Design of a Bipolar DC to DC Converter with Two Batteries for a Hybrid EV System

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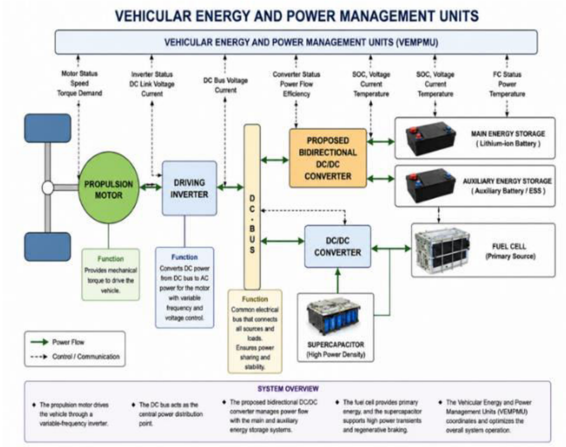
ABSTRACT.

A state-of-the-art hybrid energy system-based multi-input dc-dc converter featuring fuzzy control is proposed in this work. Since fuzzy controllers provide a number of benefits over traditional controllers, we employ them in this study. Fuzzy controllers combine the capabilities of automated devices with expert judgment, making them ideal for human decision-making. You may use the suggested converter to transfer power from one source to another. The suggested converter has two modes of operation: one for charging batteries and another for discharging them. All input sources provide power to the output. To control the output power of ESSs, the suggested converter permits active power sharing. It is possible for the voltage levels of the employed ESSs to exceed or fall below the output voltage. When applied to a nonlinear system, a fuzzy controller both improves performance and decreases the impact of control uncertainty. With the help of the simulation findings, we will investigate the new hybrid system architecture for electric cars, namely the bidirectional independent multi-input converter (MIC) topology.

I. INTRODUCTION

Vehicle technology has evolved in response to climate change and dwindling energy supplies. Future cars will make use of cutting-edge technology that are now the subject of intense investigation. One efficient and potentially fruitful use case is fuel-cell hybrids electric vehicles (FCV/HEVs). Ehsani et al. [1] investigated vehicle dynamics in the past to find the ideal electric propulsion system torque-speed profile. The operational characteristics of the designs for various cars, such as HEVs, FCVs, and additional electric vehicles, were covered by Emadi et al. [2]. To handle the heavy vehicle load, Emadi et al. also used power electronics-intensive solutions in their advanced vehicle power system [3]. According to two energy-management algorithms suggested by Schaltz et al. [4], the load power is adequately distributed across the fuel cell stack, batteries, and the ultracapacitors. The benefits of hybrids for control techniques were investigated by Thounthong et al. [5], who also looked at the impact of fuel-cell (FC) performance. Energy management architectures and models were the primary foci of Chan et al.'s assessment of electric, hybrid, or fuel-cell cars [6]. For hybrid and plug-in hybrid electric vehicles (PHEVs), Khaligh and Li laid out energy storage structures. Additionally, they analyzed and contrasted FC, UC, and battery technologies. In addition, they covered a range of hybrid ESSs that combine several storage devices [7]. In order to determine what is needed and what is already in place, Rajashekara examined the power electronics system, electric motors, and batteries, which are the three main components of electric propulsion [8]. A two-phase bidirectional dc/dc converter architecture with interleaved features was developed by Lai et al. This converter has a better voltage conversion ratio, making it ideal for use in dc-microgrid systems and electric vehicle charging stations [9]. For electric vehicle (EV) batteries linked to a direct current (DC) microgrid system, Lai also investigated a bidirectional dc-to-dc converter (BDC) architecture with a high voltage ratio of conversion [10]. Starting the FC and powering the propulsion motor are two typical uses for the primary battery storage device in FCV systems [2, 3]. The FC stack has a naturally poor reaction time, but the battery devices for storage make up for it by providing peak power as the vehicle accelerates [7]. In addition, it gets rid of peak power transients while accelerating and braking with regenerative energy thanks to its high power-density component, which includes super capacitors (SCs) [11]. As a rule, SCs may generate more power by storing regenerative energy during braking and releasing it during acceleration. In addition to improving efficiency in general of FCV systems, SCs' high power density also increases the lifespan of FC stacks and battery storage devices.



