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### **RESEARCH ARTICLE**

# **An Effective Method over Z-Source Inverter to Reduce Voltage Stress through T-Source Inverter**

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*Abstract- The main objective of this paper is to provide an effective method over traditional inverter technologies for yielding greater voltage boost and reduced voltage stress across the components. The proposed method utilises high frequency low leakage inductance transformer accompanied with a capacitor. In this analysis in PWM control methods we apply maximum boost control across inverter switches for attaining maximum boost voltage. Proposed inverter network resembles T-shape network hence thereby known as T-source inverter. TSI thus has lesser amount of components, high voltage gain and hence reduced voltage stress across network. Simulation is done for the proposed model using MATLAB/Simulink software and hardware results are also verified.*

*Keywords: TSI, ZSI, shoot through, boost*

## I. INTRODUCTION

An inverter is an electronic converter which converts dc-ac it is generally applied renewable energy generation and UPS. Thus inverter with high voltage boost with high efficiency is of great demand. The traditional inverter topologies include voltage and current fed inverters. In voltage fed inverter topology a capacitor is kept in parallel with the dc source in this effective buck operation can be obtained but this topology does not found to be satisfactory for boost operation for which it requires additional networks. Whereas though current fed inverters provide good voltage boost it produce undesirable electromagnetic distortion and does not provide buck mode of operation [9]. To overcome the main disadvantage of voltage and current fed inverters Z-source inverter topology was suggested with LC-lattice network. Though Z-source inverter provides satisfactory operation of buck-boost modes voltage stress across inverter components is considerably high, thus reducing efficient boosting of voltage levels. T-source inverter thus employing few reactive components found to be effective in operating in buck-boost modes with considerable reduction in voltage stress.

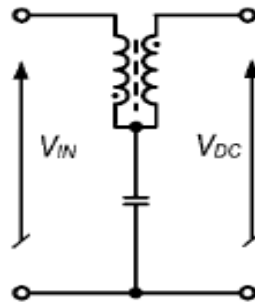


Fig 1.1 T Network

## II. Z-SOURCE INVERTER

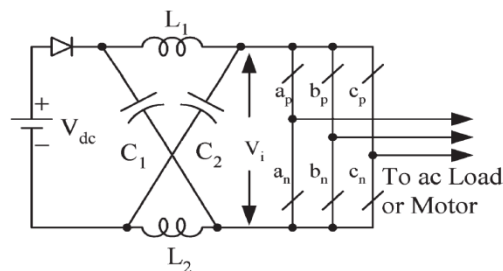


Fig 1.2 Z-Source inverter circuit

A Z-source inverter consists of LC-lattice network topology for providing voltage buck-boost modes by implementing shoot through and non-shoot through modes of operation which is not possible in traditional inverters. The lattice network is composed of two ports with split inductor and capacitor in X-shape which serves as an impedance source coupling with the inverter.

### A. Advantages of ZSI

ZSI finds advantageous over traditional VSI and CSI in following aspects

- It secures the function of increasing and decreasing voltage in single step energy processing.
- It improves power factor and reduces harmonics.
- It provides low cost, reliable buck-boost capabilities.

### B. Disadvantages of ZSI

Considerable drawbacks present in Z-source inverter are

- Voltage stress across reactive components of Z-network is more.
- The efficiency of ZSI is quite less when compared to other traditional inverters.
- Z-source inverter produces discontinuous form of input current and high values of  $di/dt$  hence it requires LC filter at input side.

## III. T-SOURCE INVERTER

T-source inverter provides a topology of network alternative to other existing inverter topologies. It consists of high frequency low leakage inductance transformer accompanied with a capacitor. Hence has lesser amount of components compared to conventional ZSI. Due to this efficiency appreciably

increases. By varying the ratio of transformer other than 1:1 facilitates the change in output voltage. It operates in two modes:

- Shoot through mode.
- Non-shoot through mode.

### A. Shoot through mode

This shoot through state prohibited in traditional voltage source inverter. It can be obtained in three different ways by shoot through via any one phase leg or two phase leg. As diode is reverse biased in this mode it separates dc link from ac. A desired voltage can be maintained at the output by controlling the interval of shoot through state. Thus the T –source inverter highly improves the reliability of the inverter since short circuit across any phase leg is allowed also it do not destroy the switches in the inverter.

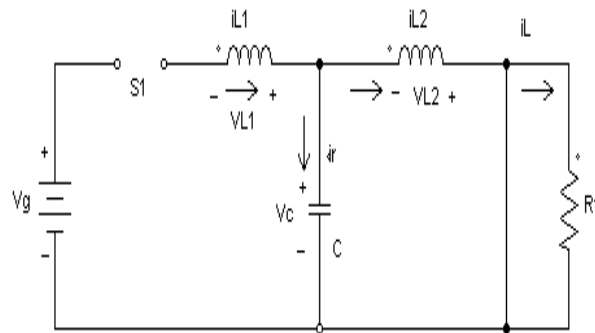


Fig.1.3.Equivalent circuit shoot through mode

### B. Non-shoot through mode

In this mode, the inverter operates in one of traditional mode, hence acts as a current source on viewing from T –source circuit. During this state, the voltage is obtained across load. The diode carries current difference between the inductor current and input dc current. Here due to coupled inductor same current exists between these two inductors.

