Load resonant for step up DC-DC converter by two stages quasi Z source network

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ABSTRACT

In this paper a novel resonant dc-dc converter using cascaded quasi Z-source network is presented. Different conventional converters like series resonant converter and LLC resonant converters suffers from wide range of input voltage and load variations since switching frequency was varied. The proposed Z-source dc-dc converter can minimize switching frequency range to lead high converter efficiency. The cascaded qzs network is derived from traditional quasi Z source inverter by including one diode, one inductor, and two capacitor to it. The cascaded qZSI operates as step up converter in normal mode i.e. output voltage is increased three times than input voltage and for boost mode output voltage is increased ten times input voltage. When compared with traditional qZSI proposed solution reduces shoot through duty cycle by over 30% at same voltage boost factor. Two stage qZSI in shoot through and non-shoot through modes are described theoretically. This proposed system is reliability is greatly improved. Its performances are verified using MATLAB\SIMULINK tool to verify theoretical assumptions and hardware is implemented by using solar energy as input.

Keywords: DC-DC converter, series resonant Converter, LLC resonant converter, pulse width modulated power converters, rectifiers, Z-source network.

INTRODUCTION

Quasi Z source isolated Dc/Dc converters have been widely used in medium power applications for distribution system. Converters have no switching loss and are more suitable for high frequency operations. Due to safety and dynamic performance requirements, the interface converter should be realized within the dc/dc/ac concept. This means that low voltage from the source first passes through the front-end step-up dc/dc converter with the galvanic isolation; subsequently, the output dc voltage is inverted in the three-phase inverter and filtered to comply with the imposed standards and requirements (second dc/ac stage).The block diagram with double and single converters is shown in fig 1.
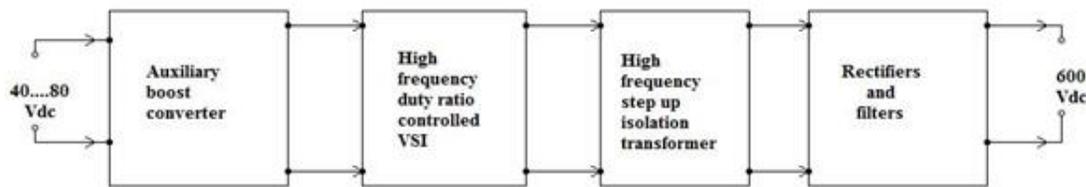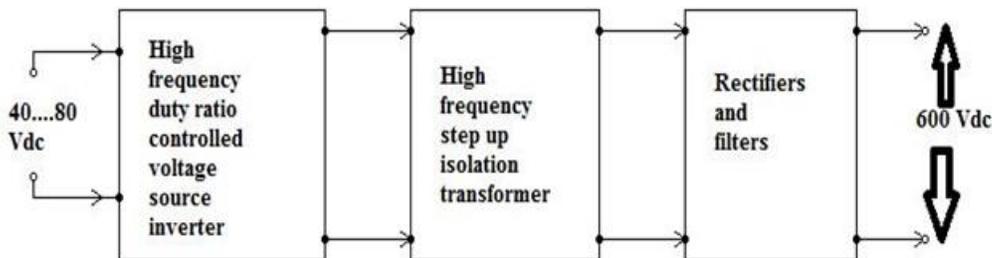

Fig 1(a) **With double converter**

Fig 1. (b) With single converter

Distributed power generation, when fully implemented, can provide reliable, high-quality, and low-cost electric power is focused. To increase the power density of the converter, a three-phase auxiliary ac link (a three-phase inverter and a three-phase isolation transformer) and a three-phase VDR are proposed. The design of the front-end isolated dc/dc converter is most challenging because this stage is the main contributor of interface converter efficiency, weight, and overall dimensions. In the first case [Fig. 1(a)], the auxiliary boost converter steps up the varying FC voltage and battery voltage to a certain constant voltage level (40–80 Vdc) and supplies the input terminals of the isolated dc/dc converter. Its main drawbacks are drawn from the multistage energy conversion structure, i.e., complicated control and protection algorithms and reduced reliability due to the increased number of switching devices. A direct step-up dc/dc converter without input voltage pre regulation [Fig. 1(b)] is simpler in control and protection. Due to the reduced number of switching devices, the converter tends to have better efficiency and reliability. The varying voltage from the FC is passed through the high-frequency inverter to the step-up isolation transformer. This paper is devoted to a new power circuit topology to be implemented in the front-end dc/dc converter to provide effective voltage step-up in the whole range of input voltage and load variations by using isolation transformer.

