Original Research Paper

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Engineering

EFFECTIVE BATTERY MANAGEMENT WITH ULTRA CAPACITOR FOR BLDC FED ELECTRIC VEHICLES

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ABSTRACT Electric vehicle (EV) batteries tend to have degradation due to high peak power and fast charging/ discharging cycles during acceleration and deceleration periods, particularly in Urban driving conditions. Oversized energy storage system (ESS) meets the peak power demand. In order to reduce overall ESS size and extend battery cycle life, battery/ultra capacitor (UC) hybrid ESS (HESS) has been considered as a solution in which UC act as a power buffer to charging/discharging peak power. One of the major challenges in a HESS for EV is to design a controller for good power split between battery and UC. A multi objective optimization problem is formulated to optimize the power split in order to increase the battery lifetime and to reduce the HESS power losses. In this energy management problem, a bidirectional dc–dc converter is used for bidirectional power flow. The proposed controller provides good control action.

KEYWORDS : Ultra capacitor, electric vehicle, supervisory controller.

INTRODUCTION

Electric vehicles play a vital role in transportation sector, because they are cost effective, better efficiency, fuel availability and pollution free. Batteries are used in electric vehicles (EV) as the main energy storage components, but battery alone EV is not suitable for peak power periods. This leads to an oversizing of the batteries in order to deliver high power and to avoid unwanted degradation due to acceleration and braking [3]. In order to improve the battery lifetime, ultra-capacitor (UC) based hybrid energy storage system (HESS) is proposed. HESS, with complementary features of high energy and high power density, can have large energy storage and good power performances at the same time [4]. In addition, battery lifetime can be significantly improved through peak shaving by UC. With the two

independent energy storage components, a degree of freedom arises for the load demand distribution. One of the major challenges in a battery/ultra-capacitor hybrid energy storage system (HESS) for electric vehicles is to design a supervisory controller for real-time implementation that can yield good power split performance. A multi objective optimization problem is formulated to optimize the power split in order to improve the battery lifetime and to reduce the HESS power losses [5]. In this paper a bidirectional DC-DC converter (BDC) is used for proper power flow from source to load and load to source.

Nowadays BLDC motors are widely used in EVs due to its characteristics like high torque, compactness, higher efficiency and easier control strategy [12].

The proposed energy management controller effectively splits the load demand and achieves excellent result of the energy efficiency.

HESS WITH SUPERVISORY CONTROLLER

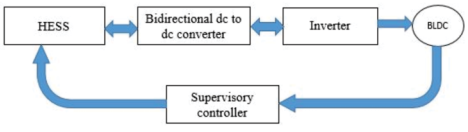


Fig.1 System architecture

Fig.1 shows architecture of proposed system. The proposed system consists of HESS, BDC, inverter, BLDC and supervisory controller. The Fig.2 shows the circuit diagram of HESS with supervisory controller. The BDC contains two switches T1 & T2, two diodes D1 and D2, inductor L and capacitor C.

During acceleration and deceleration periods, UC will act as the charging and discharging device due to its ability to fast act [11].

Fig.3 shows the equivalent circuit for boost mode of operation. In boost mode of operation, the bidirectional dc-dc converter transfers energy from UC to the DC bus by triggering the power MOSFET T2. When S2 is turned on, the UC energy is stored in the inductor. When S2 is turned off, the stored inductor energy is transferred to the load through diode D1, as the voltage at the UC side is more than the load side. Fig.4 shows the equivalent circuit for buck mode of operation. In buck mode, UC pack captures the regenerative energy from DC bus through bidirectional dc-dc converter triggering the power MOSFET T1. When T1 is turned on, the energy is stored in the inductor. When T1 is turned off, the stored inductor energy is transferred to the UC through the diode D1. This is known as regenerative braking mode of operation.

