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Design and Fabrication of Regenerative Braking in EV

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Abstract: *Charging has always been an issue in electrical vehicles. In this project, the kinetic energy is transmitted in the brakes through drive train and is directed by a mechanical system to the potential store during deceleration. That energy is held until required to the vehicle, wherein it is transformed back into energy and stored in the battery of the vehicle. The amount of the power available for conservation varies depending on the type of storage, drivetrain efficiency, and drive cycle and inertia weight. When a normal vehicle applies its brake, its kinetic energy is transformed to heat because of friction between wheels and brake pad. This heat passes through the air and the energy is wasted. The total energy lost in this way depends on how often, long and hard the brake is being applied. An energy conversion action in which a part of the energy of the vehicle is stored by a battery or storage device is known as regenerative braking. Driving within a city involves more braking representing a high loss of energy with the opportunity for savings in energy. In the case of public transport vehicles such as local trains, buses, taxis, delivery vehicles there is even more potential for energy to be regenerated*

***Keywords* –** *Brake pads, Drive Train, Electrical Vehicle, Kinetic Energy, Power Transmission.*

1. INTRODUCTION

A brake is an intuitive device that resists motion by absorbing the available energy from the moving system. It is used for stop or slow a moving vehicle. Previously, Internal Combustion Engine Vehicles used to have mechanical brakes wherein kinetic energy was dissipated in heat due to friction. New development in battery system and noteworthy development in efficiency of electrical motor has made electric vehicles an better and efficient alternative, especially for short distance travelling. Among various categories of Electrical motors, normally PMDC, Induction Motor ,Permanent magnet synchronous motor (PMSM), Brushless DC motor (BLDC), and Switch Reluctance (SRM) motor are widely opted for the electric vehicle depending on the requirement of torque-speed characteristics, slow or high speed application.

Placement of motors is also an important part of regenerative braking and controller design depends on it. Regenerative braking helps conservation of energy by charging the battery in electric vehicle, thus increasing the driving range per unit of the vehicle. There are numerous methods to implement regenerative braking in a BLDC motor by different controllers. They are Adaptive controller, H2/H controller, Sliding mode controller, Fuzzy logic controller in combination with various control techniques, Neuro-fuzzy, Artificial neural network control with PID Controllers. BLDC motors are used more often in electric vehicles due to their robustness and high efficiency; however a censored BLDC motor requires a rather complex control to manage the reversal of energy flow during the transition from motoring mode to regenerative braking mode.

This article describes how Brushless DC (BLDC) motor in an electric vehicle can be used for regenerative braking.

2. BLOCK DIAGRAM

The Regenerative Braking System consists of three basic blocks mainly the battery pack, the forward motoring MOSFET block, the regenerative braking MOSFET switching block. This is diagrammatically shown in figure 1

1) Battery pack

The battery Pack consists of four 12V,12AH battery connected in series to provide the supply to the circuit of 48V,12AH. This battery provides the power during the motoring mode and acts as an energy storage device during the regenerative mode

2) Motoring Block

   This block is a circuit which consists of Power MOSFET's, gate driver IC, and a controller which drives the motor during the initial stage and accelerate the motor to the required speed and control its speed

3) Regenerative Block

   This block consists of diodes which store the energy back into the battery pack by making the diodes conduct in forward conducting mode.

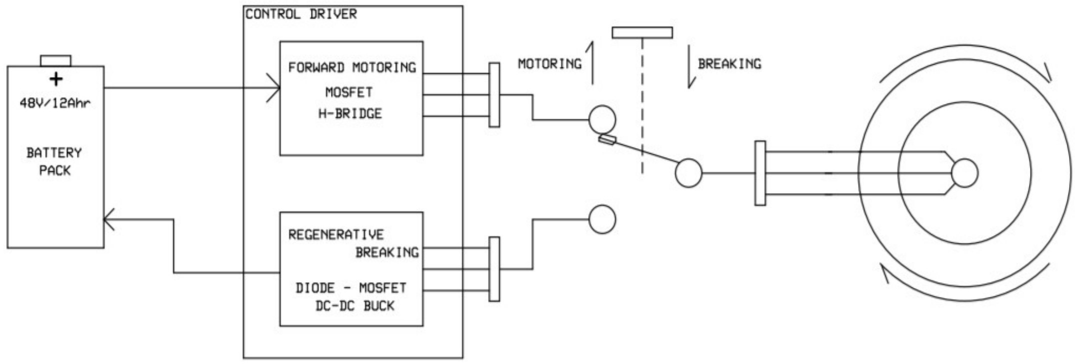

Fig 1. Block Diagram of Regenerative System

3. Related Works

As Santos et.al [2] demonstrated the control characteristics and its power converter for an electric traction system and solutions for its development.The attention was directed towards constructional strategies and problems for the converter i.e. controllers, the control and protection of the vehicle. The vehicle considered for the study used 500W – 48 V BLDC motors. The safety concerns were important to be considered for the proposed architecture because this motors needed a high current value of 20 A

