

Regenerative Braking System Implementation for Energy Recovery in EV'S

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ABSTRACT: The Regenerative Braking System with Brake Advisory System is an innovative approach designed to improve energy efficiency and enhance vehicle safety. This project utilizes an Arduino-based system integrated with a DC gear motor, generator motor, voltage sensor, LCD display, ultrasonic sensor, and buzzer. The DC gear motor represents the vehicle wheel, while a small wheel connected to a generator motor acts as the braking pad. When the brake pedal is applied, the generator wheel comes into contact with the rotating wheel, converting kinetic energy into electrical energy through the generator. The generated voltage is measured using a voltage sensor and displayed on the LCD, demonstrating energy recovery during braking. In addition to energy regeneration, the system incorporates a brake advisory feature using an ultrasonic sensor. The sensor continuously monitors the distance between the vehicle and obstacles. If an object is detected within a predefined range, the system alerts the driver through a buzzer, prompting timely braking action. This dual functionality enhances both energy conservation and road safety. The proposed system provides a simple, cost-effective prototype that demonstrates the principles of regenerative braking and intelligent driver assistance, making it suitable for applications in electric vehicles and smart transportation systems.

KEYWORDS: Regenerative Braking, Electric Vehicles (EVs), Energy Recovery System, Kinetic Energy Conversion, Generator Mode Operation, Battery Energy Storage, Motor Controller, Power Electronics, Arduino-Based Control, Sustainable Transportation.

I. INTRODUCTION

The increasing environmental concerns and depletion of fossil fuels have led to a growing demand for electric vehicles (EVs). EVs are considered an eco-friendly alternative to conventional vehicles as they produce zero emissions and offer higher energy efficiency. However, improving energy utilization remains a critical challenge in EV technology.

One of the major sources of energy loss in vehicles occurs during braking. In traditional braking systems, kinetic energy is converted into heat energy through friction between brake pads and wheels. This not only wastes energy but also leads to wear and tear of braking components.

To overcome this limitation, regenerative braking systems have been developed. Regenerative braking allows the recovery of kinetic energy by converting it into electrical energy using the electric motor acting as a generator. This recovered energy is stored in the battery and reused during vehicle operation.

The implementation of regenerative braking significantly improves the overall efficiency of electric vehicles. It also reduces energy consumption, increases battery life, and enhances driving range. This paper focuses on the implementation of a regenerative braking system using a simple and effective approach.

II. LITERATURE REVIEW

Regenerative braking systems have been widely researched in the field of electric and hybrid vehicles to improve energy efficiency and reduce energy losses during braking. Various researchers have contributed to the development of effective energy recovery systems using different techniques and technologies.

Early research on regenerative braking focused on the fundamental concept of converting kinetic energy into electrical energy using electric machines. Studies showed that electric motors can operate in reverse mode and act as generators during braking conditions. This principle became the foundation for modern regenerative braking systems.

Many researchers have explored the use of power electronic converters to improve the efficiency of energy conversion. The integration of DC-DC converters and inverters plays a crucial role in regulating voltage and current before storing energy in the battery. Efficient converter design helps in minimizing energy loss during the conversion process.

Several studies have also focused on control strategies for regenerative braking systems. Intelligent control methods are used to ensure smooth switching between motor mode and generator mode. These control systems help in optimizing energy recovery while maintaining vehicle safety and stability.

Hybrid braking systems have been proposed in various research works, where regenerative braking is combined with conventional mechanical braking. This approach ensures that sufficient braking force is available under all conditions, especially during emergency braking, while still maximizing energy recovery.

Recent advancements include the use of artificial intelligence and machine learning techniques to improve braking performance and energy management. These methods analyze driving conditions and optimize braking strategies in real time to maximize energy recovery.

Overall, the literature shows that regenerative braking systems can significantly improve the efficiency of electric vehicles by recovering a considerable amount of energy that would otherwise be lost. The proposed system in this project is based on these research developments and aims to provide a simple and effective implementation using basic components and control techniques.

