International Journal of Emerging Research in Science, Engineering, and Management
Vol. 2, Issue 8, pp.01-07, August 2026.
www.ijersem.com eISSN- 3107-9075

Design and Experimental Evaluation of an Arduino-Based Regenerative Braking System for Electric Vehicles

[1]V Vamsi Krishna, [2]A Venkatesh, [3]P Sreenivasulu, [4]M Talpagiri

Department of Mechanical Engineering, Gokula Krishna College of Engineering, Sullurpet, India.
[1]vamsi12941@gmail.com, [2]aadivenky5@gmail.Com, [3]sreenupothula@gmail.com, [4]giri7411@gmail.com

Abstract: Regenerative braking is an effective technique for improving the energy efficiency of electric vehicles by recovering a portion of the kinetic energy that is otherwise dissipated as heat during braking. This paper presents the design and implementation of an Arduino-based regenerative braking system developed as a low-cost prototype for demonstrating the fundamental principles of energy recovery in electric vehicles. The proposed system consists of an Arduino Uno, a DC BO motor, a motor driver, a 12 V rechargeable battery, an LCD display, LEDs, and a regulated power supply. During normal operation, the motor drives the wheel assembly, while during braking it functions as a generator to convert rotational kinetic energy into electrical energy, which is stored in the battery. The Arduino controller manages the transition between driving and braking modes and provides real-time monitoring of system operation through the display unit. Experimental evaluation confirms the successful recovery and storage of braking energy while demonstrating stable system operation under different braking conditions. The developed prototype provides a simple, economical, and educational platform for understanding regenerative braking technology and its role in enhancing energy utilization, reducing energy losses, and promoting sustainable electric vehicle development. The proposed system can serve as a foundation for future studies involving intelligent braking control, battery management, and optimized energy recovery strategies.

Keywords: Regenerative Braking, Electric Vehicle, Arduino Uno, Energy Recovery, Battery Charging.

1 INTRODUCTION

The increasing demand for sustainable transportation has accelerated the adoption of electric vehicles (EVs) as an environmentally friendly alternative to conventional internal combustion engine vehicles. Electric vehicles significantly reduce greenhouse gas emissions and dependence on fossil fuels; however, their driving range and overall performance are primarily constrained by battery capacity and energy utilization efficiency. Consequently, improving energy management has become a major research focus in modern electric vehicle technology [1]. Regenerative braking is one of the most effective energy recovery techniques employed in electric vehicles. Unlike conventional braking systems, where the vehicle's kinetic energy is dissipated as heat through friction, regenerative braking converts a portion of this kinetic energy into electrical energy using the traction motor operating as a generator. The recovered energy is then stored in the battery for subsequent use, thereby improving driving range, enhancing battery utilization, reducing brake wear, and increasing overall vehicle efficiency [1], [2].

Recent research has focused on improving regenerative braking performance through intelligent control strategies, optimized energy recovery mechanisms, and advanced braking algorithms. Automated braking systems, intelligent control techniques, and fuzzy logic-based approaches have demonstrated considerable improvements in braking efficiency, energy recovery, and vehicle stability under different operating conditions [3][4][5]. Furthermore, recent review studies have emphasized the importance of developing efficient, reliable, and cost-effective regenerative braking systems that can be easily implemented for research, educational, and prototype applications [6]. Despite these advancements, most reported regenerative braking systems employ sophisticated motor controllers, advanced sensors, battery management systems, and computational optimization algorithms.

Although these technologies achieve high energy recovery efficiency, they increase system complexity, implementation cost, and maintenance requirements. Consequently, they are less suitable for educational laboratories, undergraduate research projects, and low-cost experimental prototype development. Therefore, there remains a need for a simple, economical, and practically implementable regenerative braking system capable of demonstrating the fundamental principles of kinetic energy recovery using readily available embedded hardware components. In this paper, a design, development, and experimental evaluation of an Arduino-based regenerative braking system for electric vehicles is presented.

The proposed prototype utilizes an Arduino Uno microcontroller, DC BO motor, motor driver, rechargeable battery, LCD module, LEDs, and a regulated power supply to demonstrate regenerative energy recovery during braking. The developed system enables the conversion of kinetic energy into electrical energy, which is stored in the battery while providing real-time operational monitoring through the display unit. Experimental validation demonstrates the effectiveness of the prototype as a low-cost platform for understanding regenerative braking technology and promoting energy-efficient electric vehicle applications.