The typical schematic of a power system for an FCV/HEV is shown in Figure 1.

Also, the primary battery storage apparatus for providing peak power is ES1, which has a somewhat greater voltage, while the secondary battery storing device for achieving the range extender idea in vehicles might be ES2, which has a relatively lower voltage [13]. Interfacing dual-battery storage of energy with the driving inverter's dc-bus is the job of the bilateral dc/dc converter (BDC).

To achieve galvanic isolation, isolated converters use high-frequency power transformers. Some isolated multiport BDC designs have been studied, including resonant circuits, half-or full-bridge designs, dual-active bridges, and flybacks [14–17, 20, 22, 24]. Evidence from EVs shows that non-isolated BDCs work better than the more common isolated BDCs [18, 19, 21 and 23, 25-27]. Liu et al. [18] used a mix of buck, boost, Ćuk, and Sepic to construct non-isolated multi-input converter topologies. For the purpose of connecting a renewable energy source, a storage battery, and a load all at once, Wu et al. proposed three-port non-isolated multi-input-multi-output (MIMO) converters topologies in [23]. A single inductor and a single-pole triple-throw converting switch make up the three dual-input input converters mentioned in [19]. Preliminary work on a standalone MIMO converter was detailed in [26]. Hybridizing sustainable energy sources with electric vehicles is the goal of this converter, which incorporates modifications to the basic boost circuit. Due to losses associated with components like the main power switch, inductor, filtering capacitor, and rectifier diode, the voltage gain of the Mdm boost circuit is often restricted in reality. There is a small voltage differential between the high- and low-side ports and a restricted voltage range due to the limited static voltage gains of the multiport BDC described in [25], even though it can interface more than two power sources and function at higher voltage levels.

Also, while operating in low-voltage dual-source buck/boost mode, the suggested converter may autonomously regulate the flow of power between any two low-voltage sources. This is a brief overview of the key features of the proposed converter: 1) can connect to multiple dc sources of varying voltages; 2) manages the flow of power between the dc bus as well as the two low-voltage sources; 3) improves static voltage gain, leading to less switch voltage stress; 4) has sufficient duty cycle and generates a large voltage differential between its high- as well as low-side ports.

REATED WORK :

" Designing electric & hybrid vehicle propulsion systems,"

As more people become concerned about the environment, they are showing an increased interest in electric & hybrid-electric automobiles. Advancements are being made to provide a more efficient powertrain for use in EVs and hybrids. The philosophical frameworks for electric or vehicle hybrid propulsion systems are the focus of this article. Research into the vehicles' dynamics is focused on determining the best electric propulsion system torque-speed profile. When the power train is operated largely in the constant power area, the operating restrictions of the vehicles, including beginning acceleration and grade, may be satisfied with a minimal power rating, according to this research. A number of instances are given to illustrate how crucial the constant power procedure is. Multiple potential motors are tested for operation in the power constant area as well. Their actions are contrasted and findings are drawn.

" Review of the topology of power systems for vehicles that use fuel cells and hybrid electric vehicles,"

In this study, we look into the functional features of the topologies used by HEVs, FCVs, and MEVs (more electric vehicles). Fuel cell-based propulsion technologies, as well as series and parallel hybrids, are briefly described. Applications of fuel cell propulsion, particularly in light-duty passenger automobiles and heavy-duty buses, are also detailed in the article. Lastly, the difficulties in penetrating new markets are brought to light, along with some of the other key basic obstacles that these cutting-edge vehicle technologies are now facing.

