REGENERATIVE BRAKING IN ELECTRIC VEHICLES (PROTOTYPE AND TESTING)

Prof. Mrs. R.S. Ambekar[1], Abhinav Jain[2], Achal Jain[3] & Lalit Kumar[4]

[1]Asst. Professor, Department Of Electrical Engineering, Bharati Vidyapeeth (Deemed to be University) College Of Engineering Pune
[2]Student, Department Of Electrical Engineering, Bharati Vidyapeeth (Deemed to be University) College Of Engineering Pune
[3] Student, Department Of Electrical Engineering, Bharati Vidyapeeth (Deemed to be University) College Of Engineering Pune
[4] Student, Department Of Electrical Engineering, Bharati Vidyapeeth (Deemed to be University) College Of Engineering Pune

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Abstract - *With the increasing fuel prices and pollution levels around the world the general population is shifting towards electric vehicles due to their non-polluting and economic nature. Both the manufacturers and customers can benefit immensely through this shifting trend of petroleum fuel-based vehicles to electric vehicles. Another good reason is that it contributes to a healthy planet by reducing carbon emissions which petroleum-fuel-based vehicles emit generally. The main concern is to increase the range of electric vehicle, which is the distance an E-vehicle can go up to on a single charge. We have regenerative braking on a prototype, which consists of a 12V DC motor with a geared internal assembly, which simulates the vehicle engine. The aim is to control the braking system by an Arduino Controller along with microcontroller assembly. On inspection it was found that during regenerative braking, an approximate 16-20% of voltage of input is being given back by the motor to the battery. Other parameters like RPM of motor, input voltage and current and braking are controlled and observed. On appropriately scaling up the project to a full-fledged industrial model, this assembly of regenerative braking can charge the battery while the vehicle is in motion and can therefore help to extend the range of electric vehicles.*

***Key Words*: Regenerative Braking, DC Motor Control, Prototype, Electric Vehicles, Testing.**

1.INTRODUCTION

The transportation sector is one of the most important pillars of society today. Without it our entire progress will be halted and the world will come to a standstill. Since the time commercial transportation began, we have relied on fossil fuels for IC engine-based vehicles. With time we improved the efficiency by taking into account the calorific values of fuels we intend to use in our vehicle, vehicle emissions still remain a debatable concern. With new research it's been proved that vehicular emissions are the biggest contributor of air pollution after industrial emissions. The effects of air pollution have been debated for decades in various forums around the world. These include greenhouse effect, global warming, irregular rainfall, shifting weather pollutions etc. The introduction of electric vehicles is a welcome step in this attempt to reduce air pollution around the world. Electric vehicles run on clean energy which requires only electric charge and no internal combustion engines; hence they have no major emissions other than heat, and normal wear and tear. This system is aimed at increasing the battery capacity of electric vehicles by application of regenerative braking, which is a way of preventing waste of power during braking and rerouting it to our power source (which is to the battery in case of electrical vehicles) so that we have more charge to go longer distances.

Regenerative braking has been used on a prototype DC-motor-based system to simulate the same conditions as will be faced by an electric vehicle and try to prove the superiority of this type of braking over normal friction braking system. If scaled appropriately to industrial levels, this system can be applied to actual electric vehicles and can increase the overall efficiency of the given vehicle.

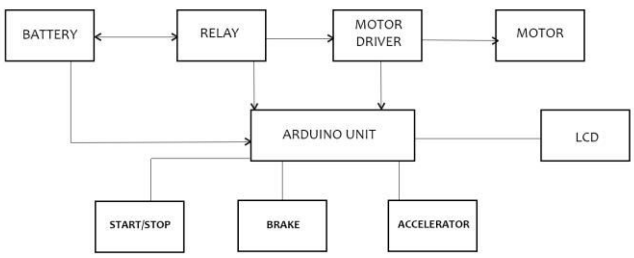


Fig.1. Block diagram of Regenerative Braking System

1.1 PRINCIPLE AND WORKING OF REGENERATIVE BRAKING

In a traditional braking system, we use brake pads to stop a vehicle by the use of friction. More friction is produced between the slowing tyres and the road surface. This friction turns the car's kinetic energy into heat. But when we use regenerative brakes, the system that drives the vehicle itself does the braking. When the brake pedal of an electric or hybrid vehicle is pressed, the brakes put the vehicle's electric motor into reverse mode, reversing the direction of torque thus slowing the car's wheels. Also, the motor acts as an electric generator during this period, producing electricity which is fed into the vehicle's batteries. To move the motor backwards, vehicle's momentum is used as the mechanical energy input. Special electronic circuitry is necessary to decide when the motor should reverse, while specialized electric circuits send the electricity generated by the motor into the vehicle's batteries.

