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CONTROL STRATEGY FOR REGENERATIVE BRAKING IN ELECTRIC VEHICLES

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Abstract – Regenerative Braking system (RBS) is energy recovery process that will slows-down a moving vehicle by converting its kinetic energy into electric energy that can be either use immediately or stores until it is needed. Regenerative braking provides an effective way of extending the driving range of battery powered electric vehicles (EVs). It approaches an analysis of maximum torque control distribution of an electric vehicle for BLDC motor with traction on wheels. This work proposes a Direct Torque Control (DTC) strategy to improve the performance of distributed torque applied to electric vehicles to act during regenerative braking. In this model FUZZY controller for BLDC motor is used and is compared with PI controller. The proposed work will be carried out using MATLAB/Simulink software.

***Key Words*:** Regenerative Braking, Fuzzy logic control, bi directional DC-DC converter, Direct Torque Control (DTC) method.

1. INTRODUCTION

Electric vehicles have become more prevalent in the automotive world due to their efficiency and ability to harness the power of renewable, sustainable energy. These features, in particular, are known to help the environment in several ways. Besides using renewable energy as a power source, electric vehicles help the environment by reducing pollution levels due to zero emissions at the point of transport. As we all know that now a day, most of the modern vehicles are making use of technologies such as regenerative braking system (RBS) for energy recovery. Electric vehicles employ brakes to enhance the roughness of the wheel in order to decelerate. Since the EV's kinetic energy is converted back into electric energy. Regenerative brakes use electric motors rather than a traditional friction braking system to slow down and stop a vehicle. Regenerative braking uses the mechanical energy from the motor by converting its kinetic energy into electrical energy. Regenerative braking system is a technology applicable in both conventional and electric vehicles. The configuration of the EV case study with traction in two front-wheels is considered a method of torque control for driving the Brushless DC machine (BLDC) with Pulse Width Modulation (PWM). Direct Torque Control (DTC) strategy is used by the high power BLDC machine reducing oscillations and providing a safety to the passengers, what allows better torque control under decelerations what can be used at electric vehicles. This work develops a simulation tool and proposes control strategy to improve the performance of distributed torque applied to electric vehicles to act during regenerative braking and store energy.

Regenerative brakes are a great way to preserve the range of an EV and improve the efficiency of a hybrid. Regenerative brakes work by reversing electric motors that propel a car. It works like a generator and feeds energy back into the hybrid or electric system to help replenish a little bit of range. These small boosts in battery range can accumulate and improve efficiency over time when used regularly.

2. PROPOSED METHOD

The main objective of this regenerative braking system is to recover braking energy which can be achieved by the reversal of current in the motor-battery circuit during deceleration, taking advantage of the motor acting as a generator, redirecting the current flow into the supply battery and to increase the efficiency of using electrical vehicles. In this dc-dc converter

In this work the regenerative braking system (RBS) is adapted to Brushless DC (BLDC) motor with a Direct Torque Control (DTC) strategy using fuzzy controller and the result obtained with fuzzy logic controller is compared with the PI controller. Fuzzy Controller and Pi Controller are the main sections in this proposed method.

3. POWER ELECTRONIC CONVERTER SYSTEMS

a. DC-DC Converter

The bi-directional dc-dc converter is used to achieve the required voltage and current values of electric machine and battery in both operation modes. The current direction is reversed according to motor and generator mode of the electric machine. The acceleration of electric machine is based on current supply of batteries in motor operation mode. On the other hand, the generator mode requires transferring the generated current of machine to charge the batteries.

b. Pulse Width Modulation

Pulse width modulation (PWM) is the most effective means to achieve constant voltage battery. It is a technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices; PWM has many advantages and is the most widely used solution for brushless DC drivers. Setting an adequate PWM voltage and using a high PWM frequency will help to reduce the ripple and can avoid the use of additional inductances. Using PWM allows precise current control in the windings. Hence, the output torque, which is linearly proportional to the average winding current, can be correctly controlled in coreless motors.

