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# Simulation And Evaluation of Regenerative Braking System For Electric Vehicles

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**Abstract -** *A key technique for increasing the efficiency of electric and hybrid vehicles in the face of the growing need for green energy is regenerative braking. This project proposes to combine the regenerative braking system (RBS) of an electric vehicle (EV) powered by an induction motor with a battery energy storage system (BESS). When the motor brakes, it converts kinetic energy into electrical energy, functioning as a generator. The DC-link voltage rises as a result, and an inverter that employs an effective switching method returns the energy to the battery. Recovered energy can be utilised to boost vehicle acceleration or to keep the battery charged during high-demand scenarios like uphill trips. A proportional integral (PI) controller is used to modify the brake current in order to ensure consistent torque braking. The performance of the recommended system is evaluated using a number of simulations. According to the results, the RBS significantly increases energy recovery and overall vehicle economy, making it a viable choice for electric vehicle applications.*

***Key Words***: electric vehicle (EV), regenerative braking system (RBS), battery energy storage system (BESS), and induction motor (IM).

## 1.Introduction

Electric and hybrid electric vehicles (HEVs), with their distinctive features including low emissions, great economy, and quiet operation, are attracting more and more attention. In the age of green technology, electric and hybrid electric vehicles (HEVs)can take the place of conventional cars with internal combustion engines (ICEs). Consequently, they are once again contributing to increased vehicle efficiency. However, the exorbitant price of EVs and HEVs has prevented many of them from being used. The objective of this project is to make EV settings less complicated for users. Finding a method to boost the amount of power that can be recovered by braking is one of the main objectives of research. A control strategy for enhancing the vehicle's overall braking performance has been created using the findings from this thesis.

Electric vehicles (EVs) are gaining a lot of attention right now because they provide a more environmentally friendly option to cars with internal combustion engines. The development of electric and hybrid vehicles is growing in popularity. Consequently, the public's awareness of global warming has grown, and the price of petrol has also increased. As a result of growing air pollution and oil prices, electric EVs have emerged as the main and last form of transportation. The main power source in a battery-operated EV is the battery, which has problems including insufficient cycles for charging and recharging and poor reactivity when it comes to driving range [2–5]. The aforementioned problems can be resolved by electrochemical batteries, flywheels, ultracapacitors, and other energy sources [5-7].

A number of techniques have been put in place to deal with this problem, including regenerative braking. The battery and ultracapacitor translate and store a portion of the vehicle's kinetic energy, which is stored during deceleration [7–10]. On a smooth road, regenerative braking is not always effective. It can be seen in places where vehicles have to apply the brake, such as speed bumps, pits in the road, and slopes. Regenerative braking is only noticeable when the battery is completely charged; otherwise, EVs must have mechanical brakes. Electric vehicles employ mechanical brakes to enhance the roughness of the wheel in order to decelerate. This loses a lot of energy since when the mechanical brake is engaged, the kinetic energy of the EV is transformed back into electric energy. The motors are easy to regulate and can regenerate. Two-wheel EVs usually use mechanical brakes to reduce or halt their speed, which causes all of the kinetic energy that has been stored to be lost [11–15]. It is possible to recover and store the kinetic energy lost during braking as electrical energy in batteries and ultra capacitors. This energy can be stored in the battery if the

motor, drive, and battery are all managed and controlled appropriately. Thus far, the market has led to an increase in the demand for electric vehicles.

### 1.1 Literature

According to the work of Y. Kim and N. Change, there are several strategies to improve the performance of hybrid energy storage systems, such as automation and design optimization. Every energy storage method has advantages and disadvantages of its own, so a hybrid approach that combines both can be used to create a high-performance, affordable battery. Energy-efficient operating systems and new design optimization techniques are presented. The author also provides a detailed description of hybrid energy storage system prototype at a scale of 300 W.

