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A Bidirectional Control Regenerative Braking Strategy for EV Applications- A Review

Shubham Anil Davane[1], Souras Ghotekar[2], Saurabh V Lawate[3]

Students of Department of Electrical Engineering Vidarbha Institute of Technology, Nagpur, India[1]

Assistant Professor Department of Electrical Engineering Vidarbha Institute of Technology, Nagpur, India[2]

Assistant Professor Department of Electrical Engineering Vidarbha Institute of Technology, Nagpur, India[3]

Abstract: *In this paper, Review on bi-directional DC/DC buck-boost converter with dual control strategy during regenerative braking is used for a two-wheeler application. To reduce the harmful emissions from automobiles and massive surges in fuel prices, automotive electric vehicles are an effective alternate solution. In this paper, a cascaded bi-directional DC/DC buck-boost converter with dual control strategy during regenerative braking is used for a two-wheeler application. The dual control strategy with the cascaded converter is used to increase the average power stored during the braking period and to reduce the vehicle's stopping time. The converter with the proposed control strategy used in this work has made it possible to charge the battery even when the back emf of the machine is less than the battery voltage. A fuzzy logic control strategy is used to consider the non-linear factors like SOC, speed of the vehicle and the required brake force. This is done in order to make the system more reliable and realistic. implementing the dual control strategy, the average power stored by the battery is increased by 2.5 times and the vehicle comes to halt faster in comparison with the existing control strategy. The versatility of the strategy is shown by examining three different scenarios during the regenerative braking process.*

Keywords: Regenerative Braking, Bidirectional Converter, Fuzzy, SOC.

I. INTRODUCTION

In today's world of dwindling resources and ever increasing prices, spending a lot on fuel has become a major part of the economic budget. Reducing fuel consumption can have a major impact on decreasing the capital spent on fuel. To achieve this, hybrid electric vehicles (HEV) and plug in hybrid electric vehicles (PHEV) [2] are an alternate solution. Installation of high energy battery packs and regenerative braking play an important role in improving the drive range [7] of the electric vehicles as well as improving the battery life.In order to extract the maximum electrical energy from the rotational mechanical energy, DC/DC converters with appropriate charging and discharging profile are required. Various topologies of DC/DC converters have been discussed in . However, regenerative braking [7], has to be carried out with the conventional frictional braking. In the braking process, there are two issues that are to be addressed. First is accurately applying the brakes which restrains the vehicle speed and maintains the vehicle's travelling course. And the second issue is to recover the braking energy to increase the energy efficiency of the battery. In practical scenario, factors like state of charge (SOC) of batteries, speed of the vehicle and driver's brake force requirements limit the effectiveness of electric braking. Thereby mechanical braking has to be incorporated along with regenerative braking. In literature, many works on regenerative braking and various algorithms for the control during the regenerative braking are proposed. The work proposed a method wherein vehicle's speed is taken into account and not the SOC. Authors in [4] have taken the SOC into account and computed the regenerative force. However, the above works have not stated any methods to utilize the regenerative power to charge the battery. Works carried out in [5] and [6] have used different topologies of bi-directional DC/DC converters to charge the battery. However, the converters used in the works do not address the issue that arises if the terminal voltage of the machine falls below the battery voltage during low speed of the vehicle. The back emf is neglected when the battery voltage is greater than the terminal voltage of the machine.In this paper, the focus is on the dual (voltage and current) control strategy which is used to extract the maximum possible energy during the regenerative braking and to ensure that the vehicle stops in an optimum time frame. In addition, fuzzy logic control is used to determine the battery charging current as its determining factors (SOC, vehicle speed and brake

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force requirement) have an uncertain relation with it. In addition, a cascaded bi-directional DC/DC buck-boost converter with a PMDC machine has been used. This is done to charge the battery even when the back emf of the PMDC machine is less than the battery voltage and at the same time have an effective braking while taking the safety issues and battery conditions into consideration. In this paper we have PV as parallel source to the battery

