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Performance Analysis of Three Phase T source Inverter

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Abstract: ***This paper investigates the performance analysis of T-source Inverter with simple boost control technique for boosting the voltage. T-source impedance network is newly invented to overcome the drawbacks of Z-source inverter. In the literature, the basic topology is called Z-source inverter (ZSI).It has less reactive components in comparing with conventional ZSI. The T source Network can perform the dc to ac power conversion and also can perform buck boost operation at one stage. In ZSI the switches which are in the same leg short circuit will takes place during switch on period. This voltage is stored by L and C circuit of z-source inverter. This stored voltage is added with regular voltage when inverter is in normal operation-Source inverter implemented with simple boost control PWM technique for boosting the voltage is simulated using MATLAB Simulink.***

Keywords: Z-source inverter, T-Source inverter, Voltage gain, simple boost control, Shoot-through control

1. Introduction

The Inverter is an electrical system which converts direct current to alternating current. It can consist of two traditional inverters: voltage-source and current-source inverters. In VSI, the output voltage cannot exceed the dc source voltage. Dead time is needed to protect the upper and lower switching devices in each phase leg from short circuit. In CSI, the output voltage cannot be lower than the DC source. Overlap time between phase legs is compulsory to avoid the open circuit of upper or lower switching devices. These problems are overcome in Z – source inverter and quasi Z – source inverter. The TSI topology requires a very low leakage inductance transformer which should be made with high accurate output. It makes use of shoot through in the inverter bridge to boost the voltage in the VSI due to the short circuit occurrence or to buck the voltage in the CSI due to the open circuit occurrence. The Z-source inverter is a buck–boost inverter. It has more LC components. By using of T-source inverter we can overcome the problems from ZSI.

2. Z-Source Inverter

The new improved L and C network has been introduced to overcome the drawbacks of the traditional VSI and CSI inverters. It can be used in ac/dc power conversion usages. The power source may be either in the form of potential or current form. The impedance network requires two inductors and two capacitors connected to each other ZSI provides a single-stage voltage buck and boost operation. Common LC impedance network particularly improves the performance of the inverter. It permits the state of shoot-through states to the inverter legs during VSI (boost) operation as well as open circuits of inverter legs during CSI (buck) operation.

Disadvantage of Z-Source Inverter:

- Conventional two-stage buck-boost Systems are more efficient than ZSI.
- By the cause of high inductance the Z-source inverter disturbed by over voltages during switches commutation. Hence high rating of Switches are needed.
- Z-source inverter produces discontinuous input current and high values of di/dt due to that passive filter is needed at input side.

3. T-Source Inverter

T-source impedance network is newly introduced to overcome the problems of Z-source inverter. T-Source Inverter is similar to Z-Source except the use of high frequency low leakage inductance transformer and one Capacitance. It has low reactive components in compare with conventional ZSI. Due to this, the efficiency greatly increases. The TSI topology requires a very low leakage inductance transformer which should be made with high accuracy. In such a way, the number of LC elements is reduced because only the transformer and the capacitor are needed. The T-Source Inverter topology functions as a common DC rail between the source and inverter. It is not same as the traditional Z-Source Inverter circuits. By use of a transformer with other than a 1:1 transformer ratio allows for a change of output voltage Z-source converters, as compared with the voltage resulting from the shoot-through index or the modulation index.

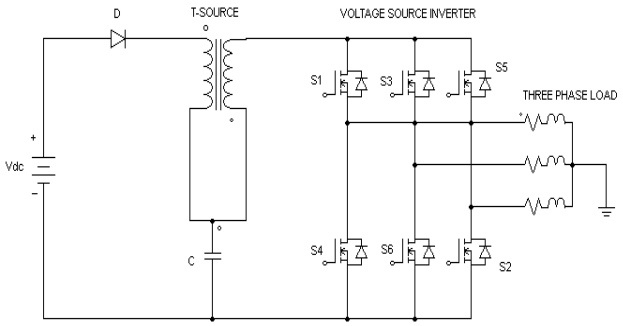

Figure 1: Circuit diagram for T-source Inverter

3.1 Principle of operation

There are two operating modes exists in T-source inverter. One is active mode and another one is Shoot-through mode. The T-network is used instead of the LC-network for boosting the output voltage by inserting shoot through states in the PWM.

3.2 Shoot through mode

Shoot through can be obtained inthree different ways such as shoot through via one phase leg or combination of two phase legs. The TSI can handle shoot through states when both switches in the same phase leg are going to one state. In this mode,diode is reverse biased and it separating DC link from AC line.Desired output voltage can be obtain by controlling the shoot through time.