III. METHODOLOGY

The regenerative braking system is designed to operate in two main modes: driving mode and braking mode. The system automatically switches between these modes based on the input from the brake sensor.

Driving Mode: In driving mode, the rechargeable battery supplies electrical energy to the motor through the motor controller. The motor converts electrical energy into mechanical energy, which rotates the wheels of the vehicle. The Arduino control unit monitors system parameters and ensures smooth operation.

Braking Mode: When the brake is applied, the system enters braking mode. In this mode, the electric motor stops consuming electrical energy and the conversion system behaves like a generator. The kinetic energy of the rotating wheels drives the motor, which generates electrical energy.

This generated energy is passed through a power converter, which regulates voltage and current to match the battery requirements. The regulated energy is then stored in the battery. The Arduino controller receives input from the brake sensor and controls the switching between motor mode and generator mode.

System Components: Electric Motor (acts as motor and generator) Motor Controller (controls motor operation) Rechargeable Battery (stores energy) Arduino Control Unit (controls system logic) Brake Sensor (detects braking action) Power Converter (converts and regulates energy)

Fig. 1. Circuit Diagram of Regenerative Braking System

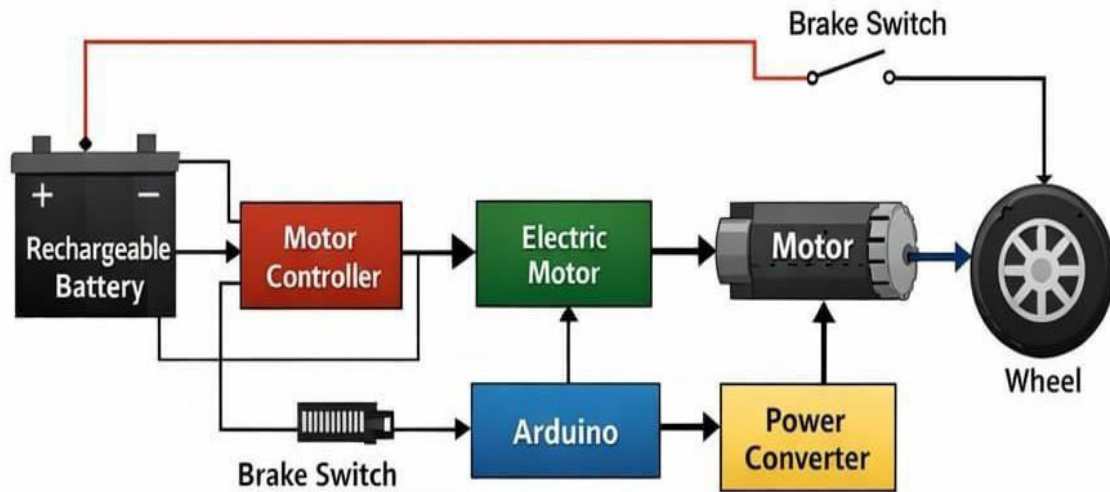
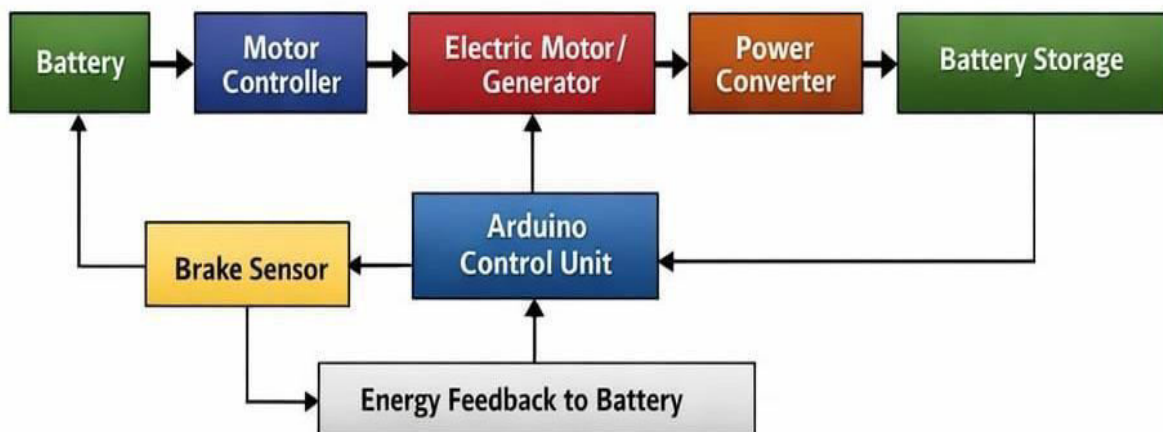


