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REGENERATIVE BRAKING SYSTEM USING BLDC MOTOR

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DECLARATION

We, Ambati V R Akhilesh, V. Gowtham Raj, R.Meher Bhavana and M. Sri Hemanth Reddy hereby declare that the project report entitled "**Regenerative braking system using BLDC Motor**" submitted to the Vellore Institute of Technology,Vellore in partial fulfilment of the requirement for the award of the degree of Bachelor of Technology in Electrical and Electronics Engineering is an original work and the contents of this report have not been submitted in part or in full, for the award of any other degree or diploma in this institute or an other institute or university.

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1.ABSTRACT

Regenerative braking systems (RBS) are an effective method of recovering the energy released and at the same time reducing the exhaust and brake emissions

of vehicles. This method is based on the principle of converting the kinetic energy created by the mechanical energy of the motor into electrical energy. The converted electrical energy is stored in the battery for later use. This braking system must meet maximum energy recovery criteria by performing its function safely within the shortest braking distance. This study was conducted to provide comprehensive information about regenerative energy systems. These systems provide economic benefits via fuel savings and prevention of material loss. Their use also contributes to a clean environment and renewable energy sources, which are among the most important issues on the global agenda. It is clear that more comprehensive studies should be carried out in this area.

2.INTRODUCTION

Regenerative braking system:

Regenerative braking system is more often used for electric vehicles. Main purpose of this is to conserve energy. We know that from law of conservation of

energy, Energy can neither created nor destroyed but can be transformed from one form to another. In this KE of running electric vehicle can be converted into electrical energy. When the electric vehicle is moving down the hill or waiting in traffic the excess of torque is available in wheels. This torque will make pass through the motor and charge to the battery. Although a small amount of energy can be recovered which will be helpful for the performance of the Electric Vehicle.

RBSs are installed along the drive train or fitted to the drive wheels of a vehicle where they inhibit the motion of the wheels using magnetic fields or mechanical torque. These methods of motion inhibition allow energy to be generated under braking, as opposed to friction brakes which simply waste away energy to slow the vehicle by turning the kinetic energy into thermal energy. Due to the maximum charging rate of the energy storage mechanisms, the braking force from an RBS is limited. Therefore, a traditional friction brake system is required to maintain the safe operation of a vehicle when heavy braking is necessary. RBS can improve fuel consumption and reduce the overall braking load taken on by the vehicle's friction brakes, reducing the wear on the brake pads.

RBSs are used in almost every electric vehicle and hybrid electric vehicles. In addition, public transportation such as buses and bullet trains make use of RBSs to decrease the environmental impacts of the transportation fleet and save money.

3.LITERATURE REVIEW

- **Modelling and Control of Regenerative Braking for Brushless DC Machines Driven Electric Vehicles**

In this research paper they have designed a regenerative braking system with the help of ADRC control which consists of nonlinear tracking differentiator, extended state observer, and nonlinear state error feedback control law.

- **Investigation of Regenerative Braking Performance of Brushless Direct Current Machine Drive System**

  In this paper by considering different parameters and battery internal resistance they have found the regenerative capability range. By considering these parameters they have found that overall efficiency and battery capacity is also increased.

- **Regenerative braking system of BLDC motor with automatic braking and brake fail detection for electric vehicles**

  In this paper they have developed a model with automatic braking and brake fail detection. For these they have used different sensors like Ultrasonic sensor and IR sensor and interfaced with the microcontroller.

- **Regenerative braking in an electric vehicle**

  In this paper they have constructed a BLDC motor control circuit which consists of a power module and control module and explained about different switching sequences which are required for regenerative braking.

- **Regenerative braking system of electrical vehicle driven by brushless DC motor**

In this paper, they have developed a BLDC motor control using PID controller and for the distribution purpose they used fuzzy logic control and found different parameters and made a comparison.

- **Design of Regenerative Braking System and Speed Control of BLDC Motor for Electric Vehicle**

  In this paper they've proposed an easy but powerful method of speed control and braking technique for EV. Arduino Uno is used in this paper which results in reduction of time and thus giving enhanced time management. The PWM switching is applied only for the MOSFET switch of the converter, hence the switching losses are minimised.

