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Utilization of Regenerative braking Energy in Electric Vehicle (EV)

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Abstract

This paper proposes a novel regenerative braking scheme for electric vehicle driven by brushless dc motor and uses a new control technique to utilize regenerative braking energy effectively and uses fuzzy logic to utilize regenerative braking energy effectively. Drawback of electric vehicle is that long travelling, distance covered between two charging stations, less accelerating power during uphill driving. The fuel efficiency and driving range of electric vehicle can be improved by regenerative braking energy. To provide smooth brake, the electric brake distribution is realized through Fuzzy Logic Controller (FLC). The battery has high energy density however low power density yet super-capacitor has low energy density yet high power density. Keeping in mind the end goal to conquer the faults a battery super-capacitor crossover energy stockpiling framework is utilized. During uphill driving the electric vehicle requires more power for climbing, according to the load and required power a hybrid super-capacitor battery energy storage system is switched. To control motoring and braking in electric vehicle several bidirectional converters are used to integrate batteries and super-capacitors. The braking action in regeneration is much affected because of discontinuous input current at motor end and regenerative braking failure at lower back-EMF.

1. Introduction

Among all type of energy sources fossil fuels are most desirable type and this kind is going to be finished. Some issues such as global warming and environmental pollutions are the effects of fossil fuel usage [1]. It is important to find other ways to reduce energy consumption and reuse wasted energy. The electrical energy can be converted from kinetic energy during braking process [2]. Regenerative braking energy can be converted by power electronic devices into electrical energy. An efficient energy storage system not only reduces the fuel consumption but also stabilizes the line voltage and reduces the peak input power, resulting in lower losses. The best way to regenerative braking energy is super-capacitor-battery HESS. The use of HESS has numerous points of interest, for example, high power density of super capacitors can be utilized to viably outfit the kinetic energy of vehicle amid braking. Super-capacitor can help the battery pack in top power requests which drags out the battery life time, as well as enhances the vehicle acceleration. Since the braking energy could be effectively saved, the vehicles driving range can be considerably increased [3]. The motor terminal voltage and voltage level of sources is different in electric vehicle. The batteries and super-capacitors are operated at low voltage level. To improve efficiency the motor unit is operated at high voltage level. Due to lower back EMF, the amount of power drawn from motor unit through regenerative braking is limited. When motor terminal voltage reduces lower than source voltage at that instant traditional power converter fails to extract power at regenerative braking mode.

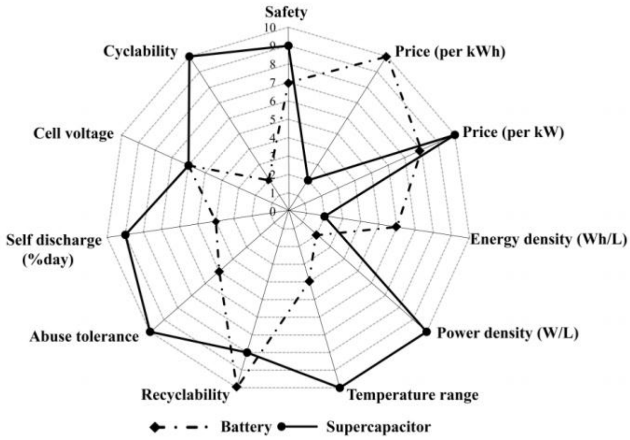

Fig. 1.Qualitative comparison of super-capacitor and battery

2. Proposed system

Through the acceleration of brake pedal and accelerator the driver block delivers the desired a brake torque and drive torque. Drive torque request is send to the vehicle through various drive train mechanism, battery and motor according to the rate of depression of accelerator pedal. Regeneration begins only when brake pedal is pressed. When brake pedal is depressed, as per the position of brake pedal relating extent of brake torque is applied. The regenerative brake control methodology is isolated into two, regenerative braking and friction braking [4]. The aerodynamic friction losses, rolling friction losses, and the energy dissipated in the brakes have an adverse effect on the amount of mechanical energy consumed by a vehicle when driving a pre-specified driving pattern. Figure 2 shows the proposed system for regeneration of energy in electric vehicle. The current from the BLDC motor and controlled current are compared and that is given to the PID controller, duty cycle is adjusted to charge/ discharge the battery and/ or super-capacitor.

