A Higher Boost Inversion Voltage and Resonant Current Suppression Capability with Improved Trans-Z-source Inverter

T.C.S. Janani[1], N. Selvarani[2]
[1]PG Scholar, Department of EEE, PSNA CET, Dindigul, India.
[2]Assistant Professor, Department of EEE, PSNA CET, Dindigul, India,

Abstract - This work deals with new family of high boost voltage inverters that improve upon the conventional Trans-Z-source inverter and Trans-quasi-Z-source inverter. The efficiency of inverter circuit decreases due to the presence of discontinuous DC input current, ripple content and high inrush current during starting. These drawbacks are filtered out using improved Trans-Z-source inverter were it provides continuous input current, suppress resonant current at starting and higher boost voltage inversion capability. The aim of this work is to present the analysis, operating principle, simulation results of improved trans-Z-source inverter.

Keywords: ***Trans-Z-source inverter,shoot through state.***

I. INTRODUCTION

The Z-source inverter was introduced [1] to obtain single stage power conversion with both buck and boost abilities. In this inverter both the power switches of the leg are turned on at the same time to eliminate the dead time and improve the reliability of the system which can be obtained in classical voltage and current source inverter. For this purpose the Z-source inverter uses two port impedance network with two split capacitors and inductors in x shape. The trans Z-source inverter [2] replaces the split capacitor and inductor connected in x shape with the transformer, one capacitor and it reduces the component usage. When the transformer turns ratio is equal to 1 the output of the inverter is same as that of the traditional inverter but when this transformer turns ratio is greater than 1 it obtains higher output voltage when compared to traditional inverter.

The switched inductor Z-source inverter [3] provides higher voltage boost inversion ability and overcome the disadvantages of classical inverter. It is also used to obtain ac-ac, ac-dc, dc-dc and dc-ac conversions and there by improves the efficiency of the overall inverter structure. The switched inductor quasi-Z-source inverter [4] is used to produce continuous input current, low shoot through current, reduced voltage and current stress in capacitors and inductors when compared to the switched inductor Z-source inverter for this purpose it adds one inductor and three diodes.

A modified single phase quasi-Z-source inverter [5] provides buck and boost function both in-phase and out of phase with input voltage. This inverter can be operated continuously in constant current mode and produce continuous input current to the inverter. Extended boost Z-source inverter was proposed in [6] uses four new extended boost inverter because the Z-source inverter has limited boost inversion capability which becomes a major drawback in several applications. They are classified as diode assisted or capacitor assisted and further divided into continuous and discontinuous current. All these inverter structure achieves higher boost voltage and low voltage stress in capacitors when compared to classical Z- source inverter.

TZ-inverter was introduced [7] to reduce turns ratio which decreases the transformer size, weight and higher boost voltage gain is obtained when the transformer turns ratio is greater than 1. In order to perform this function it uses two transformers. Operational analysis and modulation control of three-level Z-source inverters with enhanced output waveform quality [8] proposed to produce single stage power conversion with both buck and boost abilities. It has three shoot through states. This proposed system reduces the cost, obtain high voltage gain and the number of passive component usage is reduced in comparison with the traditional three level inverter.

Z-source inverter with adjustable speed drives was introduced in [9] to reduce the inrush current during starting and the harmonic content. The major advantage of this circuit is it eliminates the harmonic content. Improved modulation scheme for indirect Z-source matrix converter with sinusoidal input and output waveform was introduced [10] to produce sinusoidal input and output waveforms, low noise and commutation which can be achieved easily with minimum number of devices.

II. PREVIOUS WORK

Fig.1.shows the Quasi-Z-source inverter in which the impedance network couples the dc voltage source and the inverter. The impedance network contains capacitors and transformers with magnetic coupling. The quasi-Z-source inverter uses a transformer with turns ratio 1:1, diode and two capacitors. The impedance network used in the quasi-Z-source inverter reduces the voltage stress in the capacitors and improves the voltage profile. In classical Z-source inverter voltage stress is the major drawback which is filtered by using the quasi-Z-source inverter.

The ratio between the voltage across the inverter V_{ph} and the input voltage V_{dc} is given by the boost factor B where D is the duty cycle.

