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A REVIEW ON CURRENT AVAILABLE REGENERATIVE BRAKING SYSTEM

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ABSTRACT

Automobile is always been a major part of Modern Transportation. As per increasing demand the nature friendly machinery and fuel economy is always a big concern. One of the most demanding sector of an automobile is fuel pricing and performance enhancement. During braking of a vehicle the huge amount of kinetic energy is converted into heat energy, which is wasted in heat dissipation in surrounding, which then makes the startup heavy energy consuming. Braking energy is recovered by kinetic energy recovery system and stored in a battery reservoir. This helps in significant fuel energy saving. Also the KERS torque boost arranged in system will increasing the total torque available to accelerate the car, large engines working at very low brake. Efficiencies over driving cycles may also be converted small higher power density engines working at much higher brake mean effective pressures and will be able to handle much higher part load efficiencies. Looking forward to improve and perfect this modern way of energy conservation this paper focuses on collectively study of available technologies in RBS sector. So as to overcome energy wastage issues due to Conventional braking.

Keywords: *Automobile, Regenerative technology, Energy conservation.*

I. INTRODUCTION

Since ever hike in fuel cost, energy crisis & eco friendly measures in automobile, demands of reliable vehicles is increased. The innovative inventions are being conducted on the various component parameter of automobile so as to gain the affordability factor for the operation and utilisation to make efficient use of energy.

Huge amount of kinetic energy is wasted when brakes are applied during driving of an automobile, this will make the startup very high energy consuming and heavy loading. When the brake pedals pushed the motion of the vehicle is restricted it result in slowing or stopping the vehicle completely. The braking distance depends upon how intensively brakes are applied and the speed of vehicle at braking instant

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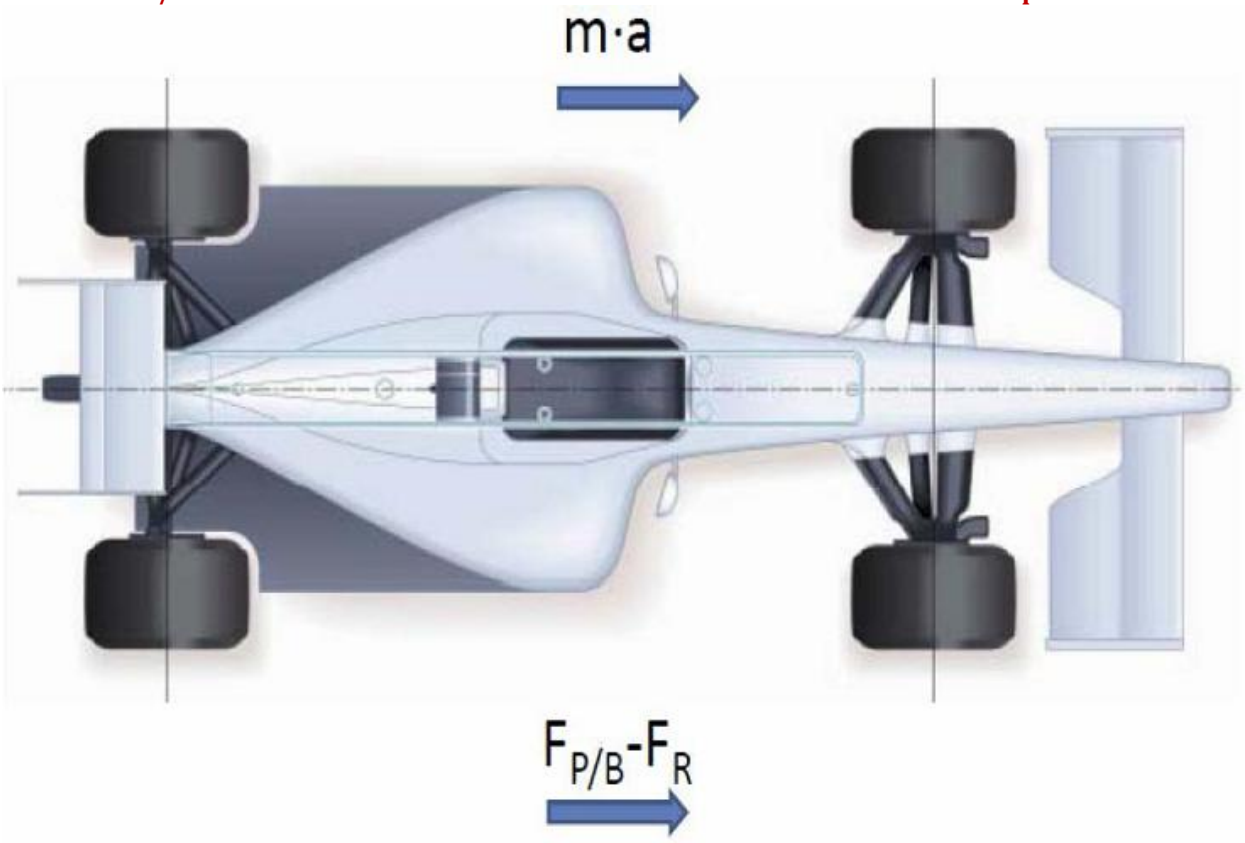

