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Energy Efficient Electric Vehicle Using Regenerative Braking System

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Abstract: The Regenerative braking can improve energy usage efficiency and can also extend the driving distance of Electric Vehicles. This can improve the battery efficiency by 16-25%, depending on the speed and the motor size. Regenerative Braking power generation could provide a remarkable power source for vehicles. The power dissipated by the vehicles can be partially taken back for powering up for some of the utilities on board. In this paper, we have proposed a method where we can use rapid storage and acquiring technique using super capacitors and control mechanism. This project needs a motor to run the vehicle, relays to convert the reverse voltage into a usable voltage, ultracapacitors or supercapacitors to store the energy that is acquired.

Keywords: Electric Vehicle, Regenerative Braking, Back Emf, Ultra Capacitor.

1. INTRODUCTION

Electric Vehicles, when invented, were a very proficient technological development, as it does not produce any emission to the air, hence no harmful gasses are released from the car that causes atmospheric pollution. The population of Electric vehicles is increasing nowadays. However, the limitation in the driving range is not yet overcome, which is still a drawback for these vehicles. Implementation of regenerative braking has increased the driving range by 10-25%. The Regenerative braking system recovers the kinetic energy lost during conventional braking and stores it in the form of useful energy in the battery which can be used for further applications.

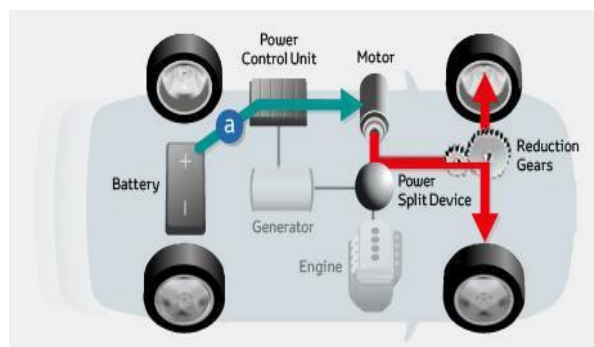


Figure 1. Braking setup in a car

1.1.1 Types of braking

There are various types of motors and hence there are various types of Braking systems too. The predominant types of Braking are:

1. Frictional braking
2. Electromagnetic braking
3. Pumping braking

1.1.2 Impacts of braking

A moving car has a lot of kinetic energy. When you apply the brakes, that energy of motion is transformed into something else, and the car slows down. Most cars use friction brakes, which inhibit motion by converting kinetic energy to heat. Because cars are massive and move fast, they have a lot of energy to convert. That means brakes get very hot, during typical use. As for brakes heat, they fade (become weaker) and eventually fail. This essentially means that, when brakes are applied, a lot of energy, which could be arrested and utilized for various activities, is wasted in the form of heat and also this heat damages the brakes.

1.1 Conventional braking mechanism

Braking is the process of using a Mechanical or Electrical equipment called 'Brake' to reduce the speed of any moving or rotating equipment, like vehicles, locomotives. Every time you step on your car's brakes, you're wasting energy. Physics tells us that energy cannot be destroyed. So when your car slows down, the kinetic energy that was propelling it forward has to go somewhere. Most of it simply dissipates as heat and becomes useless. That energy, which could have been used to do work, is essentially wasted.

1.2 Self-Generation

The electric vehicle is driven by the battery. On switching the car the motor takes current from the battery. The motor converts the electrical energy into the mechanical rotation and hence the vehicle moves forward when the car starts running then generation takes place. The synchronous generator attached to the wheels starts generation. Here synchronous generator has been used because it can operate at low power. When the driving speed of the car increases, then generation also increases. Hence the generation depends upon the driving condition. The output of the generator is the Alternating type. Hence it can be converted into DC with the help of rectifier circuit. The rectifier circuit converts this Alternating current into pulsating DC. The pulsating DC component is passed through the filter circuit which removes harmonics. Then the DC is stored in the ultra-capacitor. Hence the power can be generated without any external forces and this process is called self-generation.

2. Regenerative Braking System

The RBS is an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. This contrasts with conventional braking systems, where the excess kinetic energy is converted to unwanted and wasted heat by friction in the brakes. In addition to improving the overall efficiency of the vehicle, regeneration can greatly extend the life of the braking system as its parts do not wear as quickly. As the brake pads rub against the wheels excessive heat energy is generated. Regenerative braking technology captures the energy created by braking process back into the system in the form of charging the battery for further use.

