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# Independent Control of Two Three Phase Motors using Z-Source Five Leg Inverter

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***Abstract*— This paper presents Z-source Five Leg Inverter(ZFLI) design and its simulation result. This inverter consists of two main parts. The first part having impedance network and second part having eight switching devices and two capacitors. It can independently control two three phase motors using pulse width modulation. The number of switches used in this inverter is less than the required in Voltage-Source Inverters (VSI). In Five Leg Inverter, since the DC voltage source is shared between the two loads, the voltage across each load is less than in the case of a VSI. Therefore, a larger DC voltage source needs to be used in this method which increases system cost and size. In this paper this is improved by using Z-source structure. This inverter uses shoot through mode so both the upper and lower devices of any one leg (i.e., both devices are gated on), any two legs, any three leg or all four legs will short together. This shoot-through state provides the unique buck-boost feature to the inverter. Capacitors in the switching network act as switch during zero state operation.**

## I. Introduction

Normally AC motors are driven with three leg inverter. But two motor cannot control independently with three leg inverter, for that operation two inverter is required. To improve and simplify the control system for the independent control of two three-phase loads, some other methods have been proposed such as the FLI and NSI which consist of ten and nine switches, respectively, less than the required number of switches in Voltage-Source Inverters (VSI). This inverter (ZFLI) is a improved version of FLI, it uses only eight switches.

The impedance source or Z-source inverters are special types of inverters that provide the voltage boost capability in conventional inverters. The conventional inverters work as a buck converter only, because the output voltage is always lower than the DC input voltage. Moreover, the upper and lower power switch cannot conduct simultaneously, otherwise the DC source will short circuit. Hence, a dead band is provided intentionally between the switching on and switching off of the complimentary power switches of the same leg. This dead band causes distortion in the output current. These shortcomings are overcome in the Z source inverter.

## II. Structure of ZFLI

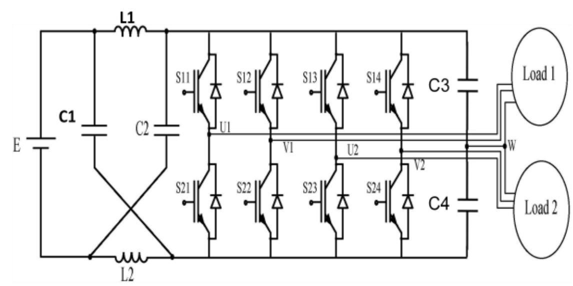


Fig1. Z-source FLI

The Fig1. Shows the Z source five leg inverter. Impedance network consists of two equal inductors (L1, L2) and two equal capacitors (C1, C2). The network inductors are connected in series arms and capacitors are connected in diagonal arms. The main inverter circuit consists of five legs. In this four legs are having switching devices and fifth leg is having capacitors. The u and v phases of motor1 are connected in a leg1 and a leg2 respectively, those of a motor 2 is connected in a leg3 and a leg4 and w phase of the both motors are connected in the neutral point of the two sprit capacitor.

The Impedance Network can either buck or boost the input voltage depending upon the boosting factor. This network is also used as a second order filter. This network requires smaller value of inductances and capacitances. This network is coupled between the source and main inverter circuit. The source can be battery, diode rectifier, thyristor converter, and inductor, capacitor or combination of those.

## III. Operation & Control of ZFLI

The unique feature of the Z-source inverter is that the output ac voltage can be any value between zero and infinity regard-less of the input dc voltage. That is, the Z-source inverter is a buck–boost inverter that has a wide range of obtainable voltage. The traditional V- and I-source inverters cannot provide such feature. The three-phase Z-source inverter bridge has three states of operation unlike the traditional three-phase V-source inverter that has two state . The traditional three-phase V-source inverter has active state when the dc voltage is impressed across the load and zero state when the load terminals are shorted through either the lower or upper three devices, respectively.

However, the three-phase Z-source inverter bridge has one extra shoot through state when the load terminals are shorted through both the upper and lower devices of any one leg (i.e., both devices are gated on), any two legs, any three leg or all four legs. This shoot-through state is forbidden in the traditional V-source inverter, because it would cause a shoot-through. The Z-source network makes the shoot-through state possible. This shoot-through state provides the unique buck-boost feature to the inverter. .

