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A CCH BOOST DC-DC CONVERTER FOR FUEL CELL VEHICLES

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ABSTRACT: *This paper includes a capacitor-clamped H-type boost DC-DC converter with a wide voltage gain in order to use the adaptive low-voltage fuel cell stack in a fuel cell vehicle with a constant high voltage (400V) DC bus. A capacitor clamped H-type arrangement is used on the input-voltage side to decrease input current ripple, prevent narrow-pulse PWM voltage waveforms, and reduce the conduction loss of power switches; while in the output-voltage side, a switched-capacitor arrangement is being used to achieve high voltage gain and lower voltage tension for both power semiconductors and capacitors.*

The operating theory, features, control strategy, parameter configuration, and contrast with other converters are all explored. As a result, the converter will convert low-voltage inputs ranging from 25V to 70V into 400V over a large voltage-gain spectrum, with a maximum efficiency of 94.72 percent. The results also affirm the above properties of the proposed converter as well as the correctness of the theoretical analysis. This converter suitably serves as power interface for fuel cell vehicles

Index Terms—Capacitor clamped H-type DC-DC converter, Fuel cell vehicles, Voltage stress, and Wide voltage-gain range

I.INTRODUCTION

Environmental issues and energy scarcity are two big issues in our human society, and the development of renewable, pollution-free energy is imminent. Because of its high reliability and lack of emissions, the fuel cell is one of the most attractive energy sources, and it has a high importance of advanced research in the fields of DC micro grid and electric vehicles. The monomer fuel cell's no-load potential electromotive force is approximately 1.16V. In practice, a large number of monomer fuel cells can be attached in sequence, which can minimize the efficiency of the fuel cell stack. Reducing the number of tandem units improves stability, but it lowers the output voltage of the fuel cell stack. Furthermore, the output voltage of the fuel cell stack varies depending on the load. They would use a DC-DC converter with a wide voltage gain as a medium to link to the high voltage DC bus in order to increase the stability of the fuel cell stack and provide a steady output voltage for the load. Because of the space limitations and reliability criteria for fuel cell vehicles, the step-up DC-DC converter should have the following specifications like small size, high efficiency and high reliability. Furthermore, the converter's input current should be constant, and the current ripple should be minimal enough to prevent reducing the life of the fuel cells. As a result, the fuel cell stack control interface converter should have the following features: (a) A wide input voltage spectrum with a high voltage-gain. (b) Input current ripple is low. (c)Compact scale, high performance, and dependability.

Several DC-DC converters supported isolated and non-isolated topologies are conferred in literatures to get the wide voltage-gain vary. As for isolated topologies, input power is transmitted to the output aspect through a high-frequency isolation electrical device. it's indispensable for the two-stage transformation of power, and these 2 stages area unit DC-AC-DC. However, given the little price and house in fell cell cars, non-isolated DC-DC converters with low price and high performance area unit higher suited to speak with the electric cell stack. The study of high voltage-gain non-isolated converters is primarily involved with the subsequent topics: multi-stage /-level ways, switched inductance and matched inductance, switched electrical condenser, and voltage multiplier factor. Coupled inductance converters area unit straightforward to attain high voltage-gain, however this ripple is

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relatively wide for single-stage single-phase-coupled inductance converters, which may shorten the service lifetime of the electric cell stack.

A switched-inductor converter with a high voltage-gain is proposed. However, the downside of high voltage tension on diodes remains. The switched capacitor arrangement is used in boost-type DC-DC converters to provide a wide range of voltage gain. A boost three-level DC-DC converter with low input current ripple is presented in to interface the fuel cell stack. This converter's voltage-gain, however, is small. Furthermore, since the input and output ports do not share a common ground and a diode is attached between them. As a result, a high frequency PWM voltage is produced between the two sides of the field, which can trigger maintenance and EMI issues. The converter uses a shared ground structure, which improves the converter's stability. The voltage-However, the gain of this converter is still small. Furthermore, to be regulated, the flying capacitor necessitates a corresponding voltage balancing technique. The converter has a large input voltage spectrum and a low input current ripple. However, its application spectrum is limited due to its non-common ground topology and lower voltage gain.

