A Review Paper on Regenerative Braking System

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Abstract - This article presents a simple but effective method for reconditioning the electric car. Regenerative braking is the best way to increase the driving capabilities of electric vehicles. Regenerative braking plays an important role in maintaining the strength and quality of your vehicle. Electric cars use mechanical brakes to increase the roughness of the wheels for deceleration purposes. However, in terms of energy saving, the mechanical brake increases the energy a lot, while the kinetic energy of the EV is adjusted to electrical energy. The vehicle's braking system is based on hydraulic brake technology. Therefore, this conventional braking method is a huge waste of energy as it generates unnecessary heat during braking. Therefore, the sign of regenerative braking eliminates these disadvantages, besides helping to save energy, this gives the vehicle higher performance. The main purpose of discussion is to discuss the consequences of regenerating braking system.

Index Terms - Electric Vehicle, Regenerative Braking, Motor, Generator.

I.INTRODUCTION

As the world looks for other ways and solutions to mitigate its problems due to global warming and rising pollution indices, there is a great opportunity to make electric vehicles safer from car accidents. Traditionally, vehicles with internal combustion engines (ICE) only use brakes, where kinetic energy is dissipated as heat due to friction. On average, 50% of all energy used for traction is sometimes wasted in the heat generated by the mechanical brakes.

According to studies, older cars lose 44% while stopping and slowing down. In most mechanical braking systems, the vehicle slows down due to the frictional force applied to the wheels. In addition, an anti-lock braking system driven by hydraulic actuators is used in non-motorized vehicles.

Most of us would only think of emergency parking before, and all we see is the brake light and undercarriage of a car. As any racer can tell you, braking is a big part of the vehicle's performance. Brakes are essential for maintenance, as everyone wants better performance and safety. We want to not only accelerate our car, but also stop quickly and safely. Regenerative braking refers to the process in which some of the vehicle's kinetic energy is briefly stored by the storage system. The **Fig.1** represents a simple regenerative braking system [6].

The energy normally dissipated in the brake is indicated by the power conversion system for energy storage during deceleration. This energy is stored until the car needs it again, where it is converted back into kinetic energy and used to accelerate the car.

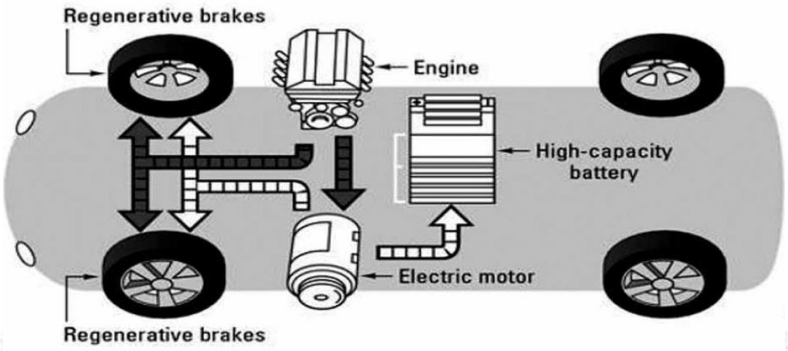

Fig. 1: Simple Regenerative Braking System

The demand for energy-efficient products has increased in recent years. Today the auto industry is working to improve performance and reduce emissions. Commercial vehicles are often used as garbage trucks, and trucks lose a lot of kinetic energy due to frequent collisions, resulting in more greenhouse gas emissions and fuel consumption. The diesel special filter (DPF) and exhaust installed in most modern cars are good ways to reduce emissions, not greenhouse gases[7]. The regenerative braking system is the biggest feature of the electric car. Energy recovery techniques help electric vehicles reduce energy consumption. There are two types of reconfigurations used in the automotive industry.

They are:

Boost recovery system and regenerative braking system

Commercial vehicles lose 50 to 80% of their braking power depending on the braking available.

Regenerative braking has many advantages over conventional braking systems, for example:

1. More braking
2. More efficient and effective in stop-and-go driving conditions
3. Prevents mechanical braking system wear
4. Better Fuel Economy

II. LITERATURE SURVEY

The research paper focused on the electric vehicle (EV), hybrid electric vehicle (HEV) and fuel cell hybrid electric vehicle (FCHEV). We have read in books on simulation, critical analysis and research using existing software. In addition, systems based on other energy sources have also been tested to some extent. However, it focuses more on information on fuel-saving targets than research on protecting the environment from global warming and reducing harmful emissions. The most important piece of information to note here is that this document clearly illustrates regulations and benefits of infrastructure, as well as the challenges and opportunities of building and using innovations related to electric vehicles (PEVs).
From the battery design to the communication and control of the vehicle and grid, the authors were able to make the most efficient way to reduce fuel consumption, with highlighting the transmission of good, clean electricity.

