Comparative Analysis of Trans-Z-Source Inverter and Cascaded Multicell Trans-Z-Source Inverter

Kavitha H, H S Sridhar

Abstract- The three phase inverters produce three phase waveform always less than the input DC voltage. To get more output from the inverter. Z-source that is combination of inductor and capacitors are used in the input side, but the boost operation is not so effective and also inverters with high-output voltage gain usually face the problem of high-input current flowing through their components. The problem might further be exaggerated if the inverters use high-frequency magnetic devices like transformers or coupled inductors. Leakage inductances of these devices must strictly be small to prevent over voltages caused by switching of their winding currents. To avoid these related problems, cascaded trans-Z-source inverters are proposed. They use multiple magnetic cells in an alternately cascading pattern rather than a single magnetic cell with large turn's ratio. In this paper comparison of cascaded multicell Trans Z-source inverter and normal trans-z-source inverter is made for increasing the boost ratio. Analysis of these inverters is made using SIMULINK software and its performance has been analyzed.

Keywords: Cascaded inverters transformers, Z-source inverters, Trans-z-source inverters.

I. INTRODUCTION

Traditional voltage-source inverter (VSI) and current source inverter (CSI) are either a buck or a boost converter and not a buck-boost converter. That is, their obtainable output voltage range is limited to either more or less than the input voltage. Z-source inverter can perform buck-boost functionality by inserting a unique X-shaped impedance network with two capacitors and two inductors in its impedance network, their power switches in a leg can be turned on at the same time which eliminates dead time and significantly improves boost operation. But its drawback are it requires high voltage capacitors which lead to cost expensive to the system, it cannot suppress the inrush current and the resonance introduced by Z-source capacitors and inductors at start up thus causing voltage and current surges, which in turn may destroy the device.[1-4]

The system was improved with reduced Z-source capacitor voltage stress and soft-starting capability though low voltage capacitors which reduced the cost of the system. The boost operation was not possible with this system moreover it had no reduction in number of components.[5]

Trans-Z-Source inverter extends the Z-Source concept to transformer based Z-Source inverter. The impedance network consist of one transformer and one capacitor thus reducing the capacitor count by one then the Z-Source inverter this new network exhibit some unique advantages such as increased voltage gain and reduced voltage stress.

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But with transformer some components would experience higher steady state voltage or current stress depending on winding to which they are connected. It has direct series connection of components this will led to common voltage sharing problem and requires balancing resistors for capacitors together with these losses are added to the circuit. The transformer itself might be tougher to design too with perfect magnetic coupling, low-leakage inductance. Any deviation from perfect coupling will lead to large transient overvoltage caused by breaking of currents. Besides overvoltage extreme high instantaneous current will flow. A simple way to overcome is to connect multiple capacitors and windings in parallel unlike series connection, will not overly complicate the circuit operation. [6] This paper presents new cascaded multicell trans-z-source inverter which is an alternate way of realizing the trans-z-source inverter with high gain. Normally the trans-z-source connection needs large turn's ratio for transformer winding, but here instead of transformer lower rating of winding of inductance are connected in parallel to share the extreme high instantaneous current stress. Although the inverter use multiple components to tolerate high voltage gain they do not have direct series connection of components so no balancing resistors and losses. Common voltage sharing problem that vary randomly with parameters are therefore not experienced by the new system. The boost operation is effective when compared to trans-z-source inverter.[7-8]

II. TRANS-Z-SOURCE INVERTER

The Trans-Z-Source inverter shown in Fig.1 extends the Z-Source concept to Transformer-based Z-Source inverter, normally the Z-Source inverter employs an impedance network of two inductors and two capacitors here two inductors which can be replaced by a coupled inductor. By doing so, the two inductors are coupled through magnetic field and one capacitor can be removed thus reducing the capacitor count by one then the basic Z-Source inverter and boost operation also effective when compared to normal Z-source inverter.

Trans-z-source inverter is heavily dependent on perfect magnetic coupling. It employs two transformer windings in the impedance network. Depending upon the turns ratio of the two windings, the trans-z-source inverter can obtain a higher boost gain with the same shoot-through duty ratio. It has advantage like increased voltage gain and reduced voltage stress. But with transformer some components would experience higher steady state voltage or current stresses depending on winding to which they are connected. It has direct series connection of components this will led to common voltage sharing problem and requires balancing resistors for capacitors together with their losses are added to the circuit.