A chopper i.e. DC to DC power converter was studied in brief to achieve power conservation and low energy dissipation depending upon the motor operational requirements, in reverse and forward direction operation of the vehicle. This paper stated the reason, importance and need for the control of varying output current of the converter i.e. controller rather than voltage control under built-in related betwixt throttle control and torque developed with respect to Internal Combustion Engine as well as for the protection and safety of motor, controller and several electrical & mechanical components.

There have also been system which propose to save more energy with the help of regenerative braking like a system proposed by Panagiotis's et. al. On the other side Dixon's et. al. put forward a system using power electronic device IGBT buck boost converter linked to the bank of ultra-capacitors at the boost side and to the main batteries at the buck side, to allow further acceleration and decelerations of vehicle with minimum loss of energy and degradation of battery.

As Chetana Kumar et.al. reviews the potential requirement of the design and development of globally competitive small electric concept vehicle for India and concluded that EVs are the solution to reduce pollution in cities, and important economic and societal benefits would result by the implementation of HEVs and EVs. The paper also outlined the role played by the Government and communities worldwide to promote and accelerate Electrical Vehicles

As Morkel et.al. scrutinize the need for framework development, challenges, and opportunities for design and deployment of emerging frameworks, related to Plug-in Electric Vehicle (PEV) and the potential benefits are summarized in detail are the solution to reduce pollution in cities, and important economic and societal benefits would result by the application of HEVs and EVs. The initiator had addressed the important thing to increase the profits from the opportunity for reducing fuel consumption, from battery manufacturing to communication and control between the vehicle and the electric power grid to provide for clean electricity with safety.

So, in the current paper a system has been implemented to regenerate maximum amount of energy wasted during braking with the help of an H Bridge Inverter Circuit with the help of P-channel MOSFET's.

4. PROPOSED SYSTEM

The main objective of our paper is to design and implement a regenerative braking system that helps to regenerate the amount of energy wasted during braking and with the help of circuit that energy is stored back in the battery which can be used for further driving. Our goal is to design and implement a regenerative braking system that will handle the task described.In this paper we have proposed BLDC motor, which has power saving advantages relative to other motor drives. It also features high efficiency and controllability. The battery used in the vehicle should be suitably selected according to the demand of the motor and controllers. The motor rating and rpm should be noted and accordingly gate drivers should be designed.

A new model of regenerative braking in EV is presented in this paper. The modelling of every component is presented with their corresponding parameters. In addition, a control system is also included. The circuit diagram is shown below in Fig 2 The performance study of each braking method is conducted separately for a specific level of SOC and speed with various duty cycle similar to simulation study. The variation of parameters such as back-EMF, armature current, stopping time and battery current is observed in the digital storage oscilloscope (DSO) from the point of braking to zero speed of the motor. The stopping time and average regenerative current over the braking period for various duty cycle are recorded and the summary is shown in the Table 1. The motor is accelerated to run at a speed of 500 rpm and subjected to braking after it attains steady speed.

