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Impedance Source Inverter for Wind Energy Conversion System

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ABSTRACT: In power electronics Inverter is device which used to convert DC power into AC power. Traditional inverters are Voltage Source Inverter(VSI) and Current Source Inverter(CSI). There are some limitations of this traditional inverter topology. Impedance Source Inverter is new topology invent for overcome this traditional inverter limitations. Impedance source inverter is new technology for convert the desire output voltage without boost converter. By using this we can improve efficiency and reduce loss & cost. It is used in Fuel cell application, Adjustable speed drive, Photo- voltaic system and used in Wind energy conversion system. It can be applied to all rectifier, inverter, chopper and cycloconverter. This work proposes a simulation of Impedance inverter by using simple boost control technique.

Keywords: Voltage Source Inverter, Current Source Inverter, Impedance Inverter, Simple Boost Control Method, Simulations and Result

I. INTRODUCTION

The main objective of static converter to getting ac output from dc input. In the static converter, there are two traditional converters which are Voltage source converter and Current source converter. In this voltage source converter, the in the DC to AC conversion the output low compare to input voltage source and in the current source inverter in the DC to AC conversion the output is high compare to input current source and some other limitations. To overcome this all limitations new topology Impedance source converter, develop.

II. RELATED WORK

Traditional converters are Voltage source inverter and current source inverter. Inverter is used to convert DC source to AC Source. In Voltage source inverter we get only buck means less output compare to input. In the current source inverter we get only boost means more output compare to input. We are not getting desirable output by using traditional converter which is VSI and CSI which is shown in fig. 3.1 and 4.1. For that we use new topology Impedance Source Inverter which used as Buck-Boost converter. This topology shown in Fig. 5.1. There are many control techniques which use for Impedance source inverter. From that one control technique is Simple Boost Control technique which is shown in fig. 6.1. By using this control technique we get good result in R and also RL load. Result is shown in the simulation and result section.

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III. VOLTAGE SOURCE INVERTER

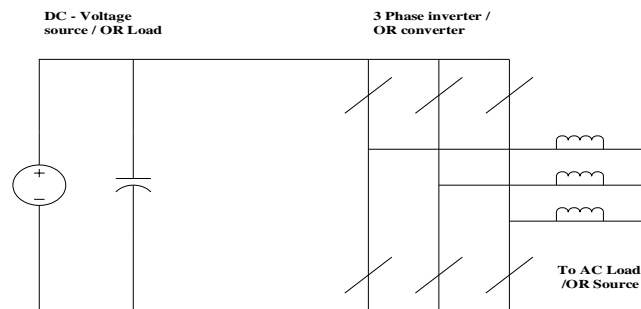


Fig.3.1 Voltage Source Inverter

Fig. 3.1 shows traditional voltage source inverter. This circuit has capacitor, six switches, a dc voltage source. In this a dc voltage source is supported by large capacitor. In these six switches composed of power transistor and antiparallel with diode to provide bidirectional current flow and unidirectional voltage blocking capability. In this Voltage source converter used dc source as fuel-cell stack, diode rectifier, and/or capacitor.

There are some limitations of Voltage Source Converter which given below

- 1) In this for getting desire output additional dc-dc boost converter is needed. When wide voltage range is desirable, the additional power converter stage increase system cost and lowers efficacy.
- 2) For providing sinusoidal voltage compare to current source inverter an output LC filter is needed in the voltage source inverter which causes additional power loss and control complexity.
- 3) Voltage source converter is a boost converter for ac-to-dc conversion and Voltage source converter is a buck converter for dc-to-ac conversion.

IV. CURRENT SOURCE INVERTER

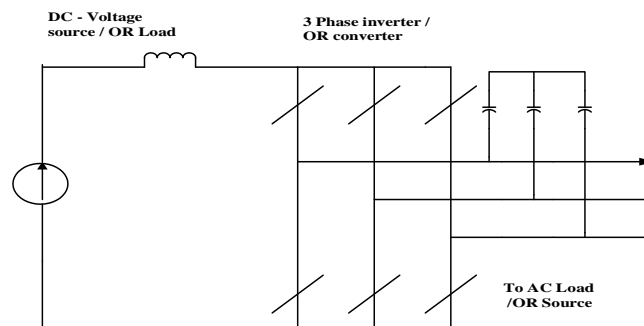


Fig.4.1 Current Source Inverter

Fig. 4.1 shows current source inverter. This circuit has inductor, six switches, a current source. In this a current source is supported by large inductor. In these six switches composed of power transistor and series with diode to provide unidirectional current flow and bidirectional voltage blocking capability. In this Current source converter used dc source as fuel-cell stack, diode rectifier, battery, and/or thyristor converter.

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There are some limitations of Voltage Source Converter which given below

- 1) Current source converter is a buck converter for ac-to-dc conversion and Current source converter is a boost converter for dc-to-ac conversion.
- 2) In the current source inverter switches are used to block reverse voltage that requires a series diode to be used in combination with high speed and high performance transistors which prevents use of low cost and high-performance IGBT modules.
- 3) In the current source inverter, at least upper and lower devices have must be gated on and maintain on at any time. Otherwise, open circuit of the dc inductor would be occur and destroy the devices. This open-circuit problem by EMI noise's misgating-off is a major concern of converter's reliability.