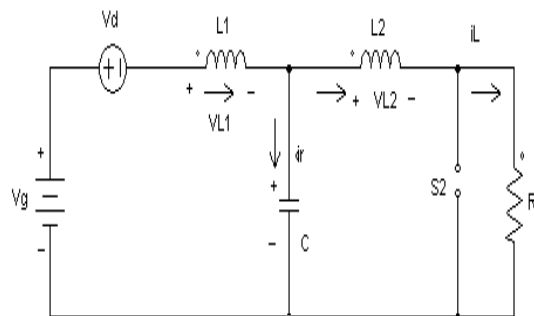


Fig.1.4.Equivalent circuit for non-shoot through mode

#### IV. DESIGN OF T-SOURCE INVERTER

During the design of TSI the most challenging is the estimation of values of the reactive components of the impedance network.. Calculation of the average current of an inductor.

Assumptions made are:

- Drop across diode is negligible.
- For symmetrical t network
- $L_1=L_2$ ;  $V_{L1}=V_{L2}=V_L$ ,
- Total switching period ( $T_t$ ) =  $T_1+T_0$
- $T_1$ -non shoots through time period (active state)
- $T_0$ -shoot through time period (zero state)

For non-shoot through mode for the time period of  $T_1$ ,

$$\begin{aligned} V_i &= V_{dc} \quad (2.1) \\ V_i &= V_{L1}+V_c \\ V_c &= V_i- V_L \quad (2.2) \\ V_i &= V_i-V_c \end{aligned}$$

$$V_{out} = V_c- V_{L2}$$

$$\begin{aligned} V_{out} &= V_c- V_L \\ V_{out} &= 2V_c-V_{dc} \\ V_i &= V_{dc} \quad (2.3) \end{aligned}$$

In shoot through mode for the time period of  $T_0$ ,

$$\begin{aligned} V_c &= V_{L2} \quad (2.4) \\ V_c &= V_1 \\ V_{out} &= 0 \quad (2.5) \end{aligned}$$

At steady state the average voltage of the inductor for one switching period ( $T_T$ ) is zero.then

$$V_i = \frac{V_c T_0 + T_1 (V_{DC} - V_c)}{T} = 0 \quad (2.6)$$

$$\frac{V_c}{V_{DC}} = \frac{T_1}{T_1 - T_0}$$

$$V_c = \frac{T_1}{T_1 - T_0} V_{dc} \quad (2.7)$$

The average dc link voltage over t source inverter bridge is,

$$V_{dclink} = \frac{0T_0 + (2V_c - 2V_{dc})T_1}{T}$$

$$V_{dclink} = V_{dc} \frac{T_1}{T_1 - T_0}$$

$$V_{dc \text{ link}} = V_c \quad (2.8)$$

The peak dc link voltage over inverter bridge is

$$V_{dc \text{ link peak}} = V_C - V_L = 2V_C - V_{DC} \quad (2.9)$$

$$V_{dc \text{ link peak}} = V_{DC} \frac{T_1}{T_1 - T_0} = B V_{dc} \quad (2.10)$$

$$B = \frac{T}{T_1 - T_0}$$

$$B = \frac{1}{1 - 2\frac{T_0}{T}} \geq 1$$

$(\frac{T_0}{T_1}) = d_0$  is shoot through duty ratio

Boost factor depends on shoot through zero time period ( $T_0$ ). the peak dc-link voltage is the equivalent dc-link voltage of inverter.

$$V_{ac} = M_i \frac{V_{dc \text{ link peak}}}{2} \quad (2.11)$$

$M$  -modulation index

Peak phase value of output voltage of inverter is

$$V_{ac} = M_i B \frac{V_{dc}}{2} \quad (2.12)$$

$$B_b = M_i b = (0 \sim \infty)$$

$B_b$  - buck boost (gain) factor

The capacitor voltage can expressed as

$$V_c = \frac{1 - \frac{T_0}{T}}{1 - 2\frac{T_0}{T}} V_{dc} \quad (2.13)$$

## V. PULSE WIDTH MODULATION

PWM signals are used to control the gate pulses fed to inverter circuit for achieving maximum boost voltage output. There are three control strategies adopted :simple boost control (SBC), maximum boost control (MBC), constant boost control (CBC).The modulation index also defined as amplitude modulation ratio ( $M$ ) which is the main control factor is defined as the ratio of amplitude of reference wave to the amplitude of carrier wave.

$$M = V_{ref} / V_{car}$$

## VI. MAXIMUM BOOST CONTROL METHOD

Reducing the voltage stress under a desired voltage gain now becomes important to the control of TSI. MBC maintains the six active states unchanged and turns all zero states into shoot through zero states. Thus maximum voltage boost is obtained for any given modulation index without distorting the output waveform. The circuit is in shoot-through state when the triangular wave is either greater than the maximum curve of the references values or smaller than the minimum of the references. It should maximize the boost factor for any given modulation index to achieve the maximum voltage gain. Consequently, we have to make the shoot through duty ratio as large as possible. The shoot through

duty cycle varies with each cycle.low frequency ripple are introduced in current and voltage waveform due to presence of inductor and capacitor in the circuit[1].

