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Quasi Switched Boost Network Based DC-DC Converter

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ABSTRACT: In this work, an isolated high step-up DC-DC converter is presented based on the quasi-switched- boost network. The important features of this converter are continuous input current and reduced turns ratio of the isolated transformer. Also this converter has increased reliability, as it can operate in either short-circuit mode or open-circuit mode without causing damage to the power converter. Although the shoot-through duty cycle is variable, this converter has unchanged primary and secondary voltage waveforms of the transformer. The operating principles and analysis of the converter is presented in this work. This converter is applicable for distributed power generation applications where a varying low DC input voltage is converted to a high stabilized DC output voltage. Simulation is carried out in MATLAB.

KEYWORDS:DC-DC converter, Shoot–through, Quasi switched boost network,Z source converter

I.INTRODUCTION

There exist two traditional converters, voltage source and current source converters.Fig.1 shows a traditional voltage source converter.A DC voltage source supported by a relatively large capacitor feeds the main converter circuit, a three phase bridge.These traditional converters have the following problem. They are either a buck converter or a boost converter and cannot be a buck boost converter. Their main circuits cannot be interchangeable ie, neither the voltage source converter main circuit can be used for current source converter, nor viceversa. They are vulnerable to EMI noise in terms of reliability. To overcome the above problems,Z source converters are introduced. Fig.2 shows the general Z source converter. It employs a unique impedance network to couple the converter main circuit to the power source. It can be used as a buck boost converter. Also this converter has the unique ability to short the DC link, which is not possible in traditional voltage source inverter. This improves the reliability of the circuit. The concept of boosting the input voltage is based on the ratio of “shoot through” time to the whole switching period. The presence of two inductors and two capacitors in Z source network allows both the switches of the same phase leg, in ON state simultaneously called as shoot through state and gives the boosting capability to the inverter without damaging the switching devices. The disadvantages of Z source inverter is that, the input current is discontinuous in the boost mode, capacitor must sustain a high voltage and also passive component ratings are high.

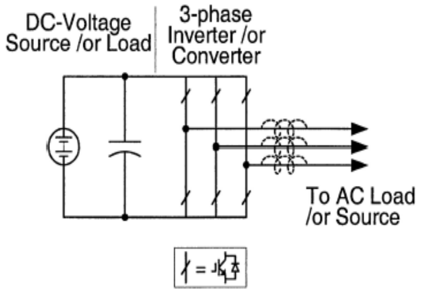

Fig.1. Voltage source

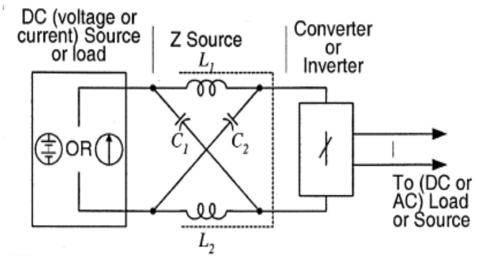

Fig.2. Z source converter

II. QUASI SWITCHED BOOST NETWORK BASED ISOLATED DC-DC CONVERTER

Fig.3 shows the qSB -based isolated DC-DC converter. This converter utilizes a qSB inverter, a high frequency step-up isolated transformer and a load. It consists of one inductor, three capacitors, eight diodes (including four body diodes in power switches), four power switches, and one step-up high-frequency transformer. As the input voltage is directly connected to the inductor, the source current in this converter is continuous.