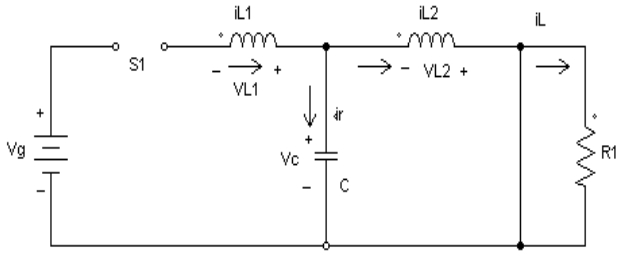

Figure 2: Equivalent Circuit of shoot through state

3.3 Non Shoots Through Mode

In Non – shoot through mode capacitor is charged, the inverter bridge operate in one of traditional active states,when viewed from T – source circuit it acting as a current source. During active state current is zero because of open circiut. The open circuit voltage is appear across inverter bridge. The diode conduct and carry the difference of current, between theinput DC current and inductor current. here both the inductors have an identical current because of coupled inductors.

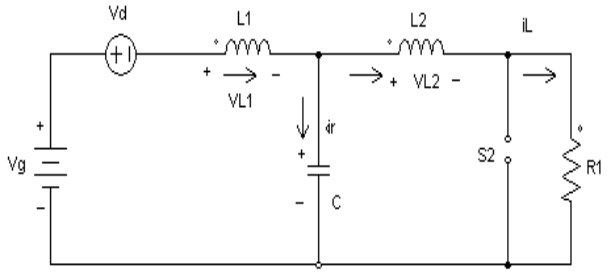

Figure 3: Equivalent Circuit of non-shoot through state

3.4 Mathematical Modelling

The TSI governing equations can be developed using Kirchhoff's laws and voltage averaging. The average voltage through the transformer inductances should be equal to zero for the switching time period T.

$$V_1 = [T_0 V_C + T_1 (V_{in} - V_c)/n]T = 0 \quad (1)$$

Both capacitor voltage Vc and output voltage Vout are functions of the shoot-through coefficient

$$D = T_0 / T \quad (2)$$

$$V_c / V_{in} = T_1 / (T_1 - n.T_0) \quad (3)$$

$$V_c / V_{in} = (T1 - D) / [1 - (n+1).D \quad (4)$$

Hence the maximum value of D for TSI n > 1issmaller than for the conventional Z-source. This is the advantage of the TSI with n > 1 in comparison with ZSI because the same output voltage can be obtained with achieved smaller time period of short-circuits transistor current. Using the amplitude Vdc of voltage Vdc in non-shoot-through states can obtain from:

$$V_{dc} = V_{in} / [1 - (n+1).D] \quad (5)$$

In practice, the influence of leakage on inductance of the transformer is very important. In T-Source inverter, the leakage inductance is very low since both the primary and secondary windings are placed in a single iron core. The performance of TSI depends on the precision of the transformer design. The peak voltage dc link across the inverter can be written as,

$$V_{dc} = T / T_1 - T_0 \quad (6)$$

Where,

$$B = T / T_1 - T_0 \geq 1 \quad (7)$$

B is the Boost factor resulting for the shoot through state T0 is represent the time in sec of shoot through state T0 is represent the time in sec of shoot through state T1 is represents the time in sec of non-shoot through state Also the output peak phase voltage from the inverter can be expressed as,

$$V_{ac} = MV_{dc} / 2 \quad (8)$$

Where M is the modulation index.
By Using of above equations the peak output voltage can be written as,

$$V_{ac} = M.\ B\ V_{dc}/2 \quad (9)$$

Thus the voltage from output can be stepped up and stepped down by choosing an appropriate Buck-Boost factor BB.

$$B_B = M \times B\,(x) \quad (10)$$

The buck-boost factor (BB) is determined by the modulation index (M) and boost factor (B). The boost factor can be controlled by the duty cycle of the shoot through state over the non shoot through states of the inverter
The features of T – Source inverter are as follows:

- Low reactive components are used.
- Use of a common voltage source and passive arrangement.
- It has reduced the number of switching devices.
- Dead time is not needed. Inrush current due to harmonics can be reduced by inductors.

