Implementation of DC/DC Converter Interface with Dual Battery Energy Storage using Fuzzy Controller

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Abstract- *In today's world most of the conventional vehicles are using fossil fuels for their operation. Using these fossil fuels leads to emission of Green House Gases (GHG) causing Global warming. Electric Vehicles technology is the alternative way to reduce Global warming and its effect. This paper proposes an interface of Advanced Power Electronics System (bidirectional dc-dc converter) for electric vehicle application using Matlab/Simulink., which can interface main energy storage (ES1) and auxiliary energy storage (ES2), and also dc bus of different voltage levels for various applications in hybrid electric vehicle systems. This proposed topology is capable of delivering power from low voltage dual source to dc link i.e Powering mode and also delivering power from high voltage dc link to dual source i.e regenerating mode. Additionally, the proposed system can control power flow between any two low voltage sources known as buck and boost mode. The proposed topology and its control strategy are designed and analyzed using MATLAB/Simulink. The simulation results are presented and discussed.*

Keywords- Bidirectional dc/dc converter (BDC), Main Energy Storage (ES1), Auxiliary Energy storage (ES2), Fuel Cell Hybrid Electric Vehicle (FCV/HEV).

I. INTRODUCTION

Sources of electric energy for industry, agriculture, civilian or military use differ in their purposes, appliance and supplied system types. Autonomous generation systems, sources based on solar and wind energy, are commonly used to supply various appliances, facilities, systems. For these reasons and due to the growing needs in systems with the ability of bidirectional energy transmission between two dc buses, Bidirectional Dc-dc Converters (BDCs) have received increased attention.

This study develops a bidirectional DC/DC converter that interfaces two energy storages and dc bus for hybrid vehicle applications. This can also independently transfer power between voltage sources. The closed loop control is done by PI controller [1, 3, 5]. In this, a novel high-gain three-port power converter with fuel cell (FC), battery sources and stacked output for a hybrid electric vehicle (HEV) is connected to a dc-microgrid [2]. In this, the ratings of battery and ultracapacitors are investigated. Comparisons of the system volume, the system mass, and the lifetime of the battery due to the rating of the energy storage devices are presented [4]. A novel, two inductor, interleaved power factor corrected boost converter that exhibits voltage doubler characteristics is introduced. By this low line range efficiency is greatly improved [6]. This paper extend an idea of introducing multiple sources and loads into an onboard vehicular integrated power system [7]. This paper presents a new soft switching DC/DC converter for high input voltage applications. Two half-bridge converters connected in series with interleaved asymmetric pulse-width modulation are adopted to limit the voltage stress of each power switch at one-half of input DC bus voltage [8]. A three-port dc-dc converter integrating PV and battery power for high step-up applications is proposed in this paper. The topology includes five power switches, two coupled inductors and two active-clamp circuits [9]. This study develops a high-efficiency dual-input interleaved dc–dc converter for reversible power sources, e.g., reversible solid-oxide fuel cell and rechargeable battery [10].

A functional diagram for a typical (FCV/HEV) power system is shown in Fig. 1. SCs directly connected in parallel with FCs and the low-voltage FC stack is used as the main power source. The dc/dc power converter is used to convert the FC stack voltage into a sufficient dc-bus voltage in the driving inverter for supplying power to the propulsion motor. In this, ES1 of higher voltage is used as the main battery storage device for supplying peak power, and ES2 of lower voltage could be an auxiliary battery storage device to achieve the vehicle range extender concept. The function of the bidirectional dc/dc converter (BDC) is to interface dual-battery energy storage with the dc-bus of the driving inverter.

