IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Design And Simulation Of Regenerative Braking System For Electric Vehicles Using BLDC Motor

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Abstract – This study presents the design and simulation of a regenerative braking system for electric vehicles using a BLDC motor. The system recovers kinetic energy during breaking and stores it in the battery, improving overall efficiency. MATLAB/Simulink is used to model and analyze system performance. The results show effective energy recovery and improved vehicle efficiency, demonstrating the suitability of BLDC motors for regenerative braking applications.

Key Words: Regenerative Braking System, Electric Vehicles (EVs), Brushless DC Motor (BLDC), Energy Recovery, MATLAB/Simulink, Pulse Width Modulation (PWM), Battery Charging, Power Electronics.

Abstract – *This paper presents the design and simulation of a regenerative braking system for electric vehicles using a Brushless DC (BLDC) motor. The system converts kinetic energy while breaking into electrical energy and stores it in the battery, improving overall efficiency. The model is developed using MATLAB/Simulink and analyzed under different braking conditions. The results show effective energy recovery and enhanced performance, demonstrating the suitability of BLDC motors for regenerative braking applications.*

Key Words: Regenerative Braking System, Electric Vehicles (EVs), Brushless DC Motor (BLDC), Energy Recovery.

1. INTRODUCTION

The increasing demand for electric vehicles (EVs) is driven by the need for energy-efficient and environmentally friendly transportation. However, energy losses during breaking reduce the overall efficiency and driving range of EVs. Regenerative braking systems (RBS) address this issue by converting the vehicle's kinetic energy into electrical energy during deceleration and storing it in the battery.

Brushless DC (BLDC) motors are widely used in EVs due to their high efficiency, reliability, and ability to operate in both motoring and generating modes. This paper presents the design and simulation of a regenerative braking system using a BLDC motor. The system is modeled in MATLAB/Simulink to analyze its performance and energy recovery capability under different braking conditions.

2. LITERATURE REVIEW

Recent studies have highlighted the importance of regenerative braking systems (RBS) in improving the efficiency and driving range of electric vehicles. Researchers have explored various control strategies, such as PID and fuzzy logic controllers, to optimize braking performance and energy recovery. The integration of advanced components like ultra-capacitors and DC-DC converters has also been proposed to enhance energy storage and system response.

Several works have demonstrated that Brushless DC (BLDC) motors are highly suitable for regenerative braking due to their high efficiency and ease of control. Simulation-based studies using MATLAB/Simulink have shown that effective control of motor operation during braking can significantly increase energy recovery. However, challenges such as reduced efficiency at low speeds and the need for proper coordination between regenerative and mechanical braking still remain areas of ongoing research.

3. METHODOLOGY

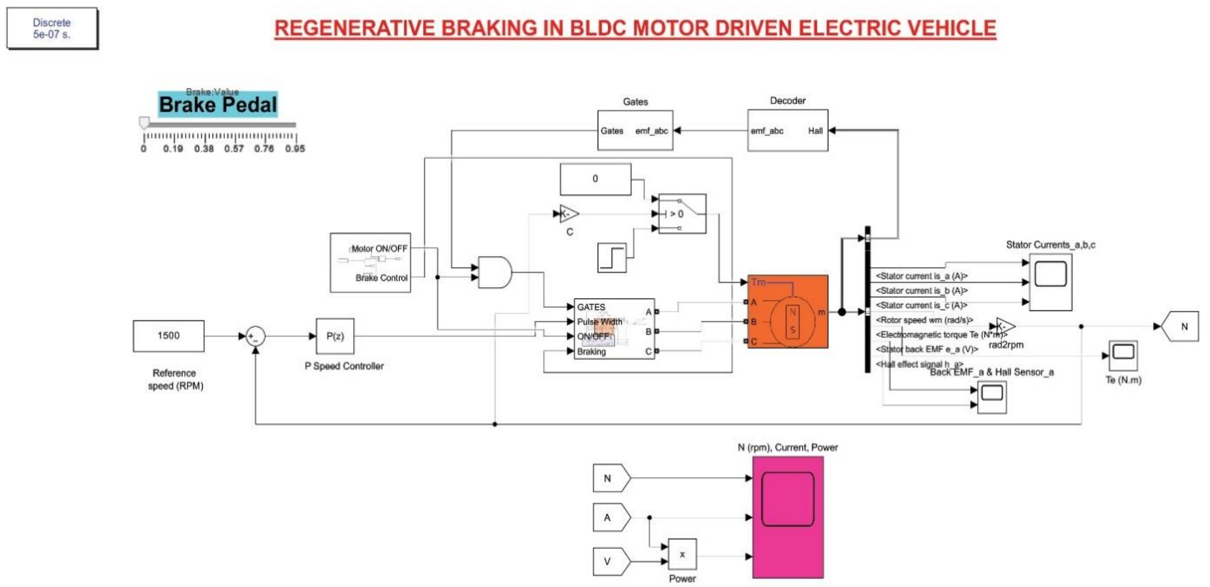
The proposed system is based on a regenerative braking mechanism using a Brushless DC (BLDC) motor. During normal operation, the motor drives the vehicle by drawing energy from the battery. When braking is applied, the motor operates in generator mode, converting kinetic energy into electrical energy and feeding it back to the battery.