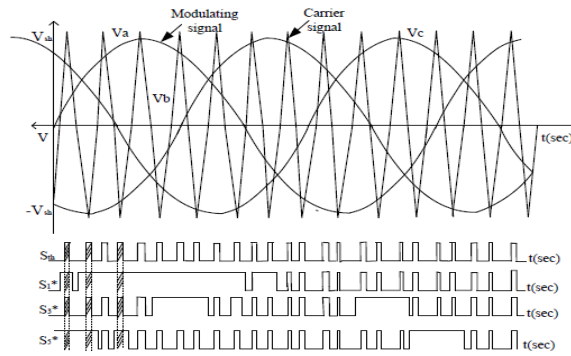


Fig.1.4.Maximum Boost Control

### VII. EXPERIMENTAL RESULT

Simulation model for three phase T-source inverter was designed by using MATLAB/SIMULINK software.fig.1.5-1.8 shows output voltage, current, operating pulse, phase voltage of T-source inverter with maximum boost control technique. In this model input voltage of 100V is boosted upto 325V by shoot through mode of T source inverter.

TABLE I  
PARAMETERS AND  
VALUES OF T-INVERTER

Parameters	Values used in simulation
T-source inverter	
DC supply voltage	100V
T-source capacitance	46 $\mu$ F
T-source magnetizing inductance	1.1mH
T-source leakage inductances	1.5 $\mu$ H
Transformer Turns Ratio	1:1
Switching frequency	10 kHz

## SIMULATION OUTPUT:

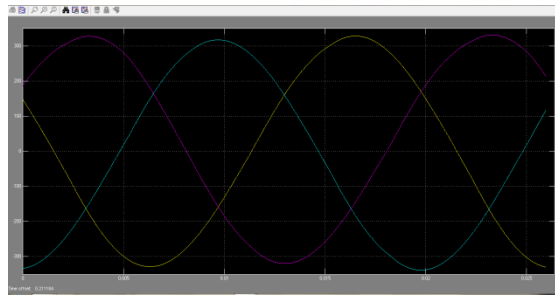


Fig 1.5-simulated output voltage.

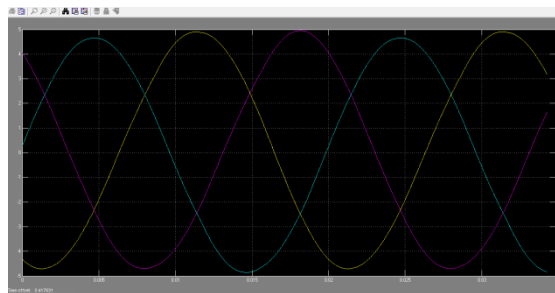


Fig 1.6-simulated output current.

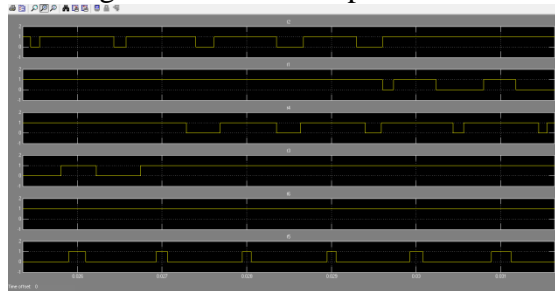


Fig 1.7-operating pulse

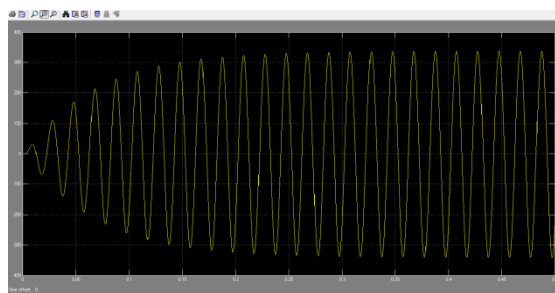


Fig 1.8-phase voltage

## VIII. CONCLUSION

The proceeded concepts are simulated and implemented and results are verified. Use of active snubber circuit in the network minimises the effect of leakage inductance. By varying modulation index through maximum boost pwm control maximum voltage boost is obtained. Reduction in number of components and usage of common voltage source for T-network and inverter reduces the voltage stress and harmonics in the circuit[2]. These satisfactory results encourage the further researches in implementing different turns ratio in transformer windings for obtaining greater efficiency.

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