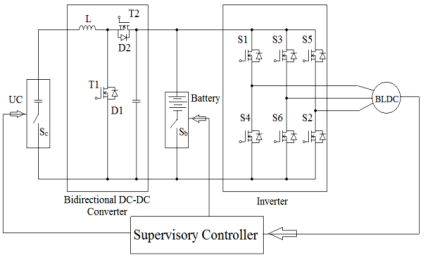


Fig.2 Circuit diagram of the proposed system

SUPERVISORY CONTROL STRATEGY

Fig.5 shows the flowchart of supervisory control strategy. There are two control parameters, minimum battery power (P_{min}) and the power delivered by the batteries to recharge the UCs (P_{Ch}). During braking of the vehicle, all available regenerative power was delivered to the UCs until they reached maximum SOC, with any excess power then delivered to the batteries. During motoring of the vehicle, minimum

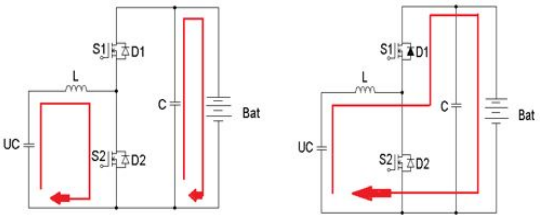


Fig.3 Equivalent circuit for boost mode of operation

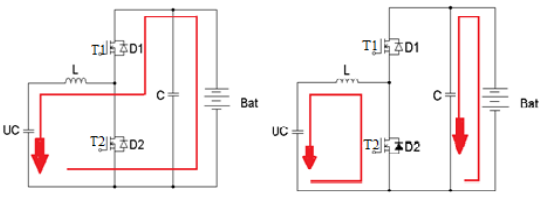


Fig.4 Equivalent circuit for buck mode of operation

power (Pmin) is supplied by the battery and the remaining power is supplied by UC if possible. If UC is not able to supply the remaining power, then batteries supply traction power to the motor and up to P_{Ch} to the UC [11].

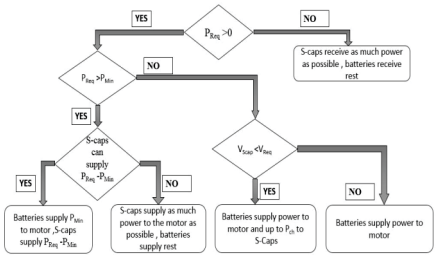


Fig.5 flowchart of supervisory control strategy

SIMULATIONS AND RESULS

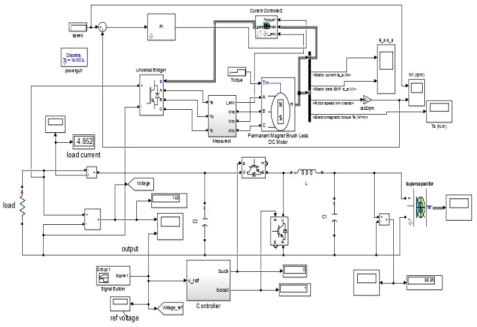


Fig.6 Simulink model for closed loop control of BLDC with UC.

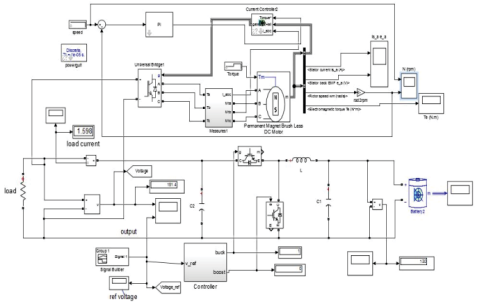


Fig.7 Simulink model for closed loop control of BLDC with battery.

The BLDC motor speed is controlled by dc link voltage control. The dc link voltage is controlled by controlling the duty ratio of switches. A reference voltage is compared with the actual dc link voltage. The corresponding PWM switching signals will be generated. Fig.6 shows simulink model for closed loop control of BLDC motor with ultra capacitor.

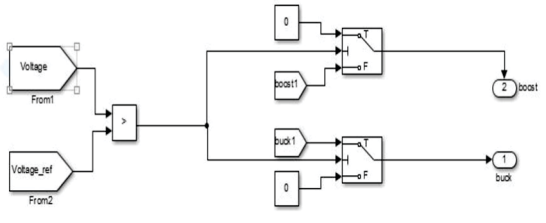


Fig.8 Simulink model for control of BDC

Fig.7 shows simulink model for closed loop control of BLDC motor with battery. Fig.8 shows simulink model for control of BDC. Fig.9 shows reference voltage and output voltage of the BDC with battery, within 0.8 seconds output voltage tracks the reference voltage. Fig.10 shows reference voltage and output voltage of the BDC with UC, within 0.2 seconds output voltage tracks the reference voltage.