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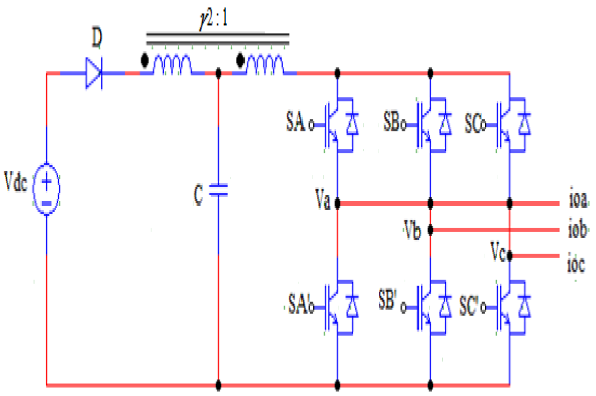

Fig.1: Trans-Z-Source inverter.

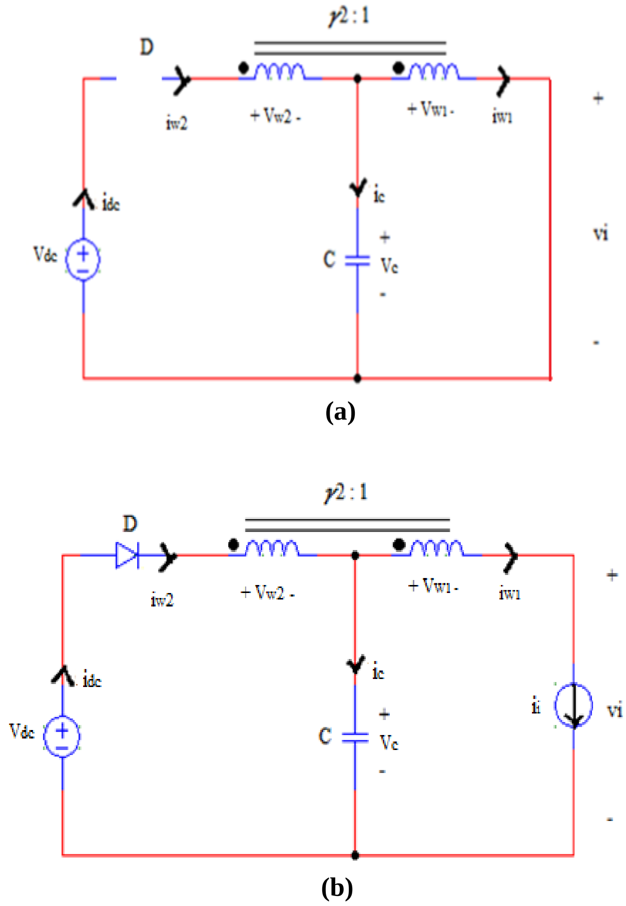

Fig.2: Equivalent circuits of Fig. 1 when in (a) shoot-through and (b) nonshoot-through states

Shoot-Through: In the shoot-through duration T0/T shown in Fig.2 (a) the trans-z-source inverter has two of its switches from the same phase leg turned ON , diode D reverse biases to form an open circuit. Voltages $VW1$ and $VW2$ across the coupled windings $W1$ and $W2$ can then be written as

$$VW1 = Vc, \quad VW2 = \gamma 2 VW1 \qquad (1)$$

Where VC represents voltage across the capacitor and $\gamma 2$ represents turns ratio of $W2$ to $W1$.

Non-Shoot-Through: During the non-shoot-through duration 1 − T0/T whose equivalent circuit is shown in Fig.2 (b), Diodes D forward-bias. Based on this voltages $VW1$ and $VW2$ can be written as

$$VW1 = VW2/\gamma 2 \; ; \; VW2 = Vdc - VC \qquad (2)$$

Averaging inductor voltage over a switching period and equating it to zero then give rise to the following voltage governing expressions for relating the, peak dc link vi and peak ac output vac voltage in terms of the source voltage Vdc:

$$VC = Vdc(1 - T0/T)/(1 - (\gamma 2 + 1)T0/T) \qquad (3)$$

$$vi = Vdc/\,(1 - (\gamma 2 + 1)T0/T) \qquad (4)$$

$$vac = 0.5\, MVdc/(1 - (\gamma 2 + 1)T0/T) \qquad (5)$$

III. PROPOSED CASCADED MULTICELL TRANS-Z-SOURCE INVERTER

An alternative way of realizing trans-z-source inverter in order to get and enhanced voltage boosting ability with better current and voltage stress distributing among the passive devices of the impedance network. In cascaded multicell trans-z-source inverter instead of transformer with large turns ratio smaller transformer with turns ratio are used. Their $W1$ windings are connected in parallel to share the extreme high instantaneous current stress, while their $W2$ windings are connected in series to withstand the higher voltage demanded.[8]Turns ratio of the transformers must be based on available core and size of the wire that can readily produce better coupling.

The Cascaded multicell Trans-Z-Source inverter shown in Fig.3 does not have direct series connection of components so common voltage sharing problem that vary randomly with parameters are not experienced by this model. The cascaded Multicell trans-z-source inverter will require parallel connections of windings and capacitors in order to manage high instantaneous current during shoot-through.

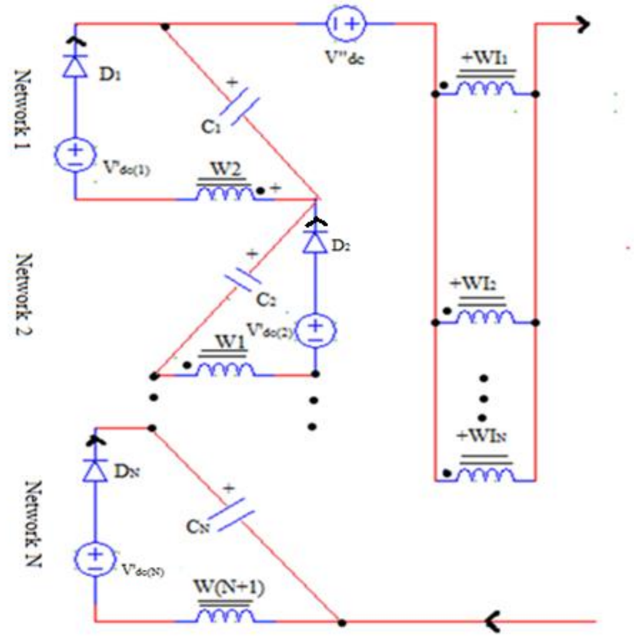

Fig.3: Proposed cascaded multicell trans-Z-source inverter

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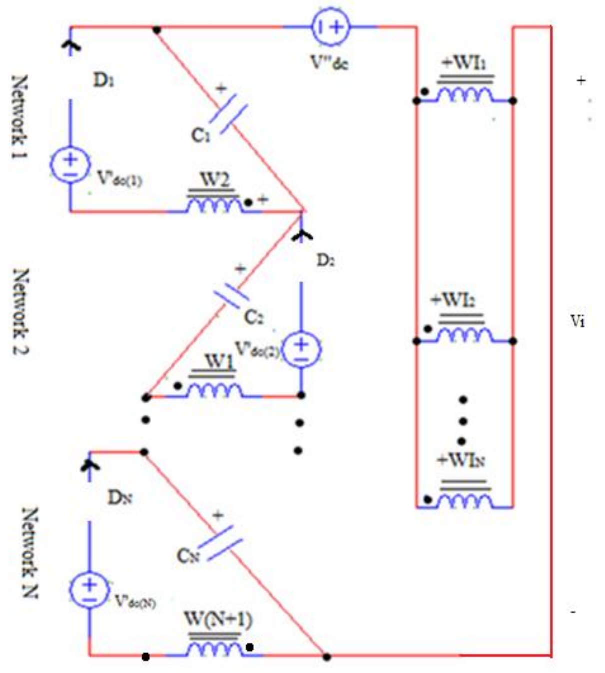
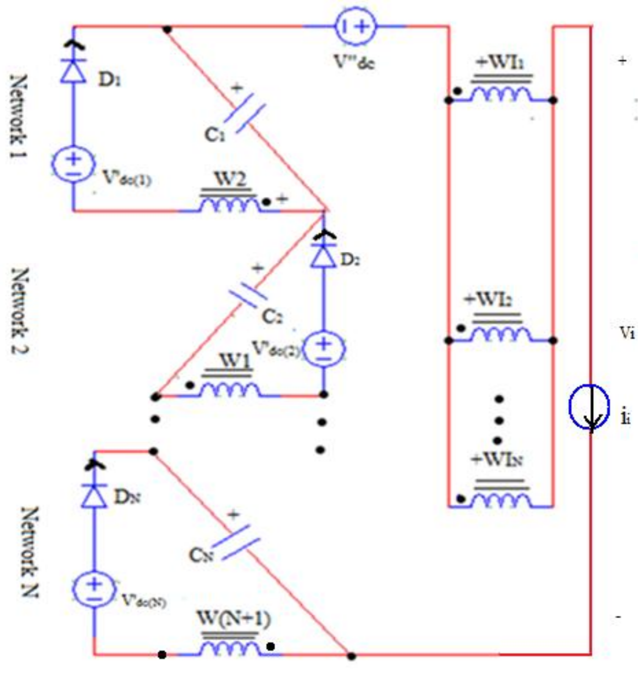