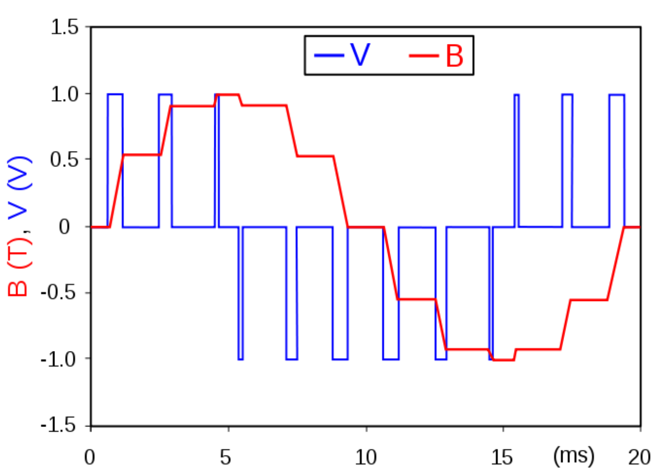

Fig 3.1 wave for combined positive and negative pulse

4. PI CONTROLLER

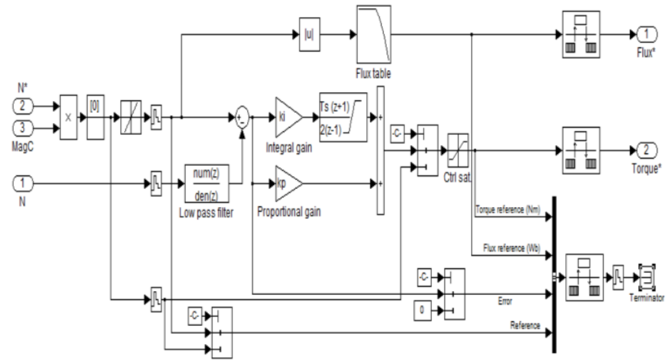

Fig. 4.1 Simulink model using DTC of RBS in EV with PI Controller

PI controller is the most part used to take out the steady state error coming about because of p controller. Be that as it may, as far the speed of the response and overall stability it has a negative effect. This controller is for the most part utilized as a part of regions where speed is not an issue. Since PI controller has no capacity to anticipate the future error, it can't diminish the rise time and wipe out the oscillations .On the off chance that connected, any measure of I ensures set point overshoot.

5. FUZZY LOGIC CONTROLLER

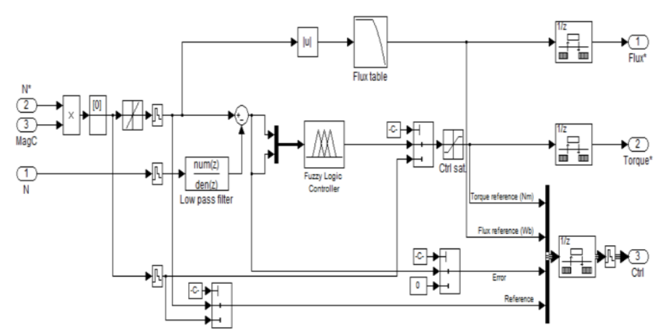

Fig. 5.1 Simulink model using DTC of RBS in EV with Fuzzy Controller

Fuzzy logic is a reasoning procedure of critical thinking control philosophy used in control system engineering, to control system when sources of info are either imprecise or the mathematical models are not present by means. Fuzzy logic can handle a sensible number of sources of info however the complexity nature increment with the

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expansion in the quantity of data sources and outputs consequently distributed processors would presumable be less demanding to execute it is an idea or problem solving methodology to control non-linear systems.