" Advanced electric, mixed electric, & fuel cell vehicle power systems that rely heavily on power electronics,"

More and more electrical systems are being used by the automobile industry to meet the increasing needs of vehicle loads. As a result, there will undoubtedly be a sea shift in the next ten to twenty years for automobile electrical power systems. The current state of affairs in the automobile sector is such that the voltages of sophisticated vehicle power systems are increasing due to the need for more electric power and better fuel efficiency. For instance, compared to the present value, the anticipated rise in overall power consumption is around a three to fourfold higher. If this trend continues, the average advanced vehicle's overall power usage in the future might approach 10 kW. One strategy for handling this massive vehicle load is to include solutions that rely heavily on power electronics into more sophisticated vehicle power systems. Keeping this in mind, the purpose of this article is to survey the current state of affairs and to forecast the future of research and development in the field of advanced automotive electrical power systems, including EVs, HEVs, and FCVs. Prior to delving into the particular uses of dc/dc & dc/ac power converters in high-tech automotive power systems, this article will provide an overview of the power system designs that are being considered for HEVs and FCVs.

" Longevity of fuel cell mixed electric vehicle batteries as a function of ultracapacitor and battery size,"

Fuel cell vehicular hybrids (FCHEVs) combine high-power ultracapacitors with high-energy-density batteries to create a lightweight, compact, efficiently powered vehicle. The battery is often graded according to its energy needs in order to minimize its bulk and volume. To extend the life of the battery, severe discharges are necessary, but this won't stop them. Assessments of batteries and ultracapacitors are explored in this work. There are comparisons made between the energy storage devices' ratings and the system's volume, mass, and battery life expectancy. It follows that the expected lifespan of the batteries should be included in when sizing storage devices of an FCHEV, in addition to the power and energy demands. In order to adequately distribute the load power across the fuel cells stack, the battery, & the ultracapacitors, two energy-management algorithms are suggested. In addition, we provide a charging approach that may charge the energy-storage devices in response to FCHEV circumstances. The study suggests improvements to the FCHEV's battery and energy storage systems based on ultracapacitors.

" Evaluation of fuel-cell vehicle hybrids using various energy storage devices, including batteries and supercapacitors,"

This research investigates how the advantages of hybridization are affected by fuel-cell (FC) control and performance tactics. A potential issue with FCs is their sluggish dynamics, which are mostly caused by the temperature and fuel-delivery system, which includes pumps, valves, and, sometimes, a hydrogen reformer. Thus, a fuel-starvation event known as a rapid decrease in voltage will occur due to excessive load demand. So, in order to use FCs in applications related to cars, the electrical system needs a second power source to boost system performance during surges in electrical load demand. Full details about the potential of using a battery bank or supercapacitor as a supplemental source in conjunction with an FC primary source are provided. The research on two different hybrid power systems—one using fuel cells and the other using supercapacitors—is detailed here for use in automobiles. In a controlled environment, experimental findings using miniature devices (a 500 W, 40 A, and 13 V polymer electrolyte membrane FC; a 33 Ah, 48 V lead-acid battery module; and a 292 F, 500 A, and 30 V supercapacitor module) confirm that storage of energy devices can aid the FC in meeting the power demand of the vehicle, improving performance, and proving the efficacy of the control schemes used during motor-drive cycles.

Methodology:

OVERVIEW AND MANUALS OF USE

As shown in Figure 2, the proposed BDC architecture incorporates dual-battery energy storage. The high dc-bus voltage (VH), the primary energy storage (ES1), & the auxiliary power storage (ES2) are represented by the variables, respectively. To activate or deactivate the current loop of ES1 & ES2, respectively, the converter structure employs 2 bidirectional power switch configurations (SES1 and SES2). The suggested converter incorporates a charging pump capacitor (CB) as a voltage divider, four active switching devices (Q1, Q2, Q3, Q4), and double-phase inductor devices (L1, L2) to enhance fixed voltage gain across the two low-voltage double sources (VES1, VES2) to the HIGH-V dc bus (VH). Not only that, active switches have less voltage stress because to the extra CB, and severe duty ratio operation is no longer necessary. Additionally, to regulate the flow of power between two voltage-limited dual sources (VES1, VES2), the three reversible switches for power (S, SES1, SES2) shown in Fig. 2 operate in four quadrants.

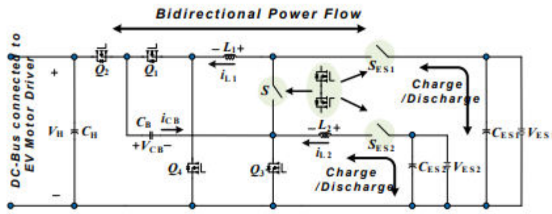


Fig. 2. Proposed BDC topology with dual-battery energy storage.