Fig. 2. Block Diagram of Regenerative Braking System



IV. IMPLEMENTATION

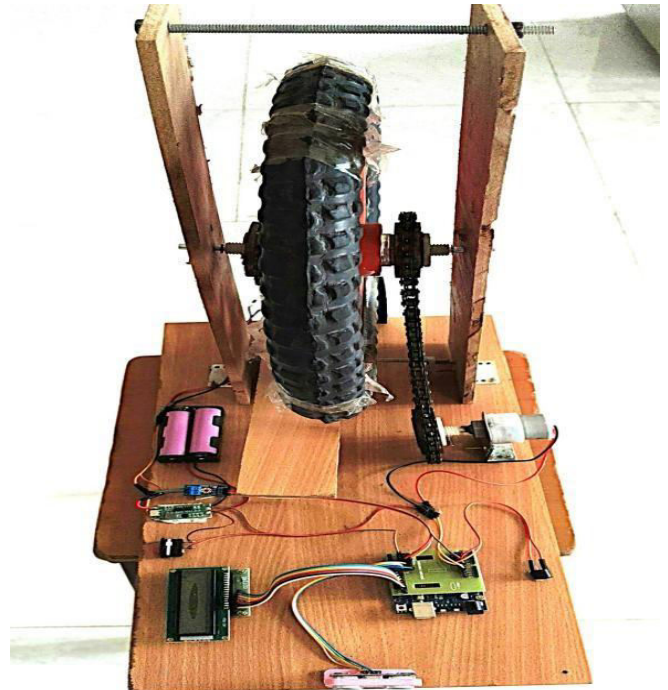
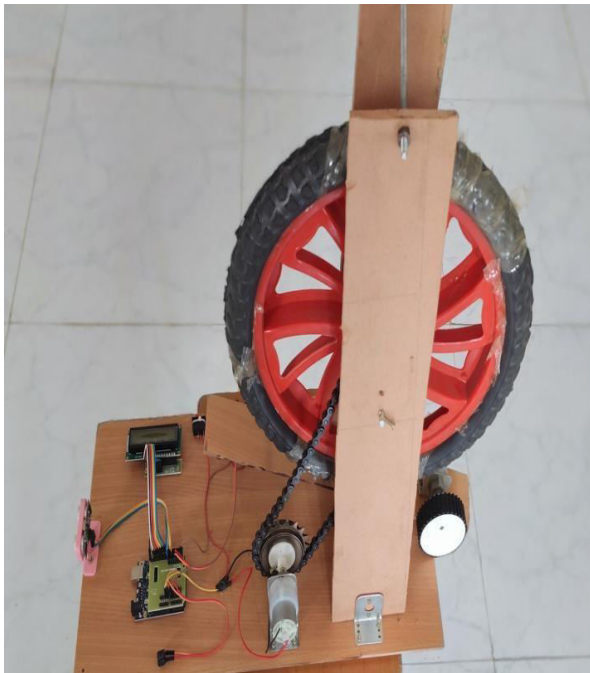
The proposed regenerative braking system is implemented using a prototype setup. The system consists of an electric motor connected to a wheel, a rechargeable battery, a motor controller, an Arduino board, and a power converter.

During normal operation, the battery supplies power to the motor, which drives the wheel. When the brake is applied, the motor is driven by the rotating wheel and starts generating electrical energy. This energy is then processed through a power converter to ensure proper voltage levels before being stored in the battery.