[a]. Sayed Nashit, Sufiyan Adhikari, Shaikh Farhan, Srivastava Avinash and Amruta G
- The project ('Design, Fabrication and Testing of Regenerative Braking Test Rig for BLDC Motor) creates awareness to readers towards conservation and efficiency of energy. The regenerative braking cannot be used as the primary braking system, it works more efficiently at higher speeds. This tells us about the bright and green future days of efficient energy due to vehicles as they help to regain the waste part of the system.

[b]. Tushar L. Patil, Rohit S. Yadav, Abhishek D. r, Mahesh Saggam, Ankul Pratap
- The project (Performance improvement of Regenerative braking system) the techniques to increase the efficiency of the regenerative braking system is described. Due to the use of lightweight automobile components increasing the overall performance, in regenerative braking systems super capacitors can be found improving the rate of conversions.

[c]. C. Jagadeesh Vikram, D. Mohan Kumar, Dr. P. Naveen Chandra
-The project fabrication must be completed according to the given measures in automotive transportation to get the best performance in braking and also in regenerative braking systems the execution is vital.

[d]. Ketan Warake, Dr. S. R. Bhahulikar, Dr. N. V. Satpute
- This system is developed to regenerate the wasted battery charge of an automobile. Generally, the friction brakes convert energy into heat which is affected to the surrounding. The mechanical energy of the generator is converted into the useful charge of the battery. As the regenerative braking system can't bring the vehicle to rest that's the reason behind it not being used as the primary braking system. The Project shows eleven percent of battery charge can be recovered by the system which is either wasted through heat because of friction brakes.

III. OBJECTIVE OF THE SYSTEM

The objectives of this project are:

1. The ability to control the speed of the car and to stop at a good speed.
2. Reduce the reaction time of the brake using regenerative braking.
3. Generating power by converting the kinetic energy into electricity

IV. WORKING PRINCIPLE OF REGENERATIVE BRAKING SYSTEM

Regenerative braking is a braking system/mechanism that helps the vehicle increase its performance by using engine power to conv ert kinetic energy into electrical energy that returns to the battery. It seems that most of the kinetic energy is converted into battery po wer via the regenerative braking system, which uses the same concept as the alternator.

In regenerative braking mode, when the driver applies force to the brake pedal, the vehicle is decelerated by the electric motor oper ating in the reverse order of deceleration [11]. When running in reverse, the engine works like a generator and charges the battery as

Fig. 2.

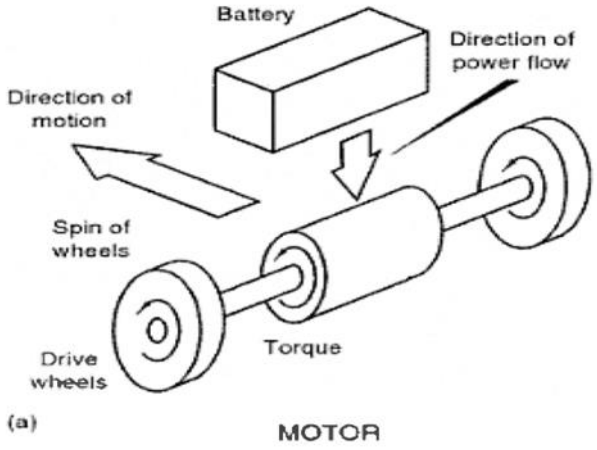

Fig. 2: Forward driving condition

It increases fuel efficiency, reduces emissions and reduces fuel consumption by using regenerative braking. This braking system works well in cities where braking is frequent [2]. As shown in **Fig 3.**