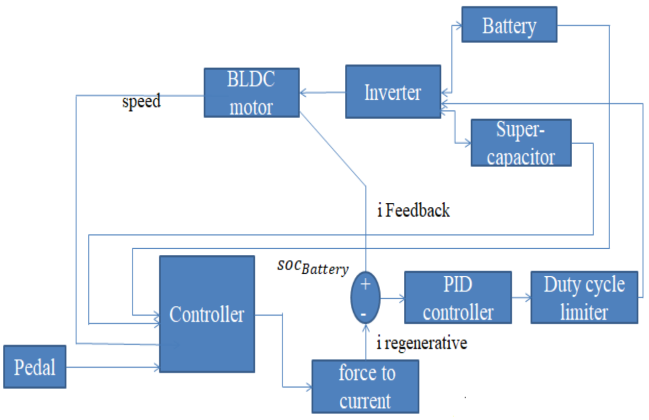

Fig. 2.Proposed System

Table I. Design parameters for modeling of brushless dc motor for electric vehicle

Sl.No	Design Parameters	Rating
1	Rated Current	33A
2	Rated Speed	3000 rpm
3	Moment of Inertia	0.0027 Kg-m^2
4	Frictional Force	0.00042924 N-m/s
5	Stator Resistance	0.0485 ohms
6	Magnet Flux Induced	0.1194 Wb

3. The Structure of Fuzzy Logic Controller

3.1 The structure of FLC

Mamdani fuzzy controller has high operational efficiency, coordinates with linear control theory, employs adaptive technology and ensures output plane continuity. As per the impact components of regenerative braking, the FLC framework essentially includes three principle subsystems i.e. FLC input fuzzy variables, output fuzzy variables, and the fuzzy rules. The input variables are the driver's required braking force, vehicle speed and batteries' SOC and output variable is the ratio between the regenerative braking force and the total braking force [8]. The structure of FLC is shown in Fig. 2.

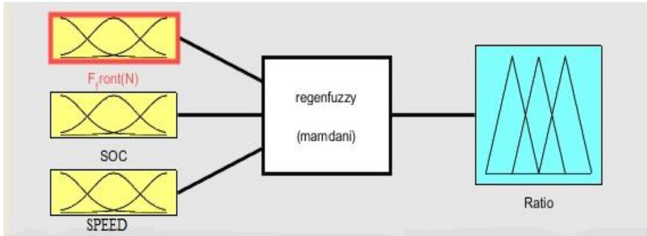

Fig. 2.Structure of FLC

3.2. Input/ Output membership Functions

Figure 3 shows the membership functions for one of the input force. We cannot determine the accurate range of membership functions and assuming the membership functions as low, middle and high and universal discourse is [0,1].

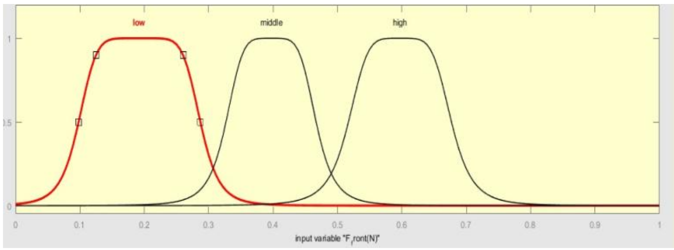

Fig. 3.Membership functions for force

Figure 4 shows the membership functions for one of the input SOC. We cannot determine the accurate range of membership functions and assuming the membership functions as low, middle and high and universal discourse is [0,1].

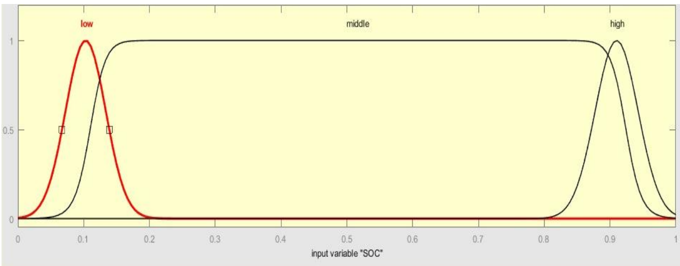

Fig. 4.Membership function for SOC

Figure 5 shows the membership functions for one of the input speed. We cannot determine the accurate range of membership functions and assuming the membership functions as low and high and universal discourse is [0, 3000].