The duty cycle range in the non-isolated boost DC-DC converters described in is 0 to 1. To achieve a higher voltage gain, a higher duty cycle is needed, which can result in a high conduction loss of power switches. The service cycle of power switches can be shortened to 0 to 0.5 to minimize conduction loss. It is planned to use a switched-capacitor-based double-switch high-boost converter. This converter's service period is between 0 and 0.5, which essentially decreases the conduction loss of the control switches. This converter, however, lacks a middle ground and the input current comprises pulse components.

II.PROPOSED CONVERTER

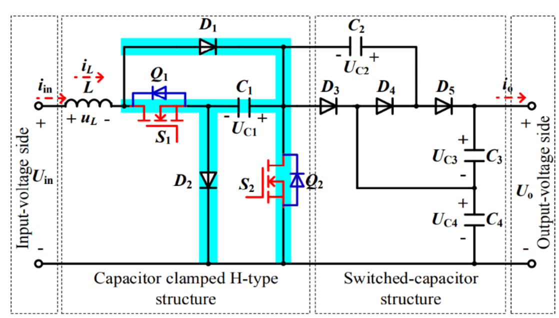
The above-mentioned DC-DC converters struggle to satisfy the specifications of the three facets of the fuel cell stack power interface converter used in fuel cell vehicles at the same time. As a result, a capacitor clamped H-type boost DC-DC converter was proposed in this article. The below are the benefits of using this converter: (a) Extensive input voltage spectrum and high voltage gain. (b) Avoiding the narrow-pulsed PWM voltage waveform when increasing voltage gain. (c) Reducing conduction loss in power switches. (d) Reducing the voltage load on power semiconductors and capacitors by reducing input current ripple. The characteristics mentioned above help to increase not only the converter's reliability but also its performance, making it more suitable for fuel cell vehicles.

The projected device may be used as a change of magnitude device in electric cell vehicles to interface the electric cell stack. As show in Fig. 1, the electric cell stack provides sure levels of power for extending the practice range of electrical vehicles, and therefore the super condenser (SC) discharge throughout the operations of fast whereas charge once electrical vehicles brake. Low DC voltages output (25-70V) by the electric cell stack can't be used directly, and should be regulated and boosted via the change of magnitude stage.

OPERATING PRINCIPLES OF THE PROPOSED CONVERTER :

Configuration of the proposed converter:

The configuration of the proposed converter divides into two modules as shown in Fig. 2. Module 1 is a capacitor clamped H-type structure (*L*, *Q*1, *C*1, *D*1, *D*2 and *Q*2), and Module 2 is a switched-capacitor structure (including a switched-capacitor unit *C*2-*D*4-*C*4). The capacitor clamped H-type structure is used to reduce input current ripple, avoid narrow-pulse of PWM voltage waveforms, and decrease the conduction loss on the power switches. The switched-capacitor structure is used to obtain high voltage gain and reduce the voltage stress of all semiconductors and capacitors.



Configuration of the proposed converter

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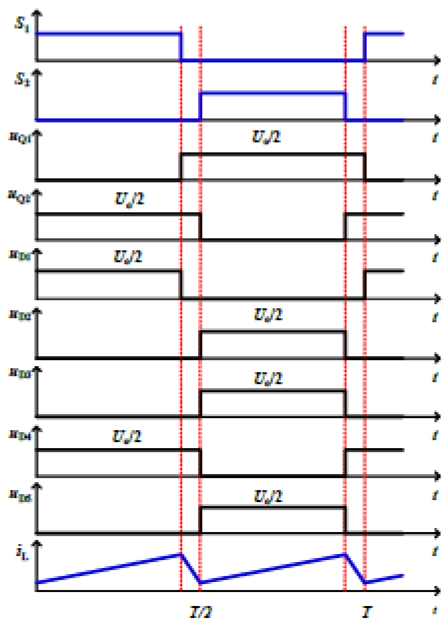
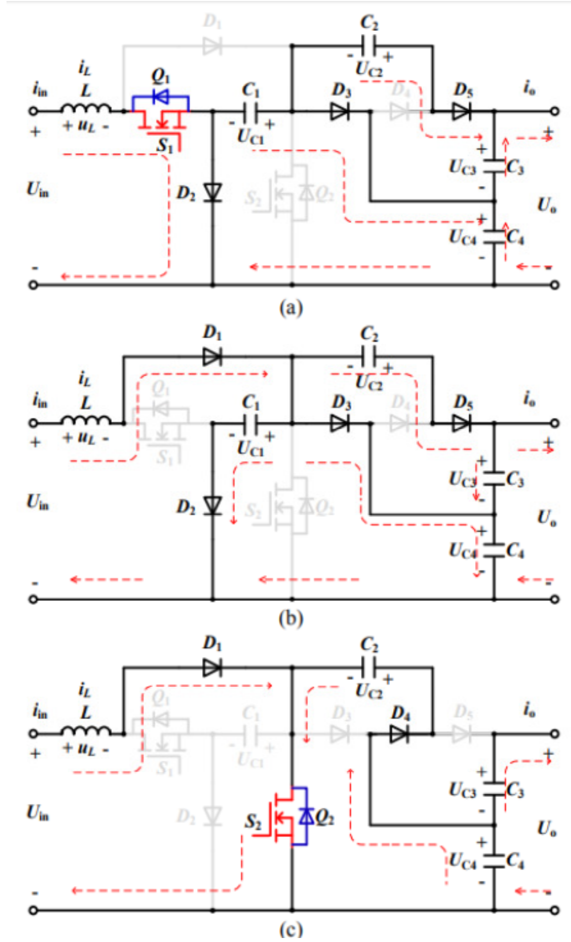
Operating Principles