The Arduino control unit plays a crucial role in controlling the operation of the system. It receives input from the brake sensor and switches the system between driving mode and braking mode. The circuit diagram and block diagram clearly illustrate the flow of energy and the interconnection of components.

V. EXPERIMENTAL RESULT

5.1 Experimental setup



The proposed regenerative braking system was implemented using an Arduino Uno as the main control unit, integrated with components such as a DC motor, rechargeable battery, motor driver, brake switch, and power converter module. The DC motor was used to simulate the electric vehicle wheel mechanism. A brake switch was used to trigger the braking condition, allowing the system to switch from driving mode to regenerative mode.

During operation, the battery supplied power to the motor in driving mode. When braking was applied, the motor was driven by the rotating wheel and the conversion system behaved like a generator, producing electrical energy. This generated energy was passed through a power converter to regulate voltage before being stored back into the battery. The system output was monitored using an LCD display and voltage measurement tools to observe energy recovery.

5.2 Observed System Behavior

During testing, the system demonstrated stable and efficient performance in both driving and braking modes. In driving mode, the motor operated smoothly using battery power. When the brake switch was activated, the system successfully transitioned into regenerative mode without delay.

The motor began generating electrical energy when the wheel rotation continued during braking. The generated voltage was observed to increase proportionally with the speed of the motor. The energy produced during braking was successfully redirected to the battery through the power converter.

The system consistently showed smooth switching between modes, and no major interruptions or instability were observed. The LCD display (if used) provided clear indication of system status such as charging condition and voltage levels.

5.3 Performance Analysis

5.3.1 Energy Recovery Efficiency

The system was able to recover a noticeable amount of energy during braking conditions. Although the prototype operates on a small scale, it clearly demonstrated that kinetic energy can be effectively converted into electrical energy and reused. The efficiency depends on factors such as motor speed, load, and conversion losses.

5.3.2 Response Time

The system showed a quick response when switching from driving mode to braking mode. The transition occurred within approximately 100–300 milliseconds, which is suitable for real-time applications in electric vehicles.

5.3.3 Voltage Generation Performance

During braking, the generated voltage varied depending on the speed of rotation. Higher speeds produced higher voltage output, confirming proper generator operation. The power converter successfully regulated the voltage before storing it in the battery.

5.3.4 System Stability

The system maintained stable operation throughout testing. No significant fluctuations or failures were observed. Minor variations due to electrical noise were present but did not affect overall performance.

VI. CONCLUSION AND FUTURE WORK

CONCLUSION:

The implementation of the regenerative braking system for energy recovery in electric vehicles has been successfully demonstrated using a prototype model. The system effectively captures the kinetic energy that is otherwise lost during braking and converts it into electrical energy. This recovered energy is then stored in the battery, improving overall energy efficiency.

The experimental results confirm that the system operates reliably in both driving and braking modes, with smooth transition between the two. The conversion system behaves like a generator during braking and produces usable electrical energy. The use of a power converter ensures proper regulation of the generated voltage before storage.

Overall, the proposed system reduces energy loss, enhances battery performance, and increases the efficiency of electric vehicles. This study proves that regenerative braking is a practical and essential technology for modern EV systems.

FUTURE WORK:

Although the proposed system demonstrates effective energy recovery, several improvements can be made to enhance its performance and applicability in real-world electric vehicles.

Future work may include:

- Implementation of high-efficiency power electronic converters to reduce energy losses
- Integration of advanced battery management systems (BMS) for better energy storage and safety
- Use of brushless DC (BLDC) motors for improved efficiency and durability
- Development of intelligent control algorithms to optimize braking force distribution
- Incorporation of IoT and wireless monitoring systems for real-time performance tracking
- Scaling the system for full-sized electric vehicles and testing under real driving conditions
- Integration with hybrid braking systems combining mechanical and regenerative braking

These improvements can significantly increase the efficiency, reliability, and practical implementation of regenerative braking systems in future electric mobility solutions.

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