According to a study that was published in the journal Energy Storage Systems for Automotive Applications et. All [2], the ability of revolutionary cars with electric propulsion capabilities to store energy effectively and efficiently has a significant impact on their performance and fuel efficiency. [2] (ESS). This study looks at how ESSs are currently being used in automotive applications. With an emphasis on battery management, protection, monitoring, and balancing strategies, battery technology options are thoroughly investigated. Other ESS solutions proposed include fuel cells, flywheels, and ultracapacitors. Finally, hybrid power sources are the idea of combining two or more energy storage devices to create a more potent power source. Both choosing the appropriate drive train architecture and putting in place an efficient power flow control method are essential for lowering fuel consumption and emissions in plug-in hybrid electric vehicles (PHEVs), according to S. G. Wira singha and A. Emadi's classification and review of control strategies for PHEVs [3]. Although control strategies for hybrid electric vehicles (HEVs) have been developed and demonstrated, they do not fully utilize the PHEV's capacity to travel long distances solely on electricity. This book examines and organizes the most recent control strategies. Both optimization-based and rule-based PHEV control algorithms have advantages, but they are not exclusive. The controllers are described in detail, and an evaluation of the best technique for maximizing PHEV performance under various driving circumstances is offered. Finally, a new classification of PHEV control strategies based on the vehicle's operation has been provided and proven by simulation results.

The active suspension (AS) system of hybrid electric vehicles (HEVs) can be utilised to create power, according to M. Montazeri and M. Soleymani's paper, Investigation of the energy regeneration of the active suspension system in hybrid electric vehicles et. all., [4]. The HEV powertrain and AS systems are simulated simultaneously in a single medium created by using simultaneous simulation and control techniques. Ultracapacitors (UCs) and electrochemical batteries make up the proposed hybrid energy storage system (ESS). The models' findings indicate that fuel efficiency is increased by the regeneration of the AS energy. By implementing a hybrid energy storage system (ESS), load variations from the batteries can be transferred to the UCs, further increasing battery life and efficiency.

Optimal design and real-time control for electric vehicle energy management et al., by L. Wang et al., [5] It has been demonstrated that an active combination of an energy-dense Li-ion battery with an ultracapacitor (UC) is a viable method for extending the cycle life of lithium-ion (Li-ion) batteries in electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs). This paper takes a novel approach to the issues of battery and UC sizing, as well as the extent of hybridization between battery and UC power, by using an optimization problem to minimize fuel use. To implement this ideal power sharing in real time, a novel energy management strategy based on forecast control based on driver commands, UC state-of-charge regulation, and battery power reference generation is recommended.

Finally, calculations and experiments employing the flywheel + generator + regulated load are given to confirm that the proposed method increases fuel economy and lowers battery current stress. Cheng-Hu Chen, Wen-Chun Chi, and Ming-Yang Cheng's paper, Regenerative Braking Control for Light Electric Vehicles et al., [6], detailed a straightforward yet efficient electric brake energy regeneration system for an electric vehicle's brushless DC motor (EV). A suggested method just modifies inverter switching sequences to control inverse torque during braking. This indicates that the braking energy of the battery is recovered. Through the removal of a converter, ultracapacitor, or a convoluted winding-changeover process, the suggested technique concurrently achieves the goals of energy regeneration and electronic braking.

### 1.2 Proposed sytem

The regenerative braking system and its several parts are shown in Figure 1. The diagram below shows a battery, a three-phase inverter, and an induction motor. First, the vehicle follows a straight path; if an obstacle arises in the middle, the driver applies the brakes, and the battery stores kinetic energy as an electrolytic charge until it is full.

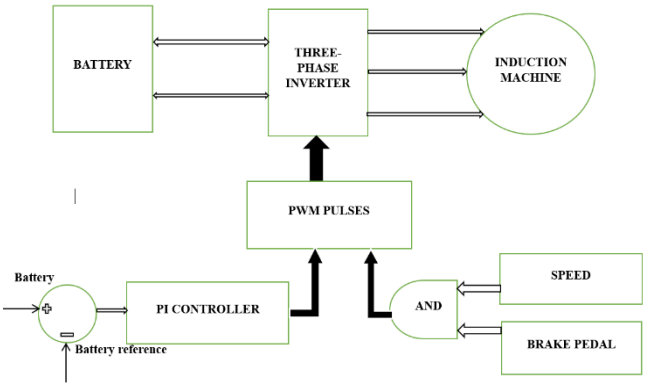



Fig 1. The Proposed system block diagram

### *A. System Of Regenerative Braking*

Regenerative braking allows the motor's mechanical energy to be converted into electrical energy that is then transferred back to the battery. In the regenerative braking mode, the motor slows the vehicle downward. When the brake pedal is depressed, the car slows down and the motor reverses direction. The engine charges the battery by acting as a generator when it is travelling in the incorrect direction. The figure2 illustrates this, The car's normal operation, in which the motor draws power from the battery to move the vehicle forward.

