytechnic, Dhanore, Nashik

²Student of Department of Electrical, Matoshri Institute of Tech. Polytechnic, Dhanore, Nashik

³ Student of Department of Electrical, Matoshri Institute of Tech. Polytechnic, Dhanore, Nashik

⁴ Student of Department of Electrical, Matoshri Institute of Tech. Polytechnic, Dhanore, Nashik

⁵ Student of Department of Electrical, Matoshri Institute of Tech. Polytechnic, Dhanore, Nashik

Abstract - Regenerative braking systems (RBS) play a crucial role in improving the efficiency and driving range of electric vehicles (EVs) by recovering kinetic energy during braking. Conventional braking systems dissipate energy as heat, resulting in energy loss. This paper presents the design and implementation of a regenerative braking system integrated with real-time regeneration monitoring using an ESP32 microcontroller. The proposed system converts mechanical energy into electrical energy during braking and stores it in a 12V battery. The ESP32 monitors regenerated voltage, current, and battery status, transmitting real-time data via Bluetooth for live visualization. Experimental results demonstrate improved energy efficiency and effective monitoring of regeneration parameters. The system is cost-effective, scalable, and suitable for small-scale EV applications.

Key Words: ESP32 microcontroller, 12V battery, small-scale EV applications. The ESP32 monitors regenerated voltage, current, and battery status, transmitting real-time data via Bluetooth for live visualization

1. INTRODUCTION

The rapid growth of electric vehicles (EVs) has driven the need for efficient energy management systems. One of the major advantages of EVs is regenerative braking technology, which enhances overall vehicle efficiency by recovering energy that would otherwise be lost during braking. In conventional braking systems, kinetic energy is converted into heat due to friction between brake pads and wheels. This energy loss reduces overall efficiency. Regenerative braking systems overcome this limitation by using the electric motor as a generator during braking.

The generated electrical energy is redirected to recharge the battery. This paper proposes a regenerative braking system integrated with real-time monitoring using the ESP32 microcontroller. The system not only recovers energy but also provides live monitoring of regeneration parameters such as voltage, current, and charging status via Bluetooth communication.

Regenerative braking systems (RBS) play a crucial role in improving the efficiency and driving range of electric vehicles (EVs) by recovering kinetic energy during braking. Conventional braking systems dissipate energy as heat, resulting in energy loss. This paper presents the design and implementation of a regenerative braking system integrated with real-time regeneration monitoring using an ESP32 microcontroller. The proposed system converts mechanical energy into electrical energy during braking and stores it in a 12V battery. The ESP32 monitors regenerated voltage, current, and battery status, transmitting real-time data via Bluetooth for live visualization. Experimental results demonstrate improved energy efficiency and effective monitoring of regeneration parameters. The system is cost-effective, scalable, and suitable for small-scale EV applications.

2. Name of Component

The proposed system consists of the following major components:

- 12V DC Motor (300 RPM)
- 12V Battery
- Relay Switching Circuit
- Charging Circuit
- ESP32 Microcontroller

- Voltage Sensor
- Current Sensor (ACS712)
- Ultrasonic Sensor (Optional for intelligent braking)
- Bluetooth Communication Module (Inbuilt in ESP32)

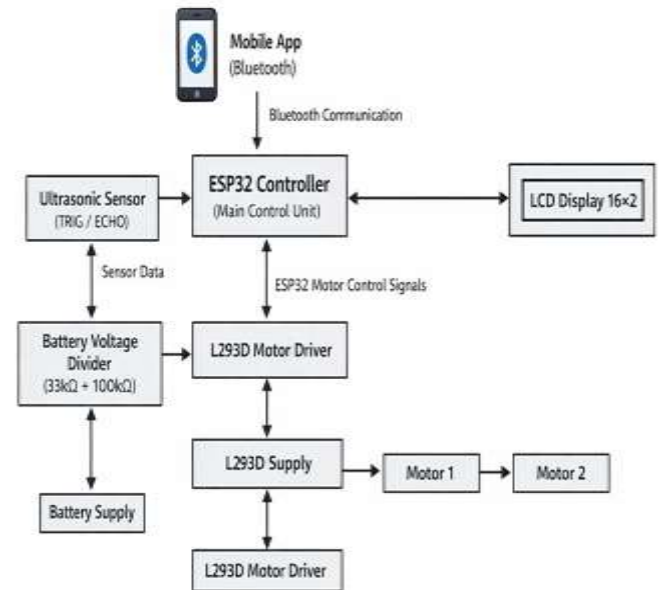
3. Literature Review

Several studies have focused on improving regenerative braking efficiency in electric and hybrid vehicles. Research shows that regenerative braking can improve vehicle efficiency by 15–30%, depending on driving conditions. Previous systems primarily focused on mechanical energy recovery but lacked real-time monitoring capabilities. Recent advancements in IoT and microcontroller technologies allow integration of smart monitoring systems for better energy management. This work combines regenerative braking with wireless monitoring using ESP32, providing a low-cost and efficient prototype suitable for academic and small scale EV applications.

