Regenerative Braking for an Electric Car

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Abstract – *Electric Vehicles function by plugging into a charge point and taking electricity from the grid and storing it in rechargeable batteries that power an electric motor and the transmission transfers the mechanical power from the motor to drive the wheels. When the vehicle is moving and brakes are applied the regenerative braking allows the electric vehicles to use the motor as a generator for pumping the vehicle energy from the brakes into an energy storage device. Regenerative braking is an effective approach to extend the driving range of the Electric Vehicle and increase the efficiency of the vehicle. The objective of the paper is to understand Regenerative Braking in an EV.*

Key Words: Electric vehicle, Regenerative braking, Brake torque, Friction braking, Regenerative ratio, Kinetic energy

1. INTRODUCTION

The electric vehicles are called means of 'Green transportation' as they consume alternative energy that prevents global warming and reduces the pollution levels and help to preserve the natural resources like oil, fuel and gas for futuristic needs. The use of such vehicles is encouraged by the government and the electric vehicles are chosen over the internal combustion vehicles as they are affordable, convenient and provide better driving experience.

In electric vehicles batteries are the energy storage means and a huge amount of batteries are required to assure a desired level of performance, which results in the increase of the vehicle weight, cost and the degradation of vehicle performance.

A moving vehicle possess a good amount of kinetic energy, and while the brakes are applied to slow down the speed, a reasonable amount of kinetic energy is lost in the form of heat to the brake discs. All of this heat energy is lost to the environment. In order to recover this heat energy and use it, regenerative braking uses the motor as a generator to convert the lost kinetic energy into the stored energy in the battery which can be used later. This helps the vehicle to use much of this stored energy from regenerative braking rather than using its own energy reserves.

2. REGENERATIVE BRAKING

The regenerative braking is classified on the basis of control strategies into: -

- Serial regenerative braking
- Parallel regenerative braking

2.1 Serial regenerative braking

Serial regenerative braking is basically based on the combination of friction-based adjustable braking system that transfers energy to the electric motors and batteries under an integrated control strategy. The overall design of serial regenerative braking is to estimate the deceleration required and distribute the required braking force between the regenerative braking system and mechanical braking system. Serial braking system requires brake by wire system and has more consistent pedal feel due to good torque blending capability. It can increase the efficiency by 15-30%.

Implementation of serial braking system

Depending upon the level of depression of brake, a brake torque is sent and passed into the brake control strategy block and checked if state of charge is below the maximum permissible level of charge. Then the brake torque requested is compared to the maximum regenerative torque limit of the motor generator. If the brake torque requested is less than or equal to the maximum regenerative torque, then the vehicle brakes purely on regenerative torque and the battery is charged, and if the requested brake torque is greater than the maximum regenerative torque, friction brakes contributes and is checked if the total brake torque requested from front(70% of requested brake torque) is less than or equal to maximum regenerative torque. If the condition is satisfied, front braking is provided by regenerative braking and rear by friction. If not, then the front friction brakes contribute along with rear friction brakes and front regenerative braking, to satisfy the overall brake torque demand.

2.2 Parallel regenerative braking

Parallel braking system is basically based on the combination of friction-based system and the regenerative braking system, operated in tandem without an integrated control. The regenerative braking force is calculated from the brake control unit by comparing the requested brake torque and the motor torque available. Parallel regenerative braking system requires more work in achieving good torque blending. This system can increase the efficiency by 9-18%.

Implementation of parallel braking system

When the brake pedal is pressed and a brake torque is requested, it is passed through the brake control strategy block to check if state of charge is less than the maximum permissible level of charge. Then the requested brake torque is compared with the maximum regenerative torque limit of

the motor generator. If the brake torque requested is less than or equal to the maximum regenerative torque, then the vehicle brakes purely by friction, and if the requested brake torque is greater than the maximum regenerative torque, it is checked if the total brake torque requested from front(70% of requested brake torque) is less than or equal to maximum regenerative torque. If the condition is satisfied then the vehicle brakes purely by friction. If not, then the vehicle brakes by front friction and regenerative braking and rear friction braking.
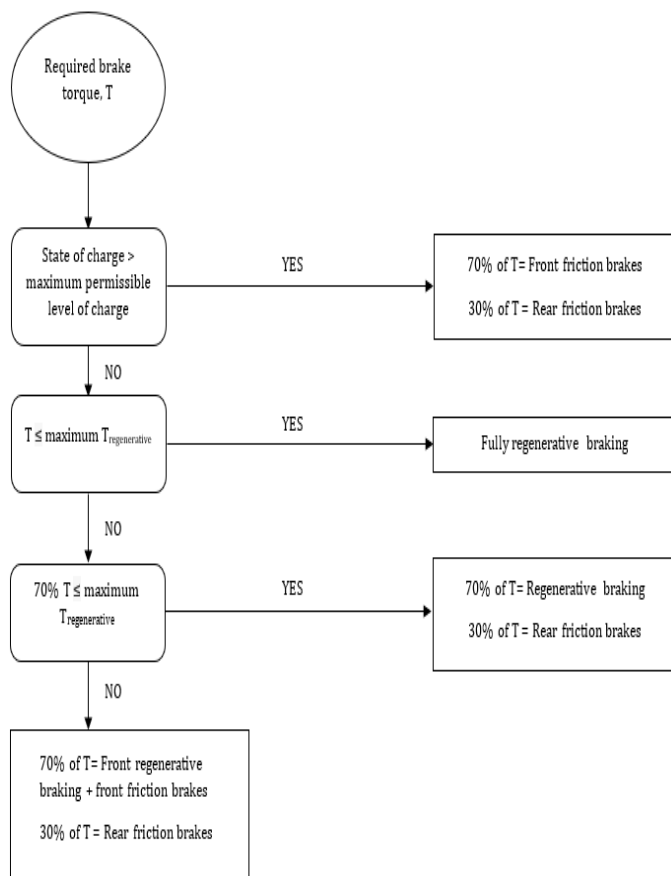