Figure 1. Free body diagram for vehicle dynamic

In the conventional Braking System, when the brakes are applied kinetic energy of a vehicle is converted into heat due to fictional energy and get dissipated into the environment. The total amount of energy dissipates into the atmosphere in this process is proportional to how often how hard and for how long the brakes are applied.

The scope of upgrading an arrangement in vehicle is that the kinetic energy of vehicle mass in a breaking process can be converted into the form of any other energy and can be stored into the storage devices. Those regenerating braking energy can be converted into kinetic energy and can further be converted into electrical energy which will be provided to start or accelerate again. [1]

If an electric vehicle runs at a high-speed mode, the transient current due to braking feedback in the motor bus will increase up to 200 A or morein passenger cars, the RBS will reduce the amount of thermal energy required to reaccelerate the car following a deceleration recovering situation of the braking energy. This translates in significant fuel energy saving technique. Also considering the RBS torque boost increasing the total torque available to accelerate the car, large engines working on very low brake mean effective pressures and efficiencies over driving cycles may also be substituted by small higher power density engines working at much higher brake mean effective pressures and therefore much higher part load efficiencies. [3]

II. LITERATURE REVIEW

After elaborative study of papers listed below and market survey we come to know about available RBS. Regenerative Braking system are widely used in Electric vehicle and some hybrid vehicle. Following are essential chapters to be known during researchon SIT system.

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A. Type of Braking System

i. Conventional Braking Systems in Automobiles

The distance between the instant of breaking and the distance up to the instant of vehicle come to complete stop or to a Desire speed is called as braking distance. When the brake pedals pushed the motion of the vehicle is restricted it result in slowing or stopping the vehicle completely.Friction is used to counteract the forward momentum of a moving vehicle in braking systems on conventional vehicles. Excessive heat energy is created, as the brake pads rub against the wheels or a disc that is attached to the axles. Wasting as much as 30 percent of the vehicle's generated power, this heat energy dissipates into the air. Over time, this cycle of friction and wasted heat energy reduces the vehicle's fuel efficiency. More energy from the engine is required to replace the energy that was lost by braking. [6]

Thus, this traditional braking methodology tend to lot of wastage of energy due to its unwanted heat release during braking.

ii. Regenerative Braking System

Regenerative braking system is a method of breaking which utilizes the kinetic energy of any vehicle and convert it into the mechanical energy, further it can be converted into electrical energy with the help of Motors and stored into the batteries.This stored energy can be further utilized to provide high starting torque.