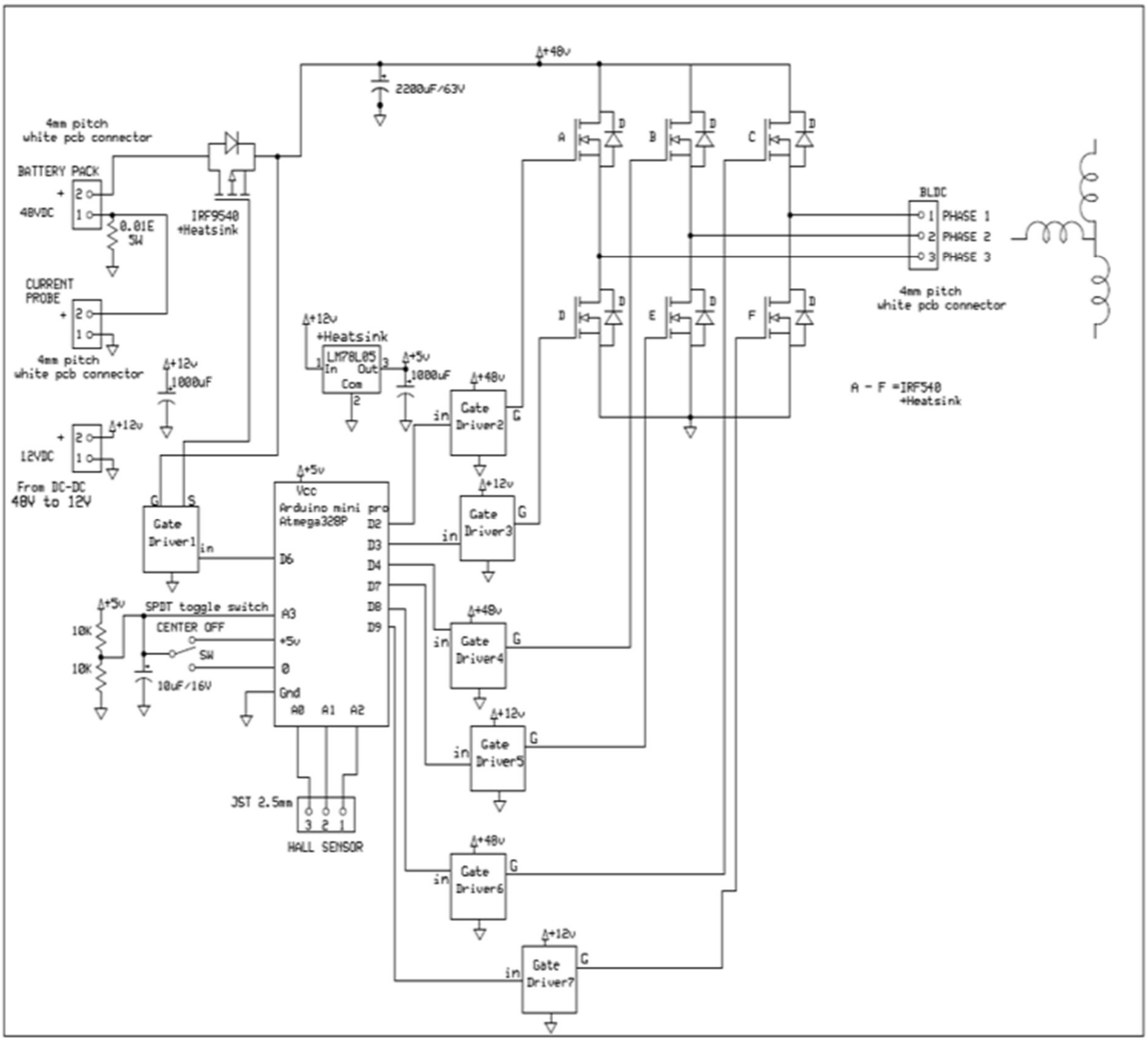

Figure 2. Circuit Diagram of Regenerative Braking System

Table 1. Stopping time and average current for various duty cycle.

Duty cycle	Stop time(Seconds)	Average current
0.2	2.3	-0.2
0.4	1.5	-0.24
0.6	1.0	0.19
0.8	0.8	0.27

The working of circuit diagram can be classified into two stages:
1) Motor stage
2) Regeneration stage

1. Motor Stage:

During motor mode (called normal mode on Figure 3.1, the high side switches A, B and C are operated in pulse width modulation (PWM) switching mode, while the low side switches D, E and F are operated in standard high/low switching mode. PWM allows controlling the torque developed by the motor. As sequence number I shows that A and E are both switched on, a current iab can flow. Now this switching takes place further in each winding and every winding gets energized one by one. The current flow changed since the last sequence number and an induction voltage eab must withstand the variation of the magnetic field according to Lenz's Law. Thus, the machine is turning.

The electric machine in this case is a permanent magnet brushless DC motor. It should be noted at this point, that brushless DC motors are formally classified as AC motors, since the DC voltage applied to the terminals is electronically switched on and off at the different stator windings in order to let the rotor rotate. This is resulting in an AC voltage with a square-wave shape or trapezoidal shape. The motor is shown with three inductances labelled with L and the three back electromagnetic forces (EMFs) Ea, Eb, Ec on the right side of Figure 4 Switches SA to SF are the switching devices and diodes DA to DF are freewheeling diodes, connected in antiparallel to the switches. Capacitor C is a DC link capacitor, which maintains the DC-link voltage $Vbatt$. The circuit is also known as an inverter circuit, because it inverts the DC voltage delivered by the battery with a controlled switching sequence of the switches SA to SF.