TRADITIONAL Z SOURCE CONVERTER

To overcome the above problems of the traditional V-source and I-source converters, an impedance-source (or impedance-fed) power converter (abbreviated as Z-source converter) and its control method for implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion is implemented and explained in. The unique feature of the Z-source inverter is that the output ac voltage can be any value between zero and infinity regardless of the input voltage. That is, the Z-source inverter is a buck–boost inverter that has a wide range of obtainable voltage. Fig 2 show the traditional voltage fed ZSI and the proposed voltage fed qZSI, respectively. Lz and Cz are connected in a shape to provide an impedance source coupling the converter to dc source/load (can be either voltage and current source/load). So, DC source can be a battery, diode, rectifier, thyristor converter, fuel cell, an inductor, a capacitor or a combination of those. With the traditional ZSI, the unique LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state. This network will effectively protect the circuit from damage when the shoot-through occurs and by using the shoot-though state, the (quasi-) Z-source network boosts the dc-link voltage obtained. The ZSI has discontinuous input current in the boost mode; while the input current of the qZSI is continuous due to the input inductor $L1$, which will significantly reduce input stress. Two high-efficiency energy recycling zero-voltage electronic loads (ELs) based on a Z-source converter can be also explained in.
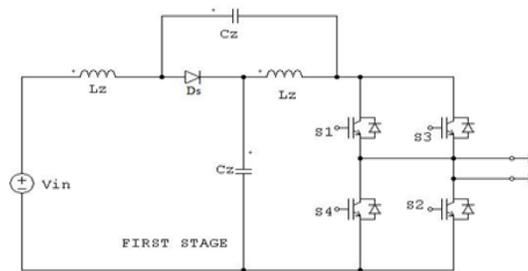

Fig.2.Traditional Z source network

The proposed Z-source resonant converter has both the buck and boost function, based on its operating states i.e.output voltage (Vdc) of the converter can be located either within or in the middle of the input voltage (*Vin*) range. The output voltage of inverter (Vo) can be connected to rectifier through series resonant circuit is discussed in. The resonant tank is connected between Z source and load in fig 3 it exhibits three operating modes based on resonant frequency.

$$fr=1/2\pi LrCr$$

Normal mode (Vin=Vdc, fsw = fr): In normal mode switching frequency is set equal to the frequency of tank circuit. The tank frequency can be defined as
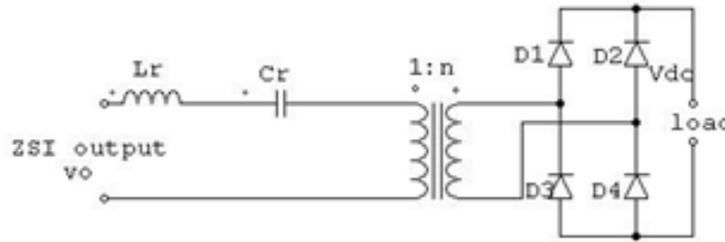
Fig.3.Resonant tank connection

Where Lr and Cr are tank circuit elements. There is no circulating current and all switches are turned on and off at perfect zcs and zvs condition.so maximum efficiency will be achieved here.

Buck mode (Vin>Vdc , fr<fsw<fsw.max): In this mode, the proposed converter operates as conventional SRC and controls *Vo* by increasing *fsw* from *fr* to its maximum switching frequency (*fsw*.max). However, unlike the SRC, frequency range of the proposed converter can be much narrower than that of the SRC because the input voltage range in buck mode is narrower than that of the SRC[4 .7]. As a consequence, light load efficiency of the proposed converter can be improved significantly.

Boost mode (Vin<Vdc,fsw = fr): In this mode, *fsw* is fixed to *fr*, same as the normal mode operation mentioned above. In this mode, however, the proposed converter uses switch shoot through to boost *Vo*. This Z source network uses shoot through mode to boost the voltage and the circuit can be analyzed to determine the boost voltage factor.