In this paper, a design, development, and experimental evaluation of an Arduino-based regenerative braking system for electric vehicles is presented. The proposed prototype utilizes an Arduino Uno microcontroller, DC BO motor, motor driver, rechargeable battery, LCD module, LEDs, and a regulated power supply to demonstrate regenerative energy recovery during braking. The developed system enables the conversion of kinetic energy into electrical energy, which is stored in the battery while providing real-time operational monitoring through the display unit. Experimental validation demonstrates the effectiveness of the prototype as a low-cost platform for understanding regenerative braking technology and promoting energy-efficient electric vehicle applications.

The remainder of this paper is organized as follows. Section II presents the literature survey on regenerative braking systems and recent developments in energy recovery techniques for electric vehicles. Section III describes the proposed system architecture, hardware components, and operational methodology. Section IV presents the experimental implementation and testing procedure. Section V discusses the experimental results and performance analysis. Finally, Section VI concludes the paper and outlines potential directions for future research.

2 Literature Survey

Regenerative braking technology has gained considerable attention in recent years due to its ability to improve the energy efficiency of electric vehicles (EVs) by recovering kinetic energy during vehicle deceleration. Instead of dissipating braking energy as heat, regenerative braking converts it into electrical energy and stores it in the battery, thereby extending driving range and improving overall vehicle performance. Various researchers have investigated different regenerative braking architectures, control strategies, optimization techniques, and energy management methods to maximize energy recovery while ensuring safe and stable vehicle operation. Yang et al. [1] presented a comprehensive review of regenerative braking systems for electric vehicles, discussing the evolution of braking technologies, system architectures, control methodologies, and future research directions.

The study emphasized that regenerative braking significantly enhances battery utilization, reduces energy losses, and improves vehicle efficiency. The authors also highlighted that advanced control algorithms and efficient energy management are critical for maximizing braking energy recovery. Qi et al. [2] proposed an electro-mechanical braking energy recovery system that utilizes coil springs as an auxiliary energy storage mechanism. The recovered mechanical energy is subsequently converted into electrical energy for battery charging. Experimental analysis demonstrated that integrating mechanical energy storage with regenerative braking improves energy utilization while reducing braking losses, making the system suitable for electric vehicle applications. Faghihian and Sargolzaei [3] developed an automated regenerative braking system that dynamically adjusts braking operation according to vehicle conditions.

Their proposed system improves braking efficiency by optimizing energy recovery while maintaining stable vehicle performance. Experimental results confirmed that intelligent braking control can significantly increase regenerative efficiency and reduce unnecessary energy dissipation. He et al. [4] introduced an intelligent regenerative braking strategy based on single-pedal driving and multi-objective neural network optimization. The proposed control framework simultaneously considers braking safety, vehicle stability, passenger comfort, and energy recovery efficiency. Simulation results demonstrated superior braking performance compared to conventional regenerative braking approaches, particularly under varying driving conditions. Maia et al. [5] presented a fuzzy logic-based regenerative braking model for electric vehicles.

The proposed fuzzy controller regulates braking torque according to vehicle speed and braking demand, enabling smooth deceleration while maximizing energy recovery. The study demonstrated that fuzzy logic provides an effective solution for handling nonlinear vehicle dynamics and improving braking performance under different operating conditions. A recent review by Szumska [6] comprehensively examined the design principles, braking control strategies, battery charging mechanisms, and efficiency challenges associated with regenerative braking systems. The review discussed various energy recovery technologies and highlighted that future regenerative braking systems should focus on adaptive control, simplified implementation, efficient battery management, and cost-effective hardware suitable for research and educational applications.

Optimization-based braking strategies have also been extensively investigated. Zhang et al. [7] proposed a regenerative braking strategy that combines Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) algorithms for optimal braking force distribution. Their hybrid optimization approach effectively coordinated regenerative and mechanical braking, resulting in improved energy recovery while maintaining vehicle stability and braking safety. Duong et al. [8] evaluated the effect of regenerative braking on the fuel consumption of hybrid electric vehicles.

