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Saving of Energy through Regenerative Braking in Railway Traction Vehicles

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Abstract

We study energy-storage equipment that is connected to chopper of diesel locomotive or traction motor. We take reference model of diesel locomotive for the study of paper. During the powering period, the acceleration of the train becomes larger due to the boosting operation of the equipment. The equipment charges a part of regenerated energy when it boosts the voltage during braking period, and discharges the stored energy when it used to operate other electrical equipment. At the time of regenerative braking we store the electrical energy it is help to save the energy. In this paper, we selected battery bank or super or ultra-capacitor for the energy storage device of the equipment.

I. INTRODUCTION

The increase of the specific power demand by present day railway traction vehicles implies to find reliable technical solution in order to reduce the energy consumption. The typical journey i.e. of subway trains, light rail vehicles (tram) is made of accelerations, coasting and braking periods. In particular, the largest part of the energy drawn by the train is ascribed to the acceleration and braking because of the reduced distance between two subsequent stations. Modern electrical drives for traction motors benefit from the possibility of regenerative braking and the advantages related to the saving of energy attempting to inject the energy into the supplying line. [1]

In the last few years people mobility has increased more and more in urban centre s, implying the necessity of rapid transit improvement in terms of passenger capacity and number of journeys. These requirements have been satisfied by the introduction of new vehicles, that draw higher power peaks and greater energy consumption than traditional ones. However, the fast developing of transportation systems has not been always followed by a corresponding modification of the power supply and overhead lines. The present loads running on railway
lines are therefore responsible of a consistent growing of power losses and amounts of the electrical energy supplied by the electrical substations (ESS). More over, greater currents drawn by trains during acceleration simply greater voltage drops on the overhead line, that
further affect negatively their safe starting. The reduction of the energy consumption should be achieved if the kinetic energy of the trains were recovered as much as possible. Actually the braking is already

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made in regenerative mode so that the kinetic energy is converted into electrical energy, but the recovery possibilities are limited to the exceptional case where another train is starting at the same time. [2]

DC series motors have been used traditionally in traction applications, regenerative braking has not often been used in conventional traction equipment in the past. The main reason for this is that a series excited generator is unstable when working into a fixed voltage supply. Thus, for running on the traction supply, a separate excitation is required. Such an arrangement, however, is very sensitive to supply voltage fluctuations, and a fast dynamic response is required to provide an adequate brake control. However, the applications of a DC chopper allow the regenerative braking of DC series motors due to its fast dynamic response. In practice, the chopper must cope with the transient conditions and should be fitted with a fast acting closed loop controller. This is necessary to felicitate the required performance characteristics in the steady-state and transient conditions. [5]

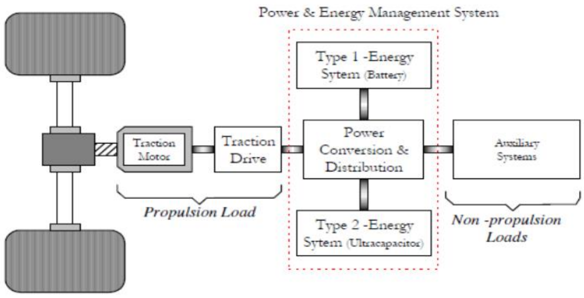

Fig 1. EV drive train and power system architecture

The driveline architecture that will be investigated comprises of the two energy storage systems categorized as Type 1 and Type 2. As depicted in Figure 1.4.1, the scope of the power and energy management problem encompasses the energy systems as well as the conversion and distribution of power. The vehicle load demand that is analysed in this dissertation is limited to the propulsion loads. Although the non-propulsion load demands have been investigated as part of this research paper, the core of the work presented here will focus on addressing the system encapsulated as power and energy management.

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, too, 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%.

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%.

II. REGENRATIVE BRAKING

Brakes are employed to stop or retard the motion of any moving body. Thus, in automobiles the brakes are having the most important function to perform. In conventional braking system the motion is retarded or stopped by absorbing kinetic energy by friction, by making the contact of the moving body with frictional rubber pad (called brake liner) which causes the absorption of kinetic energy, and this is wasted in form of heat in surroundings. Each time we brake, the momentum of vehicle is absorbed that it has gained by it and to re-accelerate the vehicle we have to start from the scratch to redevelop that momentum by using the more power from an engine .Thus, it will ultimately result in huge waste of energy. As the basic law of Physics says 'energy can neither be created nor be destroyed it can only be converted from one form to another'. It will be good if we could store this energy somehow which is otherwise getting wasted out and reuse it next time we started to accelerate. That's the basic concept of regenerative ("regent") brakes, which provide braking for the system when needed by converting the available energy to some usable form. These are widely used in electric trains and the latest electric cars. Regenerative brake is an energy recovery mechanism which slows a vehicle by converting its kinetic energy into another form, which can be either used immediately or stored until needed. Thus, the generated electricity during the braking is fed back into the supply system (in case of electric trains), whereas in battery electric and hybrid electric vehicles, the energy is stored in a battery or bank of capacitors for later use. Energy may also be stored by compressing air or in a rotating flywheel. An Energy Regeneration Brake was developed in 1967 for the AMC Amitron.