II. LITERATURE REVIEW

SR. NO	TITLE OFPAPER	AUTHOR ANDPUBLISHED	SIGNIFICANCE
1	A Dual control Regenerative Braking Strategy For Two Wheeler	Siddharth Mehta, S. Hemamalini*, Science Direct.com by Elsevier, 1st International Conference on Power Engineering, Computing and CONtrol,	This paper has focused on increasing the energy stored by the battery during the regenerative braking process in order to make the system more reliable and
	Electric Vehicle	PECCON-2017, 2-4 March 2017,VIT University, Chennai Campus	reduce the vehicle stopping time. More energy is stored in the battery during the regenerative braking process, by charging the battery even at low back emf, which is achieved by using the cascaded bi-directional converter with the proposed strategy [1].
2	Regenerative Braking System of Electric Vehicle Driven by Brushless DC Motor	Xiaohong Nian, Fei Peng, and Hang Zhang, IEEE Transactions on Industrial Electronics, vol. 61, no. 10, pp. 5798-5808, OCTOBER 2014.	By using PID control and Fuzzy control it is possible to produce constant brake torque. So, vehicle average stopping time reduces [2].
3	An Efficient Battery Charging Algorithm based on State- of-Charge Estimation for Electric Vehicle	Jung-Song Moon, Jung-Hyo Lee , In-Yong Ha Taeck-Kie Lee Chung-Yuen Won, International Conference on Electrical Machines and systems, Beijing, China 20-23 August 2011.	This paper uses the charging algorithm improved CC-CV method. This method uses the SOC and the simple SOC estimation method. By using this method the total charge time is reduced and the battery is maintained safely during battery charging [3].
4	Regenerative Braking Torque Estimation and Control Approaches for A Hybrid Electric Truck	Xiangpeng Yu, Tielong Shen, Gangyan Li and Kunihiko Hikiri, 2010 American Control Conference Marriot Waterfront, Baltimore, MD, USA, June 30- July 02, 2010	In this paper, a regenerative braking torque estimation approach is proposed which requires the wheel speed measurement only. Based on the estimated regenerative braking torque, a feedback braking torque

III. TYPES OF BRAKING

The methods of braking employed in an induction motor drive can be classified into:
Regenerative braking, b) Plugging or reverse current braking, c) Dynamic or DC Rheostatbraking.

a) Regenerative braking

In regenerative braking the generated energy is supplied to the source. Here, the rotor speed becomes greater than the synchronous speed, the relative speed between the rotor conductors and air gap rotating field reverses. This reverses the rotor induced emf, rotor current and component of the stator current which balances the rotor ampere turns. Consequently, the phase angle between the stator phase voltage and stator phase current becomes greater than 90 degrees. In this situation, the motor satisfies the condition that the back emf is greater than the rate rated voltage, reversing the directionof the armature current making it negative. Thus, power flow reverses, resulting in regenerative

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braking. For variable voltage sources, regenerative braking is possible for below rated speed. As demonstrated in Fig. 2.1., the kinetic energy available to bereabsorbed after regenerative braking undergoes losses before getting stored in the battery. However, in the case of mechanical braking, all of this dissipated energy is wasted, thus making regenerative braking advantageous. [16]

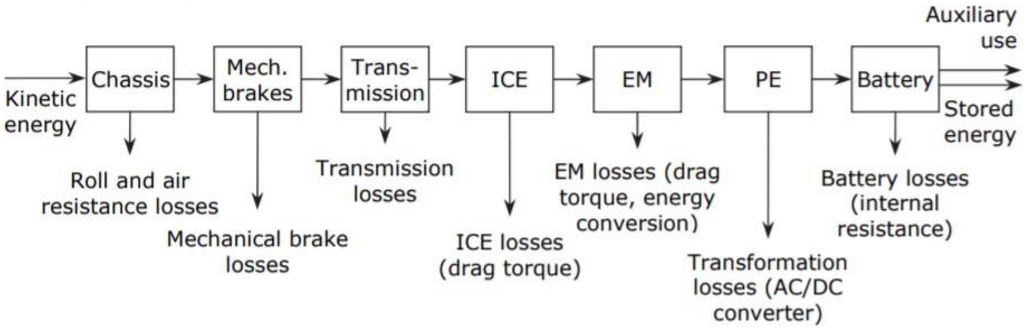

Fig. 1. Energy regeneration process with potential losses

b) Plugging or reverse voltage braking: In plugging, the supply voltage of a separately excited motor is reversed so as to assist the back emf in forcing the armature current in the reverse direction. When the phase sequence of the supply of the motor running at a speed is reversed by interchanging the connections of any two phases of the stator with respect to supply terminals, operation shifts from motoring to plugging. Reversal of phase sequence reverses the direction of the rotating field. Plugging helps reach fast braking due to the high average torque, even when there is a section of series armature resistance connected to limit the armature current. Since torqueis not zero at zero speed, when utilized for stopping a load, the supply voltage must be disconnectedwhen close to zero speed. It is a highly inefficient method due to generated power and power supplied by sources is also wasted on the resistances.[16]

c) **Dynamic or rheostat braking:** In dynamic braking, the motor armature is disconnected from the source and connected across the resistance. It is also obtained when the motor is run on a single-phase supply by disconnecting one phase from the source or leaving it open or connecting it withanother machine phase. When connected to a 1-phase supply the motor can be considered to be fed by positive and negative sequence three- phase sets of voltages. Net torque produced by the machine is the sum of torques due to top positive and negative sequence voltages. When the rotorhas a high resistance, the net torque is negative and braking operation is obtained. In dynamic braking, a large amount of energy is dissipated, which leads to the concept of regenerative braking.Dynamic braking is most commonly used when reabsorption of energy is not assured (i.e. lack of system for regenerative braking), with regenerative braking for safety and when vehicles aretravelling up sloping gradients and need to be halted. [6]