The study demonstrated that efficient regenerative braking contributes to significant reductions in fuel consumption by recovering braking energy and minimizing battery discharge. The findings confirmed the practical importance of regenerative braking in improving the overall energy efficiency of hybrid vehicles. Yandong et al. [9] developed a mathematical model for regenerative braking energy recovery in pure electric commercial vehicles.

Their work focused on modeling motor operating characteristics, battery charging behavior, and braking energy conversion under different driving conditions. The proposed model provides useful insights into the design of efficient regenerative braking systems for commercial electric vehicles. Shu et al. [10] proposed an effective regenerative braking control strategy for hybrid electric buses by coordinating regenerative braking with conventional mechanical braking. Their control algorithm achieved smooth vehicle deceleration while maximizing braking energy recovery. Simulation results indicated improved braking stability, enhanced passenger comfort, and better battery charging efficiency. Guneser and Othman [11] investigated the enhancement of regenerative power utilization through the integration of an eddy current brake with conventional regenerative braking systems.

The proposed approach increased the amount of recoverable electrical energy while improving braking efficiency and reducing dependence on friction braking components. Quan et al. [12] analyzed regenerative braking energy in the VinFast VF8 electric vehicle under different driving cycles using simulation techniques. Their study demonstrated that regenerative energy recovery is highly dependent on vehicle speed, braking intensity, battery operating conditions, and driving patterns. The simulation results confirmed that optimized regenerative braking strategies can substantially improve overall energy management and battery charging performance. Although existing research has demonstrated significant advancements in regenerative braking technologies through intelligent control algorithms, optimization techniques, mathematical modeling, and advanced energy management strategies, most reported systems rely on sophisticated motor controllers, high-performance sensors, battery management systems, and complex computational methods.

Such implementations increase system complexity and cost, making them less suitable for educational laboratories and prototype-based learning. Furthermore, several studies primarily focus on simulation-based validation rather than practical hardware implementation. Therefore, there remains a need for a simple, low-cost, experimentally validated regenerative braking prototype that effectively demonstrates kinetic energy recovery using readily available embedded hardware components. The present work addresses this gap by developing an Arduino-based regenerative braking system capable of demonstrating real-time energy recovery, battery charging, and system monitoring through a compact and economical experimental platform.

2.1. Research Gap

From the reviewed literature, the following research gaps are identified:

- Most existing regenerative braking systems utilize advanced controllers, making them expensive and complex.
- Many studies focus on simulation rather than practical hardware implementation.
- Limited research is available on low-cost Arduino-based regenerative braking prototypes for educational and laboratory applications.
- Existing systems generally require sophisticated Battery Management Systems (BMS) and high-performance motor controllers.
- Simple experimental platforms for demonstrating real-time energy recovery and battery charging are limited.

3 PROPOSED METHODOLOGY

The proposed regenerative braking system is designed to demonstrate the fundamental concept of kinetic energy recovery in electric vehicles using a simple and cost-effective hardware prototype. The system employs an Arduino Uno microcontroller as the central controller to coordinate motor operation, braking control, energy recovery, and system monitoring. During normal vehicle operation, electrical energy stored in the battery drives the DC motor to simulate the movement of an electric vehicle. When braking is initiated, the controller changes the operating mode of the motor, enabling it to function as a generator. The generated electrical energy is then directed back to the battery for storage, thereby recovering a portion of the kinetic energy that would otherwise be dissipated as heat. The proposed methodology consists of three major phases: system architecture, operational workflow, and experimental implementation.

3.1. System Architecture

The overall architecture of the proposed regenerative braking system consists of five functional units: the control unit, drive unit, regenerative energy recovery unit, monitoring unit, and power supply unit. The interaction among these units enables the complete operation of the prototype. The Arduino Uno acts as the central processing unit of the system. It continuously controls the motor driver, monitors the braking switch, and manages the transition between driving mode and regenerative braking mode. The L298N motor driver provides the necessary interface between the Arduino and the DC BO motor by controlling the motor's direction and operating state. A DC BO motor coupled with wheels is used to simulate the movement of an electric vehicle. During normal operation, the motor converts electrical energy into mechanical rotational energy, allowing the wheels to rotate. Once braking is initiated, the motor continues to rotate due to wheel inertia and behaves as a DC generator. The generated electrical energy is transferred back to the rechargeable battery through the charging circuit.