The operating principles of the proposed converter are analyzed when the input current is continuous. In this case, suppose that $d1=d2=d$, where $d1$ and $d2$ are the duty cycle of $Q1$ and $Q2$ respectively, and the phase difference between their gates driving signals is 180°.



Main waveforms of the proposed converter

According to the operation of $Q1$ and $Q2$, there are four switching states "$S1S2$"= {00, 01, 10, 11}, where "1" represents the power switches $Q1$ or $Q2$ is "*ON*", and "0" represents "*OFF*". However, the $S1S2$= 11 state only appears when d is greater than 0.5. If $0.5 \leq d < 1$, during one switching period, the converter has three switching states "$S1S2$"= {10, 01, 11}. It can be seen from Fig. 2 that at least one of $Q1$ and $Q2$ is in the "*ON*" state at any moment in this situation, so the inductor L would always being charged. Therefore, the duty cycle of this converter is limited to the range of $0<d<0.5$. During each switching period, the converter has three switching states, and their sequence is"10-00-01-00".The main waveforms of this converter are shown in Fig. 3, and the energy flow paths in each switching state are shown in Fig.



Energy flow paths in each switching state.
(a) $S1S2$=10. (b) $S1S2$=00. (c) $S1S2$=01.

When $S1S2$=10: As shown in Fig. 4(a), $Q1$ is in the *ON* state and $Q2$ is *OFF*. Diodes $D2$, $D3$ and $D5$ are directly polarized, while $D1$ and $D4$ are inversely polarized. Inductor L is charged with a linearly rising current iL from the input source. Capacitors $C1$ and $C4$ are connected in parallel. Capacitors $C2$ and $C3$ are connected in parallel. They are connected in series to supply power to the load.

When $S1S2$=00: As shown in Fig. 4(b), both switches $Q1$ and $Q2$ are in the *OFF* states. Diodes $D1$, $D2$, $D3$ and $D5$ are directly polarized, while $D4$ is inversely polarized. Capacitor $C3$ is charged by inductor L and

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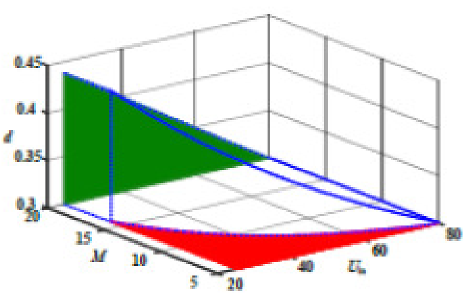
*C*2. The current flowing through inductor *L* decrease linearly, the inductor *L* transfer energy to *C*1 and *C*4, and the load is supplied by *L* and *C*2.
When *S*1*S*2=01: As shown in Fig. 4(c), *Q*1 is *OFF* and *Q*2 is *ON*. Diodes *D*1 and *D*4 are directly polarized, while *D*2, *D*3 and *D*5 are inversely polarized. Inductor *L* is charged from the input source. The current *i*L rises linearly. Capacitor *C*2 is charged from *C*4. The current flowing through *D*4 is limited by the parasitic resistance of the converter. The load is supplied by the output capacitors *C*3.