IV. PROPOSED MEHODOLOGY

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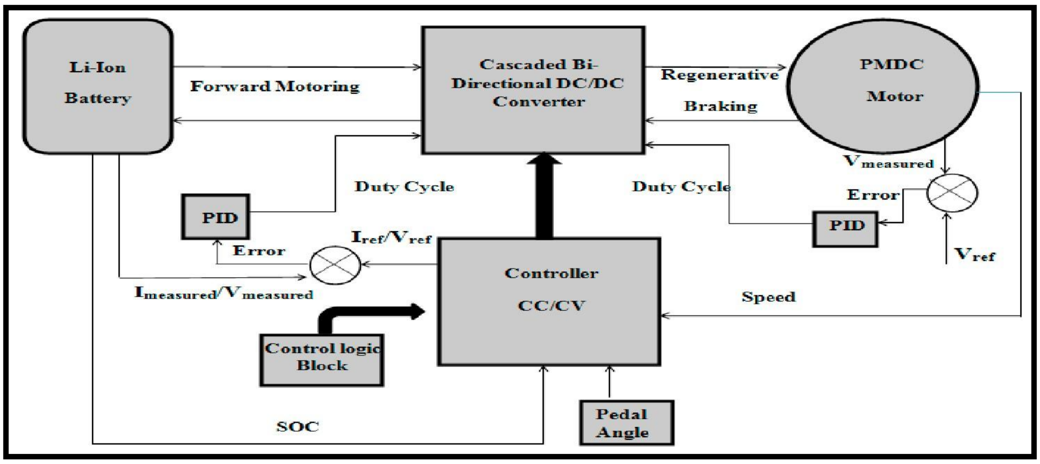

Fig-2 Proposed system

The system consists of a lithium ion battery, permanent magnet DC (PMDC) machine, bidirectional DC/DC buck-boost converter, control logic block. The bi-directional DC/DC converter can operate in both buck and boost mode. The converter operates in boost mode during motoring operation. During regenerative braking mode, the converter can operate in boost or buck mode and the power flow is from the machine to the battery. The mode of operation during the regenerative braking [depends upon the generated voltage at the terminals of the PMDC machine. If the generated voltage is less the than battery voltage, the DC/DC converter operates in the boost mode and if the generated voltage is greater than the battery voltage the converter works in the buck mode.The control logic block functions during the regenerative braking mode and irresponsible for shifting of control strategy from current control (CC) to voltage control (VC) mode during the braking process.

Figure.1. shows the overall configuration of the electric vehicle system, with the dual control strategy we propose. Different parts of this block diagram are simulated on MATLAB/Simulink. The various components include:

- Li-ion battery
- Permanent Magnet DC motor
- Cascaded bidirectional buck-boost dc-dc converter
- Fuzzy logic reference current generator
- Control logic block

V. MODES OF OPERATION OF OPERATION BIDIRECTIONAL CONVERTER

Mode 1: Boost Operation – Battery to DC Bus during motoring operation (Primary Boost Mode)

Switches S3, S4 are off, S1 is on and S2 is in PWM switching mode. The battery voltage is stepped up to the level of the terminal voltage of the PMDC machine. The converter operates in this mode when the PMDC machine is running as a motor. [1]

Mode 2: Buck operation - DC bus to battery during the regenerative braking.

Switch S1 is on, S2 and S4 are off and S3 is in PWM switching mode. The PMDC's terminal voltage is stepped down to the level of battery voltage during the braking operation. The converter operates in this mode when the PMDC machine is operating as a generator and the generated voltage is greater than the battery voltage. [1]

Mode3: Boost operation - DC bus to battery during the regenerative braking (Secondary Boost mode)

The terminal voltage of the PMDC is stepped up to the level of battery voltage. This situation occurs when the generated battery voltage is less than the battery voltage. During this mode S1 and S2 are off, S3 is on, S4 is in PWM switching mode. [1]

Table 1: switching sequence for various operating modes

Mode	S1	S2	S3	S4

1	ON	SW	OFF	OFF
2	ON	OFF	SW	OFF
3	OFF	OFF	ON	SW

V. CONCLUSION

Review on Dual Control Strategy For Two-Wheeler Electric Vehicle" suggests, through the course of this p we have thoroughly studied the proposed control strategy for two-wheeler electric vehicles. We will done so by Understanding the concept of regenerative braking in electric vehicles and why this is particularly useful but difficult for two-wheeler EVs. Understanding how the dual control strategy as well as our chosen components can help extract maximum energy and stop the vehicle safely in a limited time frame, irrespective of speed. Performing modelling of different components comprising the regenerative braking system of the vehicle as per the proposed control strategy. This helped us understand the merits of each component and their contribution to making the process as efficient as possible. The modelling performed on MATLAB/Simulink.

Overall parameter of battery ad motor observed and analyzed using MATLAB which will be better using Proposed Methodology

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