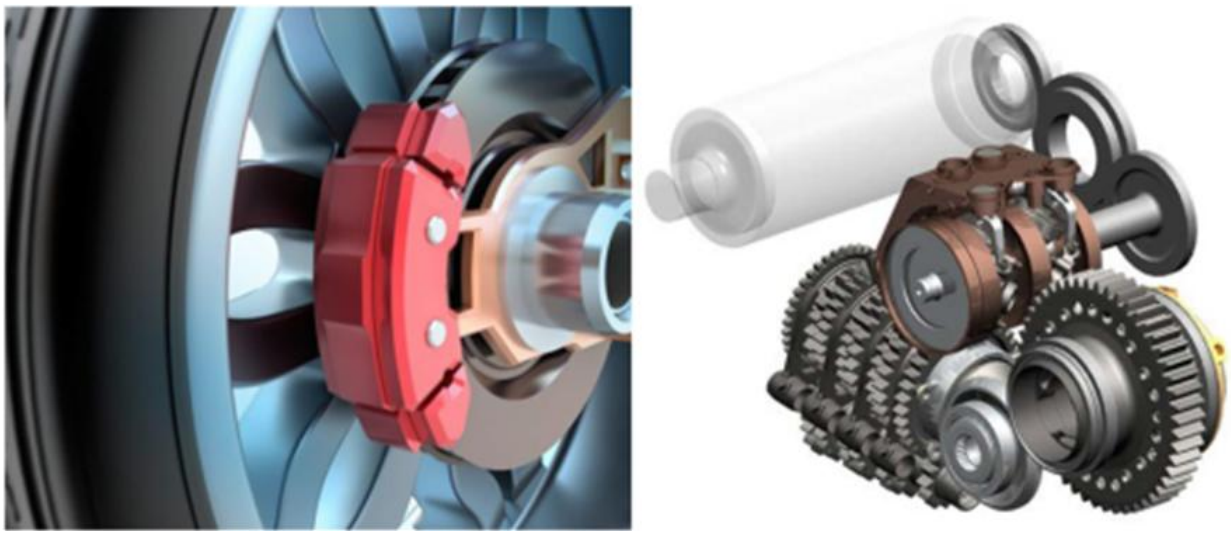

Figure 2. Friction brake (left) and mechanical KERS (right) from [3]

When running in counter clockwise direction motor acts as the generator and thus charge the battery. Thus where motor goes forward and takes energy from the battery car which is runs in normal condition. It reduces the cost of fuel, increasing the fuel financial system and emission will be loweredwhen regenerative braking is used in vehicles. The regenerative braking system provides the braking force during the speed of vehicles is low, and hence the traffic stop and go thus deceleration required is less in electric vehicles.[3] This brakes work so effectively in driving in such environment so as to stop in cities. Because of it controls the whole part of the motor in a vehiclethe braking system and controller is the key components of the structure. The brake controller functions are monitor the Speed of the wheel, hence calculate the torque, electricity which is to be generated and rotational force thus to be feed to batteries. When we apply brakes the brake controller, it controls and direct the electrical energy which is formed by the motor to the batteries. [7] [2].

Consider a 6000 kg (~13227lbs) vehicle moving at an initial speed of 70 km/h (~43mph). Now, on braking the vehicle to a speed of 30 km/h (~18mph) the amount of energy spent is around 925.9 kJ using the equation given below:

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$E_k = 0.5* mv^2$

Where,

E_k : Kinetic Energy of the vehicle;
M : Mass of the vehicle and;
V : Velocity of the vehicle.

Ideally, this is the amount of energy available for capturing at each instance of braking. If regenerative braking was used on such a vehicle it would be able to capture this amount of energy and reuse this same energy which would otherwise have been lost in the form of heat, sound etc. [5]

B. Pre-Existing Technique of RBS

i. Conversion of kinetic energy to mechanical energy using flywheel energy storage

A flywheel such as the one illustrated in Figure is a mechanical device that is commonly used to store kinetic energy associated with its rotation at high speed. The stored energy is then released to the intended application after the supplied energy is either discontinued or reduced in the magnitudes.

The kinetic energy that can be stored in a flywheel spinning at an angular velocity ω may be computed by the following expression:

$KE = 0.5* I \omega^2$

Where,

I: mass moment of inertia of the spinning wheel.

