International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 141-144
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available at : www.ijcns.com
ISSN: 0976-1345

A NOVEL QUASI-RESONANT BOOST HALF BRIDGE CONVERTER FOR FUEL CELL APPLICATION

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ABSTRACT

Isolated boost DC-DC converters are finding an increase in demand in many applications such as fuel cell, PV systems and hybrid electric vehicles. The DC-DC converters should possess high voltage conversion ratio as the output obtained from a single PV panel or a fuel cell is low. Isolated boost converter is best suited for high step-up due to small input current ripple, low diode voltage rating and lower transformer ratio. Quasi-Resonant Boost Half Bridge (BHB) converter is one of the most suitable candidates for high-current and high step-up voltage. It consists of two half bridge converters, a transformer and an output side rectifier. The two half bridge circuits convert the input DC voltage to AC, to which the QR principle is applied so that switching losses are reduced. The AC voltage obtained is given to the high frequency transformer and the output of the transformer is further given to rectifier and also filtered using capacitors. External capacitors are additionally added to the boost half bridge converter to further reduce the switching losses.

Keywords: Isolated boost DC-DC converters, Quasi-Resonant Boost Half Bridge Converter, high frequency transformer, external capacitors.

I. INTRODUCTION

Quasi-Resonant converters, a high efficiency resonant tank circuit connected around the switch (transistor or freewheeling diode) employed to shape the switch current and voltage so that high voltage are not presented simultaneously. As a result stress and switching losses in the devices are greatly reduced. Depending on the high frequency resonant circuit is connected to the switch; the QRCs can be either ZCS-QRC or ZVS-QRC.

Quasi resonant Boost Half Bridge (QRBHB) converter is one of the most suitable candidates for high-current and high step-up application. In this project a Quasi-Resonant switching technique for a Boost Half Bridge (BHB) with active clamping is introduced by which the turn-off switching loss is reduced significantly. Half Bridge Boost Converter is used to obtain high step-up output. Use of two Half Bridge circuit produces the double boost output. Efficiency of the converter is improved by incorporating the soft switching technique of Zero Voltage Switching with the reduction of turn off losses.

II. PROPOSED TOPOLOGY

The proposed QRBHB converter consists of two input filter inductors, four MOSFET switches, and two auxiliary capacitors at the low voltage side. The topology is basically two high-frequency transformers and one output side rectifiers which are employed for isolation, step-up, and rectification, are connected in series so that the diode-voltage rating becomes half of the output voltage.

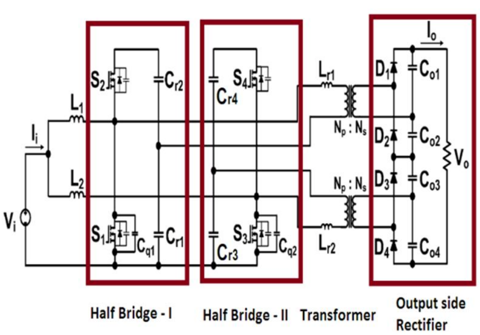

Fig.1. Proposed boost half bridge converter

The use of separate clamp capacitors for each phase helps mitigate, without the need for current sensors, the current imbalance problem caused by volt–second imbalance between the two inductors. Furthermore, owing to the capacitor connection at both sides of the transformer, there must be no dc offset in

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the magnetizing current. In the proposed converter, capacitors Cr1 − Cr4 are used to not only limit transient-surge voltage caused by transformer leakage inductance, but also resonate with the resonant inductors Lr1and Lr2 during switch turn-on process so as to reduce turn-off current. The resonant frequencies of the tanks Lr1-Cr1and Lr1- Cr2 are defined, respectively, by

$$f_{r1} = — = \frac{}{\square\sqrt{\quad .}} \qquad (1)$$

$$f_{r2} = — = \frac{}{\square\sqrt{\quad .}} \qquad (2)$$

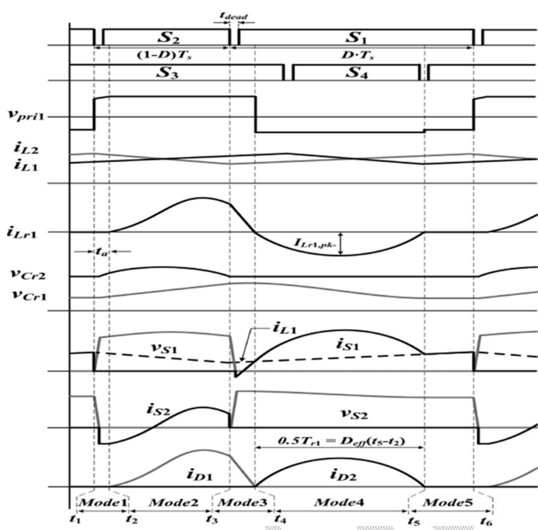

Fig.2. Waveforms of the proposed converter

Fig.3. shows key waveforms of the proposed converter to illustrate the operating principle. The two legs are interleaved with a 180◦ phase shift, and the upper and lower switches of each leg are operated with asymmetrical complementary switching to regulate the output voltage.