- **A Novel Regenerative Braking System of BLDC Motor for Lightweight Electric Vehicles: An Analysis of Braking Characteristics**

  In this paper a novel regenerative braking mechanism based on Brushless DC (BLDC) motor is proposed. Using BLDC motor to improve the mileage of lightweight electric vehicles (EVs).

- **Speed Control of Brushless DC Motor in Electric Vehicle with Regenerative Braking**

  In this paper, the switching logic for motoring and regenerative braking mode of BLDCM has been developed using MATLAB Simulink and Carried out in hardware. In this the objective of increasing the driving range of the EV is achieved without increasing the battery capacity and space consumption.

- **Compact Regenerative Braking Scheme for a PM BLDC Motor Driven Electric Two-Wheeler**

In this paper, a simple method to control the power flow from the motor to the battery by changing the switching sequence given to the inverter used in the PM BLDC motor drive is presented.

- **Regenerative Braking System in Electric Vehicles**

  In this paper, a method of regenerative braking in electric vehicle is proposed. The regenerative braking system improved by the advanced technologies of power electronic components, are ultra-capacitor, DC-DC converter.

- **Design and Fabrication of Regenerative Braking in EV**

  In this paper, regenerative braking is done by using the battery pack, the forward motoring MOSFET block, the regenerative braking MOSFET switching block. Back EMF is boosted using DC-DC converter or using any control circuit.

- **Regenerative Braking System of Electric Vehicle Driven by BLDC Motor Using Neuro-Fuzzy and PID**

  In this paper, PID is used to control the negative torque of the motor when the brake is pressed. The Neuro-fuzzy logic and PID control can recognize the regenerative braking and can prolong the driving distance of the EV.

- **Development of a BLDC motor drive with improved output characteristics**

  In this paper, a PIC microcontroller is employed to generate pulse width modulation (PWM) signals for driving the power inverter bridge. Many digital controllers are also used for fast execution.

- **A regenerative braking control strategy for electric vehicles with four in-wheel motors.**

In this paper, a model predictive controller is designed for the distribution of the brake torque between the hydraulic brake mode and the electric motor brake mode.

- **Regenerative Braking System of Electric Vehicle Driven by Brushless DC Motor**

  In this paper, BLDC motor control utilises the traditional proportional–integral–derivative (PID)control, and the distribution of braking force adopts fuzzy logic control. Because the fuzzy reasoning is slower than PID control, the braking torque can be real-time controlled by PID control.

- **A new electric braking system with energy regeneration for a BLDC motor driven electric vehicle**

  A new electric braking system is proposed for a brushless DC (BLDC) motor driven electric vehicle (EV) in this paper based on stopping time and energy regeneration. This new braking system is developed by combining various regenerative methods and plugging. Stopping time and energy recovery for various methods are studied for different running conditions.

- **Design and Implementation of BLDC Motor Using Regenerative Braking for Electric Vehicle**

  This paper proposes a simple but effective method of electric brake with energy regeneration for a brushless dc motor, or electric vehicle (EV). BLDC motor control utilises the traditional PID control and the distribution of braking force adopts fuzzy logic.

- **Review of Regenerative Braking for Electric Two-Wheeler**

This paper shows that the main drawback of electric vehicles is the low travelling range. Regenerative braking gives a green source of energy with the help of which one can improve the fuel efficiency of electric Two-Wheeler and the range of vehicle.

- **Regenerative Braking System of Electric Vehicle Driven By Brushless Dc Motor**

  In this paper, BLDC motor control utilises the conventional PID control, and the sharing of braking force adopts fuzzy logic control. As the fuzzy reasoning is slower than PID control, the braking torque can be instantaneously controlled by PID control.

- **Investigation of Regenerative Braking Performance of Brushless Direct Current Machine Drive System**

  In this paper by considering different parameters and battery internal resistance they have found the regenerative capability range. By considering these parameters they have found that overall efficiency and battery capacity is also increased.