Below Equation is used to compute the mass moment of inertia for flywheel with uniform thickness:

$I=0.5*MR^2$

Where,

M: mass and

R: Radius of the wheel

The angular velocity of the spinning flywheel ω is maintained by applying torques that is equal to

$T=I\alpha$

Where,

α: is the angular acceleration of the spinning wheel

The method of transmission of energy directly to the vehicle is more efficient rather than first storing it in the battery, as it does not consists of the conversion of energies. As during the recharging of battery. As, in the other case, there are no transmission loses since mechanical energy stored in the flywheel is directly transferred to the vehicle in its original form. As the energy is supplied instantly and efficiency is high, these types of systems are used in F-1 cars. [6]

ii. Regenerative Braking with Electric Motor and Super capacitor

To boost up the efficiency of energy conversion the regenerative energy is arrested during braking process is stored in the energy storage devices and then will be utilized to increase the driving range of Electric vehicles. They are used to withstand high current in the short time and essentially arrest more regenerative energy or current generated due to the high power density of super capacitors.An evaluation of system for energy recovery in the braking process is established using portable USB data-acquisition devices, based on the analysis of the regenerative braking energy system of a super capacitor vehicle.

The results verify the higher efficiency of energy regeneration system using super capacitors and the effectiveness of the proposed measurement method. It is also demonstrated that the maximum regenerative energy conversion efficiency can reach to 88%. [8]

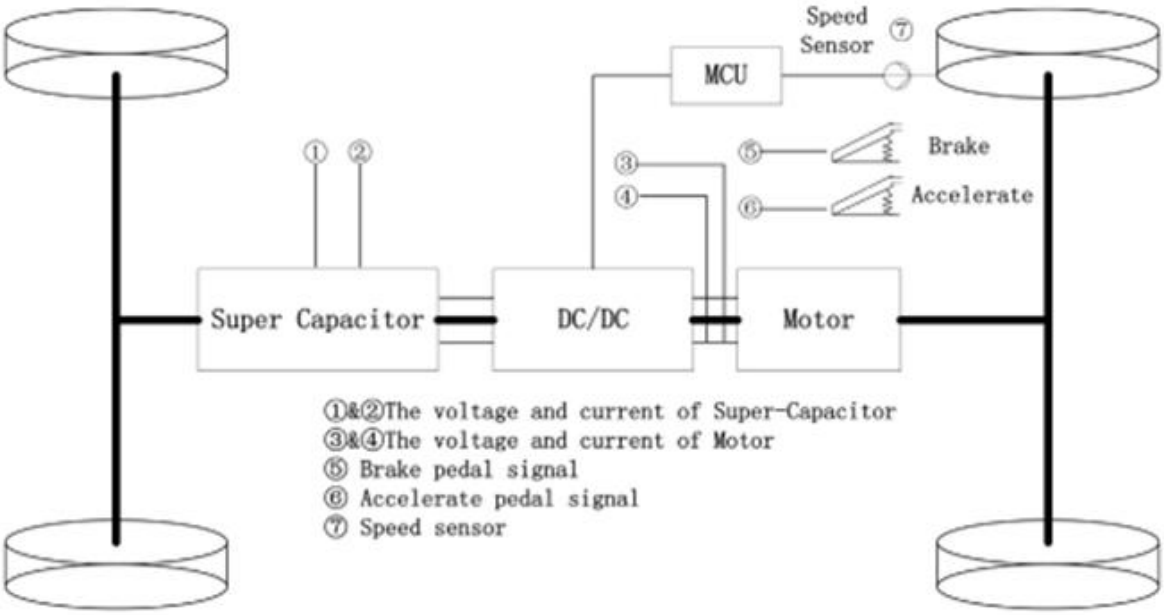

Figure3. Conversion of kinetic energy to electrical energy using KERS [6]

iii. Conversion of kinetic energy to electrical energy using KERS

Using an electric motor as an electric generator is the most common form of regenerative brake system. The working of the regenerative braking system be contingent on the working principle of an electric motor, which is the important component of the system. When some current is passed through electric motor,it gets activated when some current is passed through it. But, to activate the motor (during the braking), then it behaves as a generator and generates electricity when some external force is applied.