III. MODES OF OPERATION

1) Mode 1 operation: When applied voltage to the circuit a current starts flowing the circuit. But the switches will conduct only when gate pulses are given. When voltage is given, current iL1 starts flowing through the path Vi positive, L1, S2 (D), Cr2, Cr1and negative. When current flows in this manner the capacitors Cr1 and Cr2 will get charged. The current from Cr1 is getting divided to S1 and negative of Vi. The above current path for upper side of the transformer. Lower side of the transformer current iL2 is Vi positive, iL2 (Cr3 & S3), Lr2, transformer primary, Cr3, negative of the Vi. Switch S2 and S3 are turned ON at the moment S1 is turned OFF and ends at the moment capacitor voltage reflected in the secondary, n, vCr, becomes greater than capacitor voltage vCo1. Each switch carries both the input-inductor current and the leakage-inductor current. The voltage across the leakage inductor of the transformer is a difference between an auxiliary capacitor voltage (Vcr1 or Vcr2) and an output-capacitor voltage (Vco1, Vco2, Vco3, Vco4) referred to the primary. 2) Mode 2 operation: In the proposed converter capacitor Cr2 resonates with inductor Lr1. The current flows from the L1, Lr1 transformer primary, Cr2, S2, Cr1 and Vi negative. And the primary side voltage is induced to the transformer secondary and it's rectified, filtered the output voltage in the output side transformer. Second half bridge current path is Vi positive, lower side transformer, Lr2, S3, negative and its Cr3 discharging. 3) Mode 3 operation: During this mode, first half bridge converter current path is Vi positive, L1, Lr1, Cr1 and Cr2 discharging through the switch S2, S1 (Cq1) and Vi negative. In second half bridge, current flows from L2 to Vi through the switch S3.

4) Mode 4 operation: In this mode, the switch S2 is turned off and S1 is turned on. The capacitor is discharging though the path Cr1, Lr1, S1 and negative. Second bridge, the current flow is L2, Lr2, Cr4, S4, Cr2 and negative. D3 and Co3 rectifier and filters the output.

5) Mode 5 operation: The S1 is still conducting by the source current. In bridge II, the current path is L2, Lr2, S3 and negative.

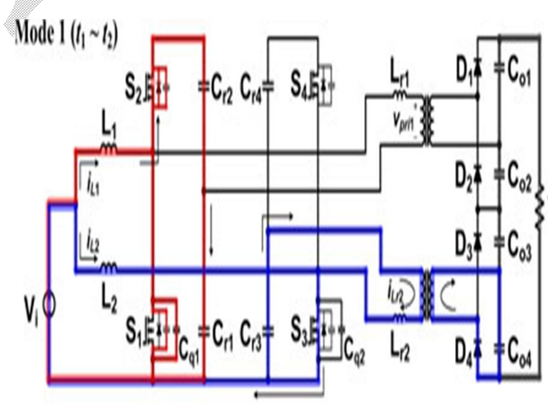

Fig.4. Circuit diagram of mode 1 operation

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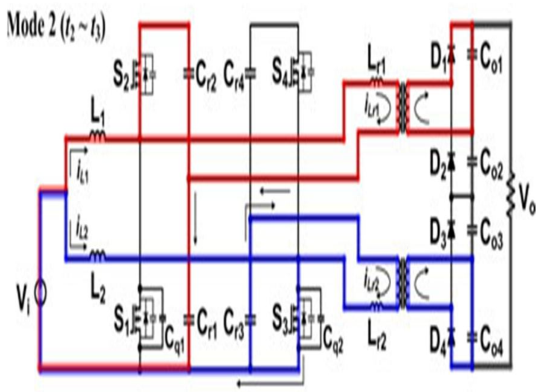

