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A Reduced switch count Soft-Switching Current-Fed Full-Bridge Isolated DC/DC Converter for Fuel Cell Vehicles

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Abstract:

A naturally clamped zero-current commutated soft switching bidirectional full-bridge isolated dc/dc converter is implemented by eliminating the necessity for passive snubbers. Switching losses are reduced significantly owing to zero-current switching of primary side devices and zero-voltage switching of secondary-side devices. Soft switching and voltage clamping are inherent and load independent. The voltage across primary-side devices is independent of duty cycle with varying input voltage and output power and clamped at rather low reflected output voltage, enabling the use of semiconductor devices of low voltage rating. These merits make the converter promising for fuel cell vehicles application, front-end dc/dc power conversion for fuel cell inverters, and energy storage in the DC/DC converter is analysed with zero current Commutation (ZCC) and the natural voltage clamping (NVC) has been analysed and in simulation results has been proposed .

Index Terms:

Bidirectional, current-fed converter, fuel cell vehicle (FCV), ZCS(zero current switching), ZVS(zero voltage switching).

I. INTRODUCTION:

In automotive industry most research takes place in the electric vehicles. Two major concepts are electric vehicles (EV) and fuel cell vehicles(FCV). Comparing with EV’s, FCV’s has clear upper hand as FCV need short charging period and greater range of driving.

In the FCV itself, earlier implementation was using voltage fed converter but it has lot disadvantages such as high input pulsating current, limited soft-switching range, high circulating current through switches and relatively low efficiency for high voltage amplifications and high current input applications. Because of the draw backs of voltage fed based converter, the later converter based on current source had been implemented using snubbers. Usually employed current fed converters were resistor-capacitor-diode(RCD) snubber. But RCD snubber leads to low efficiency owing to clamping energy dissipated in snubber resistor. As a result a novel current fed DC/DC converter is proposed.

II. PROPOSED TOPOLOGY:

A dual half-bridge bidirectional dc/dc converter is proposed as shown in fig.1. However, this topology requires four split capacitors that occupy a considerable volume of the converter. It may need an additional control to avoid any voltage imbalance across the capacitors. In addition, the topology is not modular and is not easily scalable for higher power. Peak currents through the primary switches are greater than2.5× the input current and the top and bottom switches share unequal currents.

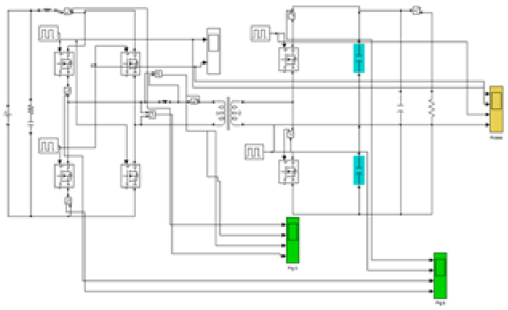

Fig. 1. Proposed ZCS CFDAB dc/dc converter.

Mainly four methods are used here to reduce the switching losses. ZVS, ZCS, ZCC, NVC, ZCS method is used in the primary switches, when current becomes zero in the switches gate signal is switches to zero, and voltage start to buildup. ZVS is used in the secondary switches, when voltage across the switch becomes zero gate signal is switched to high, so that current start to increase.

Before turning off the diagonal switch pairs of primary side switches (S1-S4), the other pair (S2-S3) is turned on. It diverts current from one switch pair to the other, causing the current through the conducting switch pair to rise and the current through conducting switch pair to fall to zero naturally resulting in ZCC.

Later the body diodes across switching pairs to start conducting and their gating signals are removed leading to ZCS turnoff of the devices. Commutated device capacitance starts charging with NVC.