This means that whenever motor runs in one direction, the electric energy gets converted into mechanical energy. It is then used to accelerate the vehicle and whenever the motor runs in opposite direction, it performs function of a generator, which then converts mechanical energy into electrical energy, this makes it possible to utilize the rotational force of the driving axle. [6]

iv. Hydraulic–Pneumatic Regenerative Braking System

Hydraulic-pneumatic hybrid power trains provide an opportunity for combined high power and high energy regenerative braking systems. For heavy duty vehicles that need to transpose both highway use and urban areas. Braking energy is recovered by a hydraulic system and stored in a hydraulic accumulator and in an air reservoir, in this kind of RBS. The compressed air is used to power auxiliaries in power-assist mode, while the hydraulic system shares the vehicle propulsion in parallel to the internal combustion engine.

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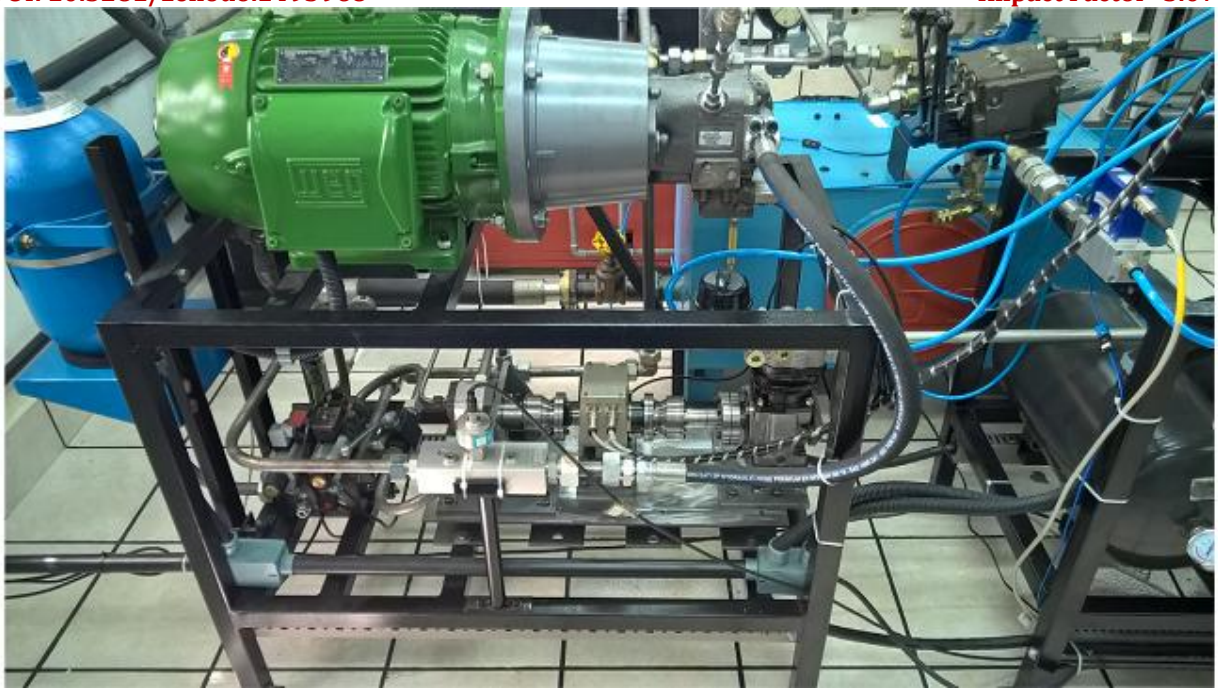

Figure 4. Hydraulic–Pneumatic Regenerative Braking System [4]

Then, two conditions of braking energy recovery for a 19 tones bus are analyzed: a full stop, typical of urban driving, and a downward. Result indicate that the system proposed is able to store 69% of the available energy during full stop and 14% in the highway downward slope. However, the total energy recovered is 2.8 times larger than the energy recovered after full stop. Also, while the pneumatic energy stored is only 20% of the energy stored in the hydraulic accumulators after full stop, it is more than twice for the road slope. These results indicate an opportunity for significantly improving the overall energy efficiency of delivery trucks and buses. [4]