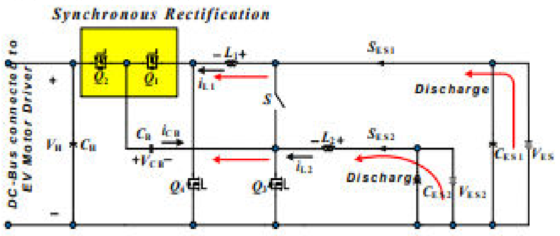
TABLE I.
CONDUCTION STATUS OF DEVICES FOR DIFFERENT OPERATING MODES

Operating Modes	ON	OFF	Control Switch	Synchronous Rectifier (SR)
Low-voltage dual-source-powering mode (Accelerating, x_1=1, x_2=1)	S_{ES1}, S_{ES2}	S	Q_3, Q_4	Q_1, Q_2
High-voltage dc-bus energy-regenerating mode (Braking, x_1=1, x_2=1)	S_{ES1}, S_{ES2}	S	Q_1, Q_2	Q_3, Q_4
Low-voltage dual-source buck mode (ES1 to ES2, x_1=0, x_2=0)	S_{ES1}, S_{ES2}	Q_1, Q_2, Q_4	S	Q_3
Low-voltage dual-source boost mode (ES2 to ES1, x_1=0, x_2=0)	S_{ES1}, S_{ES2}	Q_1, Q_2, Q_4	Q_3	S
System shutdown	--	S_{ES1}, S_{ES2} Q_1, Q_2, Q_3, Q_4	--	--

for the purpose of blocking electricity, both positive and negative. Two MOSFETs, or metal-oxide-semiconductor field-effect transistors, connected in series with each other and facing in opposing directions let the power to flow in any way. In Table I, we can see the current conduction states of all the power devices used in each mode of operation, which helps to clarify the idea behind the proposed converter. So that you can better grasp the four functioning modes, here they are.

Dual-Source Power Mode with Low Voltage

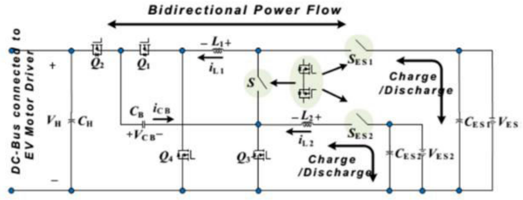
In the low-voltage dual-source-powering mode, the converter's circuit design and steady-state waveforms are shown in Fig. 3(a). Within, the dc-bus and loads are supplied with energy from two low-voltage dual sources (VES1, VES2), with the switch S turned off and the switches (SES1, SES2) turned on. Here, a synchronized rectifier (SR) is provided by the high-side switching Q1 and Q2, while the low-side switching Q3 and Q4, respectively, actively switch at a shift phase angle of 180°. There are four potential states for the circuit when the duty ratio exceeds 50%, as illustrated in Figure 4 and the usual waveforms in Figure 3(b). It is possible to provide a concise explanation of the functioning by considering the active switches' on/off state and the working principle of BDC in low-voltage powering from two sources mode.



(a)

OVERVIEW AND MANUALS OF USE

Figure 2 shows the proposed BDC architecture with dual-battery energy storage, with VH representing the high-voltage DC-bus communication voltage, VES1 representing the primary energy storage, and VES2 representing the auxiliary energy storage. The current loops of ES1 and ES2 are turned on and off, respectively, by two reversible power switches (SES1 and SES2) inside the converter construction. The suggested converter incorporates a capacitance-pump capacitor (CB) as a voltage divider, four active switching devices (Q1, Q2, Q3, Q4), with two phase inductor configurations (L1, L2) to enhance the static voltage gain across the two voltage-limited dual supplies (VES1, VES2) with the elevated voltage dc bus (VH). Not only that, active switches have less voltage stress because to the extra CB, and severe duty ratio operation is no longer necessary. Additionally, to regulate the flow of power between two LV dual sources (VES1, VES2), the three unidirectional power switches (S, SES1, SES2) shown in Fig. 1 operate in four quadrants.