This was a completely battery powered urban concept car whose batteries were recharged by regenerative braking, thus increasing the range of the automobile. Many modern hybrid and electric vehicles use this technique to extend the range of the battery pack.

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Electric trains, cars, and other electric vehicles are powered by electric motors connected to batteries. When we're driving along, energy flows from the batteries to the motors, turning the wheels and providing us with the kinetic energy we need to move. When we stop and hit the brakes, the whole process goes into reverse: electronic circuits cut the power to the motors. Now, our kinetic energy and momentum makes the wheels turn the motors, so the motors work like generators and start producing electricity instead of consuming it. Power flows back from these motor-generators to the batteries, charging them up. So a good proportion of the energy we lose by braking is returned to the batteries and can be reused when we start off again. In practice, regenerative brakes take time to slow things down, so most vehicles that use them also have ordinary (friction) brakes working alongside (that's also a good idea in case the regenerative brakes fail). That's one reason why regenerative brakes don't save 100 percent of our braking energy

In an electric system which is driven only by means of electric motor the system consists of an electric motor which acts both as generator and motor. Initially when the when the system is cruising the power is supplied by the motor and when the there is a necessity for braking depending upon driver's applied force on the brake pedal the electronic unit controls the charge flowing through the motor and due to the resistance offered motor rotates back to act as a generator and the energy is energy is stored in a battery or bank of twin layer capacitors for later use.

A. Comparison of Dynamic Brakes and Regenerative Brakes

Dynamic brakes ("rheostatic brakes" in the UK), unlike regenerative brakes, dissipate the electric energy as heat by passing the current through large banks of variable resistors. Vehicles that use dynamic brakes include forklifts, Diesel-electric locomotives, and streetcars. This heat can be used to warm the vehicle interior, or dissipated externally by large radiator-like cowls to house the resistor banks.

The main disadvantage of regenerative brakes when compared with dynamic brakes is the need to closely match the generated current with the supply characteristics and increased maintenance cost of the lines. With DC supplies, this requires that the voltage be closely controlled. Only with the development of power electronics has this been possible with AC supplies, where the supply frequency must also be matched (this mainly applies to locomotives where an AC supply is rectified for DC motors).

A small number of mountain railways have used 3-phase power supplies and 3-phase induction motors. This results in a near constant speed for all trains as the motors rotate with the supply frequency both when motoring and braking.

III. ULTRACAPACITOR

Ultracapacitors function as per secondary batteries in terms of storing and delivering energy. However, the charge storage mechanisms itself is very different compared to batteries. A supposed to batteries, which produce electric charge through chemical processes, ultracapacitors store energy in the form of static charge. Since the energy is stored in the same from that it is used, ultracapacitors offer faster charging and discharging rates compared to batteries of similar volume. The energy densities of ultracapacitors are however comparatively less than that of batteries by a factor of 10 to 20 [14]. As such, ultracapacitorsare not substitutes as secondary batteries but rather regarded as complementary power delivery device. Having a high power density enables ultracapacitors to be employed in a complementary manner with high energy density secondary batteries to form hybrid energy storage systems.

An ultracapacitor cell construction consists of two electrodes, a separator, and an electrolyte illustrated in Figure 2. The electrodes consist of two parts, a metallic current collector and a high surface area active material. A membrane called the 'separator' separate the two electrodes. The separator permits the mobility of charged ions but prohibits electronic conduction. This composite is subsequently rolled or folded into a cylindrical or rectangular form and stacked in a container. Then the system is impregnated with an electrolyte, which is either a solid state, organic or aqueous type. The decomposition voltage of the electrolyte determines the maximum operating voltage of an ultracapacitor. Owing to the very small separation distance between the electrolytes, as well as the large effective surface of the active material, large capacitance magnitudes in terms of Farads are obtainable.