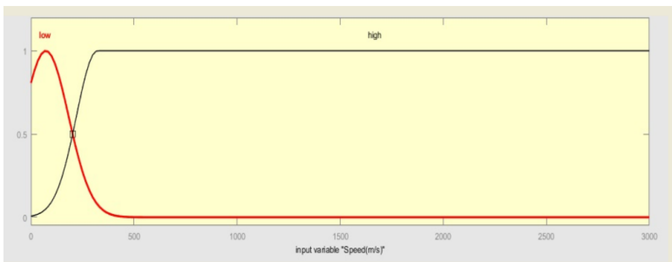

Fig. 4.Membership function for SOC

4. Simulation Results

Figure 4 shows that the MATLAB/Simulink model of brushless dc motor for electric vehicle for regeneration.

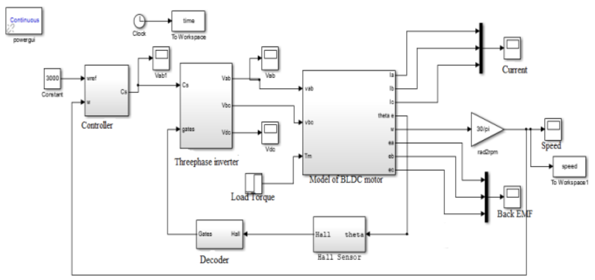

Fig. 4.MATLAB/Simulink model of BLDC motor electric vehicle

Figure 5 shows the speed characteristic of brushless direct current motor. Simulation results shows that the speed of the motor is obtained 3000 rpm which is the speed rating of the desired system.

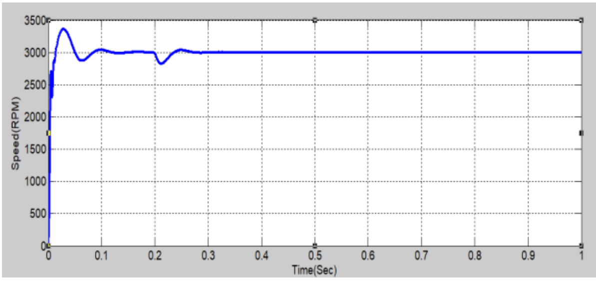

Fig. 5.Simulated speed curve of brushless dc motor for electric vehicle

Figure 6 shows the simulated current curve, the current rating according to the design parameter is 33 A.

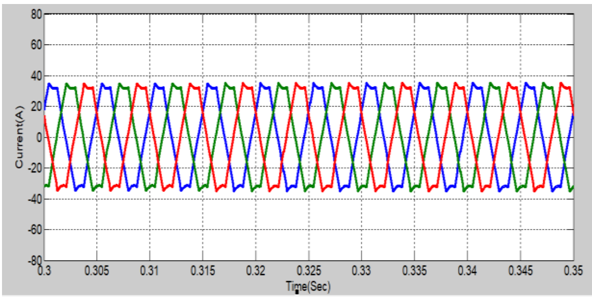

Fig. 6.Simulated current curve of brushless dc motor for electric vehicle

Figure 7 shows the torque curve of the brushless dc motor according to the design it is 5.2 A. The simulated torque is 4 A.

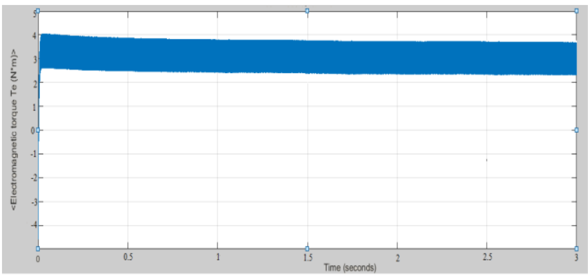

Fig. 7.Simulated current curve of brushless dc motor for electric vehicle

Figure 8 shows the MATLAB/Simulink model when brake is applied.

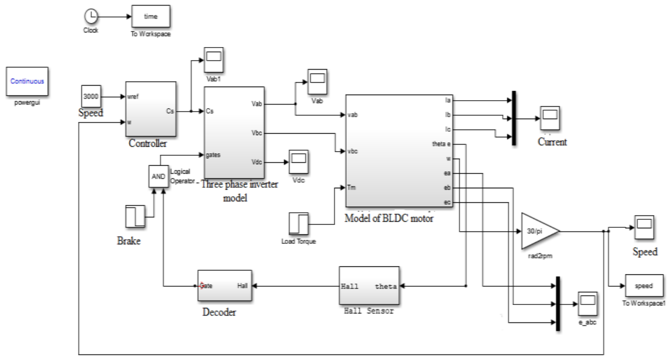

Fig. 8.MATLAB/Simulink model of BLDC motor when brake is applied

Figure 9 shows the simulation result of brushless dc motor when brake is applied.