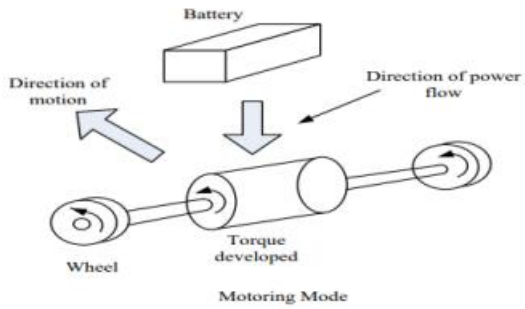



Fig 2.Normal Driving condition

Electric vehicles can minimize pollutants and save money on petrol by implementing regenerative braking. The electric vehicle's regenerative braking system provides the braking force while the vehicle's speed is low, minimizing the requirement for stop-and-go traffic and, consequently, deceleration.

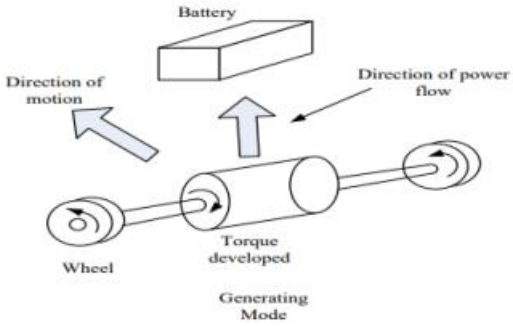



Fig 3. Regenerative action during breaking

The brakes work so well in such conditions that you can easily stop in urban areas. Because it controls the entire powertrain, a car's braking system and controller give it structure. The brake controller's two primary functions are to track the wheel's speed and calculate torque, power production, and rotational force that will be sent to the battery.

## 1.3. Control systems for EV

### A. The standard mode

The operation of electric vehicles is shown in Figure 4. The armature current flows from positive to negative voltage. Each MOSFET has a parallel connection to a diode. This type of freewheeling diode can be used to switch devices with PWM, guaranteeing optimal system efficiency.

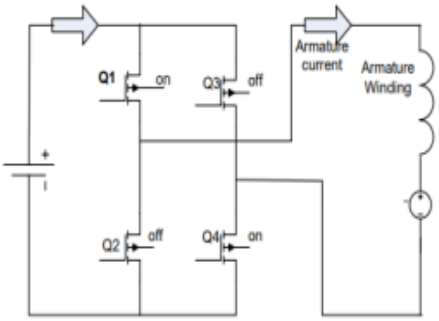



Fig 4.Driving Mode

### B. Mode of regeneration

In order to alter the direction of armature current, the battery and back-emf are linked in series during the first stage of initial braking mode. This is demonstrated in the battery and back-emf connections. This first braking approach allows the armature current to change directions automatically by activating Q2 and Q3 and deactivating Q1 and Q4. When the armature current increases and changes direction on its own, the MOSFETs' state returns to the position shown in figure

5 to recharge the battery once more. This technique makes regenerative braking feasible.

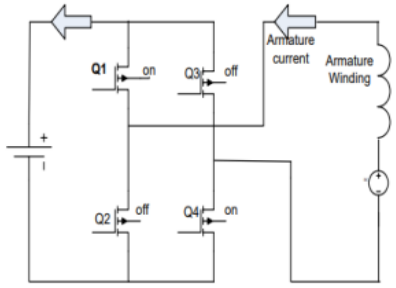



Fig 5. Regenerating mode

### 1.4 Induction motor

Generally speaking, an electrical motor's rotating components are where electrical power is converted into mechanical power. A dc motor is referred to as a conduction motor because power is transferred directly to the armature, the rotating portion of the motor, via a brush. In contrast, an induction motor obtains its electrical power through induction rather than conduction, much like the secondary of a two-winding transformer does. For this reason, this type of motor is called an induction motor.

