

# Regenerative Braking in Electric Vehicles

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**Abstract**— This paper contains of regenerative braking, which carries in the electric vehicles. The electric vehicles which are receiving much attention now-a-days, because of its advantage such as to stop pollution as well as to stop the wastage of fuel which consumes the normal vehicles. The electric vehicles which consist of electric motor, normally work as an electric generator to impress a negative torque to the wheel provides the braking effect by recovering parts of kinetic energy used for the charging batteries and capacitor. This paper also deals with the energy or power which is regenerated during braking gets stored in the batteries and when the batteries is full charge then the remaining charge will stored in capacitor. The paper shows the simulation results of regenerative braking.

**Key words:** Electric Vehicles, Regenerative Braking

## I. INTRODUCTION

In recent years electric vehicles plays an very important role in our daily life so that our life goes easy. Electric vehicles are normally receiving much attention as compared to the hybrid electric vehicles and ICE(internal combustion engine) vehicles. The development of electric vehicles [EV's] becoming more popular in small as well as large cities due to the global warming and also rise in petrol and diesel prices[1].

Now-a-days electric vehicles are preferred for transportation from one area to other area. The E-rickshaw is another transport system for the people who are travelling from one area to other, thus because for not consuming fuel and also pollution free thus e-rickshaw is getting very popular. In e-vehicle, battery is the only source for energy and those batteries facing problems such as short supply of charging to batteries[10]. These mention problems are facing in electric vehicles can be overcome by such energy storage system such as capacitor, batteries, flywheel and much more.

The main component which plays an very important role in electric vehicles for regeneration is braking. Some processes are again introduce to sort out the problem mention, such as regenerative braking, dynamic braking. The process regenerative braking is introduced in this paper and also the power get recycled again and stored in the one of the energy storage devices. In regenerative braking some kinetic energy of the vehicle some which is stored in the vehicles system during acceleration and translated in the mass energy, which is stored in the vehicles system during deceleration.

The energy provided by regenerative braking can be reused for propulsion or to power vehicle. Thus this method of reuse of the regeneration power is an effective way to improve the driving range of electric vehicles (EV's) [12]. Regenerative braking is carried out with conventional friction brakes. In EV's, the brake system which is design to slow down the electric vehicle consist of some basic problems which are identified while simulating. Firstly,

when we apply brake the braking force on front and rear wheel to quickly reduce the vehicle speed[12]. Secondly is that to make progress in the braking energy as much as possible in order to recover the energy utilisation efficiency. Specially while driving with stop-go driving pattern in urban areas or on the road which is not plain or so much pits are available on road[12]. This method of reuse of regeneration power again is the best method to utilise the wastage of energy. The simulation shows the regeneration power while driving the vehicle. The simulation is done on the basis of the disadvantages observed in the braking system.

## II. REGENERATIVE BRAKING

### A. Working Principle

In normal supply system, when the machine generates the power, the terminal voltage of the machine rises. The generated power flows to the load, which is connected to the supply and the source is pleased from supplying the lot of amount of power to the load. When loads are connected to the supply line and they are in need of power, which is more or equal to the regenerated power then regenerative braking is possible. The load capacity is less than the regenerated power, all the regenerated power which is generated will not be absorbed by the load. Thus remaining power will be supplied to capacitor in supply line. The regenerative braking should only be used, when maximum loads are connected in supply line to absorb the regenerative power. Thus excess power is diverted to resistance or supercapacitor bank, thus it will dissipated as heat energy. The mention energy will generated only when source is battery, the regenerated energy will be stored in the battery. The regenerative power flow direction shown in the figure 1 the motoring mode, in motoring mode the power flows from battery to motor and motor runs in the clockwise direction.

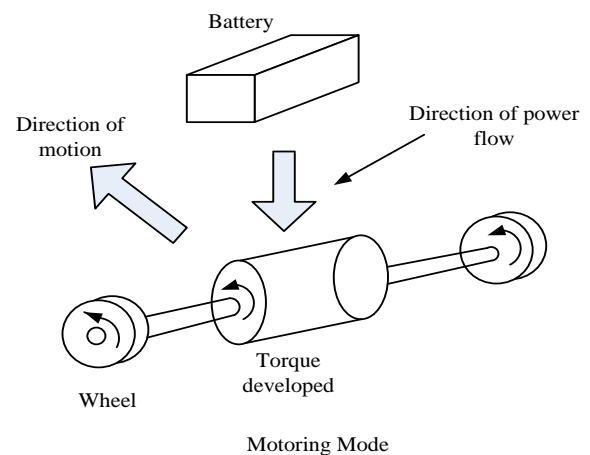


Fig. 1: Normal Motoring Mode

When we apply the brake to the motor the power generated is regenerative power and the power which is generated is save in the battery again, and the battery which is connected parallel to capacitor. The power generated goes

to battery and remaining power goes to capacitor, thus the charging capacity of battery increases and the figure 2 shows the braking mode.