(a)



(b)

Fig.4: Equivalent circuits of the proposed cascaded multicell trans-Z-source inverter when in (a) shoot-through and (b) non-shoot-through states

Shoot-Through: During the shoot-through duration T0/T, whose equivalent circuit shown in Fig.4 (a) with the voltage source inverter bridge shorted, all diode D reverse-bias, and hence giving rise to

$$Vw1 = \sum_{\sigma=1}^{N} VC\sigma + V\text{"}dc;\quad Vw\,(k+1) = \gamma k+1\ Vw1. \qquad (6)$$

Non-Shoot-Through: During the non-shoot-through duration 1- T0/T shown in Fig.4 (b), Diode D forward-bias that is when all diodes conducting, and hence giving rise to

$$Vw1 = Vw\,(k+1)/\gamma k+1;\quad Vw\,(k+1) = V\text{'}dc\,(k)\text{-}Vck. \qquad (7)$$

Averaging inductor voltage over a switching period and equating it to zero then give rise to the following voltage governing expressions for relating the, peak dc-link voltage vi and peak ac output $\hat{v}ac$ voltage in terms of the source voltage Vdc:

$$vi = V\text{'}dc + V\text{"}dc/1\text{-}\,(\gamma T+1)T0/T.\quad vac = Mvi/2 = 0.5M\,(V\text{'}dc + V\text{"}dc)/1\text{-}\,(\gamma T+1)T0/T. \qquad (8)$$

IV. SIMULATION RESULTS

The simulation study has been carried out using Sim power Systems toolbox provided within SIMULINK package for Trans-z-source inverter and proposed Cascaded multicell trans-z-source inverter . Input voltage to each inverter was set to 100V for eventually powering a three-phase ac *R* load of 50 Ω

.A. Trans-z-source inverter simulation circuit and result.

Trans-z-source topology was integrated with three phase inverter. Sinusoidal PWM is used to generate pulse signal for three phase inverter. The Trans-Z-Source inverter simulation circuit shown in Fig.5 and corresponding boosted three phase output voltage waveforms and current waveform are shown in Fig.6 and Fig.7 respectively. DC voltage fed as input is 100V.

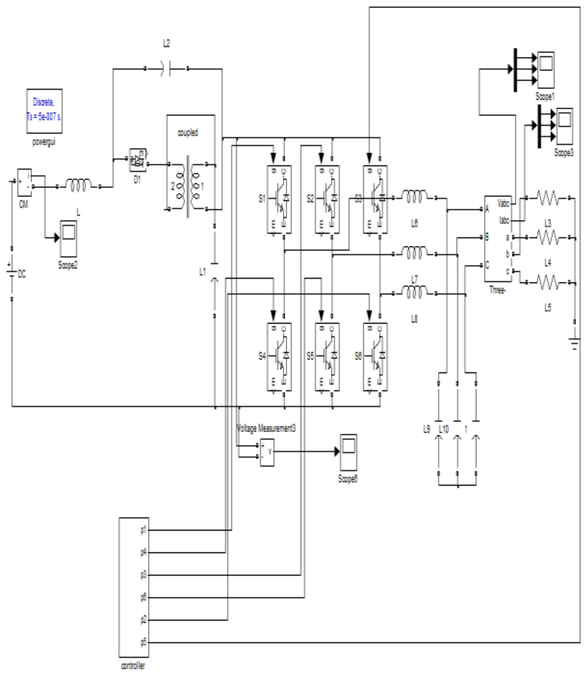


Fig.5: Trans-z-source inverter simulation circuit.