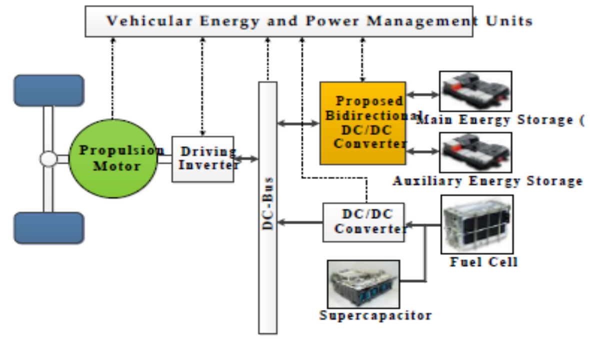


Fig. 1 Functional diagram for a FCV/HEV power system

II. TOPOLOGY AND OPERATION MODE

The proposed bidirectional DC-DC topology with dual-battery energy storage is shown in Fig. 2, where VH, VES1, and VES2 represent the high-voltage dc-bus voltage, the main energy storage (ES1), and the auxiliary energy storage (ES2) of the system, respectively. A charge-pump capacitor (CB) is used as a voltage divider with four active switches (Q1, Q2, Q3, Q4) and two phase inductors (L1, L2) to improve the static voltage gain between the two low-voltage dual sources (VES1, VES2) and the high-voltage dc bus (VH) in the proposed converter. Two bidirectional power switches (SES1 and SES2) in the converter structure, are used to switch on or switch off the current loops of ES1 and ES2, respectively. Here, CB reduces the switch voltage stress of active switches and hence no need to operate at an extreme duty ratio. Three bidirectional power switches (S, SES1, SES2) in Fig. 2 control the power flow between two low-voltage dual sources (VES1, VES2) and to block either positive or negative voltage. This bidirectional power switch is implemented via two metal-oxide-semiconductor field-effect transistors (MOSFETs), pointing in opposite directions, in series connection.

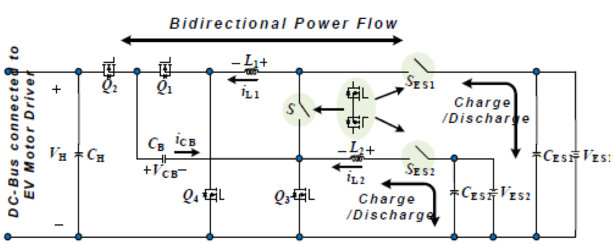


Fig. 2. Proposed BDC topology with dual-battery energy storage.

The four operating modes are as follows:

1] Low Voltage Dual Source Powering Mode:

Here the switch S is turned off and the switches SES1, SES2 are turned on and the low voltage dual sources are supplying energy to dc bus and load.

2] High Voltage DC Bus Energy Regenerating Mode:

Here the switch S is turned off and the switches SES1, SES2 are turned on and the kinetic energy stored in motor drive during braking operation is feedback to the low voltage dual source.

3] Low Voltage Dual Source Buck/Boost Mode:

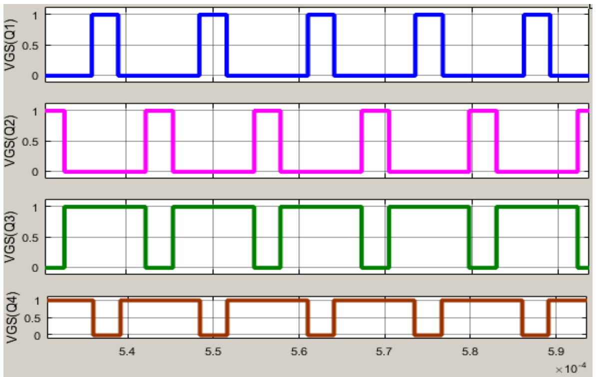
In this state the energy transfer between main energy storage and auxiliary energy storage is observed and vice-versa. When duty cycle of S is controlled then power transfer from main to auxiliary storage takes place indicating converter in buck mode and when duty cycle of Q3 is controlled then vice-versa happens indicating converter in boost mode.