STEP UP DC/DC CONVERTER WITH CASCADED qZS-NETWORK

The cascaded (two-stage) qZS-network could be derived by the adding of one diode, one inductor, and two capacitors to the traditional quasi-Z-source inverter (qZSI). The proposed cascaded qZSI inherits all the advantages of the traditional solution (voltage boost and buck functions in a single stage, continuous input current, and improved reliability). Moreover, as compared to the conventional qZSI, the proposed solution reduces the shoot-through duty cycle by over 30% at the same voltage boost factor. In traditional qZSI, the shoot through states are used to boost the magnetic energy stored in the dc-side inductors *Lz* and *Lz* without short circuiting the dc capacitors *Cz* and *Cz*. This increase in magnetic energy, in turn, provides the boost of the voltage seen on the inverter output during traditional operating states. If the input voltage is high enough, the shoot- through states are eliminated, and the qZSI begins to operate as a traditional VSI.
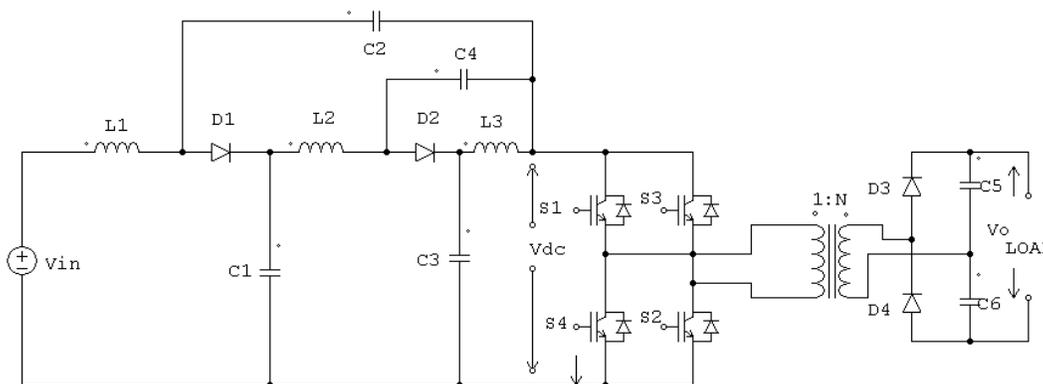

Fig.4.Cascaded two stage qZS network and a voltage doubler without resonant element
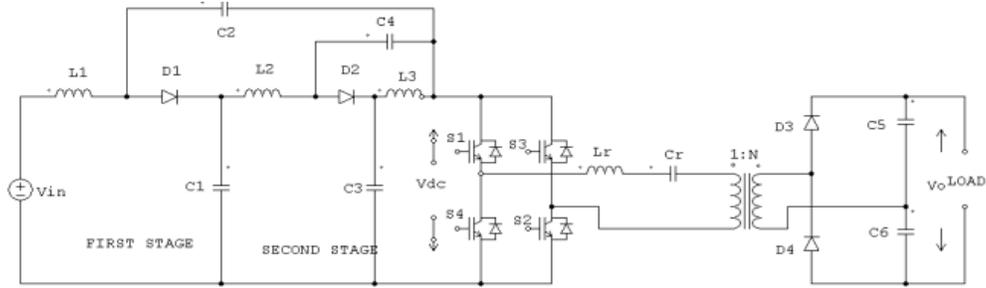
Fig.5.Cascaded two stage qZS network and a voltage doubler with resonant element

The topology proposed (Fig. 4 and 5) utilizes the voltage-fed qZSI with a cascaded qZS-network and continuous input current, a high-frequency step-up isolation transformer, and a voltage-doubler rectifier. It analyzes the design of the two-stage qZSI, whereas the design and operation of the transformer–rectifier stage of the converter remain the same as those with traditional isolated full-bridge converters. To regulate the varying input voltage, the front end/cascaded qZSI has two different operating modes:

MODES OF OPERATION

- Non shoot-through(active mode) and

- Shoot through.(boost mode)