The idea behind the fuzzy logic controller (FLC) is to fuzzify the controller inputs and infer the proper fuzzy control design based on defined rules. Fuzzy knowledge based system. The FLC output is then produced by defuzzifying these inferred fuzzy controlled decisions. Thus the FLC process contain following main components

a) Fuzzification
b) Rule Base
c) Inference Engine
d) Defuzzification

6. SIMULATION RESULTS

6.1 Simulation results of battery with PI controller

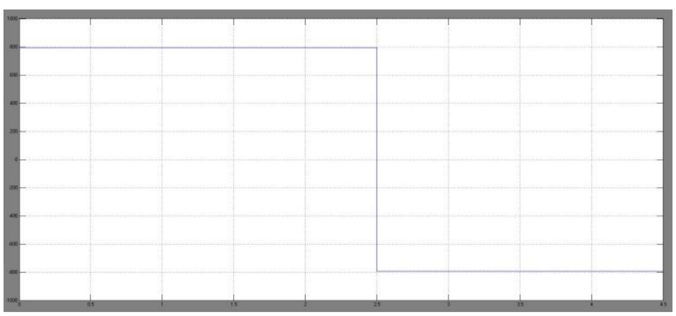

Fig. 6.1 Motor and Generator torque with PI controller

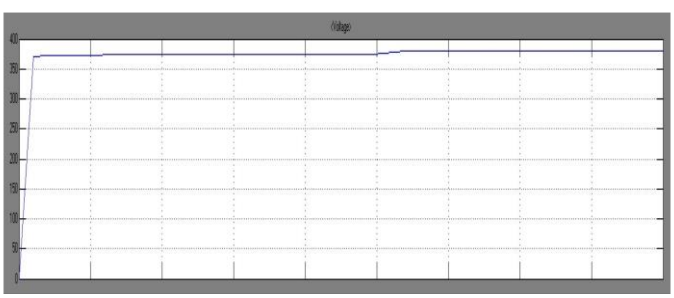

Fig. 6.2 Voltage of a battery

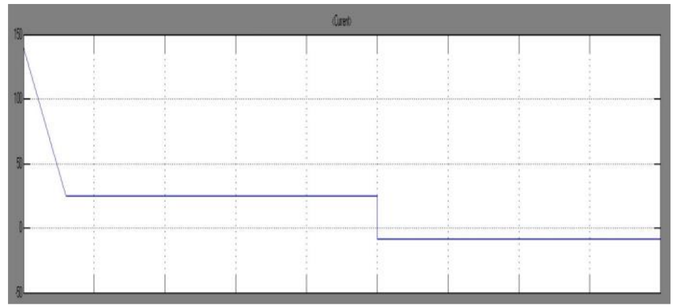

Fig. 6.3 Current of a battery

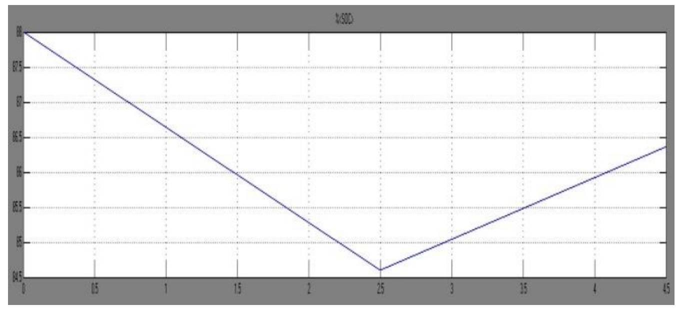

Fig. 6.4 SOC of battery with PI Controller

Fig. 6.1, Fig. 6.2, Fig. 6.3, and Fig. 6.4 shows the simulation results of Torque, Voltage, Current and State of Charging of a battery using DTC of RBS in EV with PI controller.