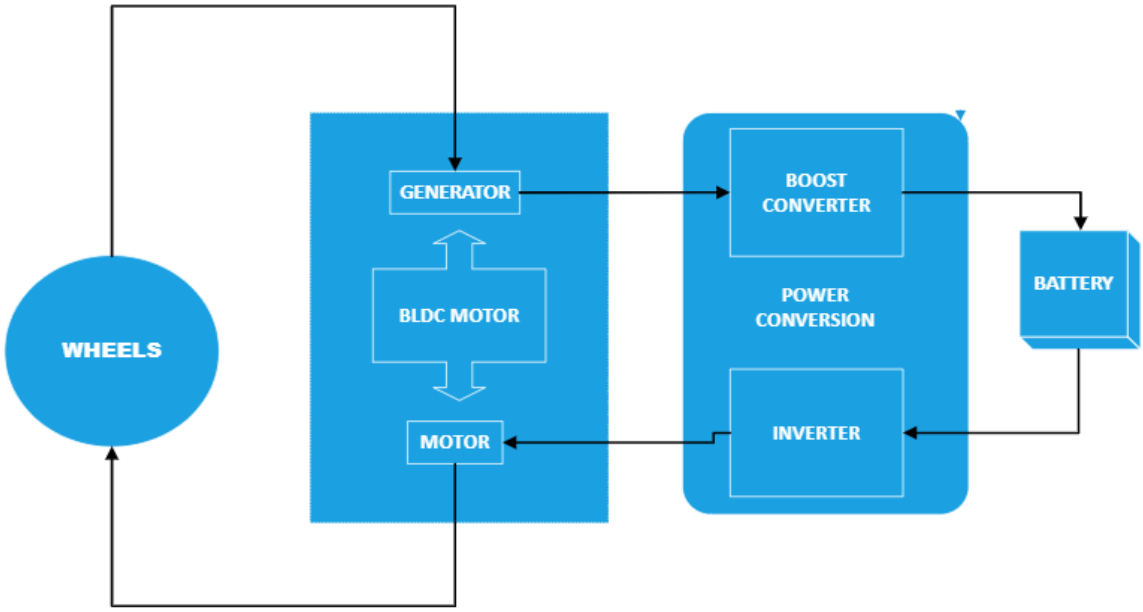
4.METHODOLOGY

The project is executed using MATLAB- Simulink.

We have used various libraries, Components, few mentions include,

- Permanent Magnet synchronous motor (BLDC)
- Subsystems for truth tables
- Battery
- Inverter using IGBT
- PWM generator
- PID controller

4.1Block Diagram:



4.2 MATLAB SIMULATION:

As the motors starts and keep working in normal condition the circuit simulated

We have a brake pedal which is simulated with a logic gate as shown in the subsystem. We get an input from the hall sensor and give it to the decoder to verify the regenerative braking to be active or not. This decoder gives the value to the gate subsystem where a logic gate provides the values to the main subsystem(subsystem 1), in this subsystem we use and or gates to keep the loop running and keep the battery chargers throughout the working of the motor.