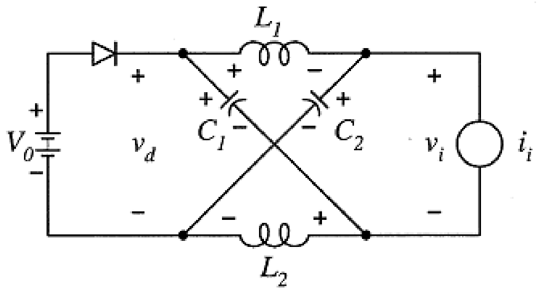


Fig2. Equivalent circuit of Z-source inverter

The Fig2. Shows the equivalent circuit of the Z-source inverter when viewed from the dc link.

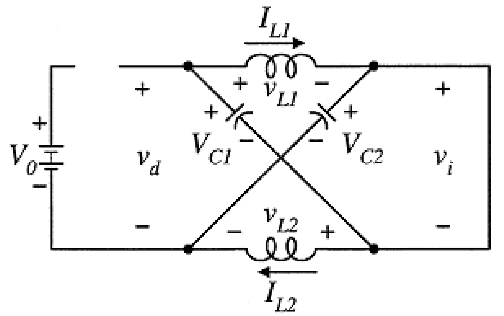


Fig3. Z-source inverter-Shoot through state

The Fig3 shows, the inverter bridge is equivalent to a short circuit when the inverter is in the shoot-through state.

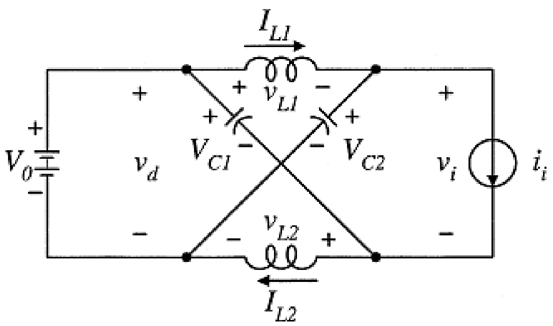


Fig4. Z-source inverter-Non Shoot through state

The Fig4. Shows, the inverter bridge becomes an equivalent current source during non shoot through state.

All the traditional pulse width-modulation (PWM) schemes can be used to control the Z- source inverter and their theoretical input–output relationships still hold. The traditional PWM switching sequence based on the triangular carrier method. In every switching cycle, the two non shoot through states are used along with two adjacent active states to synthesize the desired voltage. When the dc voltage is high enough to generate the desired ac voltage, the traditional PWM is used.

While the dc voltage is not enough to directly generate a desired output voltage, a modified PWM with shoot-through states will be used to boost voltage. It should be noted that each phase leg still switches on and off once per switching cycle. Without change the total time interval, shoot-through states are evenly allocated into each phase. That is, the active states are unchanged. However, the equivalent dc-link voltage to the inverter is boosted because of the shoot-through states. During zero state, the load terminals are shorted through either the lower or upper two devices. When two lower switches are shorted the upper capacitor act as switch and half of the dc link voltage will fed to motor and when two upper switches are shorted the lower capacitor act as switch and half of the dc link voltage will fed to motor respectively

## IV. DESIGN OF IMPEDANCE NETWORK

For the traditional V-source inverter, the dc capacitor is the sole energy storage and filtering element to suppress voltage ripple and serve temporary storage. For the traditional I-source inverter, the dc inductor is the sole energy storage/filtering element to suppress current ripple and serve temporary storage.

The Z-source network is a combination of two inductors and two capacitors. This combined circuit, the Z-source network is the energy storage/filtering element for the Z-source inverter. The Z-source network provides a second-order filter and is more effective to suppress voltage and current ripples than capacitor or inductor used alone in the traditional inverters. Therefore, the inductor and capacitor requirement should be smaller than the traditional inverters.



