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Review of Regenerative Braking in Electric Vehicles

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Abstract:
In vehicles, Considerable amount of energy is wasted to heat in friction braking. A regenerative brake is an apparatus, a device or system which allows a vehicle to recapture and store part of the kinetic energy that would otherwise be 'lost' to heat when braking. The crucial task in design of Electric Vehicles is to increase the kilometers per full charge of battery pack. This motivation results into different methods to recapture the part of energy being lost to heat by friction brakes, which is the main focus here.

Keywords: Regenerative Brake, Motor/Generator, ultracapacitor.

I. INTRODUCTION

Regenerative Braking System is the way of slowing vehicle by using the motors as brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat, the motors act as generators and return some of it to the overhead wires as electricity. This energy is stored in a large battery, and used by an electric motor that provides motive force to the wheels.[1] The regenerative braking taking place on the vehicle is a way to obtain more efficiency; instead of converting kinetic energy to thermal energy through frictional braking, the vehicle can convert a good fraction of its kinetic energy back into charge in the battery, using the same principle as an alternator.[3] Depending on the HEV configuration, vehicle fuel economy can be increased by up to 15% [11] by using regenerative braking, a capability for energy that would normally be wasted as heat generation during braking.

II. USING MOTIVATION FOR REGERATIVE BRAKE SYSTEM INSTALLATION

By studying the driving cycles (designed by U.S. vehicle standards) used for realistic and practical testing of vehicles performance, the vehicle energy being wasted into deceleration can be approximated [14]. About 80% of this energy would be wasted into brakes.

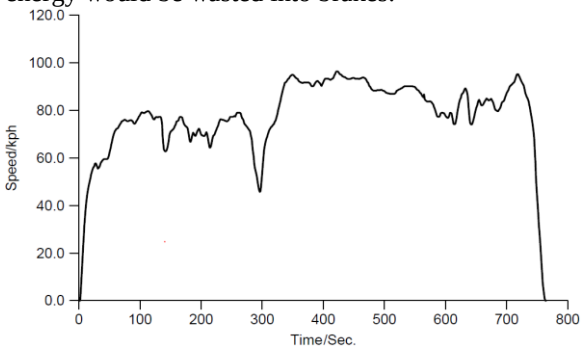

Figure.1. Federal Highway Driving Schedule [14]

Taking, the gross weight of Electric vehicle is 1200kg and considering the battery used in E2O is 48 V 200 Amp Hour. Hence the energy given by battery per hour is given by

$$E_b = 48 \times 200 \times 3600$$

$$E_b = 34560\ J$$

Table.1. Data Points On Federal Highway Driving Schedule Graph

Deceleration Start & End Points On Graph Kmph	Deceleration Start & End Points On Graph (V_0 –V1) m/s	($V_0^2 - V_1^2$)
78.5 & 63	21.80 & 17.5	169.23
78 & 67	21.66 & 18.61	123.07
79 & 46	21.94 & 12.77	318.28
96 & 90	26.66 & 25	86.11
97 & 87	26.94 & 24.16	141.97
91 & 77	25.27 & 21.38	181.97
80 & 74	22.22 & 20.55	71.29
90 & 73	25 & 20.27	213.81
96 & 0	26.66 & 0	711.11

Energy lost in deceleration can be found out using,

$$E_d = \frac{1}{2}\, m \sum (V_0^2 - V_1^2)$$

$$E_d = \frac{1}{2} \times 1200 \times 2016.377$$

$$E_d = 1209826\ J$$

$$E_d = 120.9826\ kJ$$

This energy is lost in time interval of 765 seconds as the driving cycle limited to 765 seconds. Hence for 1 hour the kinetic energy lost during deceleration is,

$$E_d = 987.962 \times \frac{3600}{765}$$

$$E_d = 5693.301 kJ$$

Hence, Percentage energy lost in deceleration from battery,

$$= \frac{E_d}{E_b} \times 100$$

$$= \frac{5693.301}{34560}$$

$$= 16.473\ \%$$

Hence, regenerative braking system would considerably increase the mileage of electric vehicle.

III. REGENERATIVE BRAKING USING TRACTION MOTOR AS GENERATOR

In this type of regerative braking system, the traction motor is so designed that it can be used as generator while braking. When vehicle is in downhill driving condition i.e. accelerator pedal is not pressed or vehicles brake pedal is pressed, the motor/generator acts as generator, hence uses the kinetic energy of wheels and converts the same into electrical energy. This electrical energy is stored in battery packs. This energy flow from battery to again battery is shown in figure 2.[8]

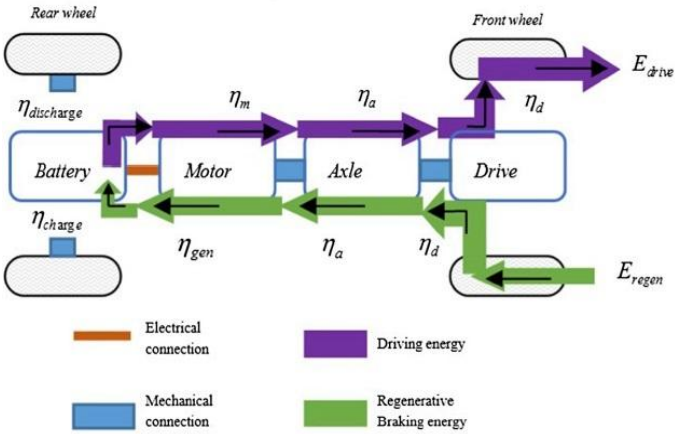

Figure.2. Energy Flow in Electric Vehicle Using Motor /Generator Unit [8]

The controlling of such system is difficult, as motor changes its operation frequently. Using this kind of motor/generator is costly and the controlling strategies are very difficult as same motor being used as generator which reverse the whole operation of motor/generator. At low speeds this system is less efficient.