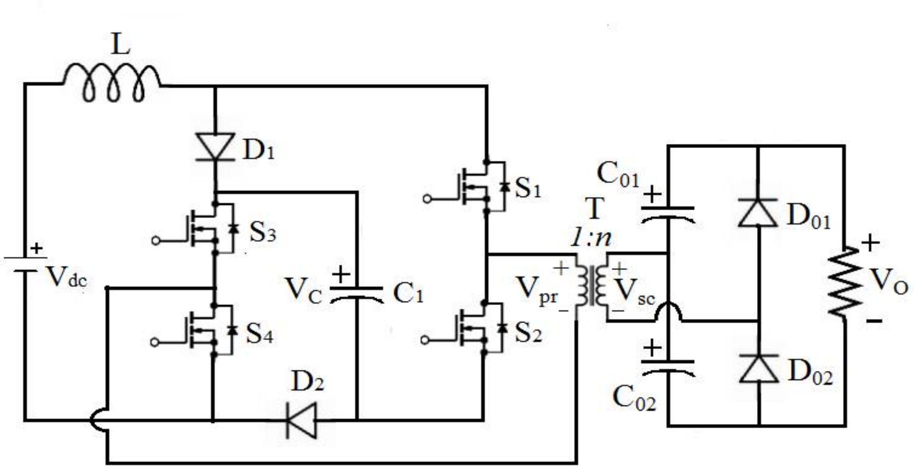

Fig.3. Circuit diagram of quasi switched boost network based isolated DC-DC converter

To simplify the circuit analysis of the converter in continuous conduction mode, the followingconditionsareassumed:1)theinverterisoperatinginacontinuousconduction mode (CCM) 2) all devices are ideal and lossless and 3) the capacitance value is large enough to maintain the constant capacitor voltage.

III. MODES OF OPERATION

(a) MODE 1

In the shoot-through mode as shown in fig.4, all switches are switched on, the diodes D 1 and D 2 are reverse-biased. The time interval in this state is D ST T, where D ST and T are the shoot-through duty cycle and the switching period, respectively. During the shoot-through mode, the inductor L is charged, while the capacitor C 1 is discharged. The primary voltage of the high-frequency transformer is -V c . After passing through the step-up transformer, the secondary voltage is negative, the diode D 01 is forward-biased and the diode D 02 is reverse-biased. By applying Kirchhoff’s Voltage

Law and Kirchhoff’s current law in fig.4,

$$V_L = V_{dc} + V_C \text{ ………………………..(1a)}$$

$$i_{C1} = -I_P - I_L \text{.......................................(2a)}$$

$$i_{C01} = I_S - V_O/R \text{………………………...(3a)}$$

$$i_{C02} = -V_0/R \text{…………………………..(4a)}$$

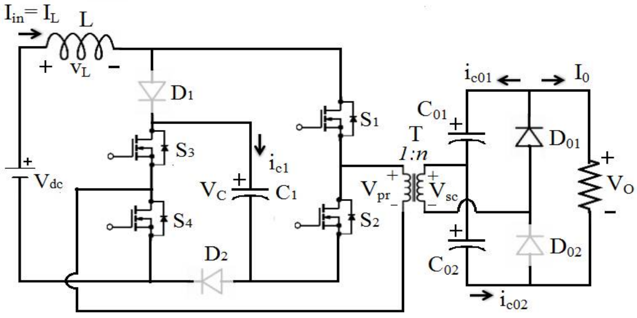

Fig.4.Shoot through mode

(b)MODE 2

In the active-negative mode, as shown in fig.5, S 1 and S 4 are switched OFF while S 2 and S 3 remains ON. The primary voltage of high frequency transformer is at -V C . The states of the secondary side are unchanged, similar to the shoot-through mode. We have

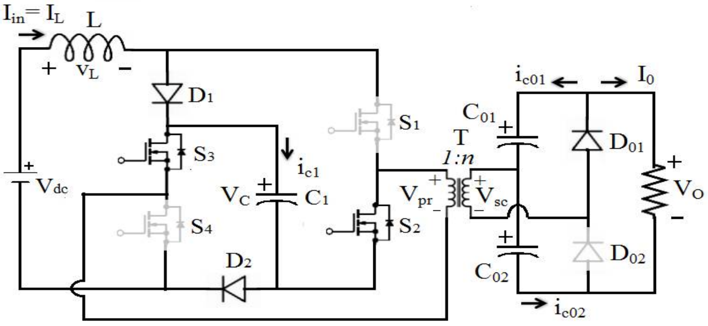

Fig.5.Active negative mode

$V_L= V_{dc}- V_C$………………………..(1b)

$i_{C1}= -I_P + I_L$…………………………(2b)

$i_{C01}= I_S-V_O/R$……………………….(3b)

$i_{C02}= -V_0/R$…………………………(4b)

(c) MODE 3

Fig.6 shows the zero mode. S 2 and S 4 are switched ON while S 1 and S 3 are switched OFF. The time interval in this state is D 0 T, where D 0 is the duty cycle of the zero mode. The primary winding of the transformer is in a short-circuit situation.