$$B = \frac{Vph}{Vdc} = \frac{1}{1-2D} \quad (1)$$

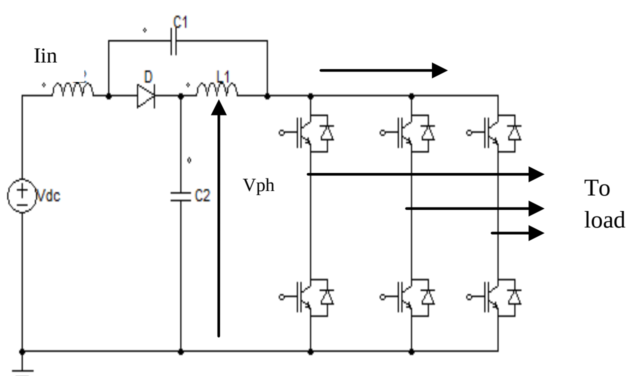
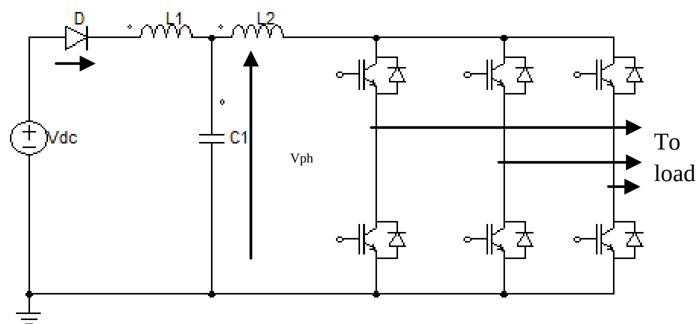
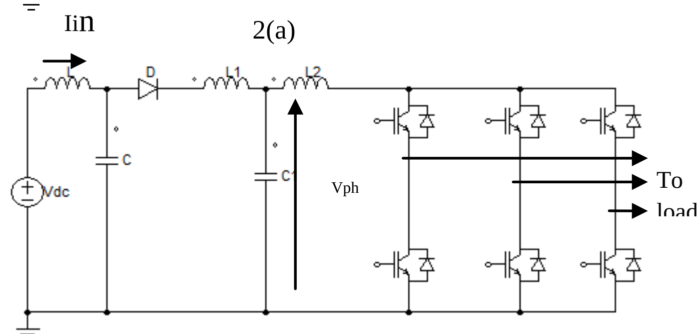


Fig.1.Quasi-Z-source inverter

Fig.2. (a) Shows the Trans-Z-source inverter (or) T-source inverter which is similar to the quasi-Z-source inverter but the components used in quasi-Z-Source inverter circuit is reduced in Trans-Z-source inverter. It uses only one capacitor, diode and transformer with turns ratio n : 1.The output voltage produced is high in comparison with quasi-Z-source inverter and classical Z-source inverter because both the inverters uses turns ratio n = 1. But the major disadvantage in Trans-Z- source inverter is that it produces discontinuous current due to the connection of dc source directly to the diode. The trans quasi-Z- source inverter uses the same amount of components as that of trans-Z-source inverter but the connection of capacitor alone gets differ here. The trans quasi-Z-source inverter produces high ripple current at the starting and this is the major drawback in many applications. In order to eliminate the ripple content an LC filter is connected in front of the dc voltage source to protect it f Iin ıage.



2(a)



2(b)

Fig.2.(a) Trans-Z-source inverter or T-source inverter.Fig.2.(b) Trans-Z-source inverter with LC filter

Fig 2.(b) shows Trans-Z-source inverter with an LC input filter. It eliminates the high amount of ripple content in the starting by using LC filter and improves the efficiency of the inverter circuit. The boost factor of this inverter is given by

$$B = \frac{1}{1-(1+n)D} \longrightarrow \quad (2)$$

Where n is the turns ratio of the transformer. When n = 1 the output voltage of inverter is same as that of classical Z-source inverter and quasi-Z-source inverter.

When n > 1 the output voltage obtained will be high and higher boost inversion capability will be obtained. The conventional Trans-Z-source inverter produces several disadvantages such as discontinuous current, high ripple current during starting, voltage and current spikes which decreases the efficiency of the inverter and also the resonant current flows through diode, transformer windings and capacitors which decreases the life span of the components.

In order to avoid all the above problems different inverters with different configurations increases the cost and size of the inverter. To obtain all the function in one inverter topology a design is made in trans-Z-source inverter (improved trans-Z-source inverter) which eliminates all the above drawbacks in a single circuit.

III. PROPOSED METHODOLOGY

The improved Trans-Z-source inverter is shown in Fig 3. In improved trans-Z-source inverter both the switches in the leg can be turned on at the same time similarly buck and boost function can also be obtained at the same time. The higher boost inversion voltage can be obtained in the single circuit by using the higher modulation index.

The improved trans-Z-source inverter consists of diode, transformer with turns ratio n: 1 and two capacitors. The capacitors are indicated as C1 and C2 and the inductors as L3. The impedance network is connected between voltage source and the inverter main circuit. The diode is connected between the transformer and filtering inductor L3 and the decoupling capacitor is connected between the diode and the inverter bridge.