IV. REGENERATIVE BRAKING USING ADDITIONAL MOTOR AND ULTACAPACITOR

Regenerative braking with the use of ultra-capacitors for energy storage could considerably reduce the fuel consumption of conventional IC-engine vehicles. For electric vehicles operating on batteries or for hydrogen fuel cell vehicles, the system operates in a similar manner but the vehicle's IC engine is replaced with a battery bank or fuel cell, and the ultra-capacitor operates in parallel to these systems. With all fuel systems, a DCDC converter and control system is required to control the state of charge of the ultra-capacitor, since this is dependent on vehicle speed. For example, at low speeds the state of charge should remain high, enabling energy boosts for acceleration. At higher vehicle speeds the ultra-capacitor should remain in a state of discharge, thus allowing regenerative energy to be stored when the vehicle slows. [4]

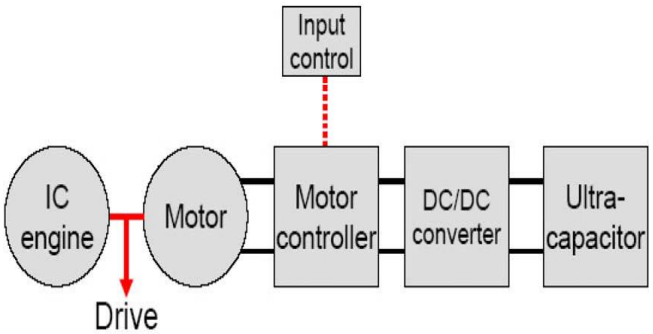

Figure.3. Regenerative Braking Systems for Use on an Electric Vehicle [4]

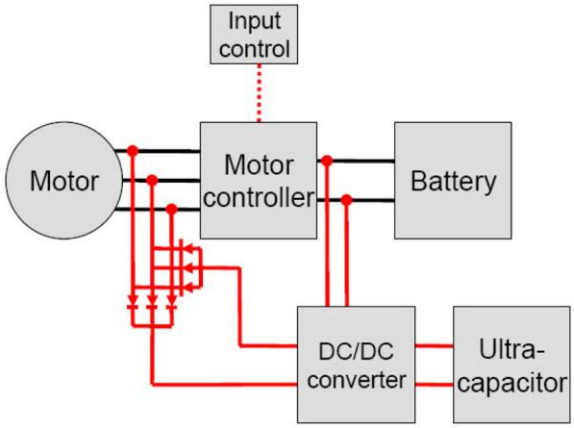

Figure.4. Regenerative Braking Systems for Use on an Electric Vehicle [4]

The general layout of a regenerative braking system for an IC engine is shown in Figure 3, while that for an electric vehicle is shown in Figure 4. [4]

V. REGENERATIVE BRAKING USING FLYWHEEL

A flywheel is a type of energy storage system which is used to store mechanical energy and then release the stored energy when needed for acceleration. Flywheel is a heavy, high-speed rotating disc that builds up kinetic energy (the force that causes movement) as it spins. The amount of energy stored depends upon how heavier it is and how fast it rotates. Heavier weight and faster rotation results in higher energy storage. The translational energy of the vehicle is transferred into rotational energy in the flywheel, which stores the energy until it is needed to accelerate the vehicle. The benefit of using flywheel technology is that more of the forward inertial energy of the car can be captured than in batteries, because the flywheel can be engaged even during relatively short intervals of braking and acceleration. In the case of batteries, they are not able to accept charge at these rapid intervals, and thus more energy is lost to friction. Another advantage of flywheel technology is that the additional power supplied by the flywheel during acceleration substantially supplements the power output of the small engine that hybrid vehicles are equipped with. 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, mechanical energy is converted into electrical energy and during discharging electrical energy is converted into mechanical energy. So, due to these conversions transmission loses occur and the efficiency reduces. 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.[8] The problem with the flywheel is its inertia, range of speed over which, its highly effective and conversion of stored energy into electrical power as electric charge of battery is difficult and need additional setup. Flywheel implantation is suited where energy is needed as extra instantaneous power.

VI. REGENERATIVE BRAKING EFFICIENCY

The energy efficiency of a conventional car is only about 20 percent, with the remaining 80 percent of its energy being converted to heat through friction. The miraculous thing about regenerative braking is that it may be able to capture as much as half of that wasted energy and put it back to work. This

could reduce fuel consumption by 10 to 25 percent. Hydraulic regenerative braking systems could provide even more impressive gains, potentially reducing fuel use by 25 to 45 percent. [3] In a century that may see the end of the vast fossil fuel reserves that have provided us with energy for automotive and other technologies for many years, and in which fears about carbon emissions are coming to a peak, this added efficiency is becoming increasingly important. The added efficiency of regenerative braking also means less pain at the pump, since hybrids with electric motors and regenerative brakes can travel considerably farther.

VII. CONCLUSION

The regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. Also it can be operated at high temperature range and are efficient as compared to conventional braking system. The results from some of the test conducted show that around 30% of the energy delivered can be 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 country.

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