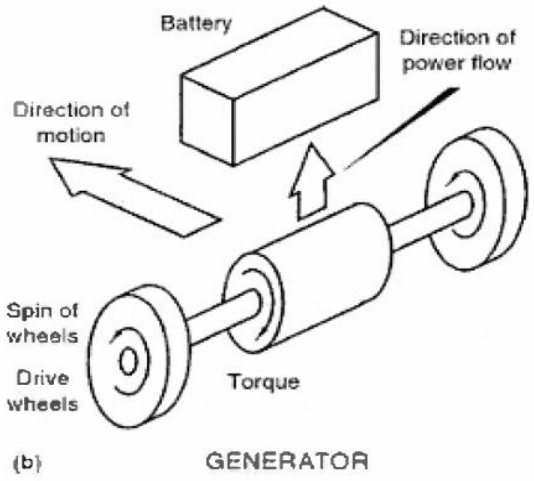

Fig. 3: Regenerative action during braking

V. DIFFERENT TYPES OF REGENERATIVE BRAKING SYSTEM

In regenerative braking there are many ways of transforming energy along with flywheel, spring, hydraulic and electromagnetic. And hybrid regenerative braking systems like electromagnetic -flywheel systems have come up in recent times. Each type of regenerative braking system uses a different energy transformation or storage system, giving different efficiency and application for every type.

a) Electromagnetic

In an electromagnetic system, the electric generator is attached to the drivetrain in vehicles, which slows down the vehicle and generation of electricity takes place. In hybrid and electric vehicles, the generated energy is given

to the batteries, which leads to charging up of the batteries. In gasoline powered the energy is used to power electronics of vehicles or store the battery for the upcoming times.

b) Flywheel

Here in this type of system, the kinetic energy of the vehicle is utilized to spin flywheel which is attached to the driveshaft trough transmission. The rotating flywheel will in turn transmit torque to the drivetrain, which in turn gives the vehicle a power uplift.

VI. Conversion of Kinetic energy to Electrical energy

An electric motor is used as an electric generator to convert from kinetic energy to electrical energy. The working principle depends on the working of an electric motor. When electrical voltage is given to the electric motor, it converts electrical energy into mechanical energy. When external force in the form of mechanical energy is applied to the motor, it will operate as a generator and will create electricity. **Fig. 4** shows the flow of energy during the process of acceleration and deceleration [6].

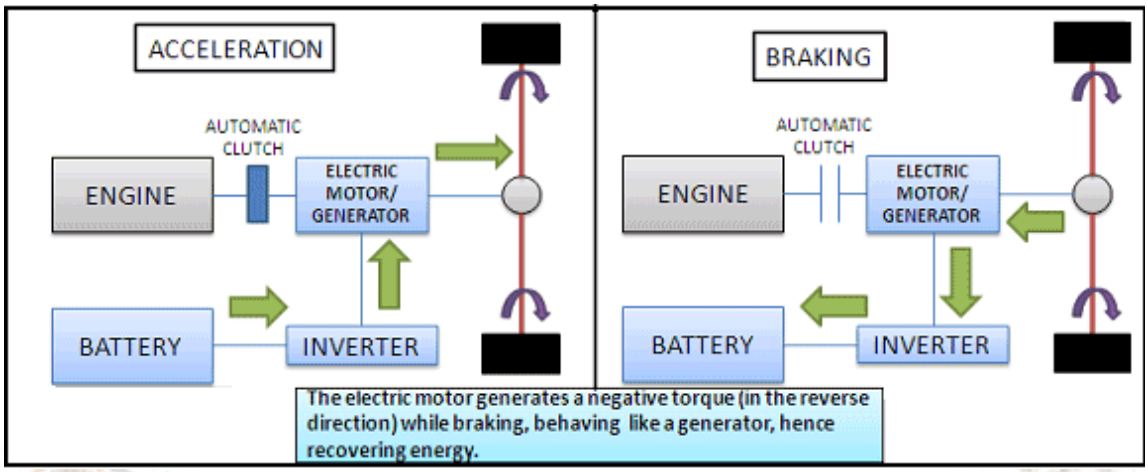

Fig. 4: Flow of energy during the process of acceleration and deceleration.

The rotational torque of the drive axle is used to rotate the engine and regenerative electrical energy is generated and stored in the batt ery at the same time the vehicle speed is reduced due to the regenerative resistance of the body. **Fig. 5** shows electric motor working as an electric generator [6].