Non shoot through mode: During light load conditions qZSI performs only voltage buck function, when the output voltage of FC or any varying dc source reaches maximum value. The inverter is controlled in the same manner as with the traditional VSI, utilizing only the active states when one and only one switch in each phase leg conducts is given in. VSI applies one of the six non-zero switching vectors to the load while drawing a load dependant current from its input source. Considering the power balance between the input and output of the VSI, the current drawn from the impedance network during this state can be represented by a constant current source Idc . The transistors in the full-bridge configuration are controlled alternately in pairs ($s1$ and $s4$ or $s2$ and $s3$,) with 180∘-phase-shifted control signals are notify in. In this operating mode, the duty cycle of inverter switches could never exceed 0.5. The equivalent circuit of the two-stage qZSI during non-shoot-through (active) states is shown in Fig. 6(a).
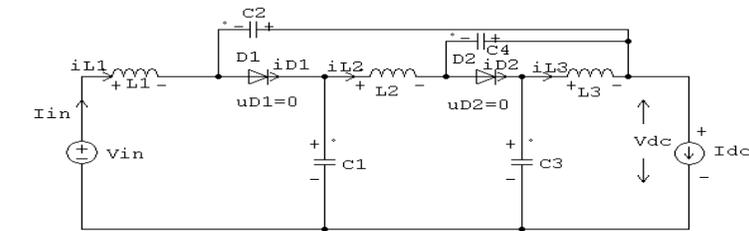
(a)
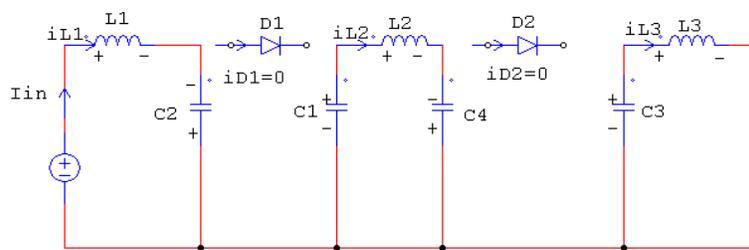
(b)

Fig 6.Equivalent circuits during (a) non shoot through (active) state (b)shoot through state

Shoot through mode: When the input voltage drops below some predefined value, the qZSI starts to operate in the shoot-through mode. In order to boost the input voltage during this mode, a special switching state—the shoot-through state—is implemented in the pulse width modulation (PWM) inverter control. The cascaded QZS network makes the shoot-through states possible, effectively protecting the circuit from damage is indicated in. Moreover, the shoot through states are used to boost the magnetic energy stored in the dc-side inductors $L1$, $L2$, and $L3$ without short circuiting the dc capacitors $C1$, . . . , $C4$. This increase in the magnetic energy, in turn, provides the boost of the voltage seen on the inverter output during the active states. The equivalent circuit of the two-stage qZSI during the shoot-through states is shown in Fig. 6(b).

Operation without resonant elements Lr and Cr: In fig 4 the circuit diagram for cascaded Z source network is shown. This circuit will be operated in active and shoot through states. Therefore output of voltage doubler (Vo) is increased at 3-9 times than input voltage (Vin). In active state Vo is three times Vin and nine times greater than Vin during Boost mode due to the presence of two stage Z source network.

Operation with resonant elements Lr and Cr: Figure 5 is referred for operation of two stage Z source network with tank circuit. This circuit also operated in active and shoot through states. Therefore output of voltage doubler (Vo) is increased at 4-10 times than input voltage (Vin).compared to without resonant elements this mode increases output voltage.