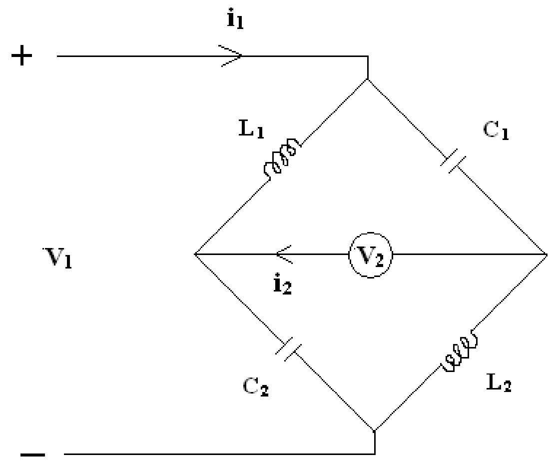


Fig5. Equivalent circuit of Impedance network

Fig5. Shows the impedance network is redrawn as bridge circuit for calculation purpose.

Now assume I2=0, the current I1enters the bridge at point 1 and divides equally between the two arms of the bridge. Using Kirchhoff's law,

$$I_1 \frac{L}{2} + V_2 = \frac{I_1}{2C} \qquad \text{- (1)}$$

$$V_2 = \frac{I_1}{2C} - I_1 \frac{L}{2} \qquad - (2)$$

$$V_2 = \frac{I_1}{2}\left[\frac{1}{C} - L\right] \qquad - (3)$$

## V. MODULATION TECHNIQUE USED IN ZFLI

Simple Boost PWM of the Z-source FLI in fig6. In method, four line signals are produced as the reference signals. Now, for a Z-source inverter modulation, additional shoot-through states need to be added to the control circuit. In simple-boost PWM method, like the conventional PWM, the switching signals are generated by comparing four reference waves with the carrier wave. The only difference is that this method utilizes two constant envelope signals $V_1$ and $V_2$ for short circuit states.

These constant envelope signals are equal to or greater than the maximum value of the sinusoidal reference signals. When a triangular high frequency carrier signal is greater than $V_2$ or is smaller than $V_1$, all switches are turned on and the circuit turns into shoot through state as illustrated in Fig. 6. In this method, boost factor can be written as:

$$\frac{T_0}{T} = 1 - V_1 \qquad - (4)$$

$$B = \frac{1}{1 - 2\frac{T_0}{T}} = \frac{1}{2V_1 - 1} \qquad - (5)$$

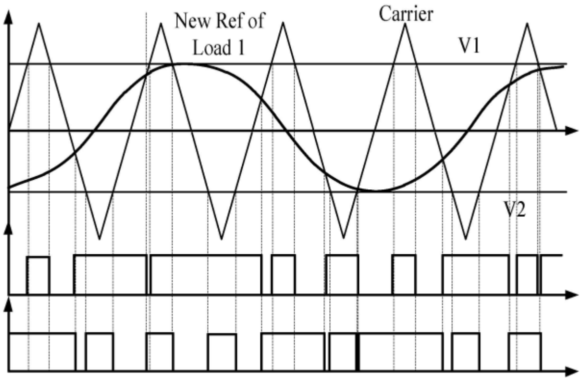


Fig6. Simple Boost modulation

The Fig 6 shows gate signals for switches in one leg using simple boost PWM. It has sine wave as reference signal, triangular wave as carrier signal and two envelope signal for shoot through mode.

From above equation it is observed that by decreasing $V_1$ , the value of B can be increased. However, it should be noted that $V_1$ cannot be smaller than M otherwise it would interfere with a reference wave and convert an active vector to a zero vector.

## 6. SIMULATION RESULT

To verify the validity of the methods, various simulations are performed. The simulation parameters are given Table1. In order to show that the Z source FLI is able to control each motor independently, the two similar rating motors are operated at different speed.