The secondary voltage of the transformer is zero, the diodes D 01 and D 02 are reverse-biased. We get,

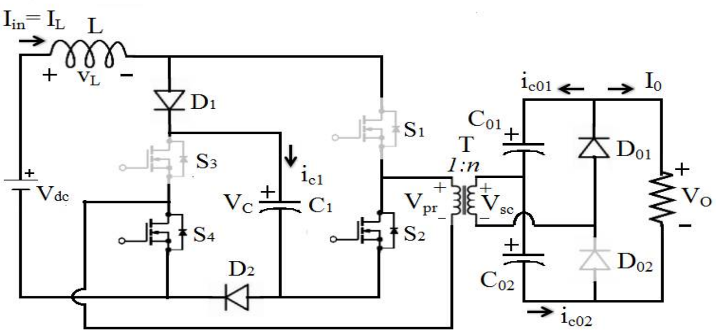

Fig.6. Zero mode

$$V_L = V_{dc} - V_C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1c)$$

$$i_{C1} = I_L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2c)$$

$$i_{C01} = -V_O/R \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3c)$$

$$i_{C02} = -V_0/R \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4c)$$

(d) MODE4

In the active-positive mode as shown in fig.7,$S_1$and $S_4$are switched ON while S_2 and $S_3$are switched OFF. The time interval in this state is (1-D_0)T/2. The primary voltage of the transformer is V_c. The secondary side voltage of the transformer is positive, the diode D_{01} is reverse-biased while the diode D_{02} is forward-biased. We have

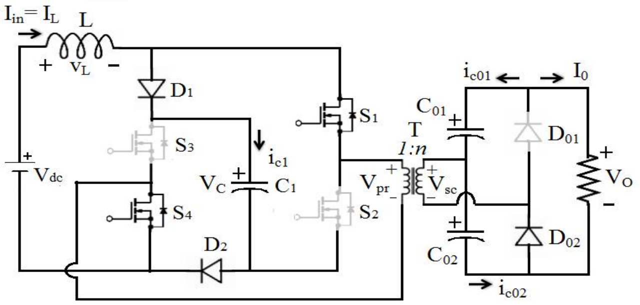

Fig.7.Active positive mode

$$V_L = V_{dc} – V_C \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1d)$$

$$i_{C1} = -I_P + I_L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2d)$$

$$i_{C01} = -V_O/R \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3d)$$

$$i_{C02} = I_S - V_0/R \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4d)$$

III. PWM CONTROL

Fig.8 shows the switching pattern of the converter. A reference voltage, V ref , is compared to a high frequency triangle waveform, V tri1 , to generate the control signals for switches S 1 and S 2 . Another reference voltage with an amplitude of (1-V ref) is also compared to V tri1 in order to generate control signals for the switches S 3 and S 4 . V ref should be in the range of (0.25, 0.75) to ensure that the duty cycle of the active states is more than 50 percent. To generate the shoot-through modes, a constant voltage, V sh , is compared to another triangle waveform, V tri2 , with 180 phase shift to V tri1 .

Ensure that V sh is in the range of [V ref , 1]. The shoot-through control signal is then inserted into the control signals of switches S 1 and S 4 through OR logic gates. When V ref = 0.5, the converter cannot generate the zero voltage. When V ref > 0.5, the zero voltage is generated by switching on S 2 and S 4 as shown in fig When V ref < 0.5, the zero voltage is generated by switching on S 1 and S 3 . From fig.8, we can observe that the operating frequency of the transformer is also the switching frequency. V ref is normally kept constant for the unchanging voltage waveforms of the transformer. Therefore, the control voltage of the proposed converter is only V sh . Here, V sh is the shoot-through control voltage. It relates to the shoot-through duty cycle as V sh = 1 - D ST . As shown in fig.8, the proposed converter operates only with a short-circuit mode and without the open-circuit mode, where all switches are turned OFF. In the operating process however, if all switches are turned OFF, the current will free-wheel through the diodes without any spike voltage generations on the devices. Therefore, this converter can operate in either short-circuit mode or open-circuit