1.2 MATERIAL AND METHODS

The following items form the major parts of a regenerative braking system:

A. Battery

The Battery is the powerhouse of this entire assembly, it will provide power to the vehicle during motoring action and will get recharged during braking action. In this model we are using a 12V 1.3Ah rechargeable Li Ion Battery.

B. Motor

The motor can vary from vehicle to vehicle. In commercial applications for cars and trucks, BLDC motors are preferred. For our specific project we are using a DC 12V geared motor. This particular motor was preferred because of its size and reverse voltage which it gave during initial tests of braking.

C. Control Circuitry

The control circuitry consists of relays, microcontroller(s), Switches, diodes, rectifiers, motor control units etc. Our specific model consists of an Arduino Uno R3 Chipset with ATMEGA8 Microcontroller embedded which in synchronization with L293D motor driver circuit will control the motoring and braking action. Relays will make sure to provide only unidirectional power flow. Two switches have been assembled, which are system power button and brake pedal button respectively.

- Arduino UNO: The Arduino Uno R3 is a microcontroller board based on a removable, dual-inline-package (DIP) ATmega328 AVR microcontroller. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs). Programs can be loaded on to it from the easy-to-use Arduino computer program. The Arduino has an extensive support community, which makes it a very easy way to get started working with embedded electronics. The R3 is the third, and latest, revision of the Arduino Uno.
- L293D Motor Driver: L293D is a dual H-bridge motor driver integrated circuit (IC). Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors. L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

D. Capacitor Bank

A capacitor bank of appropriate capacity is installed in the assembly which can quickly charge and discharge, during the regenerative action of the motor.

E. Miscellaneous

Various other items like potentiometer regulator, resistors, connecting wires and probes are covered under miscellaneous section.

2. CHARGING AND DISCHARGING OF BATTERY AND CAPACITOR

Battery:

Charging time of battery =
Battery Ah / Charging Current

T = Ah / A

Where,
T = Time hrs.
Ah = Ampere Hour rating of battery
A= Current in Amperes

Capacitor:

When a Capacitor is connected to a circuit with Direct Current (DC) source, two processes, which are called "charging" and "discharging" the Capacitor, will happen in specific conditions.

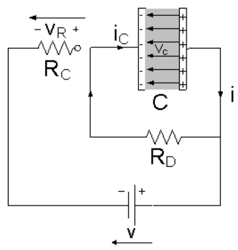


Fig. 2 Charging Of Capacitor

The Capacitor is connected to the DC Power Supply and current flows through the circuit. Both plates get the equal and opposite charges and an increasing potential difference, vc is created.

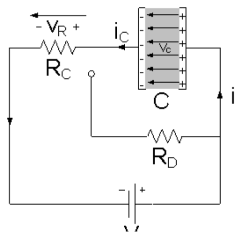


Fig. 3 Discharging Of Capacitor

While the Capacitor is charging. Once the Voltage at the terminals of the Capacitor, vc, is equal to the Power Supply Voltage, vc = V, the Capacitor is fully charged and the current stops flowing through the circuit, the Charging Phase is over.

A Capacitor is equivalent to an Open-Circuit to Direct Current, R = ∞, because once the Charging Phase has finished, no more Current flows through it. The Voltage vc on a Capacitor cannot change abruptly.

When the Capacitor disconnected from the Power Supply, the Capacitor is discharging through the Resistor RD and the Voltage between the Plates drops down gradually to zero, Vc = 0.

In Figures 4 and 5, the Resistances of RC and RD affect the charging rate and the discharging rate of the Capacitor respectively.

The product of Resistance R and Capacitance C is called the Time Constant τ, which characterizes the rate of charging and discharging of a Capacitor, Figure 5.

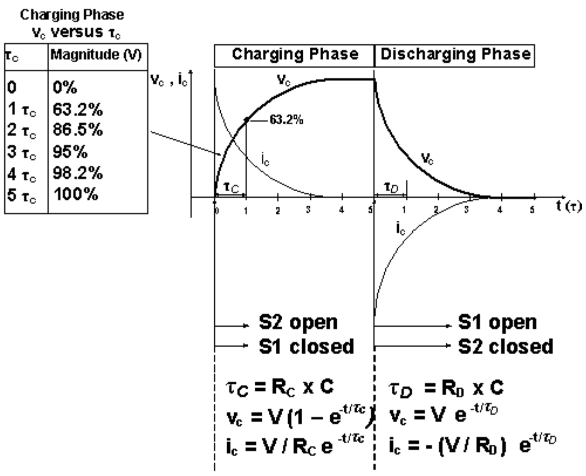
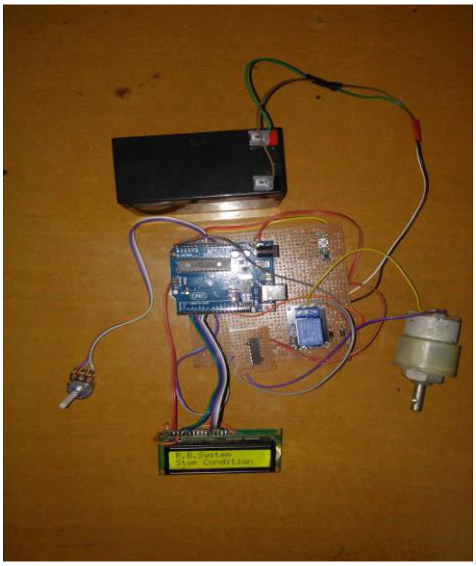