C. System & Components

Regenerative braking system itself is combination of multiple consistent system. Any design engineer is allowed to flexibly implement every individual system as pre design requirement. Following are the system and there components [5]:

i. Electrical system Component

a. Alternator

This device is been used to convert mechanical energy into electrical energy D.C. generator is for generating D.C. voltage at output.The alternator works to sync with the battery to generate power for the electrical components of a vehicle, like the interior and exterior devices, and the instrument cluster.

b. Rectifier circuit

It converts A.C. voltage into D.C. voltage. The rectifier circuit is used toproduced A.C. harmonics by D.C. generator with pulsating modulation of waves which is not in regular modulation, so for getting regular modulation of waves.

c. Filter circuit

At the output of rectifier, D.C. voltage is not in pure form therefore some A.C. components are use for purification of it, Shunt capacitor filter circuit can be used. Filter circuit minimizes or removes the undesirable A.C. component of the rectifier output & allows only the D.C. current to reach at output.

d. Charging circuit
Charging circuit is used for charging the discharged battery.

e. Battery
Battery is a source of D.C. power supply. It is the device which stores the D.C. voltage or it gives the D.C. source whenever we require according to usage.

f. Inverter
Requirement of this project is electronic inverter. The function of electronic inverter is to convert D.C. supply to A.C. supply or vice-versa. [5]

ii. Mechanical system components
a. Fly Wheel
Flywheel is basically heavy wheel mounted on a rotating shaft so as to deliver the power from a motor to a machine smoothly. The inertia of the flywheel manipulates and moderates fluctuations in the speed of the engine and stores the excess energy for further use. To overcome speed fluctuations effectively, a flywheel is given a high rotational inertia. Hence it plays a vital role in fluent working of mechanism.

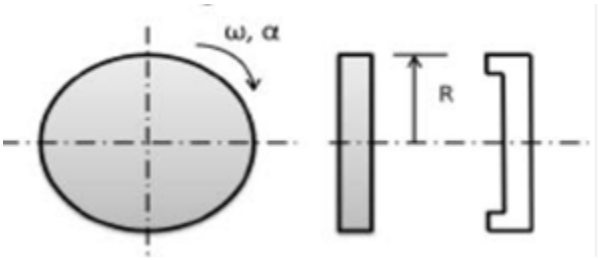

Figure 5. Typical Flywheel

b. Speed booster
As we reported recently, the Speed Booster is an adapter. It increases the speed of the motor.

c. Rotary Motion Generator
To avoid excessive wear law of inductions demands high speed for moveable electrical parts, on the reverse mechanical parts like low sliding speeds. The conventional generators can also be used for generating electrical energy. Depending on the diameter of the rotating parts the result is a desired low sliding speed of the pistons together with the desired high speed between the two interacting magnetic fields.

d. Electric energy Storage & DistributionManagement System
The electricity generated by the motor is supply back into the batteries, 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 for later use.

D. Applications of rbs
- During braking process for Kinetic energy of the vehicle is lost being recovered.
- In a manufacturing plant application of the regenerative braking is to be that moves the material from one work-station to another on a conveyor system that stops at each point.
- In some elevator and crane hoist motor Regenerative braking is also used.
- Regenerative Braking Systems are also used in metro trains. (London Underground & Virgin Trains). [6]

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E. Advantages of regenerative braking systems