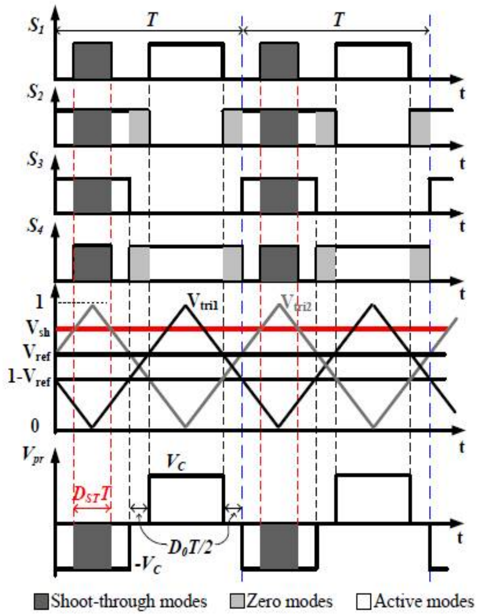

Fig.8.PWM control

mode without causing any damage to the power converter.

IV. SIMULATION MODELS AND RESULTS

(a) SIMULINK MODEL OFqSB BASEDISOLATEDDC-DC CONVERTER

The converter is simulated using MATLAB. A voltage of 40 V is given as input voltage. The switch is controlled by PWM technique. Theswitchingfrequencyistakenas10 kHz and shoot throughdutyratiois0.25. Fig.9 shows the simulation diagram of the converter. Control circuit is shown in fig.10.