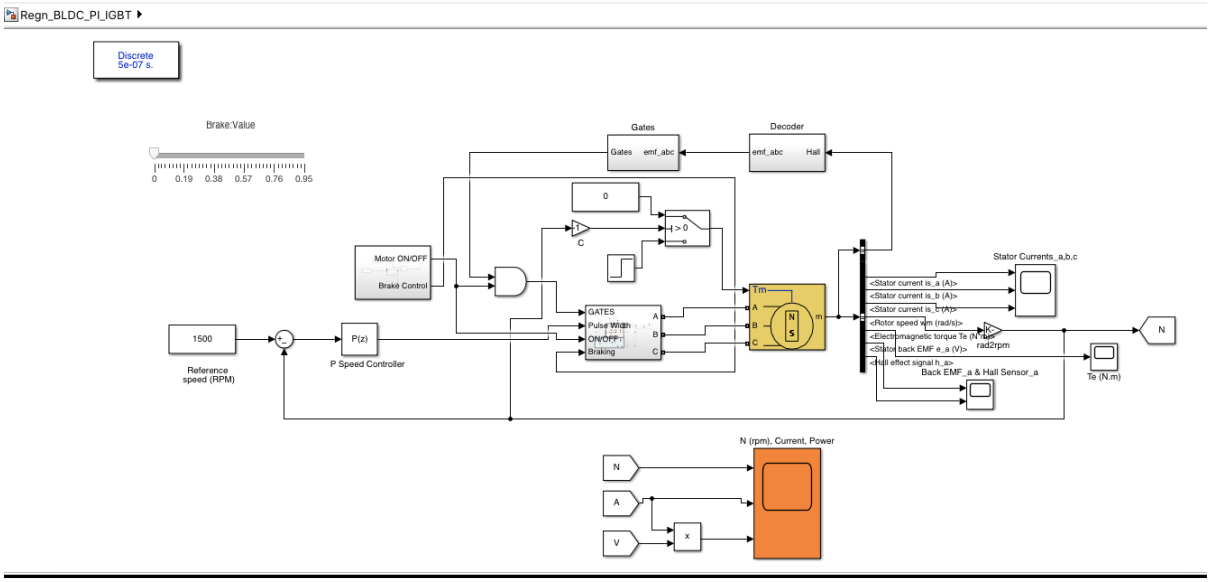
Motor on/off control in the subsystem of braking provides the information to subsystem 1 such that whenever brake is applied the motor is turned off.

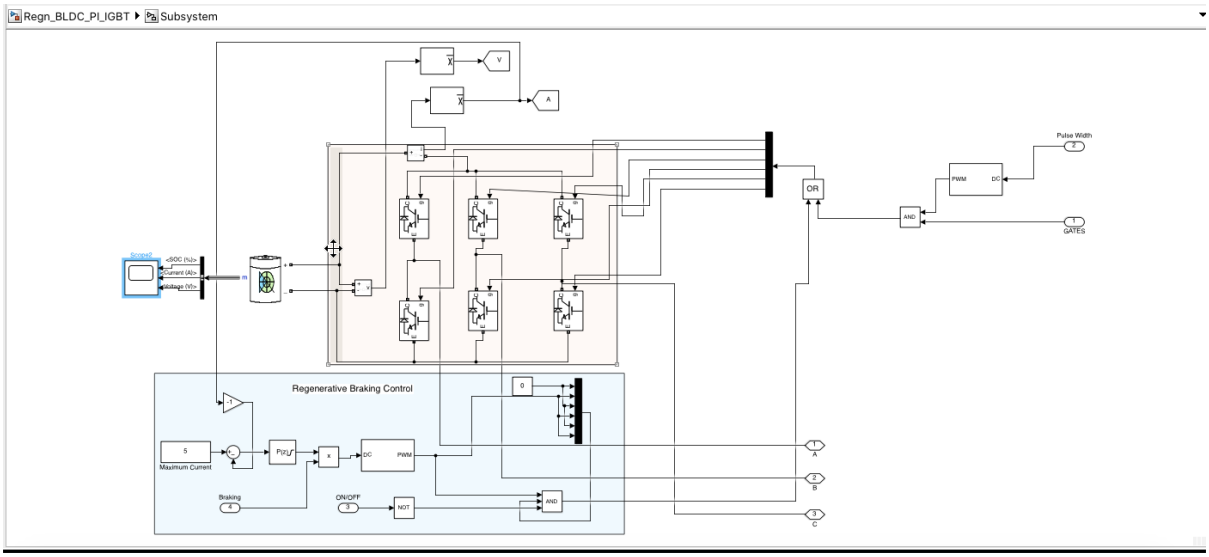
Through the control logic of the subsystem 1, we will change the duty cycle of the pulse generated by the PWM generator.