3. Operation of motor in electric vehicles

The principle behind Regenerative braking is, when an electric motor runs in one direction, it converts electrical energy into mechanical energy that can be used to perform work such as turning the wheel, and when the motor runs in the opposite direction, a properly designed motor becomes an electric generator. When the wheels spin without acceleration, the rotation induces a reverse flow of energy producing a generator effect. A back emf is induced in the motor. Back electromotive force (back EMF, BEMF) is a voltage that appears in the opposite direction to current flow as a result of the motor's coils moving relative to a magnetic field. It is this voltage that serves as the principle of operation for a generator. The back EMF is directly related to the speed of the motor, so knowing the value of back EMF allows us to calculate the speed of that motor. Its main function is to convert mechanical energy into electrical energy. This electrical energy can then be fed into a charging system for the car's batteries as back up.

4. RBS working mechanism

The relay module, which is powered by a battery, sends the status of the motor, present in the vehicle, to the microcontroller. An interlocking circuit monitors the status of the vehicle and ensures that no power is derived when the vehicle is in motion. When the interlocking circuit is active, the power is derived and is stored in the Ultracapacitor. An additional High voltage protection is given in order to sense the voltage that is obtained from the circuit. The amount of energy stored in the ultracapacitor, the amount of voltage driven by the circuit and further details can be observed by interfacing the microcontroller to a PC. In a Regenerative braking system, to get the motor to run backward is to use the vehicle's momentum as the mechanical energy that puts the motor into reverse. Once the motor has been reversed, the electricity generated by the motor is fed back into the batteries, where it can be used to accelerate the car again after it stops. Regenerative braking is used in vehicles that make use of electric motors, primarily fully electric vehicles and hybrid electric vehicles. One of the more interesting properties of an electric motor is that, when it run in one direction, it converts electrical energy into mechanical energy that can be used to perform work (such as turning the wheels of a car), but when the motor is run in the opposite direction, a properly designed motor becomes an electric generator, converting mechanical energy into electrical energy. This electrical energy can then be fed into a charging system for the car's batteries. In an RBS, the trick to get the motor run backward is to use the vehicle's momentum as the mechanical energy that puts the motor into reverse. Momentum is the property that keeps the vehicle moving forward once it's been brought up to speed. Once the motor has been reversed, the electricity generated by the motor is fed back into the batteries, where it can be used to accelerate the car again after it stops. Sophisticated electronic circuitry is necessary to decide when the motor should reverse, while specialized electric circuits route the electricity generated by the motor into the vehicle's batteries. In some cases, the energy produced by these types of brakes is stored in a series of capacitors for later use. In addition, since vehicles using these kinds of brakes also have a standard friction braking system, the vehicle's electronics must decide which braking system is appropriate at which time. Because so much is controlled electronically in a regenerative braking system, it's even possible for the driver to select certain presets that determine how the vehicle reacts in different situations

4.1 Need for Regenerative braking system

The regenerative braking system delivers a number of significant advantages over a car that only has friction brakes. In low-speed, stop-and-go traffic where little deceleration is required; the regenerative braking system can provide the majority of the total braking force. This vastly improves fuel economy with a vehicle and further enhances the attractiveness of vehicles using regenerative braking for city driving. At higher speeds, regenerative braking has been shown to contribute to improved fuel economy by as much as 20%. Consider a heavy loaded truck having very few stops on the road. It is operated near maximum engine efficiency. The 80% of the energy produced is utilized to overcome the rolling and aerodynamic road forces. The energy wasted in applying brake is about 2%. Also, its brake specific fuel consumption is 5%. Emissions reduction engine emissions reduced by engine decoupling, reducing total engine revolutions and total time of engine operation. Now consider a vehicle, which is operated in the main city where traffic is a major problem here one has to apply brake frequently. For such vehicles, the wastage of energy by application of brake is about 60% to 65%. And also it is inefficient as its brake specific fuel consumption is high.

4.2 Energy Conservation

The flywheel absorbs energy when braking via a clutch system slowing the car down and speeding up the wheel. To accelerate, another clutch system connects the flywheel to the drive train, speeding up the car and slowing down the flywheel. Energy is, therefore, conserved rather than wasted as heat and light which is what normally happens in the contemporary shoe/disc system.

4.3 Wear Reduction

An electric drivetrain also allows for regenerative braking which increases Efficiency and reduces wear on the vehicle brakes. Reduction in Engine wears. Reduction in Brake Wear- Reducing cost of replacement brake linings cost of labor to install them, and vehicle downtime. In regenerative braking, when the motor is not receiving power from the battery pack, it resists the turning of the wheels, capturing some of the energy of motion as if it were a generator and returning that energy to the battery pack. In mechanical brakes; lessening wear and extending brake life is not possible. This reduces the use of using the brake.

4.4 Fuel Consumption

The fuel consumption of the conventional vehicles and regenerative braking system vehicles was evaluated over a course of various fixed urban driving schedules. Improved Fuel Economy-Dependent on duty cycles, power train design, control strategy, and the efficiency of individual components. The results are compared as shown in the figure. Representing the significant cost saying to its owner, it has been proved the regenerative braking is very fuel-efficient.

