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ANALYSIS OF BI DIRECTIONAL BUCK-BOOST CONVERTER FOR ELECTRIC VEHICLES APPLICATIONS

D.sai madhavi, Ch.Bala Sirisha, G.Karuna Sri, A.Narendra, Mr.A.Abdul Rahiman

Abstract

This study presents the modeling and control of a bi-directional DC-DC converter integrated with a brushless DC (BLDC) motor for all-electric vehicles. The system enables energy recovery through regenerative braking and optimal battery utilization. MATLAB/Simulink simulations are employed to analyze battery performance in motor and generator modes, focusing on parameters such as state of charge (SoC), current, and voltage. The results show effective control and energy flow in both drive and regenerative modes, validating the proposed system’s performance.

1. Introduction

The transportation sector's transition toward sustainable energy solutions has significantly increased interest in electric vehicles (EVs). EVs offer lower emissions and better efficiency compared to internal combustion engine vehicles. Central to EV performance is the efficient management of battery power and regenerative braking, achievable through intelligent power electronic systems such as bi-directional DC-DC converters.

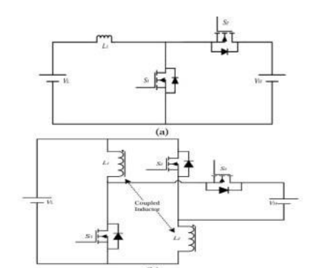

Fig.1. Bidirectional DC-DC Converters (a) Conventional Converter, (b) Proposed Converter.

The proposed bidirectional dc-dc converter employs a coupled inductor with same windings turns in the primary and secondary sides. The proposed converter has the following advantages when compared to conventional bidirectional dc dc converter,1)Higher step-up and step-down voltage gain and 2)lower average value of the switch current under same electric specifications. The operating principles and steady state analysis for step-up and step-down will be described in the following sections. To analyze the steady-state characteristics, the following conditions are to be assumed.1) The equivalent series resistances of the coupled inductor and capacitors, the ON-state resistance RDS(ON) of the switches are ignored- and 2) the capacitor is sufficiently large and the voltage across the capacitor can be treated as constant

OPERATION

1.1. Step-up Mode The proposed converter in step-up mode, the primary and secondary windings of the coupled inductor are operated in parallel charge and series discharge. The proposed converter in step-up mode

DESIGN OF THE DC/DC CONVERTER WITH INTEGRATED

MAGNETIC STRUCTURE The essential building blocks of energy transformation, sifting, electrical disengagement, and energy stockpiling are attractive components like inductors. The size of the attractive component is a significant factor in deciding the size and weight of the converter. In this study, an E-type attractive centre is used to combine the appealing aspects. L1 and L2 are the coupling inductances employed here. According to Fig. 2, Ca is an extra capacitance, L1 is the external inductance, and L2 is the output filter inductor. Table 1 shows how the hybrid energy storage system functions. Without taking into consideration the voltage of Ca is steady state and identical to the output voltages of L2 and L1, eliminating the capacitor's voltage ripple

2. System Design and Methodology

The proposed EV drive system comprises a battery, a bi-directional DC-DC converter, a fuzzy logic controller (FLC), and a BLDC motor. The converter operates in boost mode during motor action (discharge) and buck mode during regenerative braking (charge). The control system modulates the duty cycle of power switches to regulate energy flow.

Key specifications include:

Initial battery voltage: 378 V

Motor operating voltage: 500 V

Simulation analysis of SoC, current, and voltage across different torque conditions

.CLOSED LOOP OPERATION OF THE PROPOSED CONVERTER BY USING PROPORTIONAL INTEGRAL CONTROLLER P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and overall stability of the system, it has a negative impact. This controller is mostly used in areas here speed of the system is not an issue. Since P-I controller has no ability to predict the future errors of the system it cannot decrease the rise time and eliminate the oscillations. If applied, any amount of I guarantees set point overshoot.