- Regenerative Braking Systems are also used in the electric railways.
- It is used to improve performance.
- Improves Fuel Economy Dependent on the duty cycles, power train design, control strategy, and the efficiency of individual components.
- Reduces in Engine wears during motion.
- Reduction in Brake Wear-Reducing cost of the replacement brake linings, and vehicle down time.
- Emissions reduction-engine emissions reduced by engine disconnection, reducing engine revolutions and the total time of engine operation.
- Operating range is comparable with the conventional vehicles- a problem not yet overcome by the electric vehicles.[6]

f. Limitations of regenerative braking systems

- The main limitation of regenerative brakes when compared with the dynamic brakes is that needs to closely match the electricity generated with supply. (This mainly applies to locomotives where an AC supply is rectified for DC motors).
- When the batteries are fully charged Regenerative braking is needful limited. In this case because of the additional charge from regenerative braking would cause the voltage of a full battery tomount above a safe level, our motor controller will limit regenerative braking torque.
- Increases the total weight of vehicle by around 25¬30 Kilograms. [6]

g. Future scope

To develop a better system that captures more energy and stops faster Regenerative braking system require further research. As the time passes, designers and engineers will precise regenerative braking systems, so these systems will become more and more common. During braking process of vehicles in motion can benefit from these systems by recovering energy that would have been lost.

In future technology regenerative brakes will include new types of motors which will more efficient as generators, new drivetrain designs and will be built with regenerative braking in mind, electric systems will be less prone to energy losses. Of course, problems are expected as any new technology is need to be perfected, but few future technologies have more potential for improving vehicle efficiency than does regenerative braking.[6]

IV. PRINCIPLE AND WORKING

A. Principle

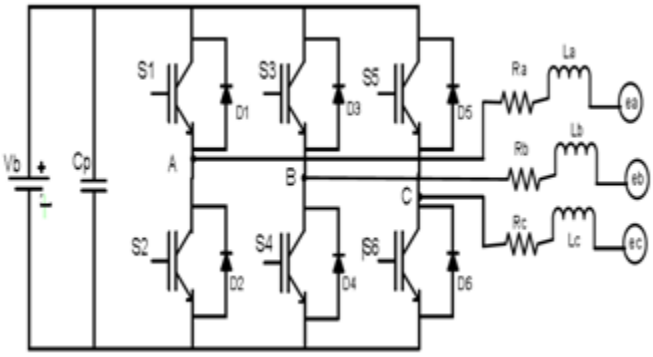

Fig 6. Equivalent circuit of an inverter driven 3 phase PM BLDC motor

Figure 6. Shows that the basic the same circuit of a 3 phase brushless DC motor, the motor is driven by an inverter which is loaded from a battery source. As shown in the figure R_a, R_b, R_c are the phase resistances, L_a, L_b, L_c are the

phase inductance and ea, eb, ec are back- EMFs in the A,B,C phase respectively. D1 to D6 are the freewheeling diode and S1 to S6 are the switching devices.

An ideal back-EMF, phase current and developed torque profiles of PM BLDC motor is the complete commutation cycle spanning 360º electrical consists of the six equal intervals. The switches S1 to S6 are operated in the sequence using a control circuit based on the position received from the rotor position sensors such as hall-effect sensors. To control torque which is developed by the motor, control by an inverter circuit shown in figure 3. This process of regenerative braking is shown by the arm under the IGBT Bridge whose switched movements are corresponding to the working module of motor [7]

B. Working

Regenerative braking is the brake method which uses kinetic energy of the vehicle and convert it to the mechanical energy and further to electrical energy which will given back to the battery.

When the vehicle is in motion on roadway, due to its mass and velocity of vehicle it possesses certain amount of inherent kinetic energy. On the application of brake the KERS tends to engage with gearing arrangement of the shaft. The kinetic energy possessed by vehicle instantly start to convert into mechanical energy with the help of fly wheel arrangement. This energy is then utilized to provide starting torque energy to vehicle or is further transmitted to electricmotors and stored in the form of electrolytic charge in the auxiliary batteries or secondary batteries.

V. CONCLUSION

The regenerative braking system used in the vehicles achieves the purpose of conserving a part of the energy lost during braking. Also it is able to be operated at high temperature range and are highly efficient as compared to conventional braking system. The results from some of the test conducted recorded that around 30% of the energy delivered is recovered by the system. Regenerative braking system has a wide scope for further development and the energy savings. The use of more efficient systems could lead to huge savings in the economy of any developing country like India.

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Although any error occurs, is our own and should not tarnish the reputation for these esteemed person.

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