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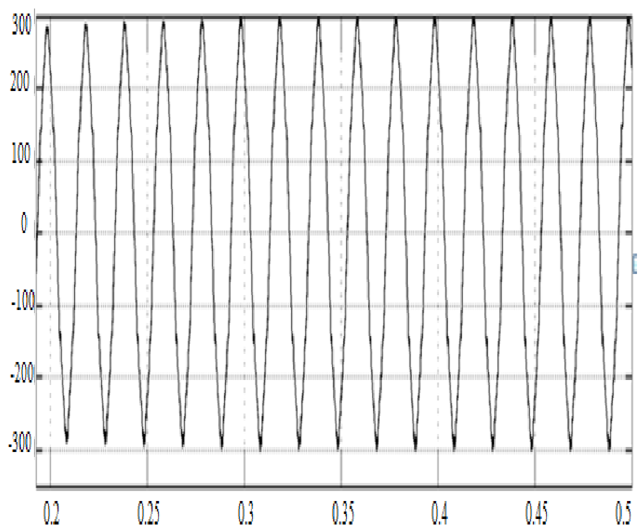

Fig.6: Trans-z-source inverter output voltage waveform

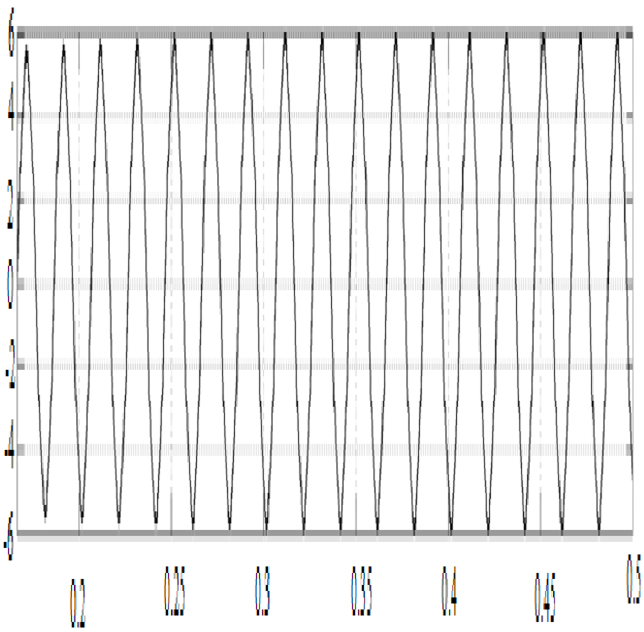

Fig.7: Trans-z-source inverter output current waveform

B. Cascaded multicell trans-z-source inverter simulation circuit and result.

Cascaded multicell Trans-z-source topology was integrated with three phase inverter. Sinusoidal PWM is used to generate pulse signal for three phase inverter. The cascaded multicell trans-z-source inverter simulation circuit shown in Fig.8 and corresponding boosted three phase output voltage waveforms aand current waveform are shown in Fig.9 and Fig.10 respectively. DC voltage fed as input is 100V.