The magnified insert in Figure 2 illustrates the large surface area of the active material. Ultracapacitors are not constrained to the same physical limitations as dielectric capacitors. The discharge characteristics and equivalent circuits of ultracapacitors are similar to conventional low farad capacitors but there are some fundamentally different properties between the two types. The large capacitance ultracapacitors arise from the very large specific area obtainable from the use of porous nano-carbon materials.

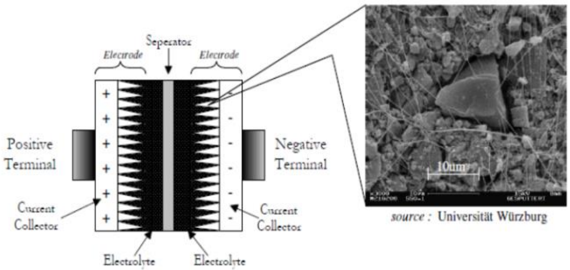

Fig 2. Basic cell construction of an ultracapacitor

At present, there are several propositions of ultracapacitor model representation [15]. The simplest of all is the classical equivalent circuit with the lumped capacitance, equivalent parallel resistance (EPR) and equivalent series resistance (ESR). Figure 2 shows the classical equivalent circuit with the three parameters. Determination of these parameters provides a first approximation of an ultracapacitor cell The EPR represents the current leakage and influences the long-term energy storage. In multiple series connections of ultracapacitors, the EPR influences the cell voltage distribution due to the resistor divider effect. [16] showed that the EPR is related to the voltage decay ratio by,

$$EPR = \frac{-V}{ln ln \left(\frac{V_2}{V_1}\right) C} \qquad (5.2.1)$$

Where

V1 is the initial voltage,

V2 is the final voltage and C is taken as the rated capacitance.

Through experimental measurements of voltage decays of several ultracapacitors having various capacitance values, it was shown that the EPR effects could be neglected for transient discharge calculations. However, the EPR value is important when cell balancing of series connected ultracapacitors is considered. Section 5.8 describes cell balancing in more detail. Examining the ESR effects, further empirical verifications [17]

IV. PROCEED MODEL

Matlab/Simulink version 7 R2009b is being used as a tool for simulation .For simulation purposes in place of OHP cable a 25KV power supply is used. Popular two quadrant chopper model DC6 is used to study normal and braking modes. The battery bank or ultra-capacitor is considered as 72V 100Ah

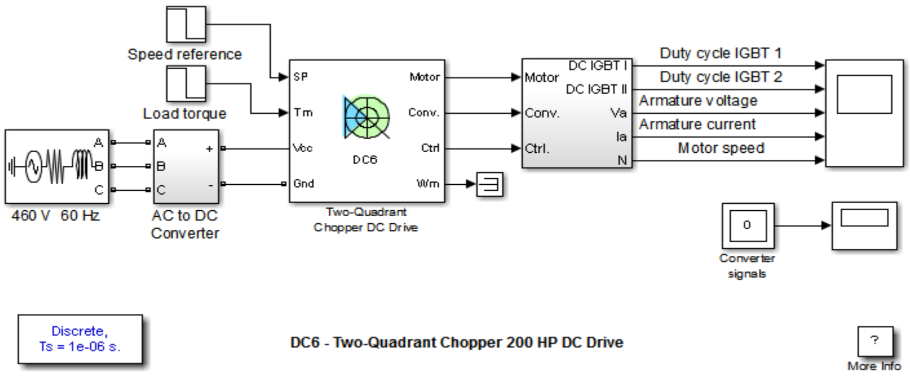

Fig.3 Block Diagram of Experiment Setup of System

To change over between battery bank and main power supply current direction is taken as feedback. At the reverse direction of current a contactor is operated automatically that redirects the braking generated EMF to the battery bank. Further a charging control system can be used to regulate the current being supplied to the battery bank. And that will also take care of overcharging and deep discharge. On normal run i.e. on first quadrant operation system operates normally in motoring mode. Speed and torque values are taken as variables that represent engine speed and torque. Depending on theses values chopper switching pulses are generated.

V. RESULT

Study of traction engine is done for the basis of our model. it is found that heat loss occurring in the resistance used in regenerative braking can be utilized for other electrical device and also for charging battery banks and ultra capacitor in this way a huge amount of power can be saved . Further this stored energy in battery banks can be transferred to other attached boogies.

VI. CONCLUSION

By the use of these techniques we save a large amount of energy which is wasted on the time of regenerative braking. Same study with some specification changes can be used for hybrid electric vehicle and other locomotives as well. In place of battery bank, ultra capacitor can be used.

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