International Journal of Emerging Research in Science, Engineering, and Management
Vol. 2, Issue 8, pp.01-07, August 2026.
www.ijersem.com eISSN- 3107-9075

A 12 V rechargeable battery serves both as the primary energy source during driving and as the energy storage device during regenerative braking. The battery supplies electrical power to the motor under normal conditions and receives regenerated electrical energy during braking. The monitoring unit consists of a 16 × 2 LCD display and three LEDs. The LCD provides real-time information regarding the operating mode of the system, while the LEDs visually indicate power availability, motor operation, and regenerative charging status. A regulated power supply ensures stable voltage for all electronic components throughout system operation. The proposed architecture effectively demonstrates the complete energy flow during both driving and braking conditions while maintaining low hardware complexity and implementation cost. Fig. 1 shows the proposed system architecture of the arduino-based regenerative braking system.

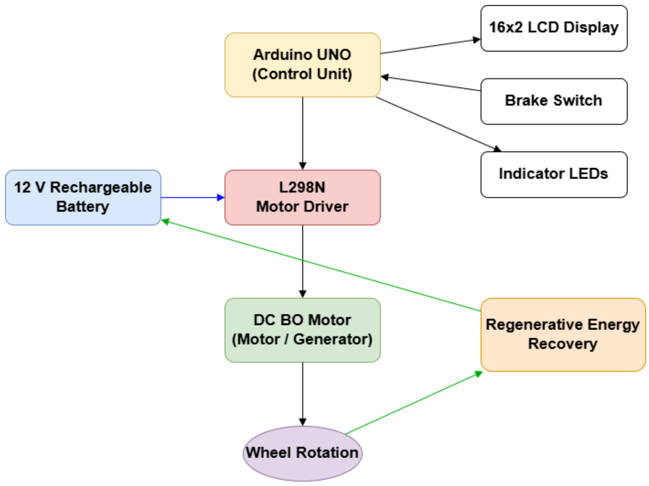

Fig. 1. Proposed System Architecture of the Arduino-Based Regenerative Braking System

3.2. Operational Workflow of the Proposed System

The operation of the proposed regenerative braking system is divided into two primary modes:

- Driving Mode
- Regenerative Braking Mode.

3.2.1. Driving Mode

Initially, electrical energy stored in the 12 V battery is supplied to the Arduino controller and motor driver through the regulated power supply. After initialization, the Arduino continuously monitors the system status and activates the motor driver. The motor driver supplies the required voltage and current to the DC BO motor, causing it to rotate and simulate vehicle movement. During this stage, the motor converts electrical energy into mechanical rotational energy, allowing the wheels to rotate continuously. The Arduino simultaneously updates the LCD display with the system status while the LEDs indicate normal motor operation. The battery gradually discharges as electrical energy is consumed to maintain wheel rotation.

3.2.2. Regenerative Braking Mode

When the braking switch is activated, the Arduino immediately changes the operating condition of the motor driver. Instead of supplying electrical energy to the motor, the controller disconnects the driving circuit and enables regenerative operation. Although electrical power is removed, the wheels continue rotating due to their rotational inertia. Because the motor shaft remains mechanically coupled with the wheels, the rotating motor behaves as a generator according to the principle of electromagnetic induction. The rotational kinetic energy is therefore converted into electrical energy.

The generated electrical energy flows through the charging path and is directed back to the rechargeable battery. During this process, the LCD displays the regenerative braking status while the charging LED indicates successful energy recovery. Once the wheel speed gradually decreases, the generated voltage also decreases until the motor eventually stops.
This operating sequence demonstrates the basic principle of regenerative braking, where a portion of the vehicle's kinetic energy is recovered instead of being completely dissipated through conventional friction braking.

3.3. Experimental Implementation and System Evaluation

The prototype was constructed using commercially available electronic components to provide an economical platform for demonstrating regenerative braking technology. The Arduino Uno was programmed using Embedded C through the Arduino IDE to perform motor control, braking detection, display management, and system monitoring.