6 IGBT based inverter is used connected to a li-ion battery with a initial SOC of 50%.

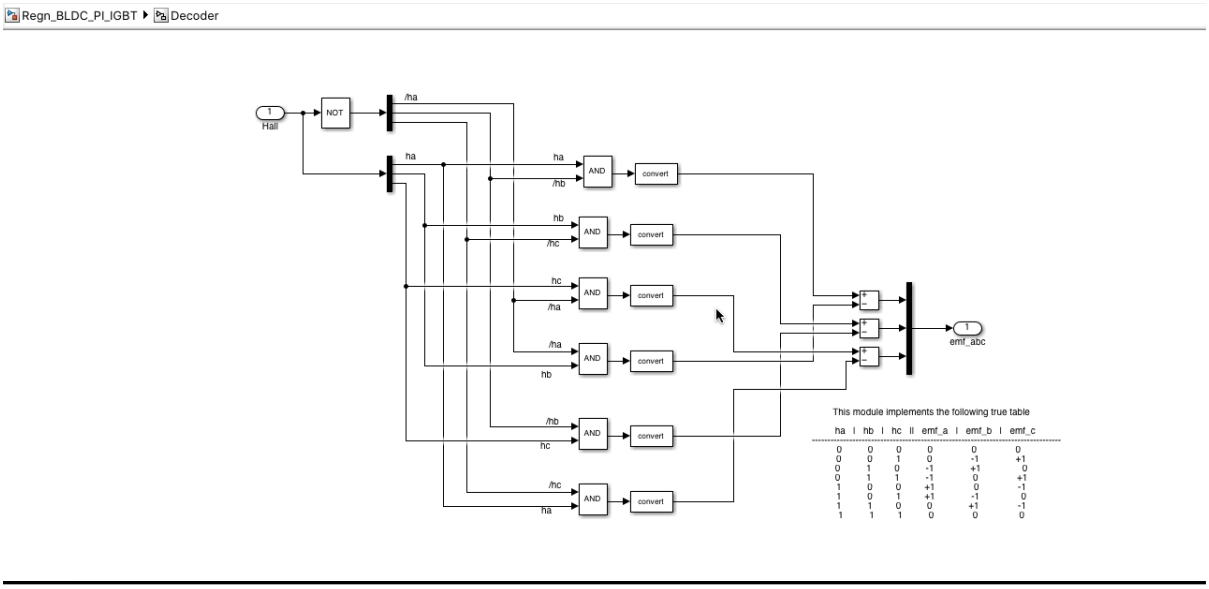
During the process of regenerative breaking, the current will be in the reverse direction.

We are considering a constant speed of 1500 rpm.

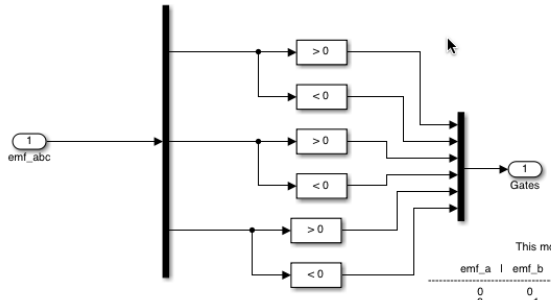



Regn_BLDC_PI_IGBT ▸ Subsystem
Regenerative Braking Control
Maximum Current
Braking
ON/OFF
PWM
NOT
AND
OR
Pulse Width
GATES
A
B
C

Subsystem 1


Regn_BLDC_PI_IGBT ▸ Decoder
Hall
NOT
/ha
ha
/hb
hb
/hc
hc
AND
convert
emf_abc
This module implements the following true table
ha | hb | hc || emf_a | emf_b | emf_c
0 0 0 0 0 0
0 0 1 0 -1 +1
0 1 0 -1 +1 0
0 1 1 -1 0 +1
1 0 0 +1 0 -1
1 0 1 +1 -1 0
1 1 0 0 +1 -1
1 1 1 0 0 0