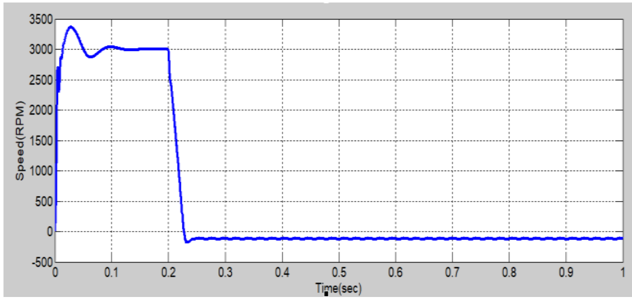

Fig. 9.Simulation of BLDC motor when brake is applied

Figure 10 shows the MATLAB/Simulink model of proposed system for regenerative braking

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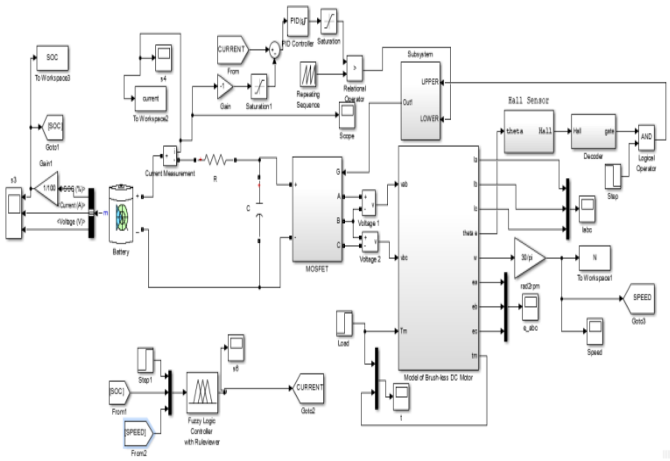

Fig. 10.MATLAB/Simulink model of BLDC motor for proposed system

Figure 11 shows the simulation result of battery state of charge (SOC) when brake is applied. The battery state of charge gradually reduced when the vehicle is running, and after the time 2sec a brake is applied at that time the SOC increases.

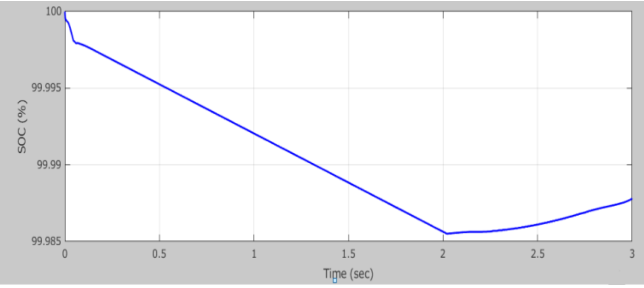

Fig. 11.Simulation result of battery state of charge

Figure 12 shows the torque curve when brake applied at 2 sec the torque become negative.

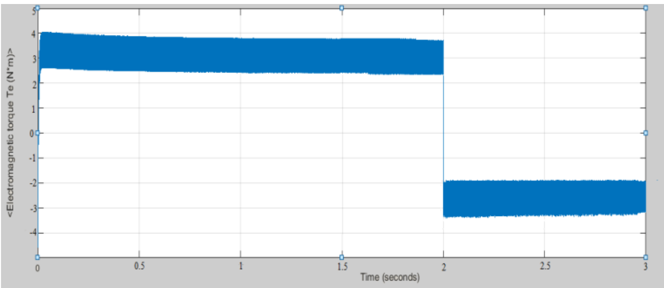

Fig. 12.Simulation result of battery state of charge

5. Conclusion

Utilizing regenerative braking of electric vehicle can reduce the energy consumption to an extent which reduces the environmental pollution and reuse the wasted energy proper switching schemes. It increases the driving range of electric vehicle. For the sudden braking of an electric vehicle instantaneous power is very high in-order to store this huge amount of power for a short time, high power density storage source is needed super capacitor is used here. By combining a high energy density source to a high power density source can get the advantage of both sources. HESS using battery and super-capacitor are proposed also nonlinear control techniques will implement for the effective utilization of regenerative braking energy.

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