A control strategy based on Pulse Width Modulation (PWM) is used to regulate the switching of power electronic devices and ensure smooth transition between motoring and regenerative modes. The system is modeled and simulated in MATLAB/Simulink, where key parameters such as motor speed, braking torque, and battery current are analyzed under different braking conditions to evaluate system performance and energy recovery efficiency.

4. SYSTEM COMPONENTS

The proposed regenerative braking system consists of key components required for efficient operation. The BLDC motor acts as both a motor and generator during driving and braking modes. The battery stores and supplies electrical energy, including the energy recovered during breaking. Power electronic devices such as MOSFETs or IGBTs are used in the inverter circuit to control power flow. Hall sensors are used to detect rotor positions for proper motor control. A controller is implemented to manage switching operations and ensure smooth transition between motoring and regenerative modes.

5. MODELING AND SIMULATION

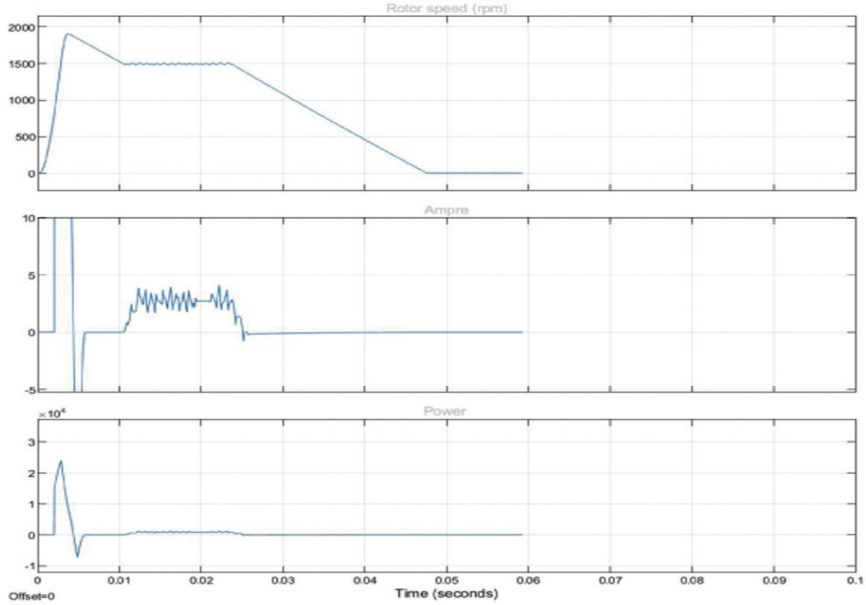


MATLAB SIMULINK MODEL FOR REGENRATIV BREAKING USING BLDC MOTOR.

The regenerative braking system is modeled and simulated using MATLAB/Simulink based on a BLDC motor drive configuration. The model consists of key components including a battery source, three-phase inverter (IGBT-based), BLDC motor, and control circuitry using Hall sensor signals. The switching of inverter devices is controlled through PWM signals to ensure proper commutation of the motor.