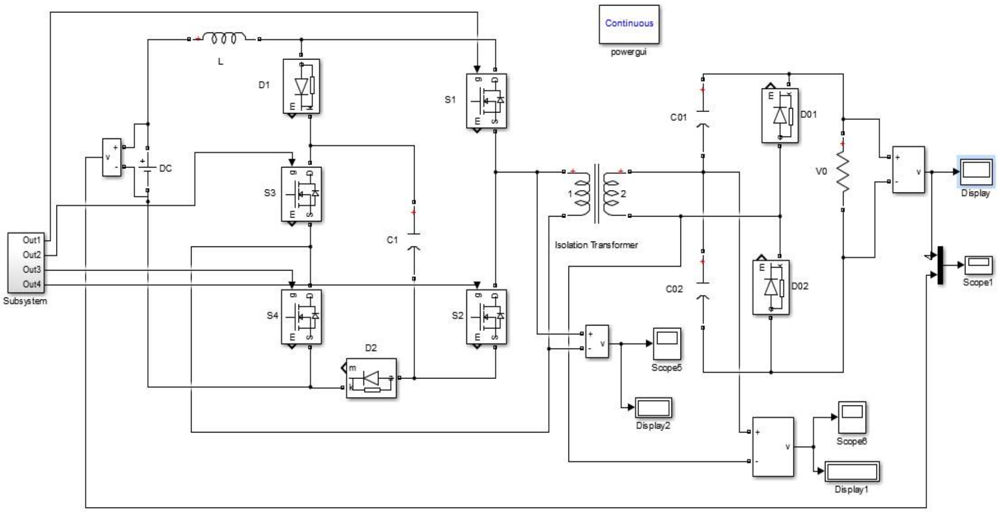

Fig.9.Simulink model of qsb based converter

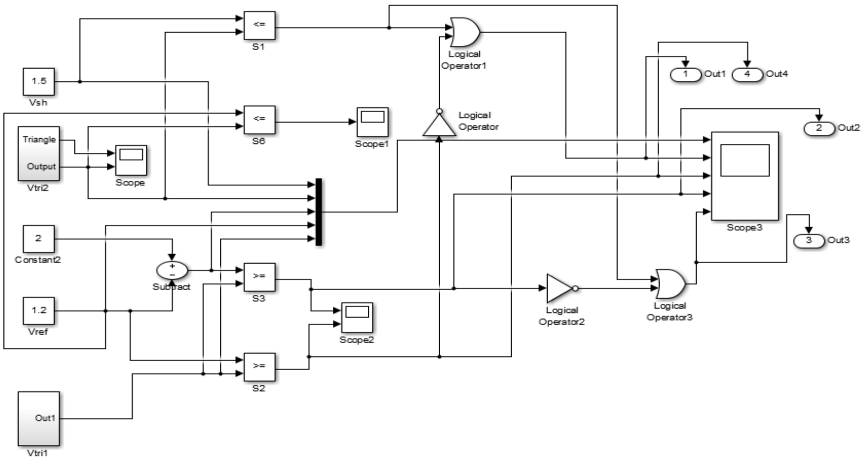

Fig.10.Control circuit subsystem

(b) SIMULATION RESULTS

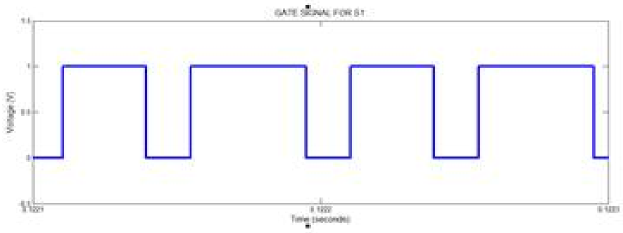

Fig .11 Switching pulse for S1

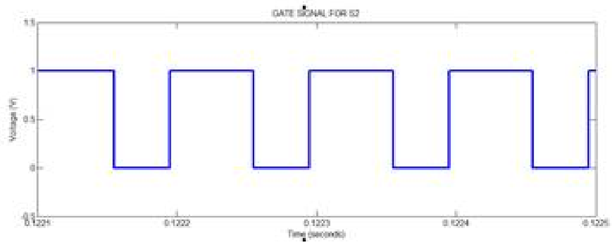

Fig .12 Switching pulse for S2

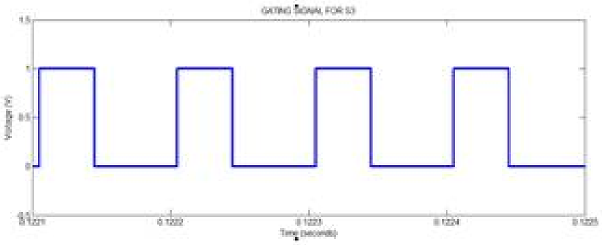

Fig.13 Switching pulse for S3

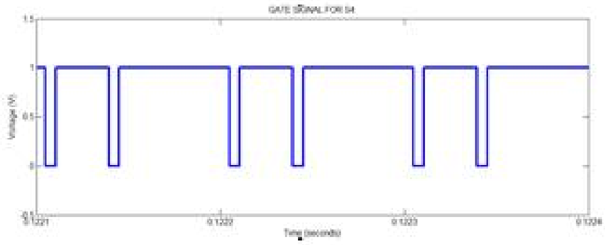

Fig.14 Switching pulse for S4

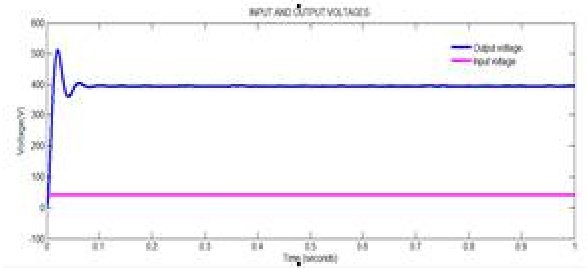

Fig.15 Input and output voltages

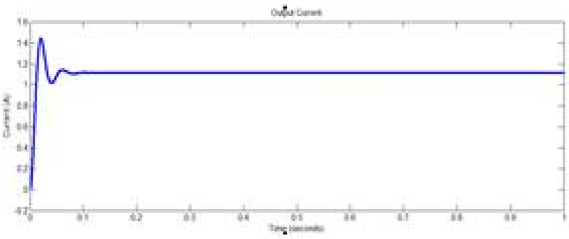

Fig.16 Output current

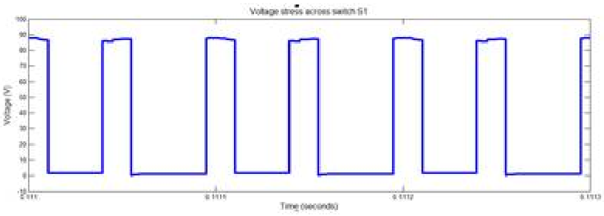

Fig.17 Voltage stress across switch S1

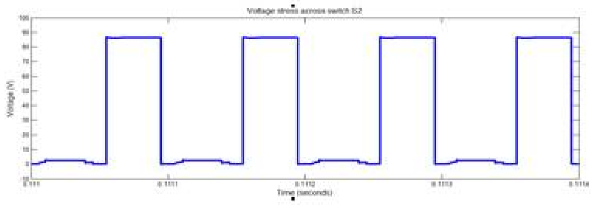

Fig.18 Voltage stress across switch S2

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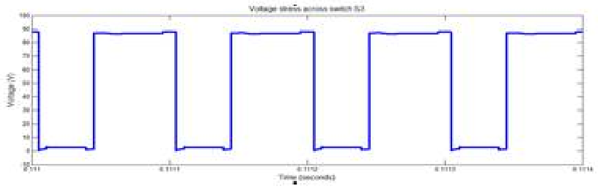

Fig.19 Voltage stress across switch S3

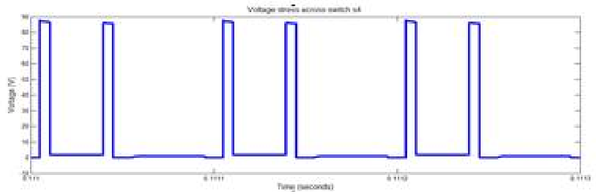

Fig.20 Voltage stress across switch S4

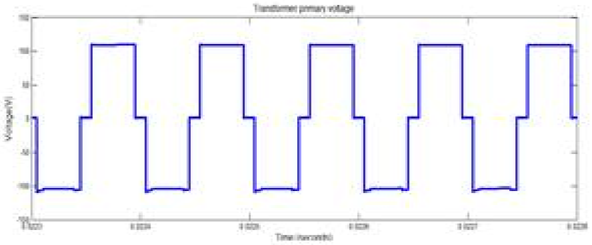

Fig.21 Transformer primary voltage

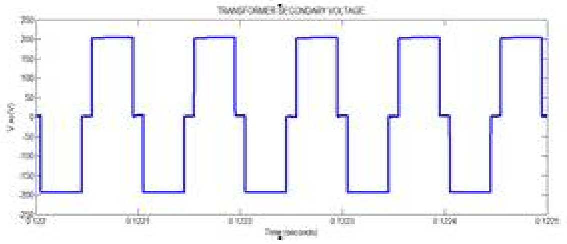

Fig.22 Transformer secondary voltage

Fig.11-14 shows the switching pulses for the four switches.The converter is given an input voltage of 40 V.The output voltage obtained is 395 V.Input and output voltages are shown in fig.15. The voltage stress across the switches are shown in fig.17-20.The stress across each switch is 88 V. During the shoot through and active negative mode transformer primary voltage is negative and during zero mode it is zero and during active positive mode transformer primary voltage is positive. This is shown in fig.21.

V.CONCLUSIONS

The qSB based isolated DC-DC converter can operate in either short-circuit mode or open-circuit mode without causing any damage to the power converter. In addition, the input current of the converter is continuous. Thus, the converter can reach the required reliability without the need for any additional components. Because the VDR and shoot-through duty cycle are used to boost voltage, the turns ratio of the isolated transformer is significantly reduced. Also this converter uses fewer passive components. Therefore, the size, weight and cost of the converter are reduced. This converter is suitable for distributed power generation applications where a varying low dc input voltage is converted to a high stabilized dc output voltage with the galvanic separation requirement.

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