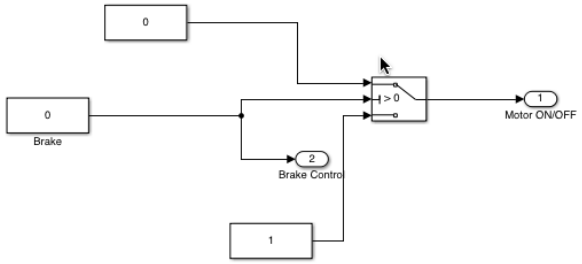
Regn_BLDC_PI_IGBT ▸ Gates



This module implements the following true table

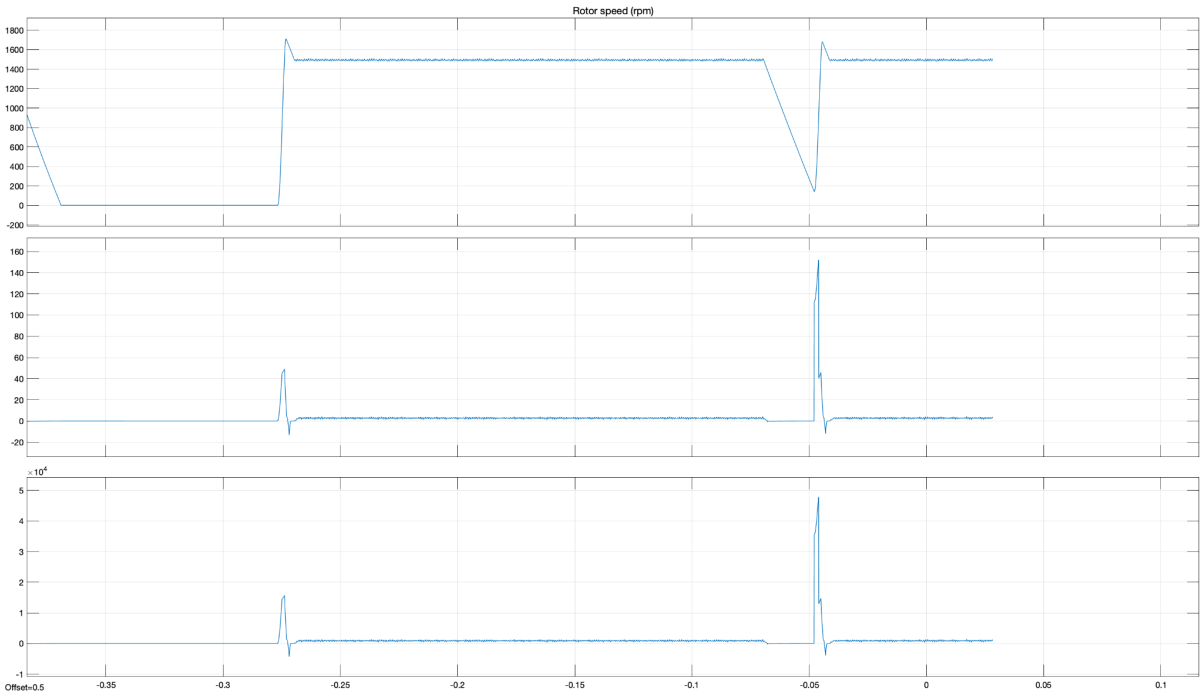
emf_a	emf_b	emf_c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	+1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	+1	0	1	0	0	1	0
+1	0	-1	1	0	0	0	0	1
+1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

Regn_BLDC_PI_IGBT ▸ Subsystem1



5. RESULTS AND ANALYSIS

After running the simulation for a certain period of time, we found a considerable change in the SOC% of the battery while the car is braking and regenerative braking is in use. Initially there is a linear decrease in the SOc of the battery but when brakes are applied there is a very slight increase in the SOC of the battery as seen in graph 2.