III. CONVERTER CONTROL

Fig 3 shows the converter control model which indicates vehicular strategic management level and the proposed BDC controller. The strategic management level consist of an electrical power demand estimation and vehicular power and voltage management unit. The inductor current iL1 or iL2 is detected and compared with the reference current to control the powerflow. In the converter controlstructure, the vehicular energy and power and voltage management unit selects the bidirectional DC/DC converter mode according to the operating conditions of the vehicle, such as power demand of different driving state (Pdem) and the dual-source voltages (VES1, VES2). It then selects the appropriate current references iL1,ref or iL2,ref that can control the active switches (S, Q1 to Q4) with fuzzy controller.

TABLE II.
SPECIFICATIONS AND PARAMETERS OF THE PROTOTYPE SYSTEM

Specifications	
ES1 voltage	V_{ES1}: 96 V
ES2 voltage	V_{ES2}: 48 V
DC-bus voltage	V_H: 430 V
Output power	P_o: 1 kW
Switching frequency	f_{SW}: 40 kHz
Parameters	
Inductors	L_1, L_2: CH330060, 250 uH
High-side capacitor	C_H: aluminum capacitor, 1880 µF
Low-side capacitor	C_{ES1}: aluminum capacitor, 400 µF C_{ES2}: aluminum capacitor, 400 µF
Charge-pump capacitor	C_B: film capacitor, 10 µF
Switches	S, S_{ES1}, S_{ES2}: IXFK360N15T2 Q_1, Q_4, Q_2, Q_3: W45NM60



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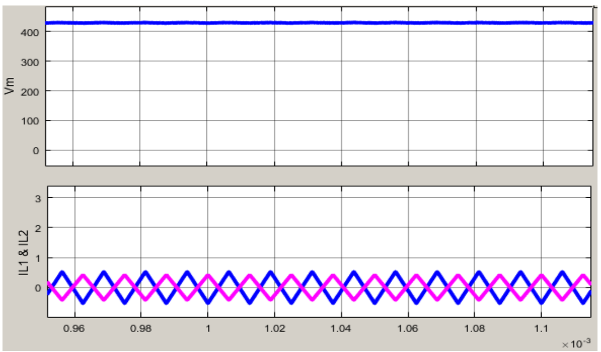

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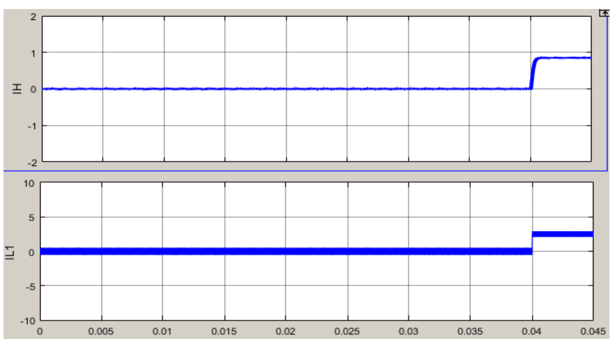
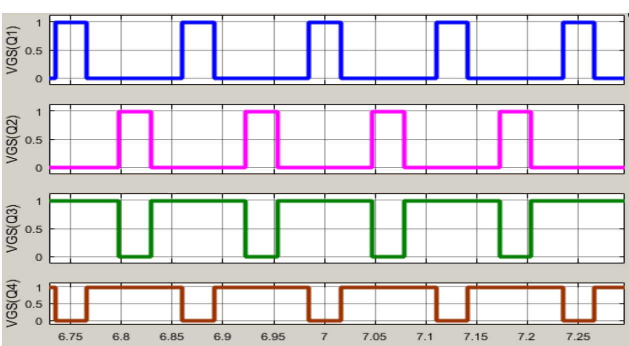


(c)

Fig.4.Measured waveforms for low-voltage dual-source powering mode: (a) gate signals; (b) output voltage and inductor currents; (c) Controlled current step change.