III.OPERATION AND ANALYSIS OF CONVERTER

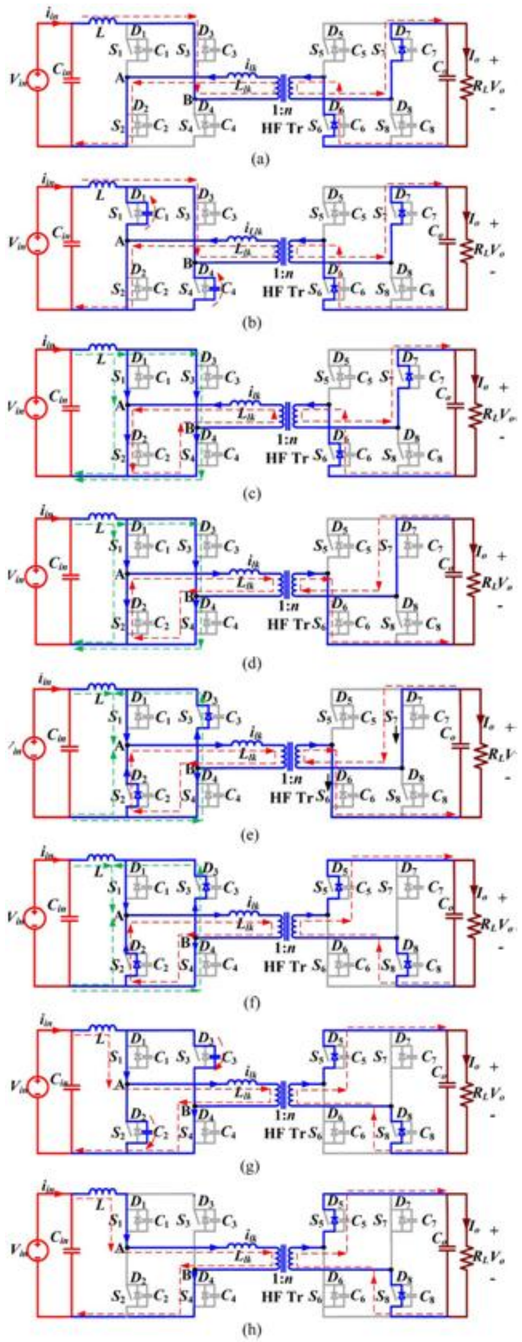

Fig. 2. Equivalent circuits during different intervals of operation.

Interval 1 (see Fig. 4(a); to < t < t1):

In this interval, primary-side H-bridge switches S2 and S3 and ant parallel body diodes D6 and D7 of secondary-side H-bridge switches are conducting. The current through inductor Llk is negative and constant. Power is transferred to the load through the HF transformer. Non conducting secondary devices S5 and S8 are blocking output voltage Vo, and non conducting primary devices S1 and S4 are blocking reflected output voltage Vo/n. The values of current through various components are iS2 =iS3 = Iin, iS1 = iS4 = 0, ilk = −Iin, and iD6 = iD7 = Iin/n. Voltage across switches S1 and S4 VS1 = VS4 = Vo/n. Voltage. across switches S5 and S8 VS5 = VS8 = Vo.

Interval 2 (see Fig. 4(b); t1 < t < t2):

At t = t1, primary switches S1 and S4 are turned on. Snubber capacitors C1 and C4 discharge in a very short period of time.

Interval 3 (see Fig. 4(c); t2 < t < t3):

Now, all four primary switches are conducting. Reflected output voltage Vo/n appears across leakage inductance Llk and causes its current to increase linearly. It causes currents through previously conducting devices S2 and S3 to reduce linearly. It results in conduction of switches S1 and S4 that started conducting with zero current, which helps reduce associated turn-on loss Since the ant parallel body diodesD6 andD7 are conducting, switches S6 and S7 can be gated for ZVS turn-on. At the end of this interval t = t3, D6 and D7 commutate naturally. Primary current reaches zero and ready to change polarity. Current through all primary devices reaches Iin/2. Final values areilk = 0, iS1 = iS2 = iS3 = iS4 = Iin/2, and iD6 = iD7 = 0.

Interval 4 (see Fig. 4(d); t3 < t < t4):

In this interval, secondary H-bridge devices S6 and S7 are turned on with ZVS. Currents through all the switching devices continue increasing or decreasing with the same slope as interval 3. At the end of this interval, primary devices S2 and S3 commutate naturally with ZCC and their respective currents iS2 and iS3 reach zero obtaining ZCS. The full current, i.e., input current Iin, is takeover by other devices S1 and S4, and the transformer current changes polarity. Final values are ilk = Iin, iS1 = iS4 = Iin,iS2 = iS3 = 0, and iS6 = iS7 = Iin/n.