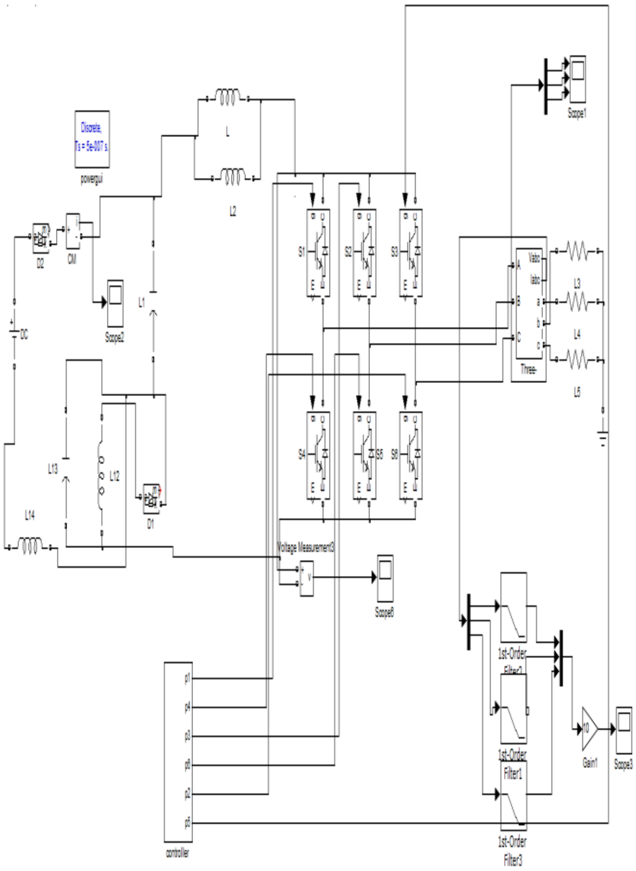

Fig.8: Cascaded multicell trans-z-source inverter simulation circuit

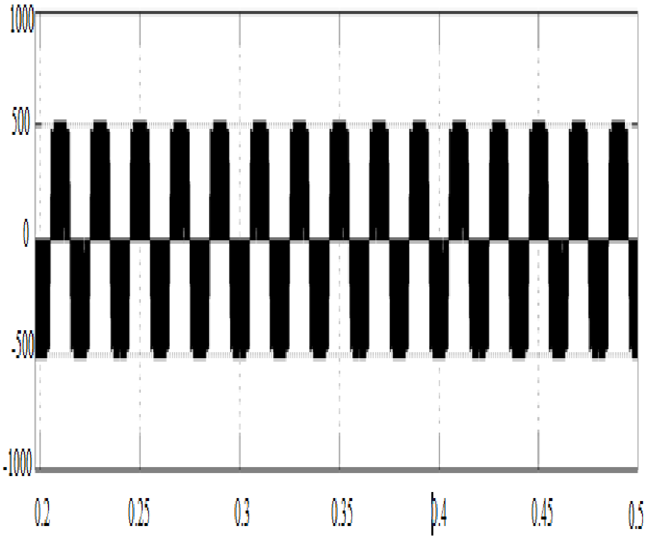

Fig.9: Cascaded multicell trans-z-source inverter output voltage waveform.

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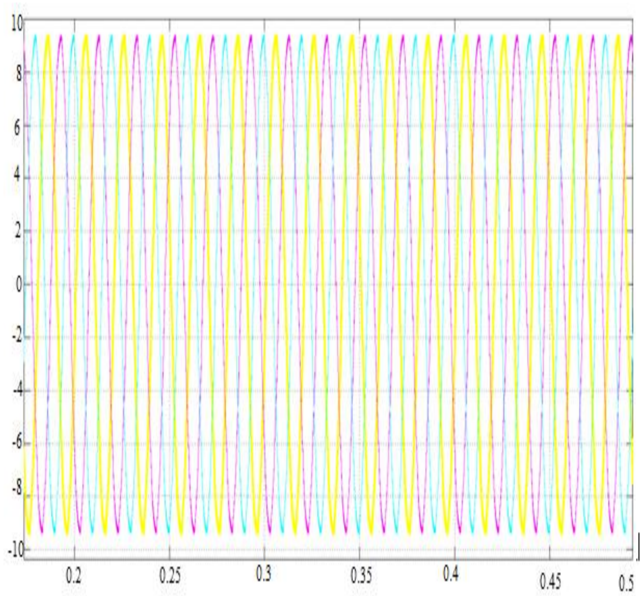

Fig.10: Cascaded multicell trans-z-source inverter output current waveform.

TABLE.1: Output voltage comparison of proposed system

Input voltage	Output voltage	
	Trans-Z-source	Cascaded Multicell Trans-Z-Source
100V	200V	500V

Table.1 shows output voltage comparison of trans-z-source inverter and proposed cascaded multicell trans-z-source inverter for a input voltage of 100V.

V. CONCLUSION

In this paper the performance of trans-z-source inverter is compared with proposed cascaded multicell trans-z-source inverter. The comparison result shows that the cascaded multicell trans-z-source inverter can enhance high voltage boost capability compared to Trans-z-source inverter. Although the inverter uses multiple components to tolerate high voltage gain, they do not rely on direct series connection of the components. Common voltage sharing problems that vary randomly with parameters are therefore not experienced by the proposed inverter. Moreover here instead of transformer, lower ratings of winding of inductance are connected in parallel to share the extreme high instantaneous current stress among windings better. Performances of the inverters are analyzed in simulation.

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