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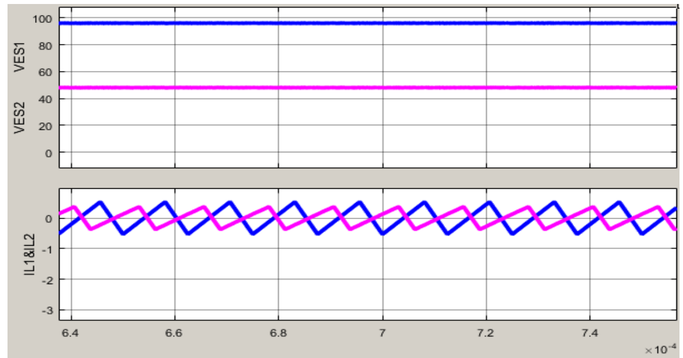

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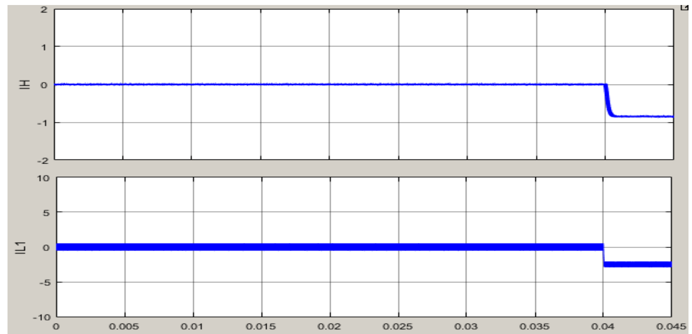

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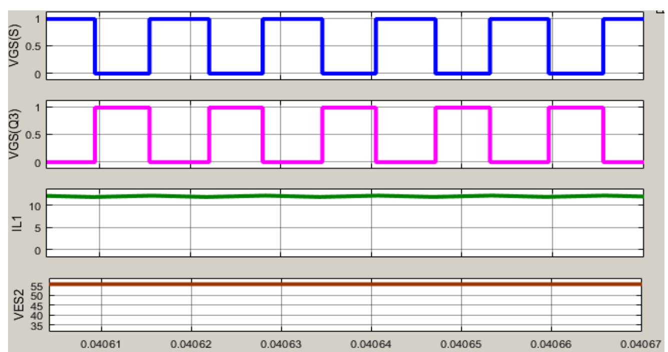
Fig.5. Measured waveforms for high-voltage dc-bus energy-regenerating mode: (a) gate signals; (b) output voltage and inductor currents; (c) Controlled current step change.



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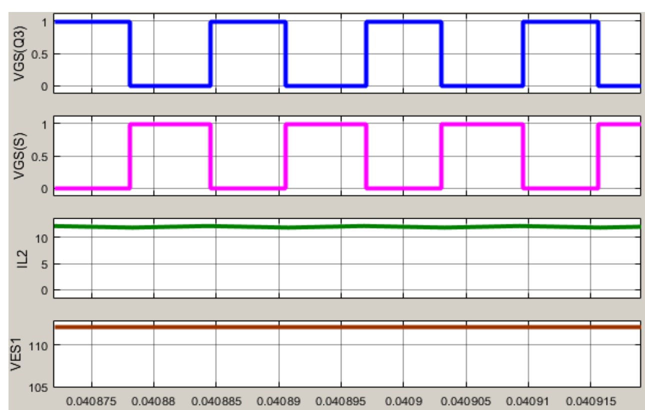

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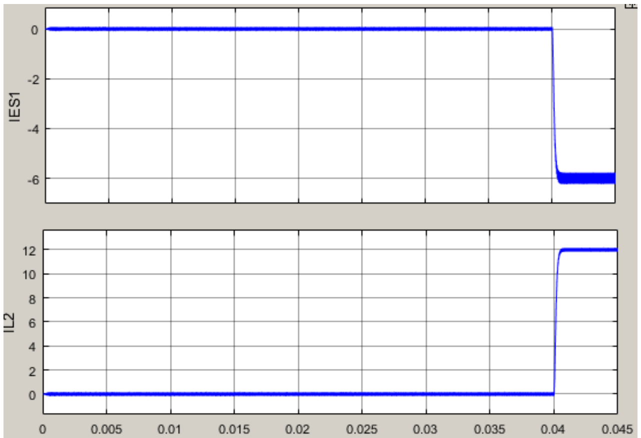