Nichols Method To tune in the parameters for the PI controller can be a challenge, and if the time constants in the process are huge the time to do the optimization can be too long! But there are Nichols back in 1942 is well known. It can be used for simulations and is probably the most common for use in real life. This method is used for both open and closed loop systems in the concern project a closed loop converter is to be tuned so explaining about the tuning of closed loop converter. The converter control system should be "closed". This statement means that the controller should be in normal operation. This method follows a given procedure. The procedure is as follows: i. ii. iii. iv. Turn off the I-term and the D-term in the controller. This can be done by setting the reset time (τN =tau_N) to "infinite" and the derivative time (τV =tau_V) to 0. Turn KP =K_P to zero, and the increase it slowly, while you are looking at the controllable variable (y) or - some times better - the output of the controller,u. Increase KP until the output exhibits sustained oscillations. At this "quasi steady-state" point you have the critical gain, called KP,crit=K P crit, and a given period of time, Tcrit=T_crit.

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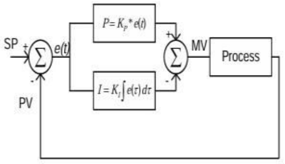

Basic block of a PI controller

3. Battery Storage System

A comprehensive review of battery technologies reveals lithium-ion batteries as the most promising due to their energy density and recharge ability. The battery model incorporates real-world aspects such as SoC monitoring, internal resistance, and charging/discharging characteristics.

To supply a steady load voltage, a straight-line voltage and current regulator is selected. Super-capacitors are able to respond more quickly and recycle the energy when the DC side voltage considerably rises during slowing down. The super capacitor regulators control In Fig. 3, a block diagram is displayed. Where Vdc and Vdc-sen represent the actual and estimated voltages of the DC engine, the supercapacitor, and *UC I and *UC sen I, respectively, and fs is the exchanging recurrence. G1 and G2 are the exchanging signs of T1 and T2,

4. DC-DC Converter Design

The buck-boost topology facilitates both step-up and step-down voltage conversions, supporting the energy dynamics of EVs during acceleration and braking. Simulation analysis covers both continuous and discontinuous conduction modes, validating voltage regulation and power flow continuity.

5. Brushless DC Motor Modeling

The BLDC motor offers advantages like high efficiency, compact size, and low maintenance. The motor's behavior is modeled with electronic commutation and position feedback using Hall sensors. Simulation parameters evaluate torque-speed characteristics under varied load conditions.

6. Simulation and Results

MATLAB/Simulink is used to simulate the integrated system. In motor mode, battery SoC drops from 88% to 87.337%, while in generator mode (regenerative braking), it increases from 87.337% to 87.445%. The results demonstrate stable voltage regulation (500 V), effective torque control, and energy recovery. measured output close to the reference value. The term "two-step controller" is used to describe it. The configuration of the control system, which uses a fuzzy controller to regulate current, is shown in Figure 4. The difference between the measurements of the reference voltage and the actual voltage serves as the input to the fuzzy controller.

Key observations:

Effective battery charge/discharge cycles

Consistent motor voltage under varying torque

Smooth BLDC motor speed response

RESULT : A bidirectional dc-dc converter in Closed Loop Mode by Using Proportional Integral Controller is designed and simulated in this paper. The dynamic performance of the proposed converter by using P-I is better than the open loop performance and also the proposed converter achieves the higher step-up and step-down voltage gains than conventional bidirectional boost/buck converter. The efficiency of the proposed converter in step-up mode is 99.2% and in step down mode is 88.5% at full load condition, which is higher than the conventional bidirectional boost/buck converter.

7. Conclusion

The study confirms the feasibility of using a bi-directional DC-DC converter in EVs to optimize battery usage and enhance regenerative braking. Simulation results demonstrate the system's robustness, making it a suitable candidate for future EV powertrains. Further research can explore hardware implementation and real-time control strategies.

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