The switching sequences can be viewed and are split in six sequences, depending on the position of the rotor. The figure below also gives insight into the sinusoidal back EMF, the Hall sensor output and the energy regenerative mode switching signals. The Hall sensor is necessary to give feedback about the rotor position, which is crucial for correct switching sequences and therefore a smooth rotation of the rotor.

2. Regeneration Stage:

The theory about braking energy regeneration for electric RBS implies that the electric machine is used as a generator and a back EMF (voltage) is induced. However, it cannot be expected that this back EMF is larger than the voltage of the battery. In order to charge the battery, the back EMF induced must be boosted. This can be done by a DC-DC converter or with the control circuit presented in . Latter case can be explained as follows: The switching mode is changed to the energy-regenerative mode this mode is triggered once a braking signal from the driver is sent to the controller. In the regenerative braking mode, every switch from A to F is operated in PWM switching mode Because of the PWM signal, which is continuously switching the switches on and off, it must be distinguished from now on between ON and OFF PWM condition. Still observing sequence number I, for ON PWM condition, the switches E and A are switched on. Voltage is supplied from the battery to the winding L, which is energized.

Compared to the motor mode, the current changes its flow of direction through the electric machine and can be named i_{ba}. The total voltage VL at the winding L amounts to the sum of $V_{batt} + e_{AB}$. However, no energy is yet being delivered to the battery. To accomplish this, switches S3 and S2 are switched off, changing to the off PWM condition. In that case the voltage VL causes a current i_{off} to flow through the freewheeling diodes D1 and D4 to the battery. Thus, energy is supplied to the battery. However in single switch braking method, only one switch out of switches SD, SE, SF is operated in pulse width modulation (PWM) switching mode at each commutation state

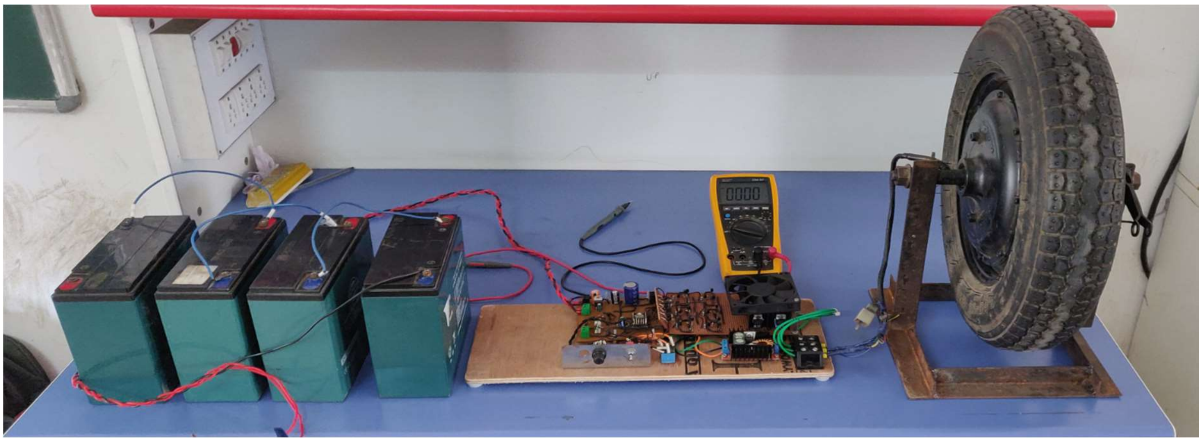

Fig 3 Experimental Setup of Regenerative Braking in EV

5. Calculations

Motor Ratings: Voltage= 48V, 5 A
Power required for motor = 48 * 5 = 240 Watt
Battery Pack Rating: 48V, 20 A-H
Battery Pack Power Input= 48 * 20 = 960 Watt-hr.
Hence this battery can supply power to the motor for 960 Watt-hr. /240 Watt = 4 hours
Since Lead Acid batteries need to be recharged after 70% usage
Hence 70% of 960 Watt-hr. is 672 Watt-hr. (Practical Batteries)
Therefore Battery can supply power for 2.8 hr. =3 hrs. (Approximately)
Rpm of Tyre=500 rpm (Limited for safety purpose)
Diameter of Tyre = 25.4 cm
Hence Speed in Km/hr. = 23.939 km/hr.
Now as per the battery power the wheel can run up to 23.939 km/hr. * 3hrs = 71.817 km
However Power regenerated during each braking is 15 V * 1.4A = 21 Watt
Hence 21 watt is saved Per Braking
Suppose we brake 10 times hence power saved is 168 watt