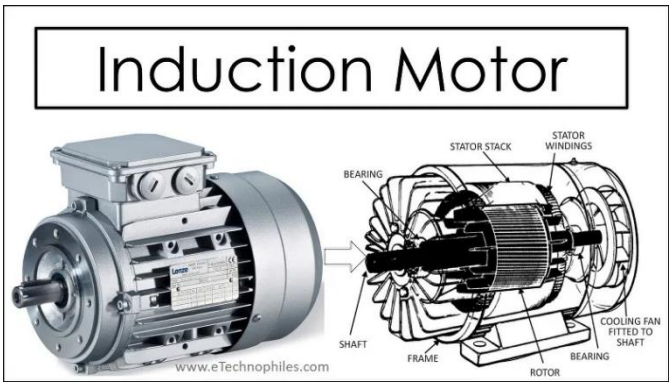



Fig 6. Diagram Of the Induction Motor

An induction motor can actually be thought of as a rotating transformer, meaning that the secondary winding is free to rotate while the primary winding remains motionless. The polyphase induction motor is the most often utilized a.c motor for a variety of industrial drives that are available. A revolving magnetic field is created when the stator windings are coupled to a three-phase supply. An e.m.f. is created in a bar on the rotor when the magnetic flux cuts it, and because the bar is connected to another bar one pole pitch away by end conducting rings, current flows across the bars.

When the spinning magnetic field and the magnetic field connected to the current flowing in the bars interact, a force is created that tends to rotate the rotor in the same direction as the rotating magnetic field. All of the rotor's conductors receive comparable forces, which results in a torque that rotates the rotor.

Both the stator and rotor sides of an induction motor can alter its speed. Three-phase induction motor speed regulation from the stator side is further divided into:

- V/F control or frequency control.
- Changing the number of stator poles.
- Controlling supply voltage.
- Adding rheostat in the stator circuit.

The speed controls of three phase induction motor from rotor side are furth

- Adding external resistance on rotor side.

- Cascade control method.
- Injecting slip frequency control emf into rotor side.

The SOC cannot exceed 100% if the battery is overcharged. The above-mentioned assumptions are true in theory, but in reality, the SOC limit ranges from 20% to 40%. One of the lightest metals with good electrical qualities is lithium. Because of its stated benefits, a lithium-ion battery model served as the foundation for this thesis.