Table 1. Parameters of simulation

| | |
|---|---|
| DC voltage source | 220 V |
| Carrier signal | 1KHz |
| Motor 1 | 0.37kW,400V,50Hz, 750 rpm |
| Motor 2 | 0.37kW,400V,50Hz, 750 rpm |
| Z source capacitor | 1000µf |
| Z source inductor | 160µH |
| Sprit capacitors | 5000µf |



Fig 7 to 14 shows the simulation result for simple boost modulation method. In this figure, with DC input voltage is equal to 220V, DC voltage of Z source network is boosted to a value nearly equal to 250V. In this method DC link voltage is unstable. The reason is that here two envelope signals are producing short circuit signal for each load. This causes the short circuit time to increase.

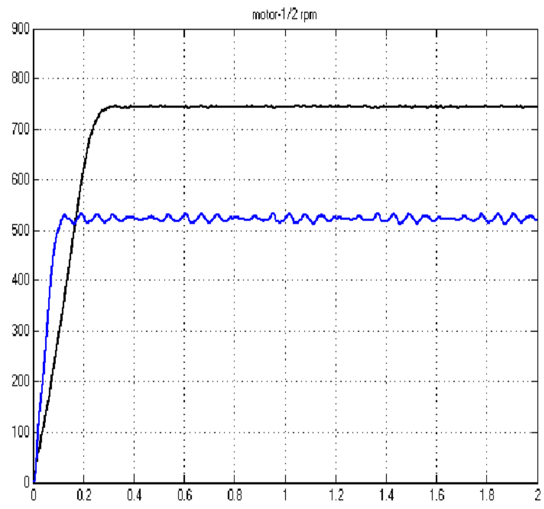


Fig 7 .Motor1&2 speed

Fig 7 shows the motor1 and 2 running at speed of 750 rpm and 520 rpm respectively.

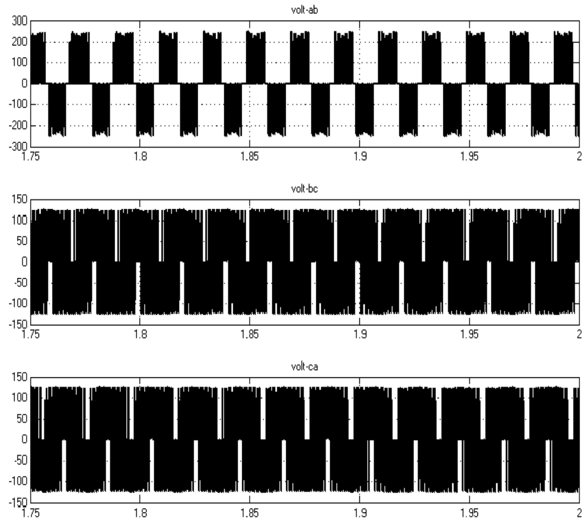


Fig 8 .Motor1voltage

Fig8. shows the voltage wave form for motor1 and voltages are 240/120/120V.

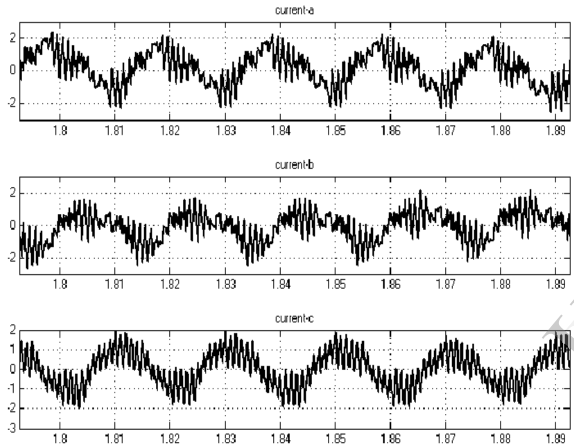


Fig 9 .Motor1 current

Fig9. shows the current wave form for motor 1 and currents are 2/2/2Amps.