Fig.5. Circuit diagram of mode 2 operation

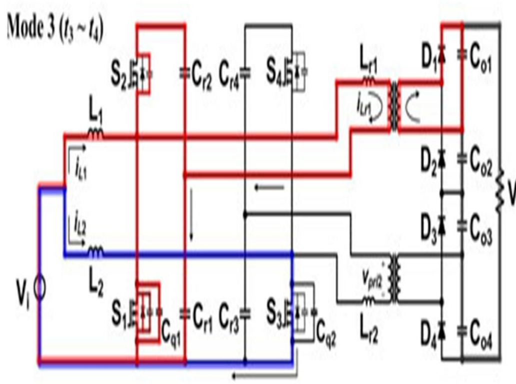

Fig.6. Circuit diagram of mode 3 operation

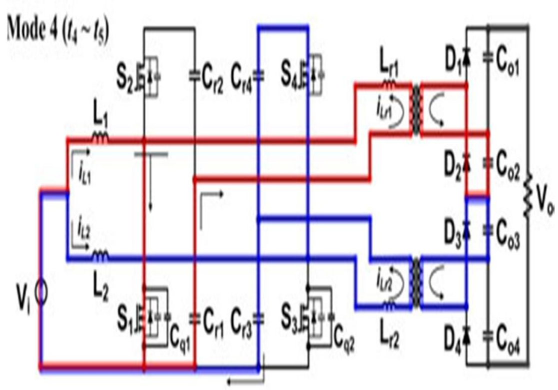

Fig.7. Circuit diagram of mode 4 operation

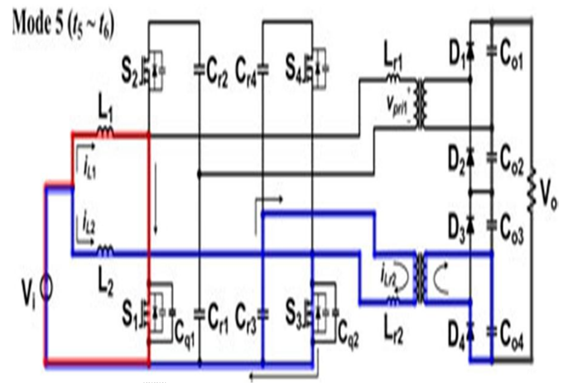

Fig.8. Circuit diagram of mode 5 operation

IV. SIMULATION RESULTS

The proposed Quasi-Resonant Boost Half Bridge converter is simulated using MATLAB/Simulink software package. The voltage gain is obtained to be 8. The increase in efficiency is higher than the PWM current fed isolated converter. For an input voltage of 20V, at 50 KHz the output voltage of 145V and the power of 212W are obtained. Thus a voltage gain of 7.3 is achieved. The input and output waveforms are shown in Fig. 12 & Fig 13.

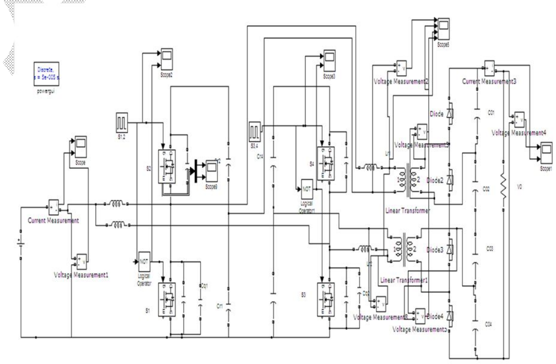

Fig.9. Simulation diagram of proposed system

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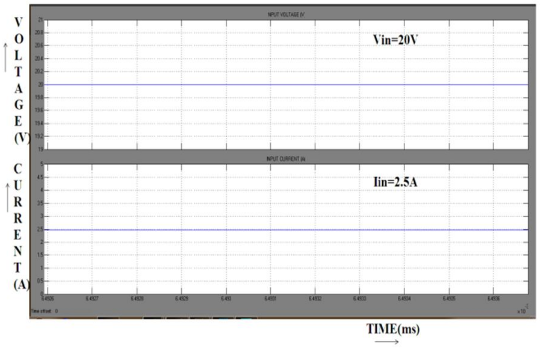

Fig.12. Input voltage and current waveforms

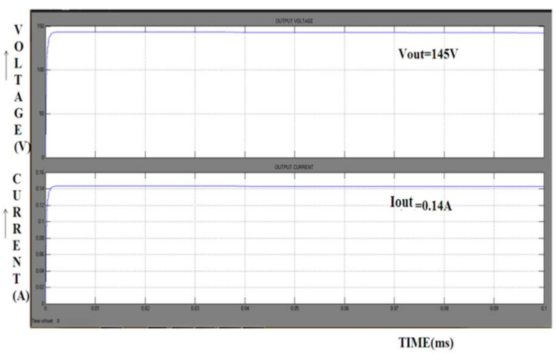

Fig.13.Output voltage and current waveforms

MATHEMATICAL CALCULATIONS

1)Voltage Gain = Output Voltage / Input Voltage

Existing system:

Vin = 20V; Vout =60.52V

Voltage gain = 60.52/20 = 3.02

Proposed system:

Vin = 20V; Vout = 145V

Voltage gain = 145/20 = 7.25

2)Efficiency = (Output power / Input power)%

Existing system:

Pin = 15.2W; Pout =3.66W

Efficiency in terms of power (Pe)

= (3.66/15.2)*100 = 24%

Proposed system:

Pin = 50W; Pout = 20.3W

Efficiency in terms of power (Pp)

= (20.3/50)*100 = 40%

Percentage increase in efficiency

= {(Pp – Pe) /Pe} * 100

= {(40-24) / 40} * 100

= 66%

V. CONCLUSIONS

This work explains a Quasi-Resonant Boost Half Bridge converter. The proposed converter achieves ZVS turn ON of switches and ZCS turn OFF of diodes. The turn OFF current of switches is reduced by the resonant operation. By adding an external capacitor across the lower switches the switching losses can be further reduced. High voltage gain and efficiency can be obtained. The proposed system achieves a voltage gain of 7.3 and an efficiency of 66% greater than the converter.

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