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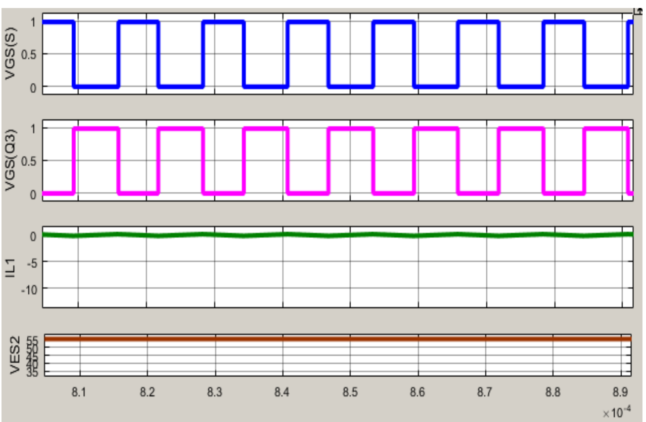
Fig.6. Measured waveforms for low-voltage dual- source boost mode (a) & (b) gate signals, output voltage and inductor currents (c) Controlled current step change.



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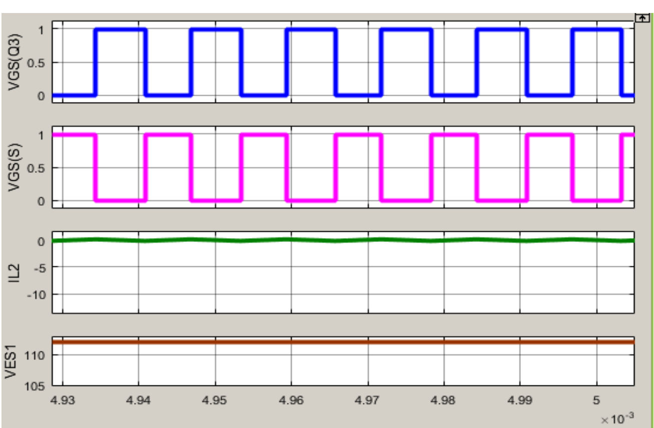

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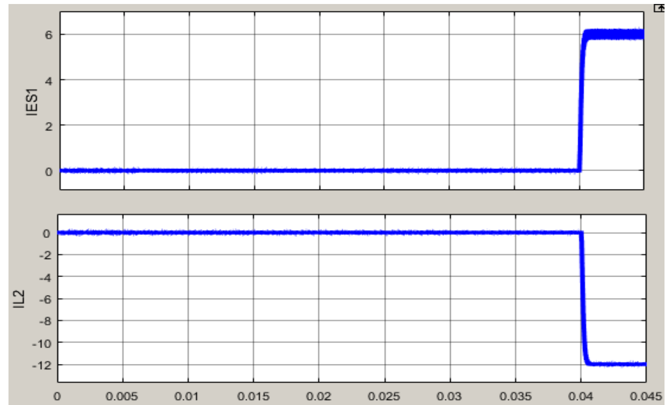

(c)

Fig.7. Measured waveforms for low-voltage dual- source buck mode (a) & (b) gate signals, output voltage and inductor currents (c) Controlled current step change.

IV. CONCLUSION

A Bidirectional DC-DC converter has been developed which interfaces low voltage dual energy storage and high voltage dc bus and also permits energy transfer between low voltage dual sources. The circuit diagram and its various operating modes arestudied and explained in detail along with its simulation results using fuzzy controller and it can be observed that oscillations are reduced using this controller. Higher efficiencies can be achieved using this proposed model and can be applied in Hybrid Electric Vehicle System.

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