During simulation, the motor initially operates in motoring mode, and regenerative braking is applied by altering the switching sequence and control signals. The back electromotive force (EMF) generated during breaking is captured and directed back to the battery through a suitable control mechanism. The model evaluates parameters such as motor speed, current, and voltage under different brake conditions, demonstrating effective energy recovery and system performance

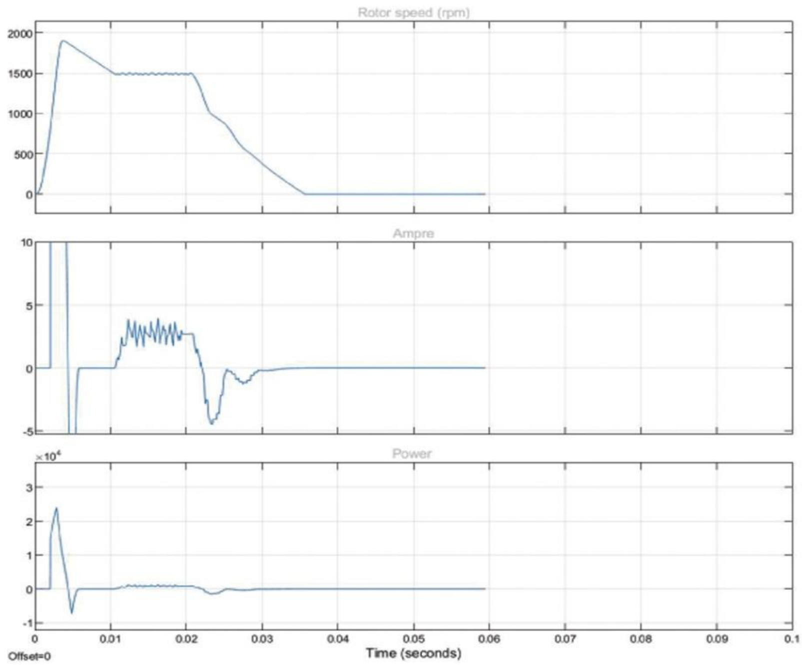
6. RESULTS AND DISCUSSION



Output waveform for the Break 0.19

The energy of the BLDC motor in MATLAB/Simulink was supplied by a battery. The operating voltage and battery voltage of the motor was 48 V. Two methods were specified in the method section to obtain the back EMF to be used during regenerative braking. The changes in time of the back EMF obtained from 20 Ω by means of both the first and the second methods are shown in Figure

Frist We will start the BLDC motor to obtained the desired output of our module after the starting the Simulink model the motor will start with the high Starting speed and current after this the motor will run at the rated speed of our BLDC motor 1500 RPM and the running current will may be constant near its value, After of 0.02 sec we will take brake pedal position at the 0.19 will mild break will be applied and the motor will gets the slow down and gets stop in this breaking the motor will work as the generator and the generate the EMF as per the speed of motor and the current drawn to battery in negative direction and the energy will be stored by the boost converter.



The output waveform for a braking input of 0.95 represents a strong braking condition. It is observed that the motor speed decreases rapidly due to the high braking torque applied. During this period, the BLDC motor operates in generator mode, producing a significant back electromotive force (EMF).

The current waveform shows a reversal in direction, indicating the flow of energy from the motor back to the battery. This confirms the effective operation of the regenerative braking system. Additionally, the power waveform demonstrates that a higher amount of energy is recovered compared to lower braking inputs. The results indicate that increased braking intensity leads to improved energy regeneration, enhancing overall system efficiency.

7. CONCLUSION

This paper presented the design and simulation of a regenerative braking system for electric vehicles using a BLDC motor. The system successfully converts kinetic energy during braking into electrical energy and stores it in the battery, improving overall efficiency. The MATLAB/Simulink results demonstrate effective energy recovery under different braking conditions, with higher braking input resulting in greater energy regeneration. The study confirms that BLDC motors are suitable for regenerative braking applications due to their high efficiency and reliable performance. Overall, the proposed system enhances energy utilization and contributes to extending the driving range of electric vehicles.

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