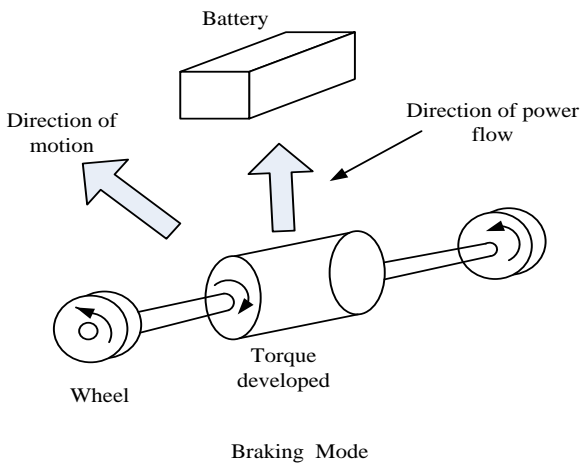


Fig. 2: Normal Braking Mode

**B. Operation**

The inverter circuit of dc motor which is used in braking circuit is shown in figure 3. The process of regenerative braking is shown by the arm under the IGBT bridge whose switched movements are correspondence to the working module of the motor.

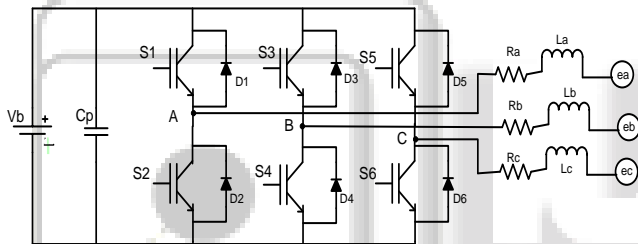


Fig. 3: Inverter Circuit of Motor

The operation of the motor is shown in the figure 3 the source is given by the battery and capacitor is connected and the resistance, inductance and back emf is generated through the motor.

**III. ENERGY STORAGE SYSTEM**

The power which is generated is stored in the form of energy in battery and capacitor. The power is again reuse in the form of usable energy in the motoring mode thus efficiency increases and, thus the life span of the battery and capacitor increases and the vehicle capacity also increases. The storage capacity of energy are more relevant in new technologies, mainly focused on ultra capacitor, batteries and converter needed to connect power system in electric vehicles. The table 1 shows the battery type, density, number of cycles and temperature of batteries.

Battery	Density of battery (Wh/kg)	Number of cycle	Temperature range (°C)
Lead acid battery	20-50	400-1200	20°-60°
Ni-Cd	45-80	2000	40°-60°
Ni-Zn	60-85	1000	20°-60°
Ion-Li	110-160	500-1000	20°-60°
Li-polymer	100-130	3000-4000	0°-60°

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Table 1: Parameters of the Batteries

**A. Battery**

The battery pack is a heart of the whole system of an electric vehicle. Many types of batteries such as lead-acid, lithium ion, nickel-metal hydride, etc. Thus, today the lithium ion is preferable choice of the every person due to its relatively high specific energy and power.

**B. Ultra Capacitor**

Ultra capacitor plays a very essential role in the system, so that the new technologies have the such abilities to control the motor. In the ultra-capacitor system, the important contents are the converter based on the IGBT, inductor and battery packet. Ultra capacitor is mainly used because it store up to 20% times the electrolytic charge which is shown in figure

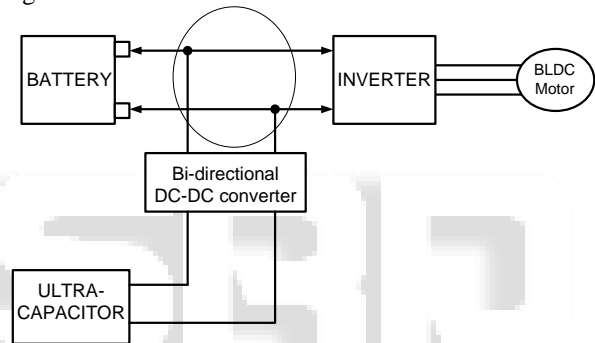


Fig. 4: Use of Ultra-Capacitor

**IV. PROPOSED WORK**

The model which is performed in the Matlab is shown in the figure. The regenerative energy in the motor is shown through the graph, the simulated diagram of the power is shown in the figure 5.