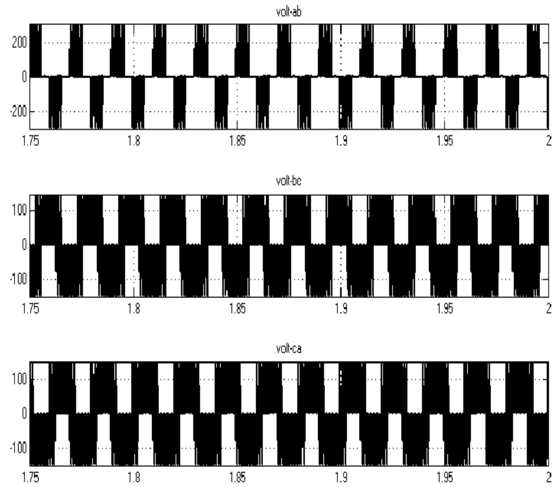


Fig 10. Motor 2 voltage

Fig10. shows the voltage wave form for motor2 and voltages are 250/125/125V.

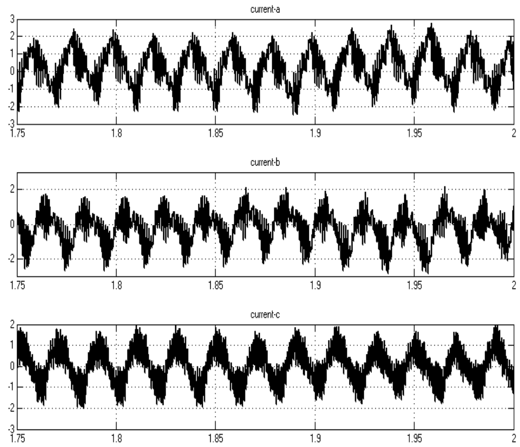


Fig 11. Motor2 current

Fig11. shows the current wave form for motor 2 and currents are 2/2/2Amps.

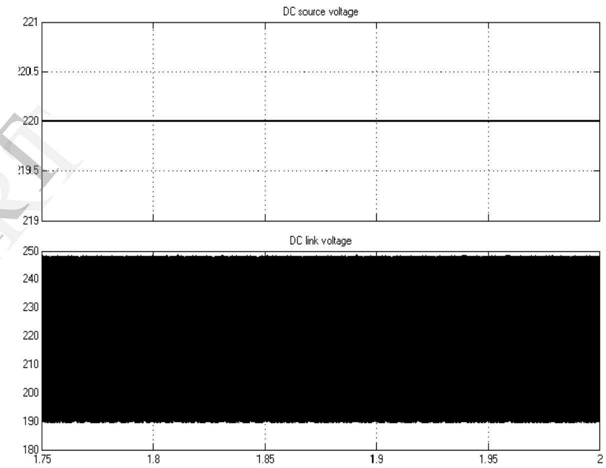


Fig 12. DC voltage

Fig12. shows the DC source voltage of 220V and DC link voltage is varying from 190V to 245V,due buck-boost operation.