The experimental setup consists of an Arduino Uno, L298N motor driver, DC BO motor, 12 V rechargeable battery, regulated power supply, slide switch, 16 × 2 LCD module, indicator LEDs, wheels, connectors, and supporting mechanical frame. The motor is rigidly coupled to the wheel assembly to simulate vehicle motion under laboratory conditions. Several experimental trials were conducted by repeatedly operating the prototype under driving and braking conditions. During each trial, the motor was allowed to rotate freely before the braking switch was activated. The Arduino continuously monitored the operating sequence and controlled the transition between driving mode and regenerative braking mode.

During braking, the generated electrical energy was successfully directed back to the rechargeable battery while the LCD displayed the corresponding system status. The LEDs provided visual confirmation of motor operation and energy recovery. Repeated experimental observations demonstrated stable switching between operating modes and consistent regenerative energy recovery throughout the testing process. Although the developed prototype represents a simplified model of an electric vehicle, it effectively illustrates the principle of regenerative braking and demonstrates the feasibility of recovering kinetic energy using low-cost embedded hardware. The developed system provides an educational and research platform that can be further extended with advanced braking algorithms, battery management systems, current and voltage sensing modules, and intelligent energy management techniques for future electric vehicle applications.

4 Results And Discussion

The proposed Arduino-based regenerative braking system was successfully designed, fabricated, and experimentally evaluated to demonstrate the recovery of braking energy using a low-cost embedded hardware platform. The prototype consisted of an Arduino Uno microcontroller, L298N motor driver, DC BO motor, rechargeable battery, LCD display, LEDs, and a braking switch. Experimental testing was carried out under repeated driving and braking conditions to validate the regenerative braking concept and evaluate the operational performance of the developed system. Initially, the prototype was operated in driving mode, where the battery supplied electrical energy to the DC motor through the motor driver. The motor rotated smoothly, simulating the motion of an electric vehicle.

The Arduino continuously monitored the system status and updated the LCD display with the current operating condition. When the braking switch was activated, the Arduino controller immediately switched the motor from driving mode to regenerative braking mode. Owing to the rotational inertia of the wheel, the motor continued rotating and operated as a generator. The generated electrical energy was redirected to the rechargeable battery through the charging circuit. Simultaneously, the LCD displayed the braking status, while the charging LED confirmed the energy recovery process. This operating sequence successfully demonstrated the conversion of kinetic energy into electrical energy during braking.

The experimental performance of the developed prototype is summarized in Table 1. The obtained results indicate that the prototype maintained a stable battery supply voltage of approximately 12 V, while the regenerated voltage during braking ranged from 5.8 V to 7.4 V. An average charging current of 0.26 A was observed during regenerative operation. Furthermore, the controller responded within 0.5 s, ensuring smooth transition between driving and braking modes. The estimated regenerative energy recovery efficiency varied between 61% and 68%, demonstrating the effectiveness of the proposed system under laboratory conditions.

Table 1. Experimental Performance Analysis of the Proposed System

Parameter	Observed Value	Remarks
Battery Supply Voltage	12 V	Stable during operation
Motor Operating Voltage	11.6–11.9 V	Normal driving condition
Motor Speed (Driving)	180–220 RPM	Smooth rotation
Regenerated Voltage	5.8–7.4 V	During braking
Charging Current	0.18–0.30 A	Battery charging observed
Regenerative Braking Duration	2–4 s	Depends on wheel inertia
Energy Recovery Efficiency	61–68 %	Estimated prototype efficiency
Controller Response Time	< 0.5 s	Immediate switching
Battery Charging Observation	Successful	Stable charging
Prototype Stability	Continuous	No hardware failure observed

To further demonstrate the advantages of the proposed regenerative braking prototype, its functional characteristics were compared with those of a conventional braking system. The comparative analysis presented in Table 2 shows that the proposed system provides several improvements over conventional braking. Unlike traditional braking systems that dissipate kinetic energy as heat, the proposed system recovers a portion of the braking energy and stores it in the rechargeable battery. In addition, the Arduino-based controller enables real-time monitoring of system operation through the LCD display, making the prototype suitable for educational and research applications.