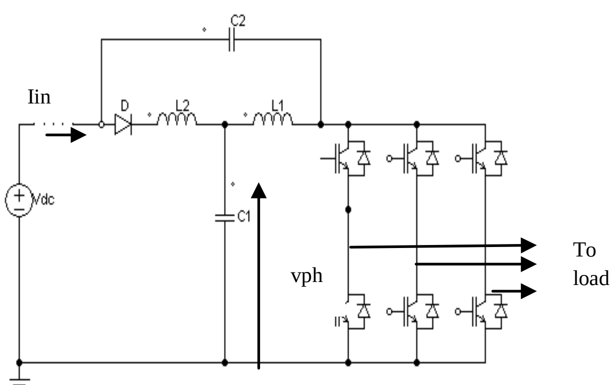


Fig 3. Improved Trans-Z-source inverter

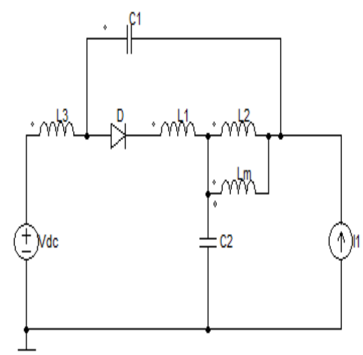
The presence of inductor L3 prevents the discontinuous dc input current and also provides resonant current suppression at starting. For this purpose the improved trans-Z-source inverter includes an addition of one capacitor, one inductor and then higher boost inversion ability is obtained for the same turns ratio. By varying the modulation index of the reference and carrier an improvement in the output waveform is obtained.

In the improved trans-Z-source inverter the transformer with turns ratio is replaced by the coupled inductor which works on the principle of mutual inductance. The inductors are indicated as L1 and L2 in which the voltage of the inductor L1 is transferred to L2.

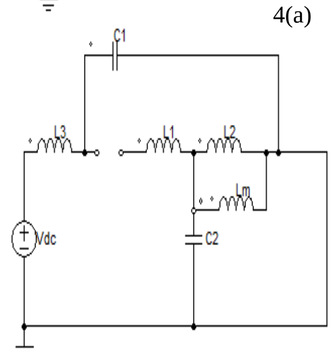
The percentage of reducing shoot-through duty cycle in the improved inverter is high compared to the conventional trans-Z-source/quasi-Z-source inverters for the same boost factor. When the turns ratio increases, the shoot-through duty cycle used in the improved inverter is close to the conventional trans Z-source/-quasi-Z-source inverters to produce the same boost factor.

IV. OPERATING PRINCIPLE

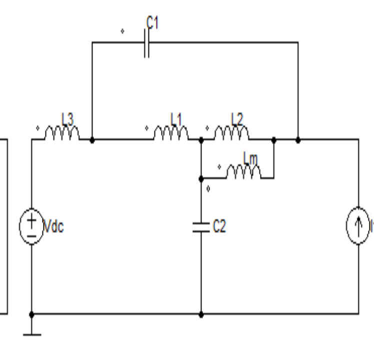
The improved trans-Z-source inverter has additional shoot through state which is not present in classical Z-source inverter.



4(a)



4(b)



4(c)

Fig.4(a).Equivalent circuit, 4(b). Shoot through state, 4(c).non-shoot through state

The improved trans-Z-source inverter has two states of operation. They are shoot through and non-shoot through state. Fig 4(a) shows the equivalent structure of improved trans-Z-source inverter which contains coupled inductor, diode, inductor and two capacitors.

$$VL1 = Vc1$$

$$VL2 = nVL1 = nVC1$$

$$VL3 = Vdc + Vc2$$

Fig 4(b) shows the shoot through state. In shoot through state the diode is shorted i.e., diode D is turned off. Fig 4(c) shows the non-shoot through state in which the diode D is turned on. The corresponding voltage is given by the following equations.

$$VL1_{non} + VL2_{non} = -Vc2$$

$$VL3 = Vdc - Vc1 - VL2_{non}$$

$$Vpn = Vc1 - VL1\_non$$

When the improved trans-Z-source inverter uses lower transformer turns ratio then the inverter acts as the traditional Z-source inverter. By applying turns ratio n = 0 in equation (2) the boost factor is obtained as

$$B = \frac{1}{(1-D)}$$

When the turns ratio of transformer is greater than one i.e. n>1. Then the boost factor becomes

$$B = \frac{1}{(1-2D)}$$

The higher modulation index M can be used to reduce the output waveform distortion and the voltage stress across the capacitor and inductor . Hence compared to conventional Z-source inverter the improved trans-Z-source inverter is highly beneficial to obtain to higher boost inversion ability.