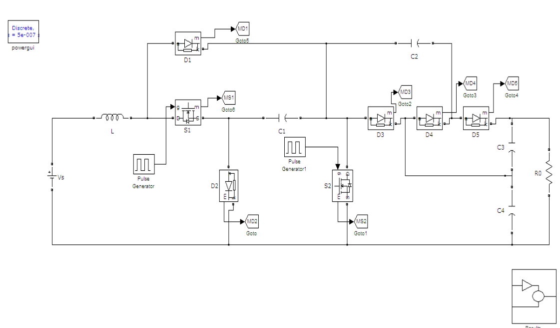
CHARACTERISTIC OF THE PROPOSED CONVERTER

Assuming all components are ideal and all capacitances and inductances are large enough, the voltage of each capacitor can be considered constant



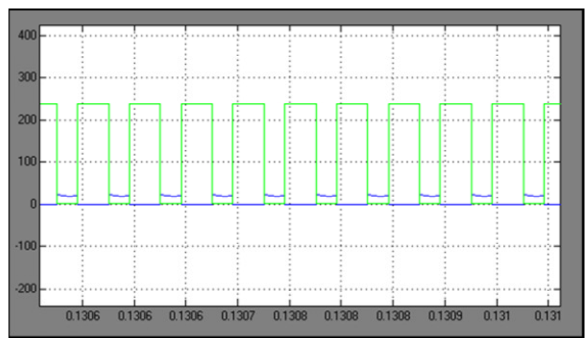
Voltage gain and duty cycle with wide-range changed input voltage from 25V to 80V.

III. SIMULATION RESULTS

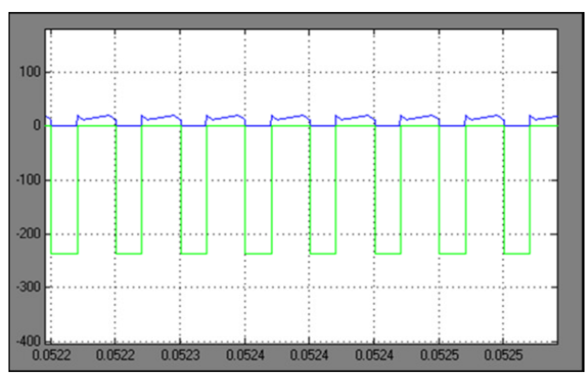


SIMULINK MODEL FOR THE TEST SYSTEM

Output waveforms for switch S1



Output waveforms for switch S2



Output waveforms for diode D1

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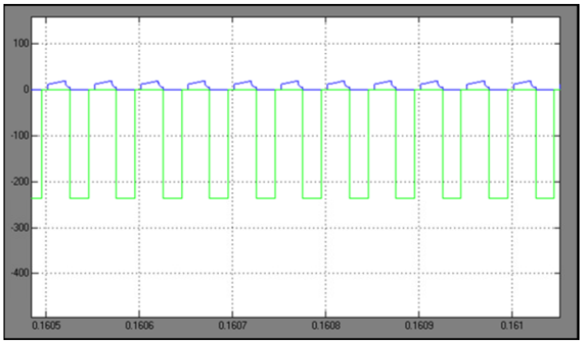
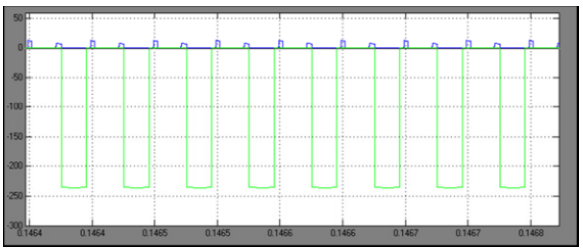
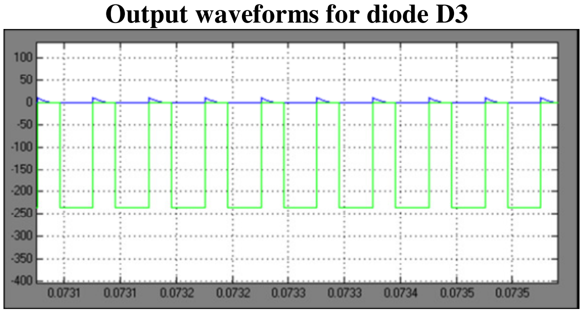