Furthermore, to prevent the passage of negative or positive voltage. Two MOSFETs, or metal-oxide-semiconductor field-effect transistors, connected in series with each other and facing in opposing directions let the power to flow in any way.

In Table I, we can see the current conduction states of all the power devices used in each mode of operation, which helps to clarify the idea behind the proposed converter. The following are illustrations of the four functioning modes to help you understand them better.

RESULT S :

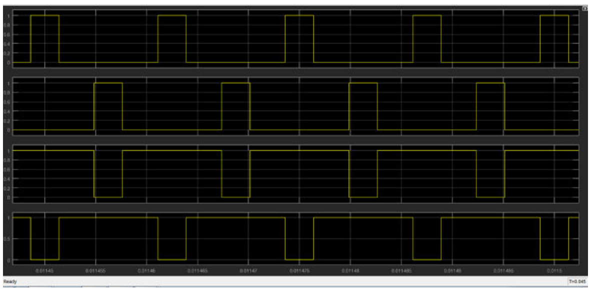


Fig.19a

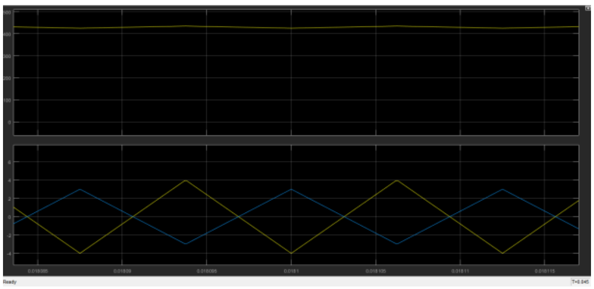


Fig.19b

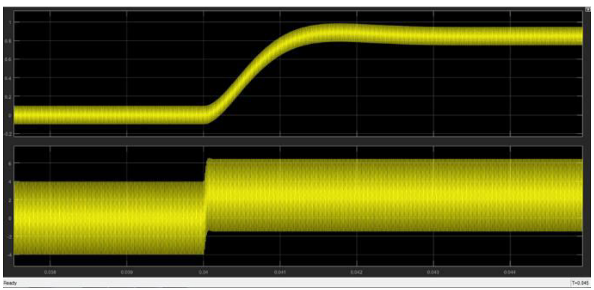


Fig.22a

HEV1

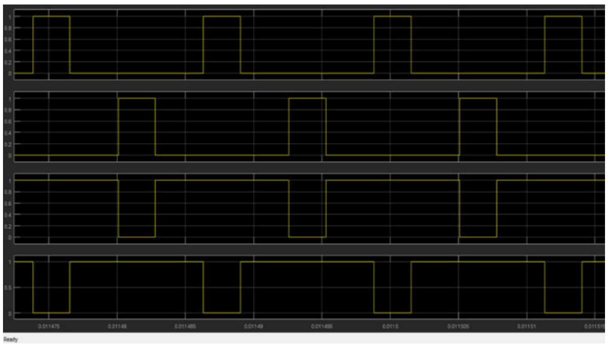


Fig.20a

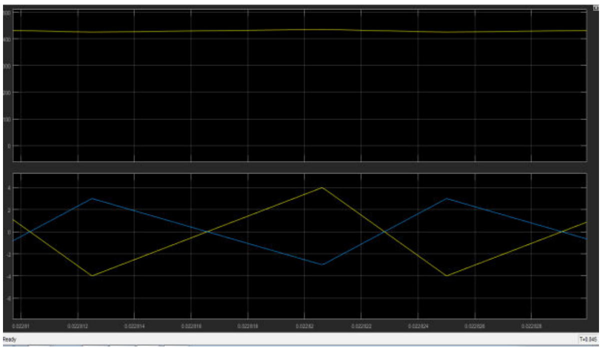


Fig.20b

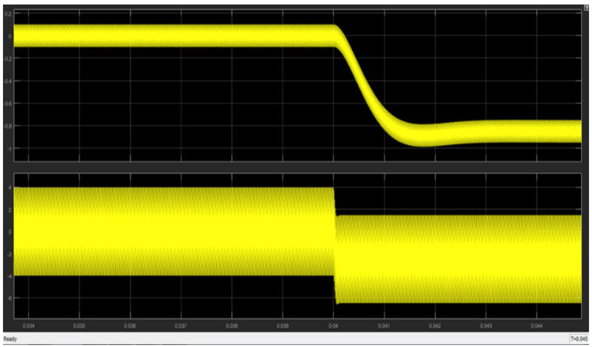


Fig.23a

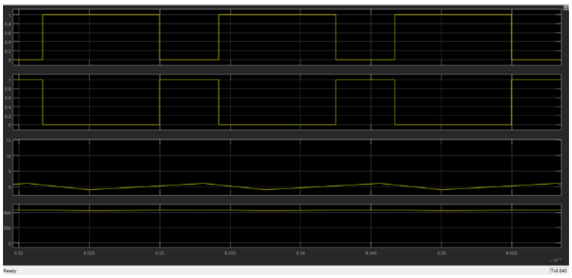


Fig.21a

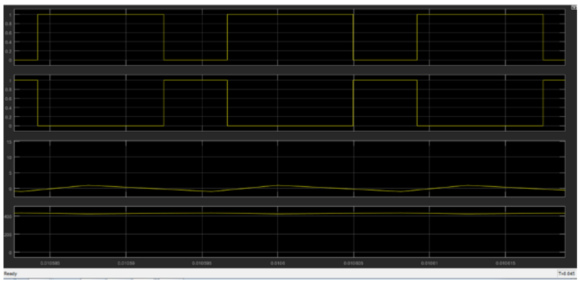


Fig.21b

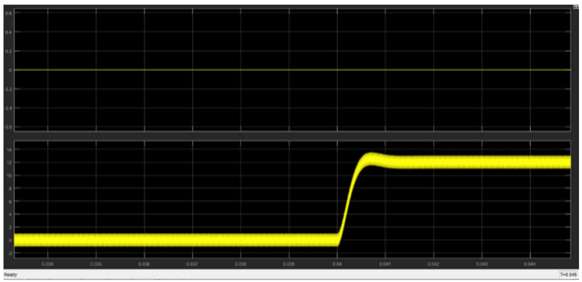