Interval 5 (see Fig. 4(e); t4 < t < t5):

In this interval, the primary current or leakage inductance current ilk further increases with the same slope. Anti parallel body diodes D2 andD3 start conducting, causing extended zero voltage to appear across the outgoing or commutated switches S2 and S3 to ensure ZCS turnoff. Now, secondary devices S6 and S7 are turned off. At the end of this interval, currents through the transformer and switches S1 and S4 reach their peak value. This interval should be very short to limit the peak current through the transformer and switches, and thus their kilovolt ampere ratings.

Interval 6 (see Fig. 4(f); t5 < t < t6):

During this interval, secondary switches S6 and S7 are turned off. Ant parallel body diodes of switches S5 and S8 take over the current immediately. Therefore, the voltage across the transformer primary reverses polarity and the current through it starts decreasing. The currents through switches S1 and S4 and body diodes D2and D3also start decreasing.

Interval 7 (see Fig. 4(g); t6 < t < t7):

In this interval, snubbercapacitors C2 and C3 charge to Vo/n in a short period of time. Switches S2 and S3 are in forward blocking mode now.

Interval 8 (see Fig. 4(h); t7 < t < t8):

In this interval, currents through S1 and S4 and the transformer are constant at input current Iin. The current through ant parallel body diodes of the secondary switches D5 and D8 is Iin/n.

The final values are iS1 = iS4 = ilk = Iin, iS2 = iS3 = 0, and iD5 = iD8 =Iin/n. Voltage across switches S2 and S3 VS2 = VS3 = Vo/n. In this half HF cycle, current has transferred from one diagonal switch pair to the other diagonal switch pair, and the transformer current has reversed its polarity.

IV.SIMULATION RESULTS

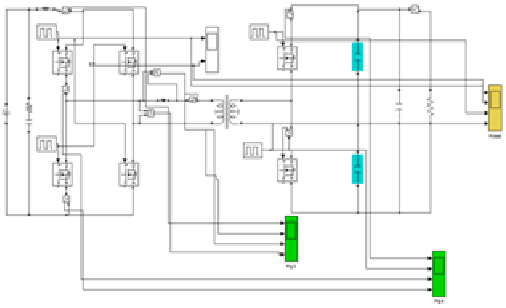

Fig 3. Simulation circuit pv based bidirectional converter

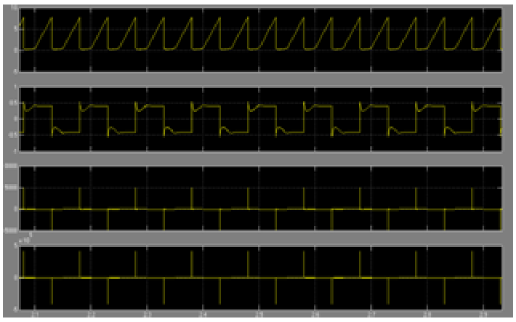

Fig 4. Current waveforms through input inductorI(L) and leakage inductanceI(Llk), voltage waveform across leakage inductance V(Llk),and voltage waveformVAB.

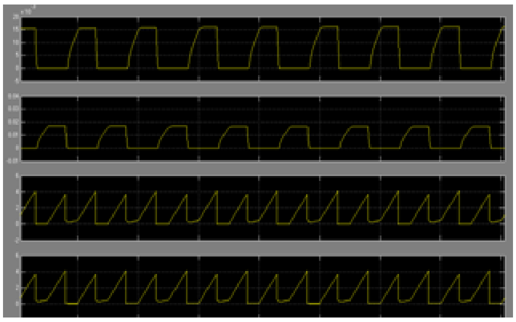

Fig 5. Current waveforms through primary switches I(S1) and I(S2)and secondary switches I(S5) and I(S6).

V.CONCLUSION:

A new dc/dc to converter is proposed in which use ZCS technique in the primary and ZVS technique in the secondary which ensure minimum switching loss. In the converter also use the possibility of ZCC and NVC. It therefore eliminates the need of an active-clamp or passives nubber. Usage of low-voltage devices results in low conduction losses in primary devices, which is significant due to higher currents on the primary side. The proposed modulation method is simple and easy to implement. This dc/dc and dc/ac converter find applications in the modern electric vehicles as interface between battery and three phase motor. These merits make the converter promising for interfacing alow voltage dc bus with a high-voltage dc bus for higher current applications such as FCVs. Can be employed in frontend dc/dc power conversion for renewable (fuel cells/photovoltaic) inverters, uninterruptible power system, microgrid and energy storage.

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