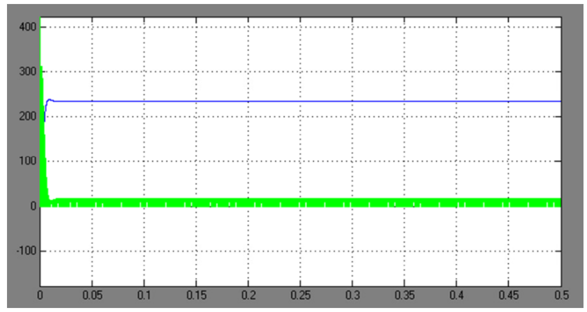
Output waveforms for diode D2



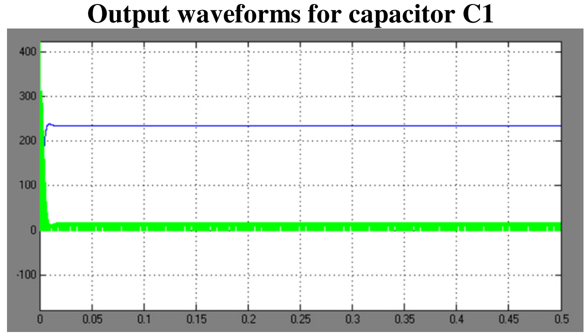
Output waveforms for diode D3



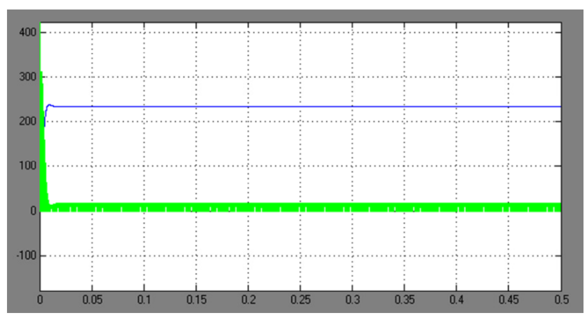
Output waveforms for diode D4 53



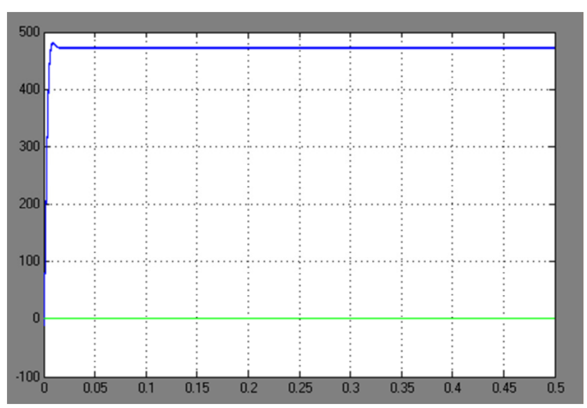
Output waveforms for capacitor C1



Output waveforms for capacitor C2



Output waveforms for capacitor C3



Output voltage waveform for Load

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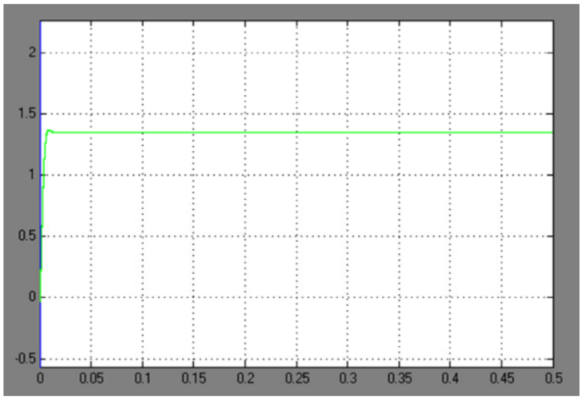

Output current waveforms for Load

IV.CONCLUSION

A capacitor clamped H-type boost DC-DC converter was proposed in this paper, which has the advantages of wide voltage gain range, lower voltage stress (Uo/2) on power semiconductors and capacitors as well as lower input current ripple and lower conduction loss of power switches. In addition, this converter can avoid the narrow-pulse of PWM voltage waveform of power semiconductors while obtaining high voltage gain. In order to prove the feasibility of this converter, a prototype was implemented of which the output voltage was kept at 400V when the input voltage varied from 25V to 70V. Experimental results show that with the proper voltage gain range (5.71-16), all power semiconductors do not have a narrow-pulse PWM voltage waveform. Meanwhile, the conduction losses of the power switches are decreased. The experiment of the hybrid energy source system further validates that this converter can operate well in fuel cell vehicles, where a high voltage gain is needed.

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