4. PWM Techniques

TSI as an alternative and improved form for traditional voltage source and current source inverters (VSI/CSI), the modified switching schemes from the traditional schemes has reached the point where the further improvements in firing the switches and inserting the shoot-through states bring crucial benefits. In addition to the six active switching states of the VSI, T-Source Inverter has seven shoot-through zero states, switches of a same phase leg are simultaneously switched on by positive and negative. This shoot-through state is danger in VSI/CSI and can result short circuiting and damaging of entire application. The number of control

methods to control T-source inverter, which include the sinusoidal PWM techniques, there are three types of Pulse Width Modulation control algorithms exists: 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

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

The linearity between the modulation index and the output voltage is achieved by under the modulation index (M < 1).

4.1 Simple Boost Control Method

In SBC, the shoot-through periods are introduced by two straight lines which are equal or greater than the (maximum and minimum) peak values of the modulating reference sinusoidal signals. Shoot-through switching pulses are generated by comparing the dc signal (with magnitude equal or greater than the peak of Triangular signal) with the high frequency triangular carrier signal. Comparator compares these two signals and produces pulses (when Vsin>Vtri, on and Vsin<Vtri, off). Shoot-through pulses are inserted into the switching waveforms by logical OR gate.

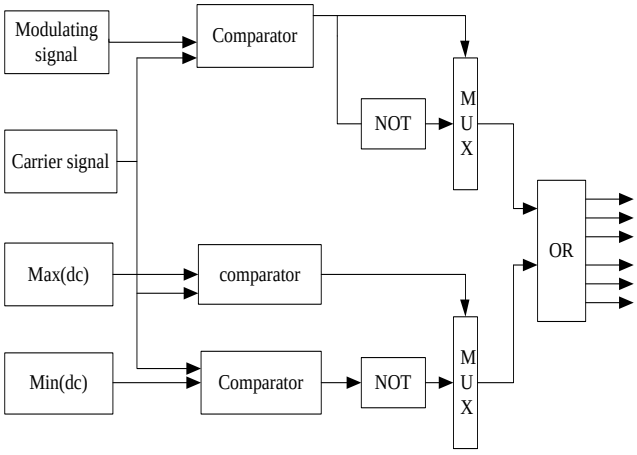

Figure 4: Block Diagram of SBC

$$\text{Shoot through duty ratio} : D_0 = 1\text{-}M \quad (11)$$

$$\text{Boost Factor} : B = \frac{G}{M} \quad (12)$$

$$\text{Gain Factor} : G = \frac{M}{1-2D_0} \quad (13)$$

In order to produce an output voltage that requires a maximum voltage gain, by a small modulation index. However, small modulation indexes result in greater voltage stress on the devices. Using this control method, the voltage stress across the switches is quite high, which will restrict the obtainable voltage gain because of the limitation of device voltage rating.

5. Simulation Result

The parameters of T-source inverter used for simulation with the turns ratio one. The three phase T-Source inverter with R_L load is used to implement the various simple Boost control PWM techniques for investigation.

Table 1: System Parameters

S.NO	Parameters	Values for simulation
1	DC supply voltage(Vdc)	50V
2	Modulation Index(Mi)	0.6
3	Shoot Through Duty Ratio(D_0)	0.4
4	Capacitance	1000µF
5	Transformer Turns Ratio	1:1
6	Switching Frequency	5kHz
7	L_1=L_2=L	1mH
8	R_{Load}	10Ω
9	L_{Load}	5mH
10		

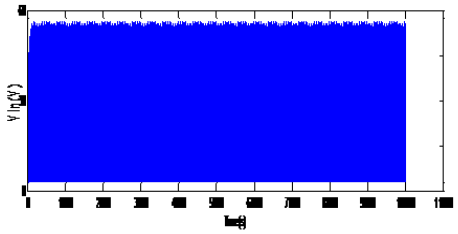

Figure 5: Input voltage (V_{in})

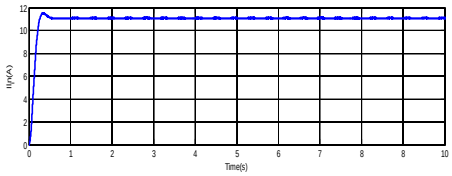

Figure 6: Inductor Current (I_L)

Table 2: System parameter variation with respect to modulation index and shoot through duty ratio

M_i	D_0	V_{dc} *link*	V_{rms}	I_{rms}
0.6	0.4	304	183.5	6.4
	0.3	247	134	5.2
	0.2	197	93	4.3
	0.1	167	57	2.9
0.7	0.3	238.7	136.5	5.3
	0.2	190	94	4
	0.1	152.2	58	4
0.8	0.2	188.6	97	3.9
	0.1	144.2	61	2.2
0.9	0.1	140.8	61.5	2