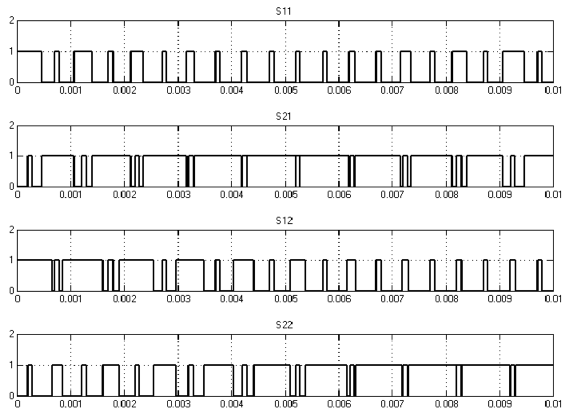


Fig 13 .PWM signal for Motor1

Fig13.shows gate pulse signals of switch S11, S21, S12 & S22 for motor1

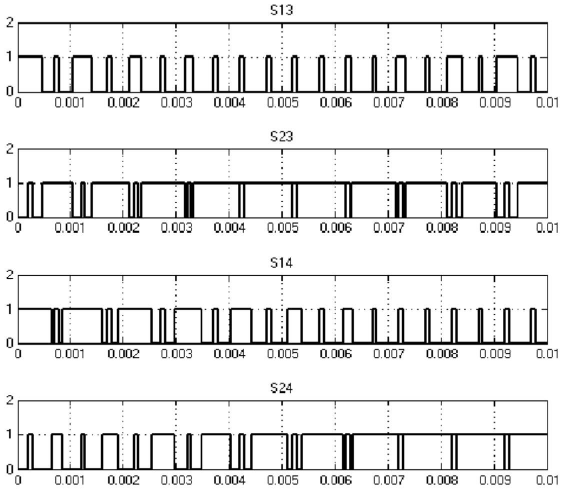


Fig 14. PWM signal for Motor2

Fig14.shows gate pulse signal of switch S13, S23, S14 & S24 for motor2.

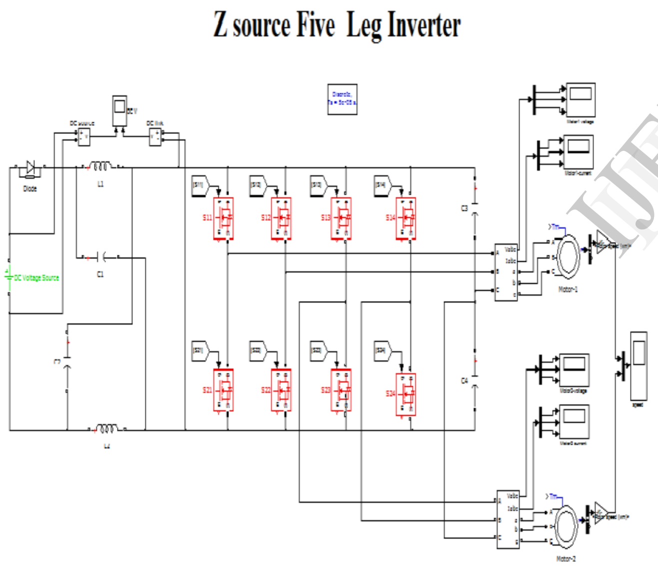


Fig 15. Simulation circuit for Inverter

Fig15.shows simulation circuit of ZFLI with DC source, Z network, five leg inverter with eight switches & two capacitors and two similar rated three phase induction motors.

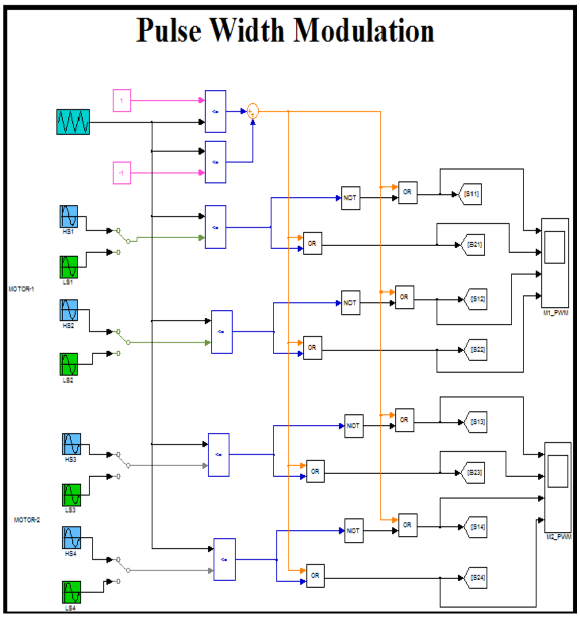


Fig 16. Simulation circuit for PWM

Fig16.shows simple boost pulse width modulation circuit. This circuit generates gate pulse signal for switches in the inverter.



## VI. CONCLUSION

In this paper, Z source five leg inverter operation, simulation and design are explained and proved that it can be control two motors independently at different speed. This inverter can use Battery or fuel cell or solar cell or rectifier circuit as DC source. This inverter used less number of switches than other conventional inverter so cost is saved and size of the main and control system are reduced. This also reduces the inverter losses and increases the efficiency. This inverter can operate for wide speed range with proper selection of inductor and capacitor value in the circuit. Energy saved in the impedance network is utilized to circuit. For more stable operation of the inverter, feedback circuit can be introduced.

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