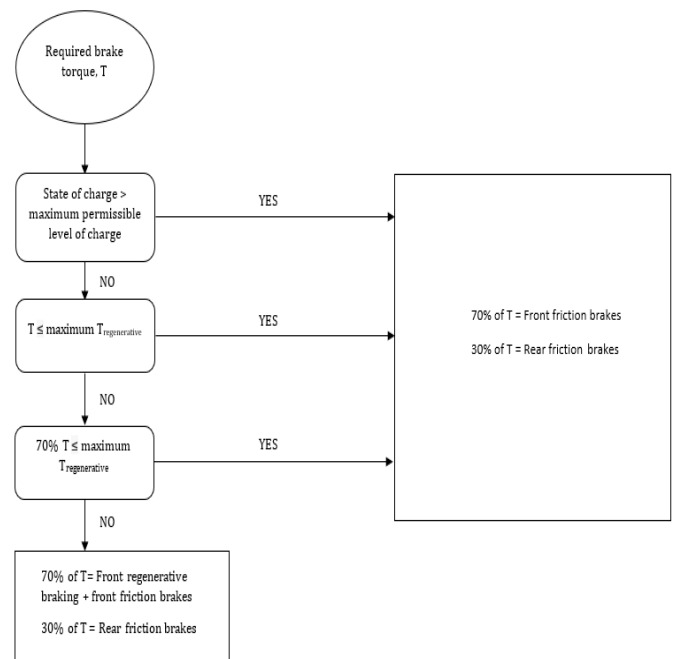**Fig -1**: Flow chart representation of serial regenerative braking

Fig -2: Flow chart representation of parallel regenerative braking

3. REGENERATIVE RATIO

The estimation of energy recovered is very necessary as it helps to find out which regenerative braking system is more effective for a particular type of vehicle. For this regenerative ratio is used which the ratio of regenerative electrical energy and kinetic energy of the vehicle.

$$\varepsilon = \frac{\sum E_{Regen}}{\sum E_{Kinetic}}$$

with,

$$\text{Kinetic Energy, } E_{Kinetic} = \sum \frac{1}{2} m (V_2^2 - V_1^2)$$

$$\text{Re generative Electrical Energy} = \int_{t=0}^{t=end} (E_K - I(t)R(t)) I(t) dt$$

where,

    E_K is the battery voltage

    $I(t)$ is the battery current

    $R(t)$ is the charging resistance

    V_1 is the initial velocity

    V_2 is the final velocity

It is advisable that the majority of braking at high speeds be regenerative as higher generator torque is necessary for braking at high speeds, which allows for higher battery charging effectiveness. On the other hand, at lower speeds, relatively little current is being produced by the generator to ensure desirable battery recharge effectiveness. Hence, at these speeds the frictional brakes are applied to decrease electrical cycling through the generator and batteries.
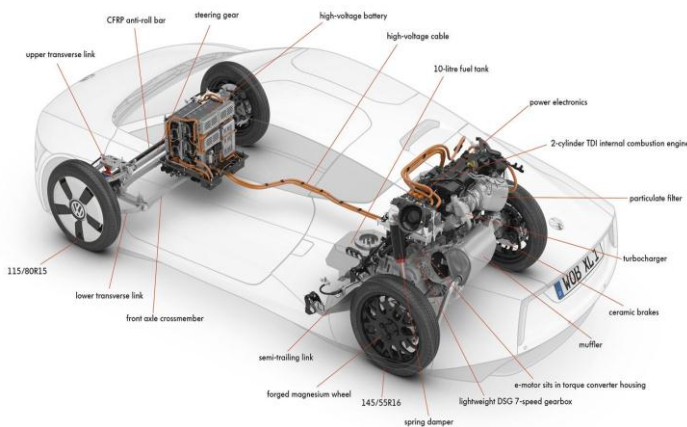

Fig -3: Electric vehicle components

4. CONCLUSION

We have studied the two regenerative braking concepts. The driver block simulates a driver by pressing the accelerator pedal to drive and brake pedal to stop the car and depending upon the position the torque is applied. For serial regenerative braking a certain brake torque is requested, and upon feeding to the brake control strategy block gets split into regenerative and friction braking. When the brake torque requested is small then regenerative braking occurs, otherwise friction braking comes into play along with regenerative braking. For parallel regenerative braking the requested brake torque is split between regenerative and friction braking considering consistent pedal feel. It is observed that the regenerative braking is only active when braking from a speed equal to or less than the base speed of generator.

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BIOGRAPHY

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