5. Energy Storage

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. There are so many types of batteries such as lead- acid, nickel-cadmium, nickel metal hydride, nickel zinc, etc. To use battery correctly and properly so that system cannot be damaged. Ultracapacitor is the main technology which is based on electrochemical double layer capacitor. The main advantage of ultra-capacitor is those ultra-capacitors present a higher cycle life and their capacity to capture energy peaks, due to their fast response, as compared with batteries. If we use any ultra-capacitor and batteries which are installed in the system, need a power converter which converts the output energy into required proper level.

6. Ultracapacitors

Electric double-layer capacitors, also known as supercapacitors, electrochemical double layer capacitors (EDLCs) or ultra-capacitors are electrochemical capacitors that have an unusually high energy density when compared to common capacitors, typically several orders of magnitude greater than a high-capacity electrolytic capacitor. Electrical energy is stored as charge in the electric field between its plates and as a result of this stored energy, a potential difference, that is a voltage, exists between the two plates. During charging (current flowing through the ultra-capacitor from the connected supply), electrical energy is stored between its plates. Once the ultracapacitor is charged, current stops flowing from the supply and the ultra-capacitors terminal voltage is equal to the voltage of the supply. As a result, a charged ultra-capacitor will store this electrical energy even when removed from the voltage supply until it is needed acting as an energy storage device. Then an ultra-capacitor does not consume any energy itself but instead will store and release electrical energy as required with the amount of energy stored in the ultracapacitor being in proportion to the capacitance value of the capacitor. As previously mentioned, the amount of energy stored is proportional to the capacitance C and the square of the voltage V across its terminals giving:

Potential of capacitor $=q/C$. A small amount of work done in giving an additional charge dq to the capacitor is $dW=q/C \cdot dq$. Total work is done in giving a

charge Q to the capacitor is $W=Q \cdot Q/C$.

$W=1/2 \cdot Q^2/C$

Energy stored in the capacitor

$U=W=1/2 \cdot Q^2/C$

$Q=CV$

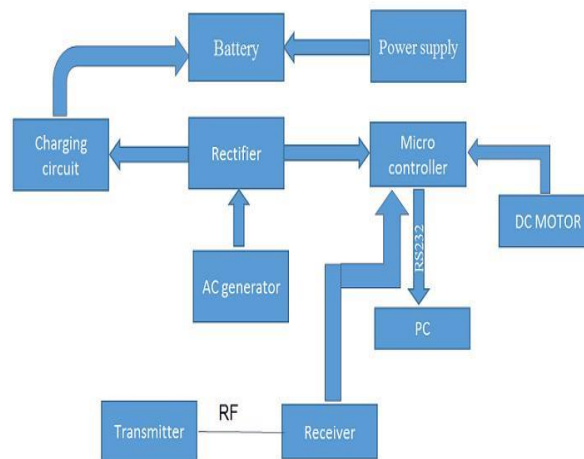
$U=1/2 \cdot (CV)^2/C=1/2 \cdot CV^2$

$CV=Q$

$U=1/2 \cdot QV$

Thus, $U=1/2 \cdot Q^2/C = 1/2 \cdot CV^2 = 1/2 \cdot QV$

7. PROPOSED WORK



Regeneration happens only when brakes are applied and the amount of energy derived depends on the running speed of the vehicle. It is a simple process that involves ultra-capacitors, for storing the energy. The interlocking circuit is implemented to prevent the generation of power when the vehicle is in motion. Storage can be designed in a way that different voltage levels are stored and used for different purposes. Ultra-capacitor storage acts as an alternative in several cases hence increasing the efficiency of the battery of an electric or hybrid car.

The stored energy can be further used to move the vehicle at a lower speed which will increase the fuel efficiency in case of conventional or hybrid vehicles.

CONCLUSION

Regenerative braking is a small, yet very important, step toward our eventual independence from fossil fuels. These kinds of brakes allow batteries to be used for longer periods of time without the need to be plugged into an external charger. These types of brakes also extend the driving range of fully electric vehicles. In fact, this technology has already helped bring us cars like the Tesla Roadster, which runs entirely on battery power. When you think about the energy losses incurred by battery-electric hybrid systems, it seems plausible to reason that efficient flywheel hybrids would soon become the norm. But of course it's not quite so black and white, and further analysis shows that a combination of battery-electric and flywheel energy storage is probably the ideal solution for hybrid vehicles. As designers and engineers perfect regenerative braking systems, they will become more and more common. All vehicles in motion can benefit from utilizing regeneration to recapture energy that would otherwise be lost.

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