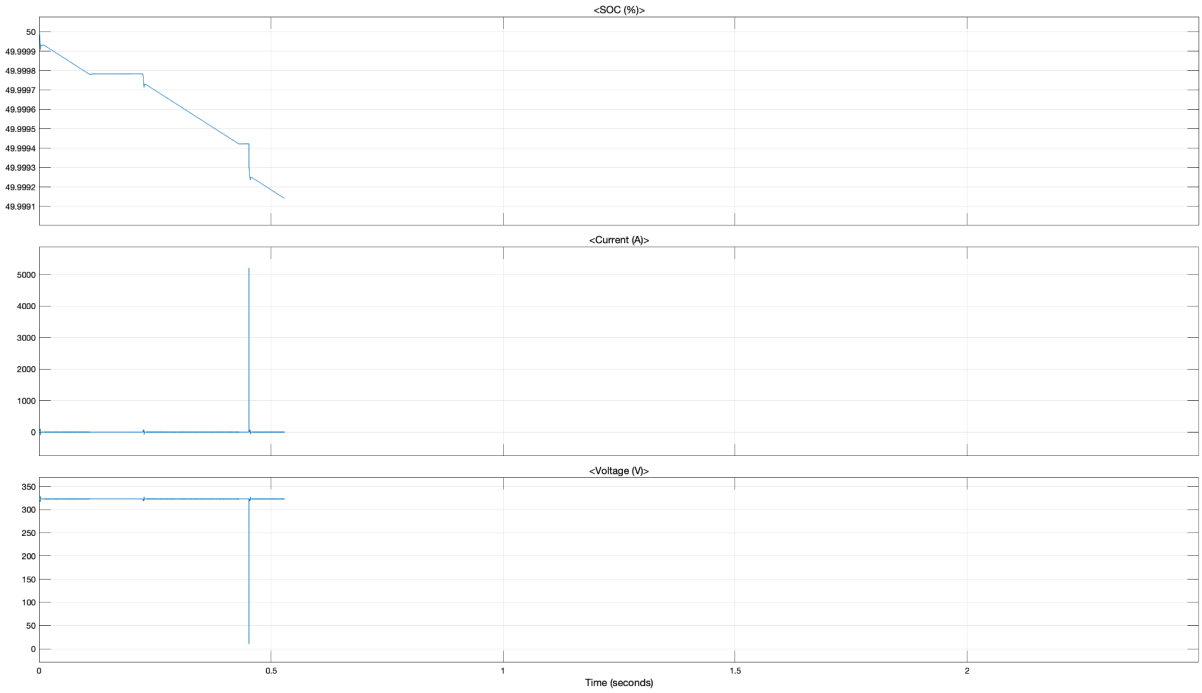


Graph 1

We can see a spike in the current through the circuit which is the starting current of the motor. As the current becomes zero and regenerative braking comes into play the current goes into the negative part of the graph, which indicate reverse current or back EMF by the motor.

As the intensity of the braking increases we can see the reverse current to increase proportionally with the brakes applied , and the reverse power is increased.

Inverter acts as a boost converter in during the process of regenerative braking, because during the process should be greater than the voltage of a li-ion battery for that reason we use a boost converter.



Graph 2

6. FUTURE SCOPE

Regenerative braking systems require further research to develop a better system that captures more energy and stops faster. As the time passes, designers and engineers will perfect regenerative braking systems, so these systems will become more and more common. All vehicles in motion can benefit from these systems by recapturing energy that would have been lost during the braking process. Future technologies in regenerative brakes will include new types of motors which will be more efficient as generators, new drive train designs which will be built with regenerative braking in mind, and electric systems which will be less prone to energy losses.

Of course, problems are expected as any new technology is perfected, but few future technologies have more potential for improving vehicle efficiency than does regenerative braking.

7. CONCLUSION

The regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. Also it can be operated at a high temperature range and is efficient as compared to conventional braking systems. The results from some of the tests conducted show that around 30% of the energy delivered can be recovered by the system. Regenerative braking system has a wide scope for further development and energy savings. The use of more efficient systems could lead to huge savings in the economy of any country.

We have successfully simulated and showed that regenerative braking using matlab simulations, even if there isn't a lot of regenerative power, as in a famous saying ,a drop and a drop make a ocean, cumulatively all the power is saved and regenerated is considerable. In the near future we might be able to increase the regenerative power to such an extent that all of the kinetic energy can be saved.

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