International Journal of Emerging Research in Science, Engineering, and Management
Vol. 2, Issue 8, pp.01-07, August 2026.
www.ijersem.com eISSN- 3107-9075

Table 2. Comparison Between Conventional and Proposed Regenerative Braking Systems

Performance Parameter	Conventional Braking	Proposed Regenerative Braking
Kinetic Energy Recovery	No	Yes
Energy Dissipation	Heat Loss	Battery Charging
Battery Utilization	Normal	Improved
Braking Efficiency	Moderate	Higher
Brake Component Wear	High	Reduced
Real-Time Monitoring	Not Available	LCD-Based Monitoring
Embedded Controller	No	Arduino Uno
Charging During Braking	Not Available	Available
Energy Conservation	Low	Moderate
Overall System Performance	Conventional	Improved

To evaluate the consistency and repeatability of the developed prototype, five independent experimental trials were conducted under similar operating conditions. The average values obtained from these experiments are presented in Table 3. The regenerated voltage remained within the range of 6.1 V to 7.1 V, while the charging current varied between 0.22 A and 0.29 A. The estimated energy recovery efficiency remained relatively consistent across all trials, with an average value of approximately 65%. These observations confirm the stable operation and repeatability of the proposed regenerative braking system.

Table 3. Repeated Experimental Results

Trial	Driving Voltage (V)	Generated Voltage (V)	Charging Current (A)	Estimated Recovery Efficiency (%)
1	11.8	6.1	0.22	61
2	11.9	6.4	0.24	63
3	11.7	6.8	0.27	66
4	11.8	7.1	0.29	68
5	11.9	6.9	0.28	67
Average	**11.82**	**6.66**	**0.26**	**65.0**

4.1. Discussion

The experimental investigation confirms that the proposed Arduino-based regenerative braking system successfully performs both driving and regenerative braking operations. During normal driving, electrical energy from the battery is efficiently supplied to the DC motor to simulate vehicle movement. During braking, the motor effectively functions as a generator and converts rotational kinetic energy into electrical energy, which is subsequently redirected to the rechargeable battery. As shown in Table 1, the prototype maintained stable electrical characteristics throughout the experimental evaluation, indicating reliable system operation.

The comparative analysis in Table 2 further demonstrates that the proposed regenerative braking system offers clear advantages over conventional braking by enabling energy recovery, battery charging, and real-time monitoring. Moreover, the repeated experimental observations summarized in Table 3 indicate that the developed prototype provides consistent regenerative performance with an average recovery efficiency of approximately 65%. Although the developed prototype represents a simplified laboratory-scale implementation, the obtained results clearly validate the feasibility of regenerative braking using low-cost embedded hardware.

The proposed system offers advantages such as simple hardware architecture, economical implementation, reliable operation, and ease of maintenance. These characteristics make the prototype highly suitable for engineering laboratories, undergraduate projects, and research on embedded electric vehicle technologies. Future work may focus on integrating battery management systems, current and voltage sensing modules, IoT-based monitoring, and intelligent braking control algorithms to further improve energy recovery efficiency and practical applicability in modern electric vehicles.

5 CONCLUSION

This paper presented the design, development, and experimental evaluation of an Arduino-based regenerative braking system for electric vehicle applications. The proposed prototype was developed using an Arduino Uno microcontroller, L298N motor driver, DC BO motor, rechargeable 12 V battery, LCD display, LEDs, and associated electronic components to demonstrate the recovery of kinetic energy during braking. Unlike conventional braking systems that dissipate braking energy as heat, the developed system converts a portion of the kinetic energy into electrical energy and stores it in the battery for subsequent utilization. Experimental investigations confirmed that the prototype successfully operated in both driving and regenerative braking modes with smooth switching and stable system performance. The Arduino controller effectively managed the braking process while providing real-time system status through the LCD and LED indicators. The experimental results indicated consistent energy recovery with an average estimated efficiency of approximately 65%, validating the feasibility of implementing regenerative braking using low-cost embedded hardware. Furthermore, the comparative analysis demonstrated that the proposed system improves battery utilization, reduces energy loss, and provides an economical platform for understanding regenerative braking technology. Owing to its simple architecture, low implementation cost, and reliable operation, the developed prototype is well suited for engineering laboratories, academic research, and educational demonstrations. Future work may focus on integrating battery management systems, current and voltage sensors, IoT-based monitoring, and intelligent control algorithms to enhance energy recovery efficiency and facilitate practical implementation in modern electric vehicle systems.

FUNDING INFORMATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ETHICS STATEMENT

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest related to this study.