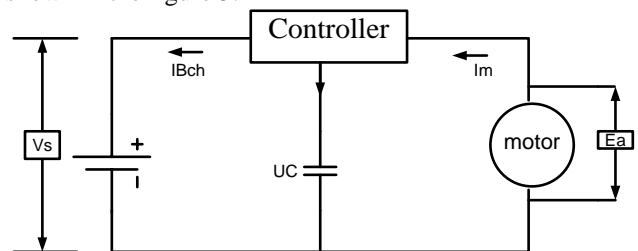


Fig. 5: Block Diagram of the System

The block diagram of the following system is shown in the simulation manner. The graph shows the regeneration power and the braking system of the motor.

**A. Simulation**

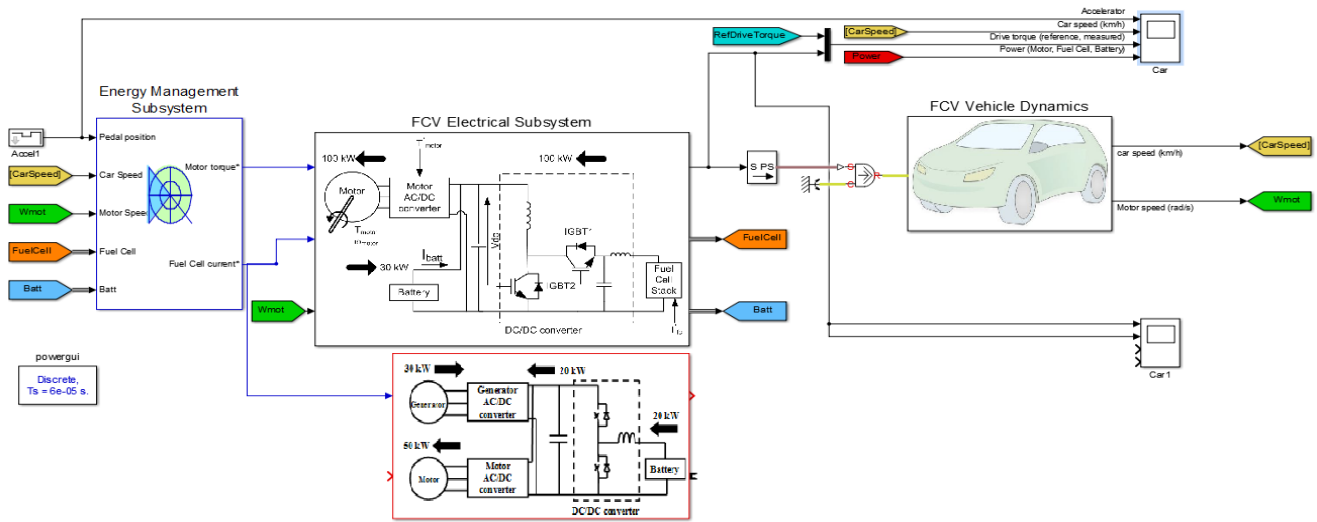


Fig. 6: Simulation Model of Regenerative Braking in Electric Vehicles

B. Graphs

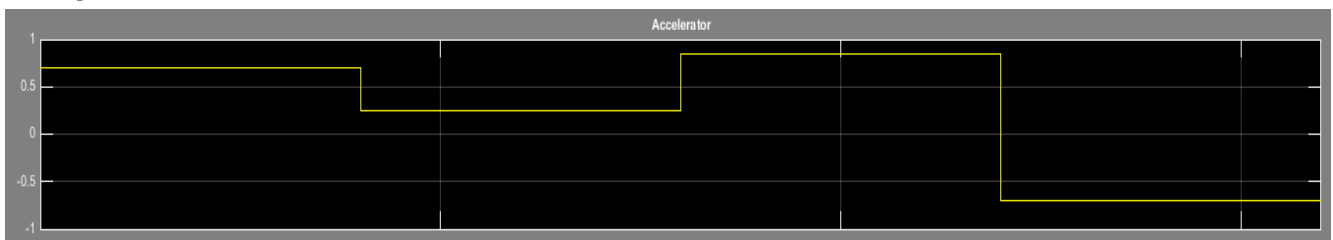


Fig. 7: Acceleration

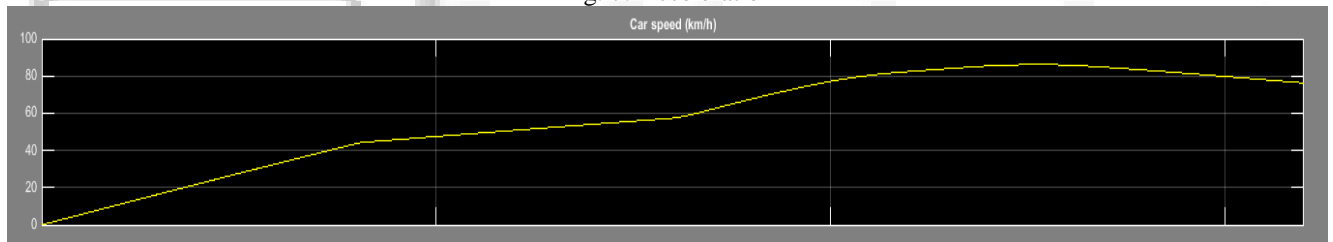


Fig. 8: Speed of the Car

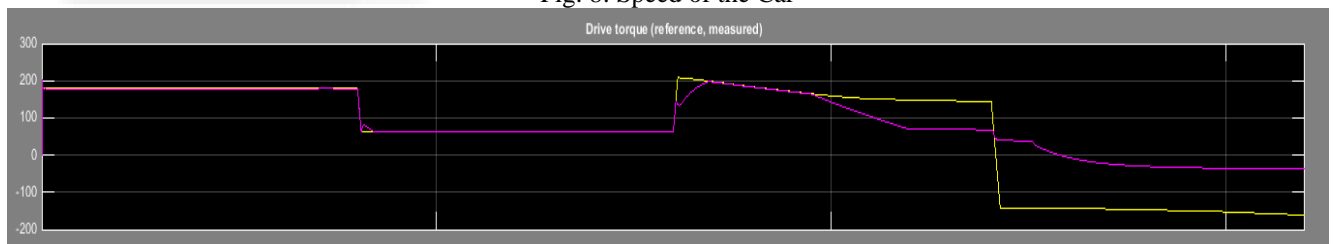


Fig. 9: Torque Driven.

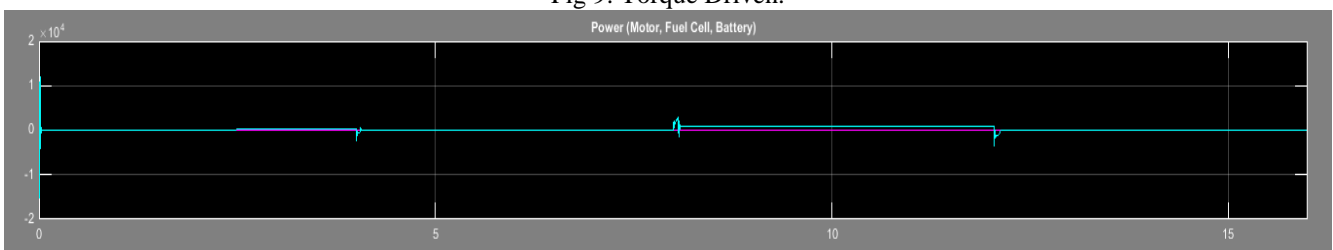


Fig. 10: Power of the Motor, Fuel Cell, Battery