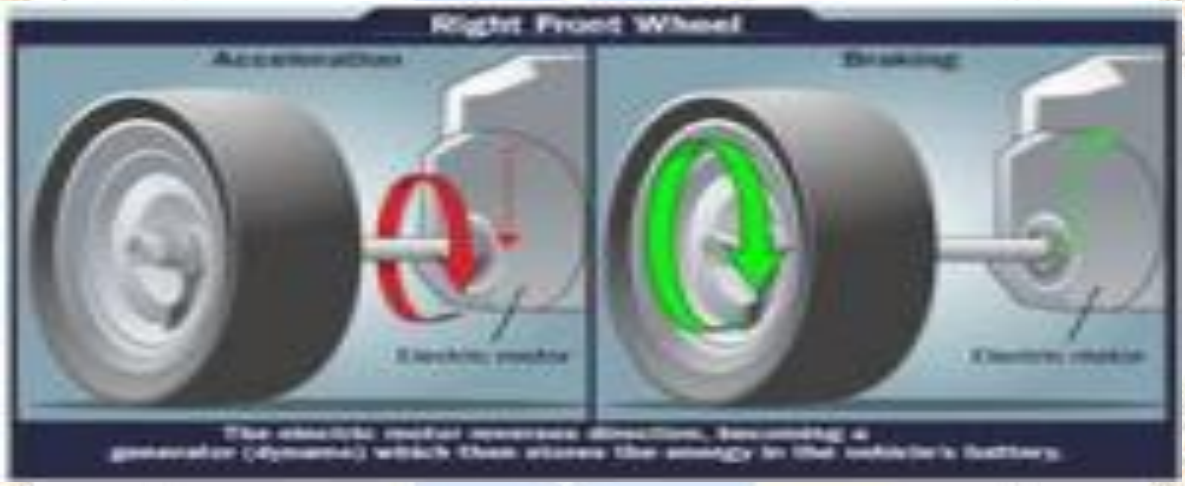

Fig. 5: Electric motor as Electric generator.

VII. The Efficiency in case of Regenerative Braking System

Regenerative braking efficiency is nothing but the measure of how effective the individual components are in recapturing braking energy. Hence, it is defined as the percentage of how much energy is recaptured from the energy consumption caused by a specific driving style at any point in time.
The objective is to regenerate as much energy as possible while also maintaining the stability of the vehicle and allowing effective operation of control systems.

The performance of vehicle depends on factors such as the weight of the car, the aerodynamics of the car, the transmission and engine of the car. In the case of cars, only about 20% of the energy gets restored, with the rest of this energy getting wasted as heat energy, in the matter of hydraulic regenerative braking systems, it is seen up to 25 to 45 percent. Hybrid vehicles travel farther per gallon of fuel with electric motors and regenerative brakes, several achieving more than 55 miles per gallon.

VIII. IMPROVEMENTS IN REGENERATIVE BRAKING SYSTEM

A. Implementation of Flywheel in Regenerative Braking System

The flywheel is an inertial energy storage device or electromechanical battery. It is used to absorb electricity and act as a storage facili ty. The flywheel is supported in vacuum by magnetic sliding bearings that convert electricity into kinetic energy and kinetic energy int o electricity via the same motor/generator. Basically, it stores energy when the energy supply is more than the demand and releases th e energy when the energy demand is high**. Fig. 6** shows the cross-sectional view of a flywheel storage system [10]. Regenerative braking systems use a flywheel to smooth out changes in shaft speed from torque fluctuations.
It kicks in when the basis of drive torque or load torque fluctuates by nature. The flywheel design can be improved by increasing its sp eed and changing the stored energy by decreasing its speed. Compared to a flywheel with the same power factor, the specific power of the flywheel increases in proportion to the weight of the rotating object. There are some good reasons to choose flywheels:
1. They are mechanical equipment with no external force applied.
2.Simple design and operation.
3. It does not contain chemicals such as chemical batteries, does not pollute the environment, is ecologically clean and natural.
4. Long lifetime for longer operation.
5. High cycle efficiency around 90%.
6. Little impact on lifecycle even in fast mode.
7. Over 10 years service life, reliability and low maintenance cost.