Fig. 4 The Voltage Vc and the Current iC during the Charging Phase and Discharging Phase

The smaller the Resistance or the Capacitance, the smaller the Time Constant, the faster the charging and the discharging rate of the Capacitor, and vice versa.

ACTUAL MODEL

The actual working model is shown in the figure. As is visible, the battery, Arduino circuit, L293D Motor driver, DC Motor, Potentiometer and LCD can be seen. The two switches mounted on top right corner of the breadboard are “Stop/Start” and “Brake” respectively. The “Stop/Start” button will turn ON and OFF the whole assembly, it will reflect on the LCD as such. The “Brake” button will work the relay ON and OFF, thus forcing the motor in regenerative mode until it is released. This will keep the motor in regenerative mode as long as it is kept pressed. On the DC motor can be connected a flywheel which can simulate a vehicle tyre and can provide a good amount of inertia. The entire assembly has been mounted on a board. Additionally, the system can be powered by using a 12V DC external supply using an AC adapter.



Photograph 1: Actual assembly

3. RESULTS

The following results were obtained during testing of system:

Time elapsed after brake pressed till motor stops completely (S)	SPEED (RPM) of Motor	VOLTAGE (Volts) (Given back by the motor)
~4.49	250	0
~4	500	~2V
~3	750	~3V
~1.98	1023	~5V

Table -1: Results during braking tests of DC Motor

The above table indicates the practical values observed during working of assembly.

It was observed practically that at max speed (1024RPM) approximately 5V was being given back by the motor. This voltage would rapidly decrease to 0 as motor stops. To make this momentary voltage available to charge the main battery or an auxiliary battery, we are using a capacitor bank of appropriate rating.

Also, it was observed that as the battery potential decreases, the maximum speed of the motor will also decrease and therefore the voltage given back will also decrease proportionately.

Therefore, it can be inferred that for a large-scale project this system can deliver a significant (16-20%) range extension of the battery i.e. the maximum distance an electric vehicle can go on a single full charge.

4. DISCUSSIONS

MARKET SURVEY

- The idea of making a prototype was agreed upon by the project partners and the guide after it was found that various difficulties are there in making a full-fledged regenerative braking model on higher rating motor assembly; some of them being overall cost, scalability, operating restrictions, and technical difficulties.
- In initial phase it was found that BLDC motors, which are normally used at industrial levels for regenerative braking assembly, do not give significant amount of voltage back to the battery at small voltages. Therefore DC geared motor of 12V specifications was used.
- A custom designed controller is generally required for regenerative assembly with a BLDC motor at industrial levels. For this project the controller used is Arduino Uno with ATMEGA8 Microcontroller because of the voltage level similarities.
- For controlling the DC motor we used L293D chip which is readily available with electronics retailers. This chipset can easily control the speed of DC motor upto a certain level.
- As per the need various components were procured as and when required with help of discussions with electronic technicians and repairmen.
    - Discussion about the components being used, the process and sticking to standards.
    - Report and presentation making, error rectification, plan of action at various stages.
    - Support from electrical department on our miscellaneous needs as and when required.
    - Assistance provided in assembly and soldering of components.

5. CONCLUSIONS

Regenerative braking is an effective method for increasing the battery range of electric vehicles. It is more dependent on the terrain and size of vehicle, the larger is the vehicle the more power will be regenerated during braking action, since inertia of vehicle plays an important role in the regenerating action of motor.
In the prototype there was an approximate 5V-7V regenerated by the DC geared motor. However due to low inertia being a small DC motor, the time duration of this regenerated voltage was quite small, lasting only for 1-2 seconds max. To give a constant power output the motor can be additionally connected with a buck converter and a DC booster circuit, with capacitor banks to amplify the charge. This model, when scaled properly to industrial levels with appropriate calculations may yield better results and may provide effective way to charge the battery at a constant pace while braking is in action.

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