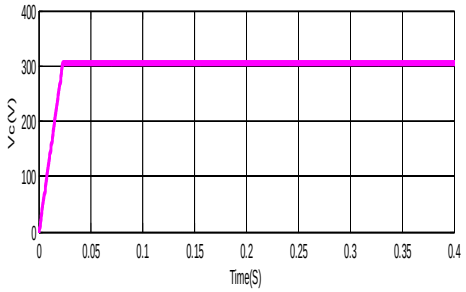

Figure 7: Capacitor Voltage (V_c)

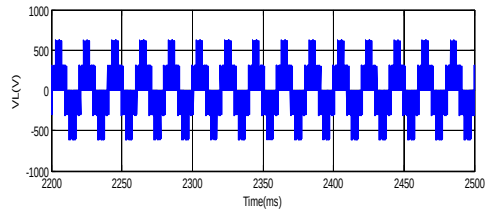

Figure 8: Inverter line to line voltage without filter(VL)

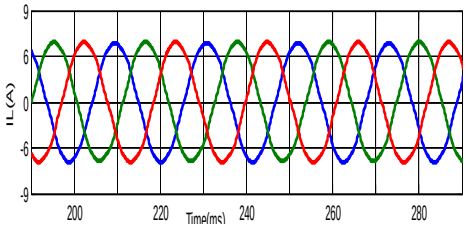

Figure 9: Load Current (IL)

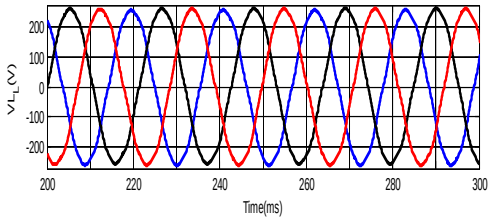

Figure 10: Voltage across load (VL_L)

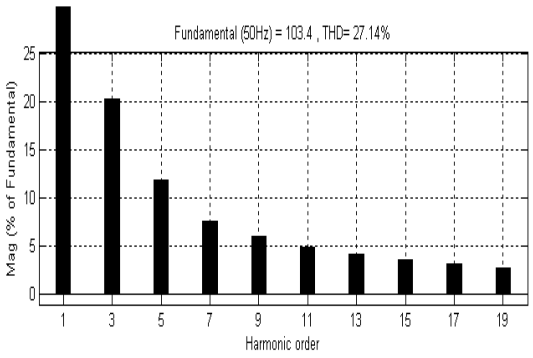

Figure 11: Output current of Harmonic spectrum

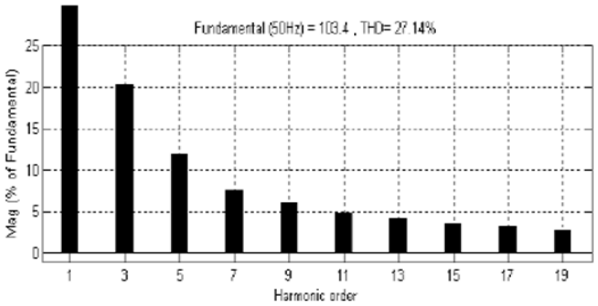

Figure 12: Harmonics spectrum of the Output voltage

Table 3: The profile of Harmonics

	ZSI		*Proposed TSI*	
D_0	*V_thd*	*I_thd*	*V_thd*	*I_thd*
0.4	42.2	5.02	27.1	4.79
0.3	41.9	4.9	27.1	4.59
0.2	40.9	4.7	26.95	4.05
0.1	40.2	4.62	26.9	4.03

The harmonic profile of the output voltage and current of TSI with Maximum boost control method. Total harmonic distortion of proposed TSI is low compared to Z-Source inverter of same rating. Figure 11 and Figure 12 illustrates the harmonic spectrum of load current and load voltage

6. Conclusion

This research deals with the Analysis of T-source inverter with simple boost control technique for improving voltage gain. The T-source inverter overcomes the problems of the Z-source inverter and provides buck-boost operation in a single stage. The T-source impedance network provide the output voltage larger than the input voltage by proper maintaining the duty ratio of shoot-through state, voltage-source inverter and current-source inverter can't be provide these advantages. When compared with ZSI, the T-source inverter has less passive components .All Pulse Width Modulation methods can be used to control T-source inverter. In this research deals with simple boost control techniques which are used to control the T-source inverter.

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