Fig.24a

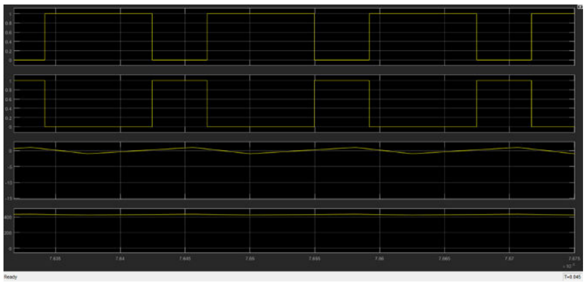


Fig.21

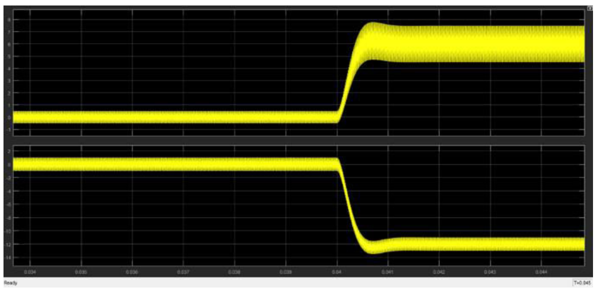


Fig.25a

Conclusion:

A novel BDC architecture was introduced to connect two energy sources—batteries—and high-voltage dc buses with different voltage levels. Several power transfer mechanisms served as the basis for the circuit design, operational principles, evaluations, and static voltage gains of the suggested BDC. The fuzzy controller prolongs the life of the battery by lowering the DC connection voltage's peak overshoot and settling time while smoothing out the current. The fuzzy logic controller controls the current flowing from the battery using a bidirectional buck-boost converter. Every part of the system for energy management has been put through its paces in MATLAB/SIMUINK, with modes of operation ranging from high voltage regeneration to low voltage multi source powering and boost/buck.

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