LICENSING

REFERENCES

[1] M C. Yang, T. Sun, W. Wang, Y. Li, Y. Zhang, and M. Zha, “Regenerative braking system development and perspectives for electric vehicles: An overview,” *Renewable and Sustainable Energy Reviews*, vol. 198, p. 114389, Apr. 2024, doi: 10.1016/j.rser.2024.114389.

[2] L. Qi *et al.*, “An electro-mechanical braking energy recovery system based on coil springs for energy saving applications in electric vehicles,” *Energy*, vol. 200, p. 117472, Apr. 2020, doi: 10.1016/j.energy.2020.117472.

[3] H. Faghihian and A. Sargolzaei, “A novel energy-efficient automated regenerative braking system,” *Applied Energy*, vol. 390, p. 125746, Apr. 2025, doi: 10.1016/j.apenergy.2025.125746.

[4] H. He, C. Wang, H. Jia, and X. Cui, “An intelligent braking system composed single-pedal and multi-objective optimization neural network braking control strategies for electric vehicle,” *Applied Energy*, vol. 259, p. 114172, Nov. 2019, doi: 10.1016/j.apenergy.2019.114172.

[5] R. Maia, M. Silva, R. Araújo, and U. Nunes, “Electrical vehicle modeling: A fuzzy logic model for regenerative braking,” *Expert Systems With Applications*, vol. 42, no. 22, pp. 8504–8519, Jul. 2015, doi: 10.1016/j.eswa.2015.07.006.

[6] E. M. Szumska, “Regenerative Braking Systems in Electric Vehicles: A Comprehensive review of design, control strategies, and efficiency challenges,” *Energies*, vol. 18, no. 10, p. 2422, May 2025, doi: 10.3390/en18102422.

[7] Y. Zhang, W. Wang, C. Yang, L. Han, Z. Zhang and J. Liu, "An effective regenerative braking strategy based on the combination algorithm of particle swarm optimization and ant colony optimization for electrical vehicle," *2019 IEEE 28th International Symposium on Industrial Electronics (ISIE)*, Vancouver, BC, Canada, 2019, pp. 1905-1910, doi: 10.1109/ISIE.2019.8781183.

[8] T. -T. Duong, P. -S. Huynh and Q. -T. Ngo, "Research to Evaluate the Regenerative Braking System Effect on Fuel Consumption of Hybrid Vehicle," *2021 International Conference on System Science and Engineering (ICSSE)*, Ho Chi Minh City, Vietnam, 2021, pp. 252-256, doi: 10.1109/ICSSE52999.2021.9538417.

[9] F. Yandong, W. Zhicheng, M. Chunjiang, Y. Guoliang and L. Guoqiang, "Modeling Designed for Regenerative Braking Energy Recovery of Pure Electric Commercial Vehicles," *2024 IEEE 2nd International Conference on Electrical, Automation and Computer Engineering (ICEACE)*, Changchun, China, 2024, pp. 470-474, doi: 10.1109/ICEACE63551.2024.10898310.

[10] Jie Shu, Weiwei Xiong, Chengliang Yin and Yong Zhang, "Effective regenerative braking control for smooth stop of a hybrid electric bus," *2008 IEEE Vehicle Power and Propulsion Conference*, Harbin, 2008, pp. 1-5, doi: 10.1109/VPPC.2008.4677695.

[11] M. T. Guneser and A. Ridha Othman, "Enhancement of Regenerative Power Utilization for Electric Vehicle by Using Eddy Current Brake," *2021 International Aegean Conference on Electrical Machines and Power Electronics (ACEMP) & 2021 International Conference on Optimization of Electrical and Electronic Equipment (OPTIM)*, Brasov, Romania, 2021, pp. 254-258, doi: 10.1109/OPTIM-ACEMP50812.2021.9590037.

[12] V. H. Quan, N. A. Ngoc, N. M. Tien, V. Van Khai and N. D. Khanh, "Surveying the Regenerative Braking Energy of the Braking System on the Vinfast VF8 Electric Vehicle Through Simulation Cycles," *2024 7th International Conference on Green Technology and Sustainable Development (GTSD)*, Ho Chi Minh City, Vietnam, 2024, pp. 467-472, doi: 10.1109/GTSD62346.2024.10675193.