6.2 Simulation results of a battery with Fuzzy controller

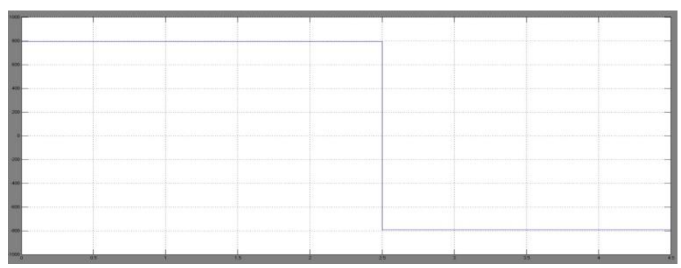

Fig. 6.5 Motor and Generator torque with Fuzzy controller

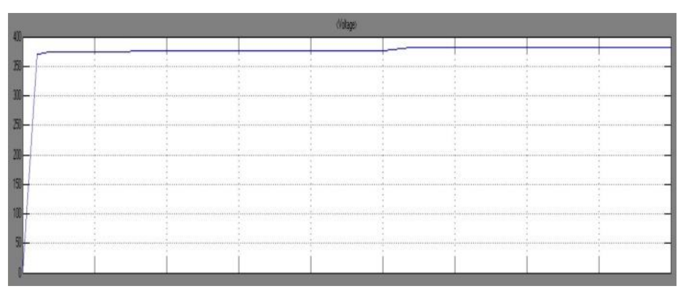

Fig. 6.6 Voltage of a battery

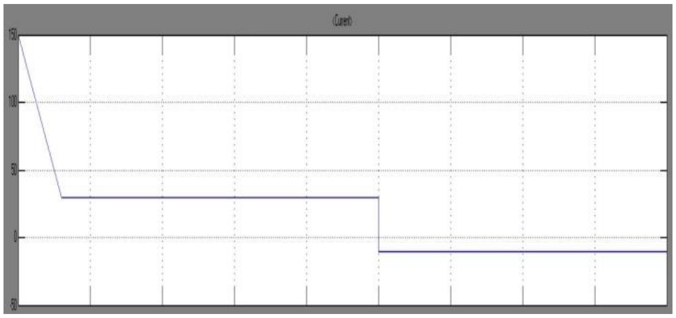

Fig. 6.7 Current of a battery

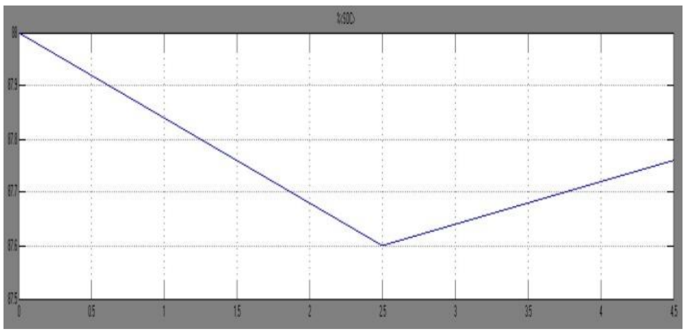

Fig. 6.8 SOC of battery with FUZZY Controller

Fig. 6.5, Fig. 6.6, Fig. 6.7, and Fig. 6.8 shows the simulation results of Torque, Voltage, Current and State of Charging of a battery using DTC of RBS in EV with Fuzzy controller.

The bi-directional dc-dc converter is controlled with PI Controller and Fuzzy Controller according to the rules. When the battery is discharged, the BLDC machine is operated in motor mode and variable positive torque values are applied to the BLDC machine and condition of the battery is observed.

i. According to simulation result, as shown in the fig. 6.4 the battery SOC of Battery with PI Controller is reduced from 88% to 84.5% and after the regenerative breaking the battery SOC is increased from 84.5% to 86.4%.
ii. According to simulation result, as shown in the fig.6.8 the battery SOC of Battery with Fuzzy Controller is reduced from 88% to 87.337% and after the regenerative breaking the battery SOC is increased from 87.337% to 87.7%.

By comparing the results obtained using fuzzy controller with the results of PI controller it is observed that the state of charging using Fuzzy Controller after Regenerative Braking is more than the state of charging using PI Controller and the battery voltage and current remains same for both the cases.

7. CONCLUSION

This work puts forward control strategy for regenerative braking with electric vehicle modeling driven by a Brushless DC Machine (BLDC) in a passenger vehicle. The use of Direct Torque Control (DTC) strategy allowed us to obtain an adequate procedure of braking.

The bi-directional dc-dc converter is controlled with PI and Fuzzy Logic Controller according to rules. When the battery is discharged, the BLDC machine is operated in motor mode and bi-directional dc-dc converter is operated in boost mode. When variable positive torque values are applied to the BLDC machine the voltage, current and SOC of the battery is observed. When the battery is charged, the dc machine is operated generator mode and bi-directional dc-dc converter is operated in buck mode. Variable negative torque values are applied to the BLDC machine the voltage, current, SOC of the battery is observed.

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