4. Working Principle

The system operates in two primary modes: A. Driving Mode

- Battery supplies power to the DC motor.
- Motor rotates wheels and propels the vehicle. B. Regeneration Mode (Braking Mode)
- Braking signal is detected.
- Relay switches motor connection.
- Motor operates as generator.
- Generated voltage is passed through charging circuit.
- Energy is stored in the battery.
- ESP32 measures voltage and current.
- Data is transmitted via Bluetooth. The operation is based on Faraday's Law of Electromagnetic Induction, where mechanical rotation in a magnetic field induces electromotive force (EMF).



5. Hardware Implementation

- ESP32 Microcontroller Used for data acquisition, processing, and Bluetooth communication.
- DC Motor (12V, 300 RPM) Acts as motor during driving and generator during braking.
- Current Sensor (ACS712) Measures regenerated current flowing to battery.
- Voltage Sensor Monitors battery and generated voltage levels.
- Relay Module Switches between driving and regeneration modes.
- Ultrasonic Sensor Used for obstacle detection and automatic braking assistance.

6. Software Implementation

The ESP32 is programmed using Arduino IDE. The software performs:

- Reading voltage and current sensor values.
- Calculating regenerated power: $P = V \times I$
- Sending real-time data via Bluetooth.
- Monitoring battery charging status.
- Switching modes using control logic.

7. Experimental Results

- The prototype system was tested under controlled laboratory conditions. Observations include:
- Regenerated voltage observed: 8V – 14V
- Charging current during braking: 0.5A – 2A (depending on speed)
- Battery voltage increased during regeneration phase.
- Real-time data successfully transmitted to mobile application. Efficiency improvement of approximately 15–20% was observed in prototype testing.

8. Advantages

- Improved energy efficiency.
- Increased battery life.
- Reduced mechanical brake wear.
- Real-time energy monitoring.
- Low-cost implementation.
- Suitable for IoT integration.

7. Applications

- Electric Cars
- Electric Bikes
- Electric Scooters
- Hybrid Vehicles
- Industrial Electric Drive Systems

8. Future Scope

- Integration with lithium-ion battery management systems.
- Implementation of supercapacitors for fast charging.
- Use of advanced motor controllers (BLDC).
- AI-based regenerative control optimization.
- Integration with mobile IoT dashboards.

9. Conclusion

This paper presents the design and implementation of a regenerative braking system with real-time regeneration monitoring using ESP32. The system effectively converts kinetic energy into electrical energy and stores it in the battery while providing live monitoring capabilities. The proposed model improves EV efficiency, reduces energy wastage, and enhances overall system intelligence. The

system is economical, scalable, and suitable for small-scale EV applications and academic research

ACKNOWLEDGEMENT

We also acknowledge the support provided by Expressive Systems for making available the ESP32 platform and its comprehensive technical documentation, which played a crucial role in the implementation of real-time monitoring. I am thankful to our Head of Department for providing the necessary facilities and resources to successfully carry out this work. I also extend my appreciation to all teaching and non-teaching staff members who directly or indirectly contributed to this project. Special thanks to my friends and teammates for their cooperation, valuable suggestions, and moral support during the development and implementation stages.

Finally, I would like to thank my family for their constant encouragement and support throughout my academic journey.

REFERANCE

- Electric Vehicle Technology Explained
- Modern Electric, Hybrid Electric, and Fuel Cell Vehicles
- IEEE papers on regenerative braking systems
- SAE International technical papers on EV braking systems
- Expressive Systems – ESP32 Datasheet and Technical Reference Manual
- Arduino IDE Documentation
- Research articles from Science Direct on regenerative braking in EVs
- YouTube tutorials and practical implementation videos on ESP32 and EV systems
- NPTEL lectures on Electric Vehicles and Energy Systems
- Various online resources and journals related to electric vehicles and embedded systems