The graphs shows the regenerative power of the motor developed in the electric vehicle to generate and reuse energy in the form of power and thus increases the efficiency and capacity of the electrical vehicle.

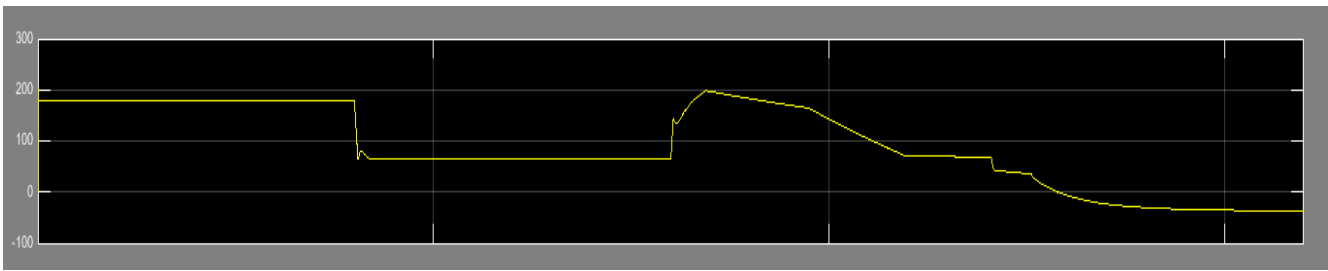


Fig. 11: Regenerative Power

## V. CONCLUSION

The simulation shows the life span of the electric vehicles and the regenerated power of the motor gets used and thus the braking has the ability to save and reuse the wasted energy and use upto 8-25%. The research says that regenerative braking is already in used in many Electric Vehicles. Due to petrol price increase gives rise to research and progress in energy conservation. It also improves the fuel consumption by 33%.

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