V. SIMULATION RESULTS

The simulation diagram of improved trans-Z-source inverter is shown in Fig.5. It produces low voltage stress on dc link and low current stress on the diode because of higher modulation index. In improved trans-Z-source inverter both the switches in the legs are turned on at the same time which reduces the output waveform distortion. The discontinuous dc input current, ripple content and high inrush current during starting are eliminated in the improved trans-Z-source inverter that improves the efficiency of the inverter and makes it to use in high voltage application.

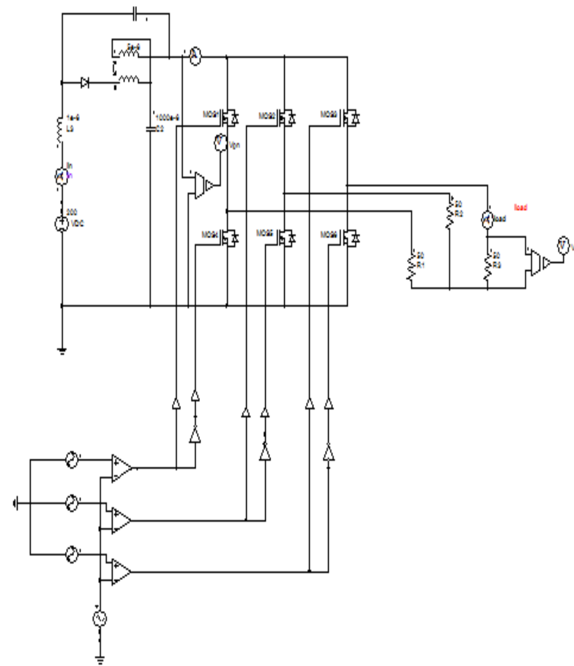


Fig.5.Simulation of improved trans-Z-source inverter

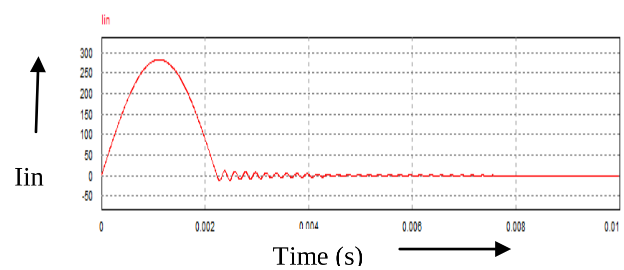


Fig. 5(a). Simulation graph of line current

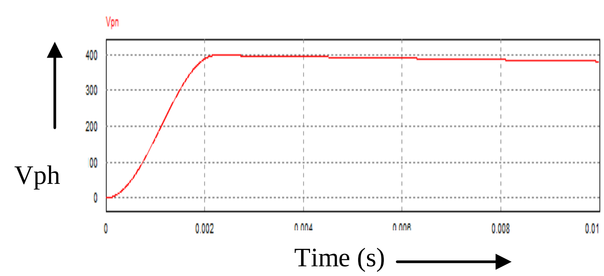


Fig. 5(b). Simulation graph of inverter voltage

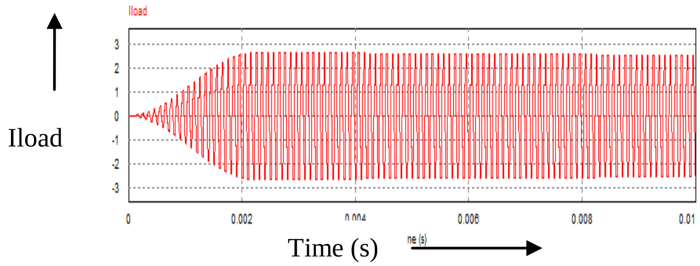


Fig. 5(c). Simulation graph of load current

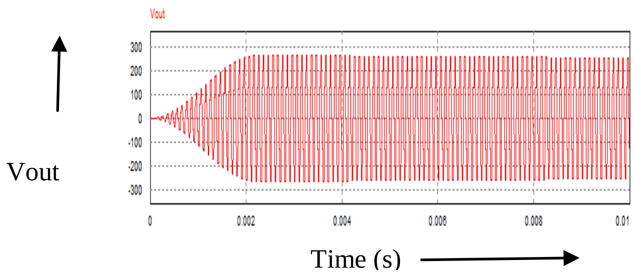


Fig. 5(d). Simulation graph of output voltage

VI. CONCLUSION

A new topology was proposed to improve the trans-Z-source inverter with the following main characteristics: high boost voltage inversion ability, continuous input current, and resonant current suppression at startup. The improved tans-Z-source inverter also eliminates the dead time and improves the reliability by reducing the output waveform distortion. The improved trans-Z-source inverters are used in the application of renewable energy resources such as PV-system and wind energy conversion system for generation of electricity.

VII. FUTURE SCOPE

Further works has to be carried in calculating the power loss in the inductor, core loss and copper loss in transformer to improve the effectiveness of the proposed inverter.

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