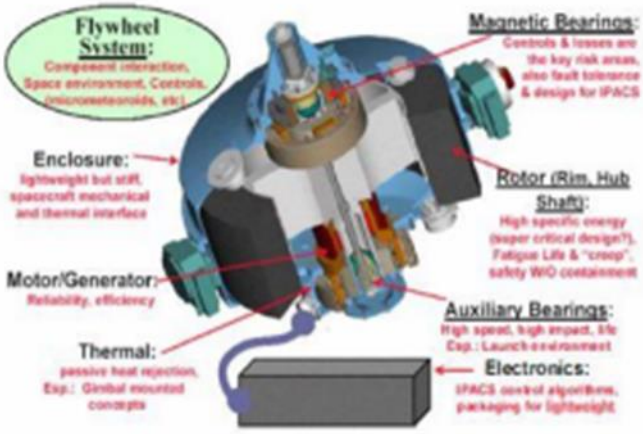

Fig. 6: Flywheel System and its components

B. Implementation of Ultracapacitor and DC-DC Converter in Regenerative Braking

In the supercapacitor system, the 4 main components are the Insulated Gate Bipolar Transistor (IGBT) as a DC-DC converter, a smoothing aluminium inductor Ls, a supercapacitor bank, and a battery pack. A buck-boost converter is connected in parallel to the main power supply from the battery. During acceleration, the capacitor voltage is allowed to drop from its full value to one third of its rated voltage. During deceleration, the energy returns and charges the supercapacitor. DC-DC converters for buck-boost circuits. Boost delay is used for acceleration while buck delay is used for deceleration, which helps charge the capacitor. The location of the ultracapacitor [2] in the vehicle can be seen in the below **Fig.7.**

Supercapacitors play an important role in the body because this new technology can:

1. Store 20 times more energy than Electrolytic Capacitor.
2. Charge and discharge thousands of times without negative function.
3. Improve EV Transient performance.
4. Extend battery life.
5. Can prevent rapid battery discharge during acceleration or braking and gives the vehicle more power to keep going.

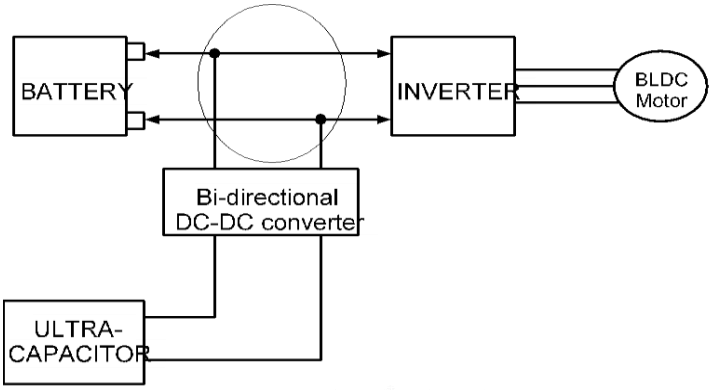

Fig.7 The Ultracapacitor in EV

IX. Applications of Regenerative Braking System

Below are the few applications of Regenerative Braking System

1. Kinetic energy recovery mechanism.
2. Regenerative braking system for electric hoist and crane lifting motors.
3. Used in electric and hybrid cars, electric trains, electric bicycles, etc.
4. Can be used in businesses that use delivery machines to move from one office to another and stop at a certain distance.

X. Limitations of Regenerative Braking System

There are few limitations of the system

1. In practice, regenerative brakes take time to slow down the vehicle, so most cars that use them also have co-operating friction brakes.
2. This is one of the reasons why regenerative braking cannot save 100% of braking energy.
3. High prices for products, engineering and installation.
4. Unlike dynamic brakes, regenerative brakes have input power (DC and AC power).
5. Regenerative braking safety is limited when the battery storage energy recovery is 100% charged.
6. More maintenance - depending on the complexity of the design.

XI. 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 loss.

XII. Conclusion

Regenerative braking is a vital system in electric vehicles since it possesses the capability to save the waste energy up to 5-10%. The regenerative braking system can surely be enhanced by the modern power electronic components such as ultracapacitor, Buck-Booster circuit and flywheel. The ultracapacitor which aids in improving the transient state of the car during starting, provides a smoother charging characteristic for the battery and boosts up the overall performance of the electric vehicle system. The Buck-Boost converter helps maintain the power management in the regenerative braking system such as boosting the acceleration. Finally, the flywheel is used to enhance the power recovery process through the wheel of the car.

In the end, regenerative braking is a tremendous concept that has been developed. In the near future, regenerative braking techniques can be further developed by using different methods.

XIII. REFERENCES

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