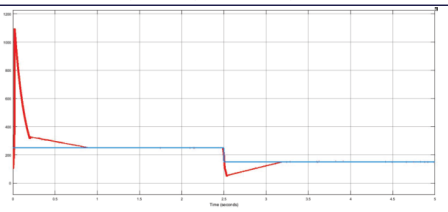


Fig.9 reference voltage and output voltage of BDC with battery

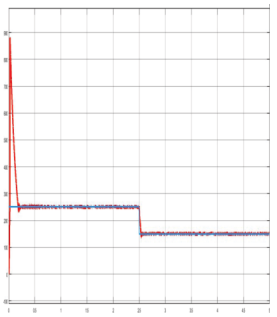


Fig.10 reference voltage and output voltage of BDC with UC

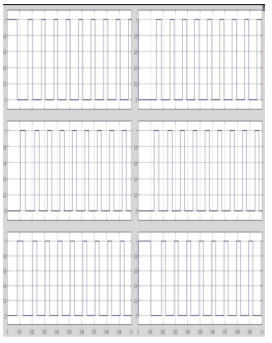


Fig.11 Six inverter pulses for BLDC

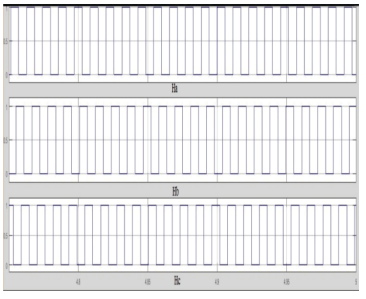


Fig.12 Hall signals of BLDC

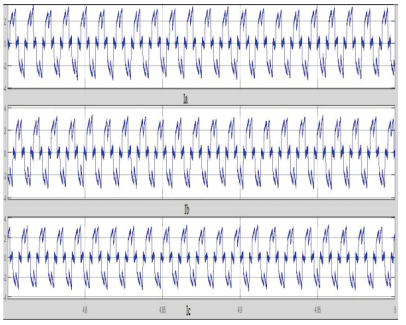


Fig.13 Stator current waveforms of BLDC

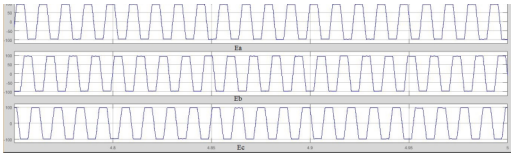


Fig.14 Back emf signals of BLDC

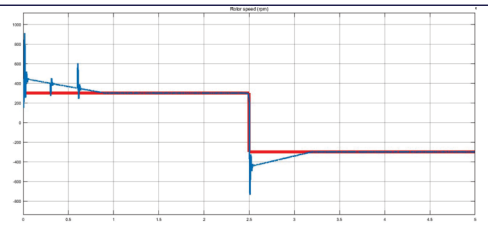


Fig.15 Reference speed and speed response of BLDC with battery

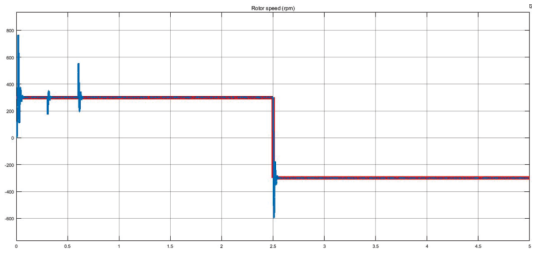


Fig.16 Reference speed and speed response of BLDC with UC

Fig.11 shows six inverter pulses for BLDC motor. Fig.12, 13 and 14 shows hall signals (HA, HB, HC), stator currents (ia, ib, ic) and back emf signals (Ea, Eb, Ec) of BLDC motor.

Fig.15 shows reference speed and speed response BLDC motor with battery. The speed tracks the reference speed within 0.8 seconds. Fig.16 shows reference sped and speed response BLDC motor with UC. The speed tracks the reference speed within 0.05 seconds. BLDC with battery takes more time to track the reference speed as compared to BLDC with UC.

CONCLUSIONS

The motor with UC provides better performance as compared to motor with battery, therefore combination of battery and UC gives faster and better response. The supervisory controller effectively splits the load demand for an UC/Battery HESS and achieves excellent result of both the energy efficiency and the battery lifetime extension. In this HESS energy management problem, a detailed dc–dc converter model is also considered. If the output voltage is higher than the reference voltage, then activate the buck circuit, otherwise activate boost circuit. The proposed system is simulated through Matlab toolboxes.

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