$$\frac{X}{100} * 240 = 21$$

Thus X=8.75%
Hence 8.75% power is saved per braking
Thus Extra distance covered is 8.75% of 71.817 km

$$\frac{8.75}{100} * 71.817 = 6.28\ km\ ,$$

Thus Total distance Covered = 71.817 + 6.28 = 78.10 km

6. Analysis and Advantages

The proposed system has many advantages

1. Better fuel economy - Depending on duty cycle of drive train, control strategy and the efficiency of the individual components the consumption of fuels has been reduced.
2. Emissions reduction - Engine emissions is reduced by engine decoupling, reducing total engine revolutions and total time of engine operation (engine on - off strategy).
3. Reduction in brake wear -reducing cost of replacement brake linings, cost of labor to install them and vehicle down time.
4. Smaller accessories - hybrid vehicle offers potential for eliminating (electric starter) and downsizing (fuel tank) some accessories, thus partially offsetting the increased vehicle weight and cost due to the hybrid hardware additions.
5. Operating range is comparable with conventional vehicles – a problem not yet overcome by electric vehicles.
6. Reduced CO2 emissions.

7. Reduction in Engine wears.
8. Increase the lifespan of friction braking systems.

7. CONCLUSION

In this paper, how regenerative braking increases mileage of the vehicle, how it can be operated at high temperature range and benefits optimum use of a battery is shown. Theoretically in regenerative braking system there is 30% saving on the fuel consumption. The extension of the project work will be to test the circuits on a prototype vehicle. Figure 3 shows the practical efficient circuit of regenerative braking. Also the ultracapacitor bank can be used when the system is working on a high voltages. These systems can be used in developing countries like India where buses are the preferred means that of transport within the cities. Regenerative braking could be a little, however important, step toward our freedom from fossil fuels.

REFERENCES

[1] https://www.researchgate.net/publication/252050989_Analysis_of_regenerative_braking_efficiency_-_A_case_study_of_two_electric_vehicles_operating_in_the_Rotterdam_area Last Accessed on 10th January, 2019.

[2] Xiaohong Nian, FeiPeng, Hang Zhang, "Regenerative Braking System of Electric Vehicle Driven by Brushless DC Motor" IEEE, 2010.

[3] Jeongwoo Lee, Douglas J. Nelson, "Rotating Inertia Impact on Propulsion and Regenerative Braking for Electric Motor Driven Vehicles" IEEE, 2015.

[4] Y. Xiao, M. Nemec, L. J. Borle V. Sreeram, H.H.C IU, "Regenerative Braking of Series- Wound Brushed DC Electric Motors for Electric Vehicles" IEEE, 2011.

[5] Phaneendra BabuBobba, K. R. Rajagopal, "Compact Regenerative Braking Scheme for a PM BLDC Motor Driven Electric Two-Wheeler" IEEE,2010.

[6] Cheng-Hu Chen, Wen-Chun Chi, Ming-Yang Cheng, "Regenerative Braking Control for Light Electric Vehicles " IEEE PEDS, 2011.

[7] Zhang Chuanwei, BaiZhifeng, Cao Binggang, Li Jingcheng, "Study on Regenerative Braking of EV". IEEE, 2010

[8] C. SheebaJoice, S. R. Paranjothi, and V. J. Senthil Kumar, "Digital control strategy for four quadrant operation of three phase BLDC motor with load variations"IEEE,2013.

[9] J. Fang, X. Zhou, and G. Liu, "Instantaneous torque control of small inductance brushless DC motor," IEEE, 2012.

[10] P.Champa, P.Somrisi, P.Wipasuramonton, and P.Nakmahachalasint, "Initial rotor position estimation for sensor less brushless DC drives," IEEE, 2009.

[11] G. H. Jang, J. H. Park, and J. H. Chang, "Position detection and start-up algorithm of a rotor in a sensor less BLDC motor utilizing inductance variation," IEEE, 2002.

[12] https://ieeexplore.ieee.org/abstract/document/4781535 Last Accessed on 01th February, 2019.

[13] https://patents.google.com/patent/US5915801A/en Last Accessed on 19th January, 2019.

[14] https://ieeexplore.ieee.org/abstract/document/1028079/ Last Accessed on 21th January, 2019.

[15] https://www.sciencedirect.com/science/article/pii/S2215098617317366 Last Accessed on 4th April 2019.