SIMULATION RESULTS

The supply voltage can be varied from 50V-150V as per load and value of source inductor and capacitors. The resonant frequency is set to 49.3 kHz.
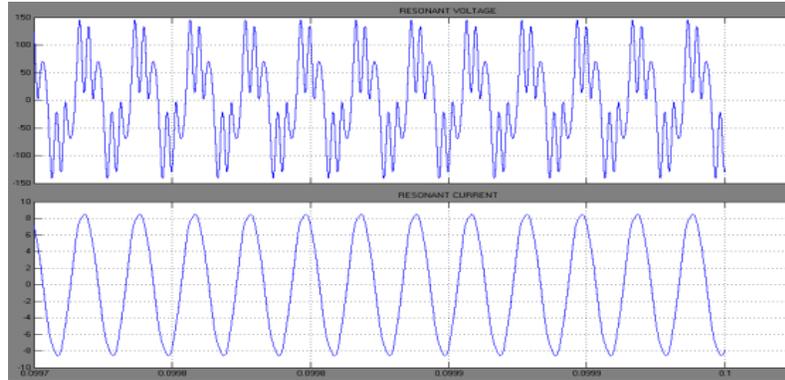
Traditional Z source network: The Supply voltage of converter is 40V and achieved output voltage is 800V in boost mode. And in buck mode the 80V is applied voltage and achieved output voltage is 60V as per the load variations. In normal mode the 80V is supplied voltage and same is achieved. And the experimental parameters are source inductor=5e-6, capacitor=.54e-6, isolation transformer=1:1 turns ratio, series resonant of series inductor =74e-6H, capacitor= 141e-09F. All the simulations in traditional are observed using resistor load (20Ω-100Ω) in fig 8. Larger source inductor and capacitor can be used at 100e-6H, 220e-6F respectively.
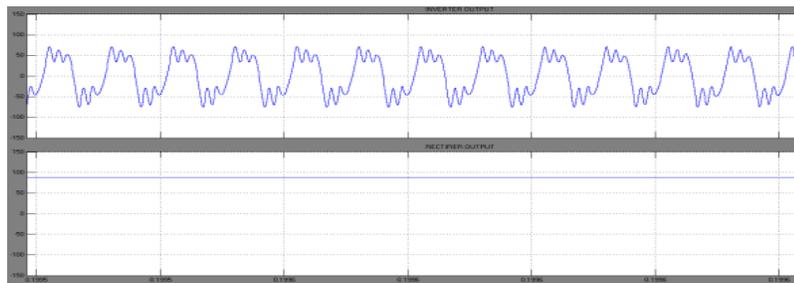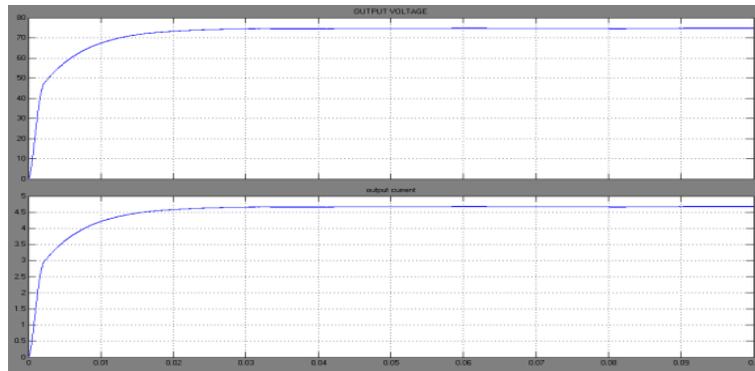

a.   Normal mode inverter and rectifier output
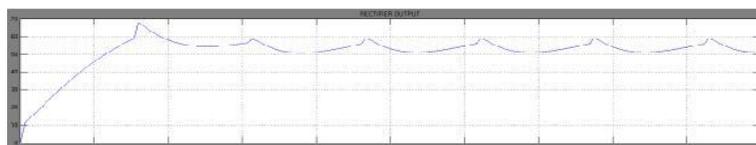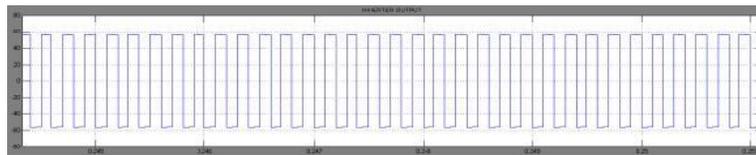
b.   buck mode inverter and rectifier output

**c. Boost mode inverter output voltage and current**

**(d) Boost mode rectifier output voltage and current.**
Fig 7.output waveforms of traditional Z network in normal (a) , buck (b) and boost(c&d) modes.

Cascaded two stage Z source network: The values of source inductor and capacitor are same in traditional network. But input voltage is 100V for both active and shoot through states. This circuit does not work in boost mode.

Without tank circuit: For 100V supplied voltage output of voltage doubler is varied from 300V to 900V in normal (a) and boost (b)modes in fig 8.
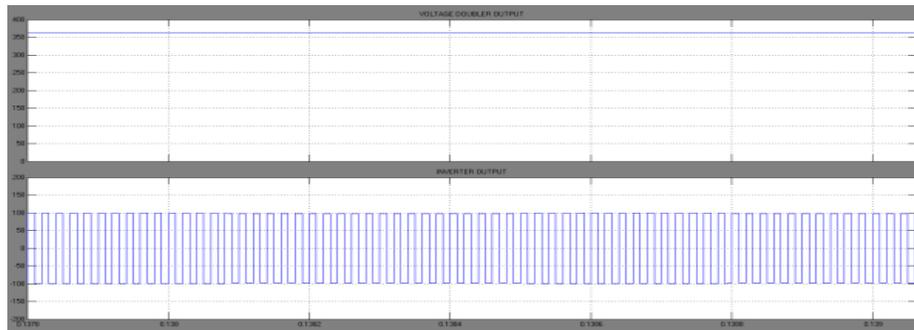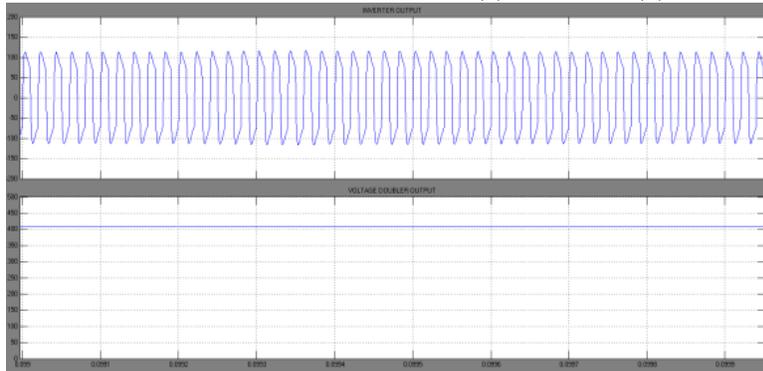