## 2.RESULT

### 2.1Simulation Result(before braking action)

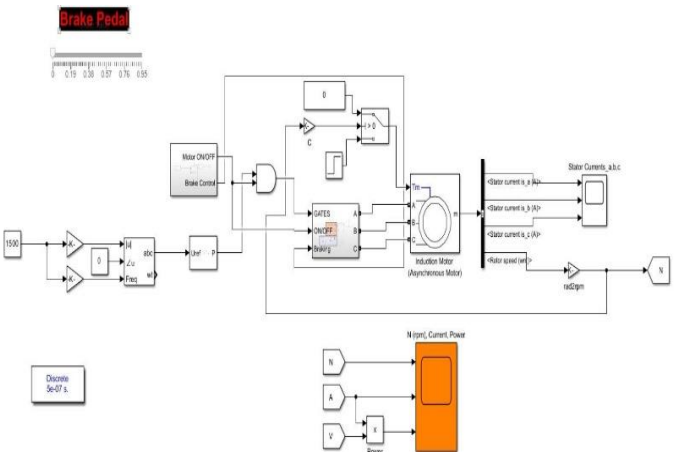



Fig 8. Simulation diagram before braking action

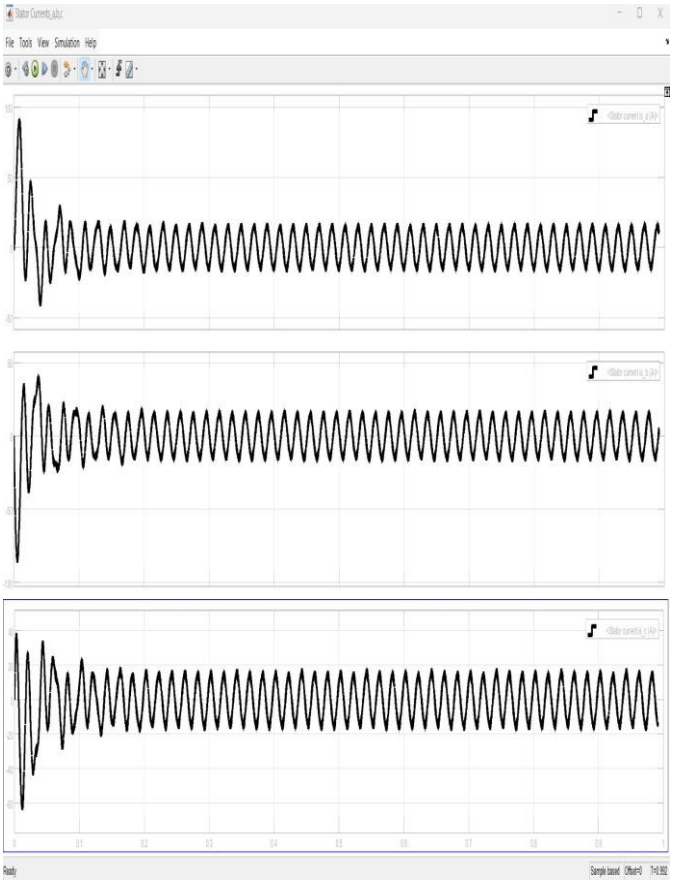


**Fig 9.simulation results of stator speed before braking action**

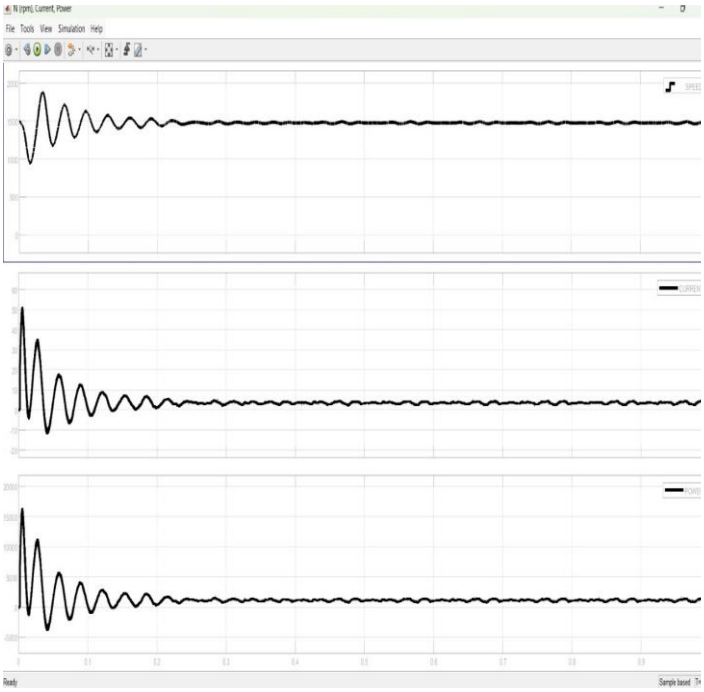


Fig 10.simulation results of speed , current,power

## 2.2Simulation Result (After Braking Action)

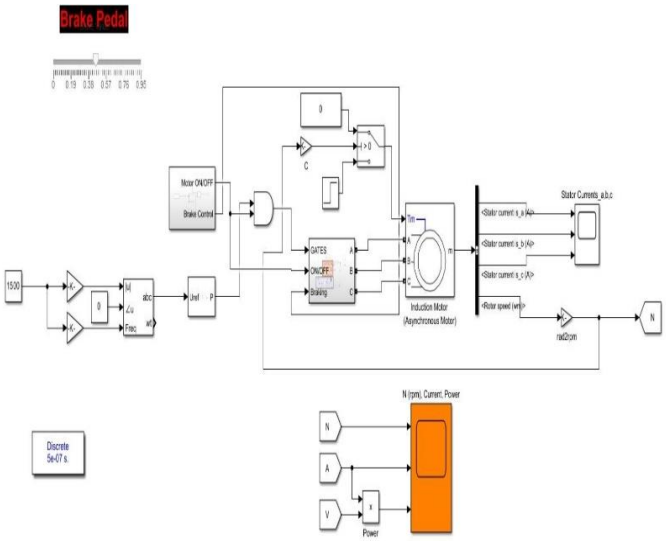



Fig 10 .simulation diagram after braking action

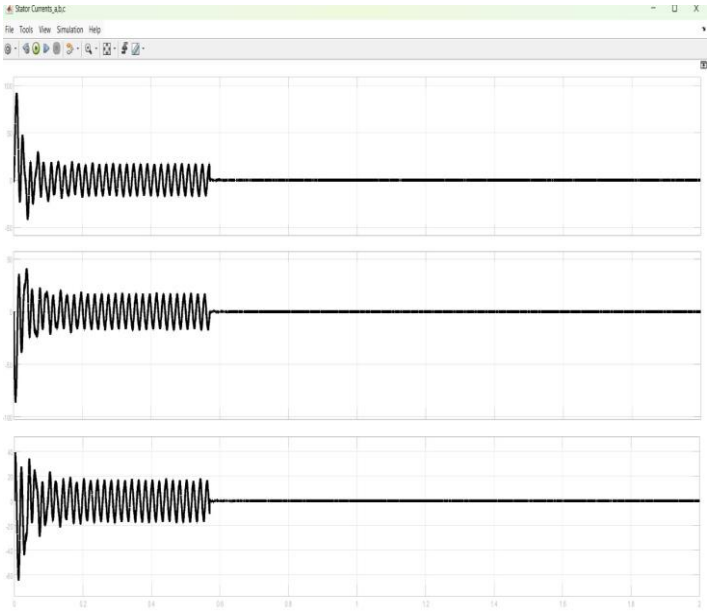
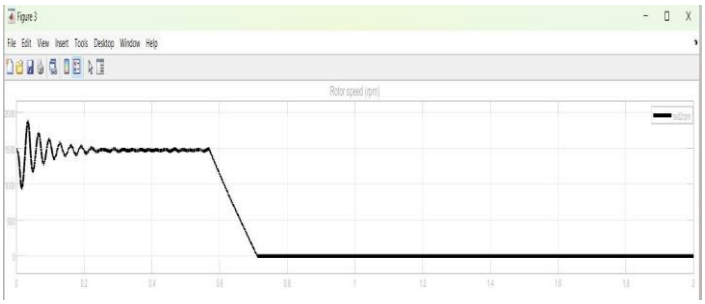


Fig 11.Simulation Result Of Stator Currents After Braking Action



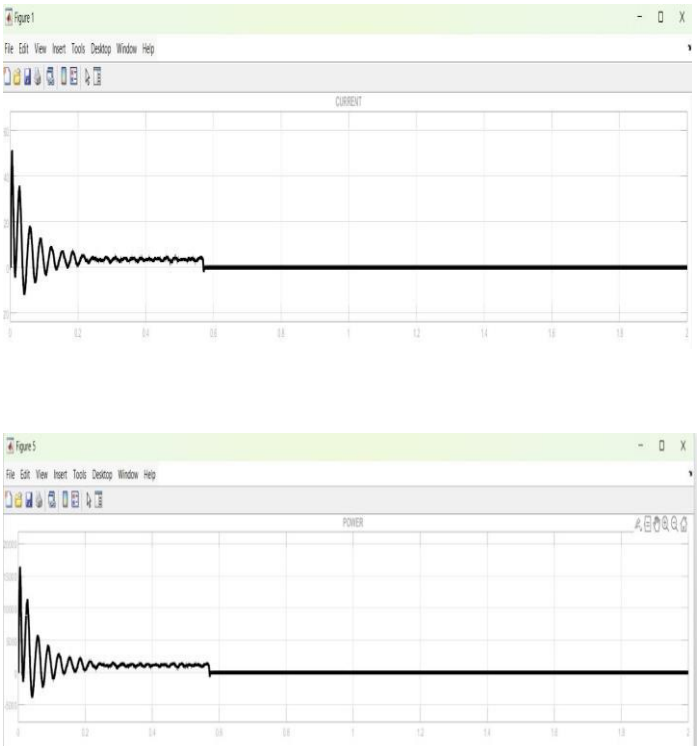



Fig 12. Simulation Results After Braking Action

## 3. CONCLUSIONS

Regenerative braking has been shown to be efficient in improving the performance and energy efficiency of electric vehicles through simulation and evaluation using MATLAB/Simulink. With energy recovery up to 85% in some circumstances, the system greatly minimizes energy loss and increases driving range by transforming kinetic energy into electrical energy during braking and reserving it in the battery. Using metrics like brake torque and motor currents, the results confirmed efficient energy regeneration, steady power flow, and smooth deceleration. According to this study, regenerative braking is an essential part of environmentally friendly electric vehicle technology that also extends battery life. In order to further maximize system performance and reliability, future improvements can concentrate on implementing real-time hardware implementation and adaptive control techniques.

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