(a)Normal mode voltage doubler and inverter output
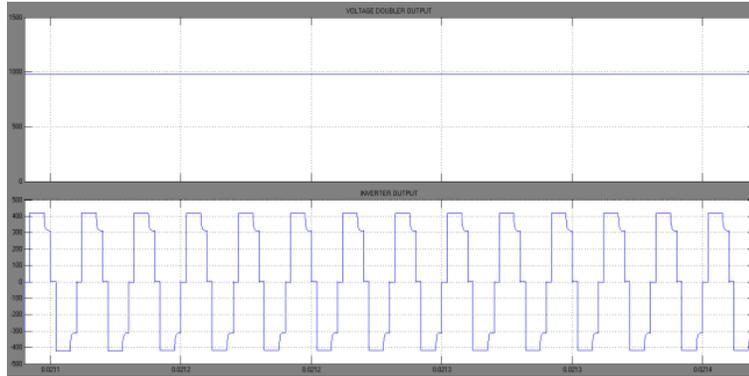
(b) Boost mode voltage doubler and inverter output
Fig.8.Cascaded two stage ZSI network without tank circuit

With tank circuit: The value of series Lr and Cr are same in traditional Z source network. For 100V supplied voltage, output of voltage doubler is varied from 400V to 1000V in normal (a) and boost (b) modes in fig 9.

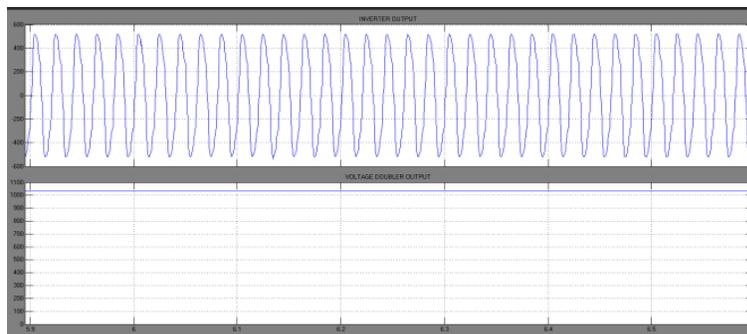**a) Normal mode voltage doubler and inverter output**

b) Boost mode voltage doubler and inverter output
Fig.9.Cascaded two stage ZSI network with tank circuit

CONCLUSION

This paper has presented traditional and cascaded Z source network with/without resonant elements. To compose the cascaded qZS-network, one diode, one inductor, and two capacitors were added to the traditional voltage-fed qZSI. The output voltage is boosted 3 to 10 times greater than input voltage in two stage cascaded qZSI network. The novel configuration inherits all the advantages of traditional solutions (voltage boost and buck functions in a single stage, continuous input current, and improved reliability). The voltage-fed qZSI with the cascaded qZS-network reduced the shoot-through duty cycle by over 30% at the same voltage boost factor and component stresses as the traditional qZSI. The proposed cascaded qZSI can be applied to almost all dc/ac, ac/dc, ac/ac, and dc/dc power conversion schemes. To further decrease the shoot-through duty cycle at the same voltage boost factor, the number of stages of the qZS-network

could be increased. Due to addition of resonant circuit two stage cascaded network also has merits in traditional network with tank circuit. The proposed two stage converter can be short- and open circuited without damaging switching devices. Therefore, it is very strong to EMI and its robustness and reliability is significantly improved. The output voltage is be greater than input voltage at a wide range so applicable is residential applications. Thus it is a very desirable circuit topology when the input voltage and load range of the converter is very wide. The proposed cascaded qZSI converter can achieve good efficiency over the entire input and load range.

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