V. IMPEDANCE SOURCE INVERTER

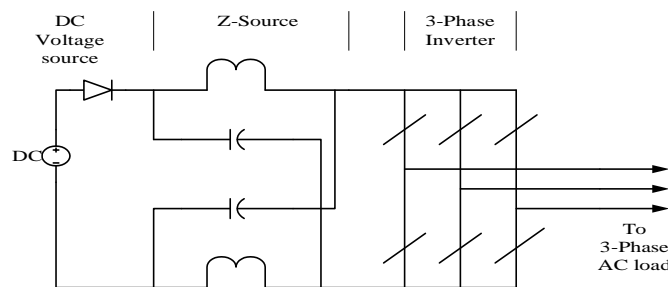


Fig. 5.1 Impedance Source Inverter

Fig. 5.1 shows impedance source inverter. This circuit has DC Source, two inductors, two capacitors, six switches, load. To overcome limitations of Voltage source inverter and Current source inverter impedance source converter topology developed. In this dc source can be diode rectifier, thyristor converter, inductor, capacitor or combination of those. Switches can be antiparallel combination. Impedance source converter consist of Source, load or another converter. Z source inverter provide unique features which can't be observed in VSI and CSI. This converter no need dc-dc converter to obtain the desirable output. Impedance source inverter needs lowest semiconductor and control circuit costs. Impedance source inverter also used in dc-dc, ac-ac, ac-dc, dc-ac power conversion.

In the VSI have some benefits such as dc capacitor is energy storage and filtering element to suppress voltage ripple and serve temporary storage. CSI have also some benefits such as dc inductor is energy storage device and suppress current ripple. In impedance source inverter have two inductors and two capacitors. So this circuit provide energy storage as well as filtering. It provide secondary storage device so it suppress voltage as well as current ripples. In the ZSI requirement of inductor and capacitor lower values compare to traditional converter which are CSI and VSI.

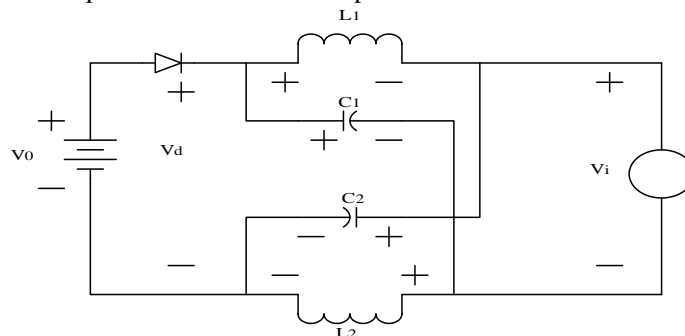


Fig. 5.2 Equivalent circuit of Impedance Source Inverter

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Fig. 5.2 shows the equivalent circuit of impedance inverter. In this circuit diode is used to block the reverse current. Impedance source inverter has nine permissible switching state whereas traditional voltage source inverter has eight switching state. In this eight states six active vectors when dc voltage impressed across the load and two zero states when load terminals are shorted either upper and lower device. In the impedance source inverter has one extra zero states when upper and lower device gated on of any one phase leg, two phase leg or all three phase leg. If upper and lower device gated on in traditional voltage source inverter then shoot-through problem occur. Shoot-through means rush of current when two device gated on. In the impedance source inverter this shoot through is forbidden because of one extra zero state present in the impedance source inverter in which upper and lower device of one phase leg or two phase or all three phase gated on. It also called as shoot-through zero state which provide the unique buck-boost feature to the inverter.

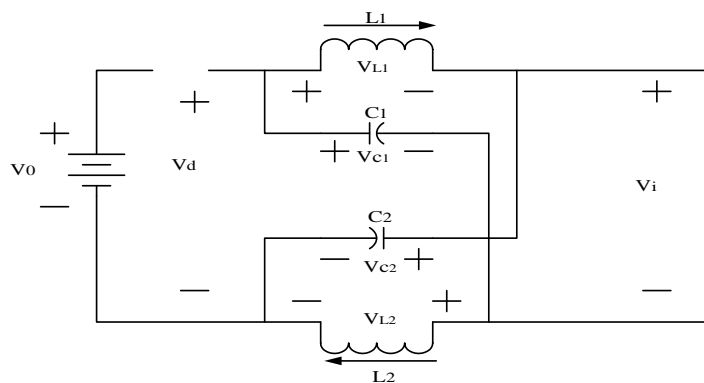


Fig.5.3 Equivalent circuit of the ZSI when the bridge is in the shoot-through zero state

Fig. 5.3 shows the equivalent circuit of ZSI when the bridge is in the shoot through zero state. In this diode is open circuited. Assuming that inductors L1 and L2 as well as capacitors C1 and C2 having symmetry so,

$$V_{L1} = V_{L2} = V_L$$

$$V_{C1} = V_{C2} = V_C$$

At the zero state interval is T_0 during switching cycle T ,

$$V_L = V_C$$

$$V_d = 2V_C$$

$$V_i = 0$$

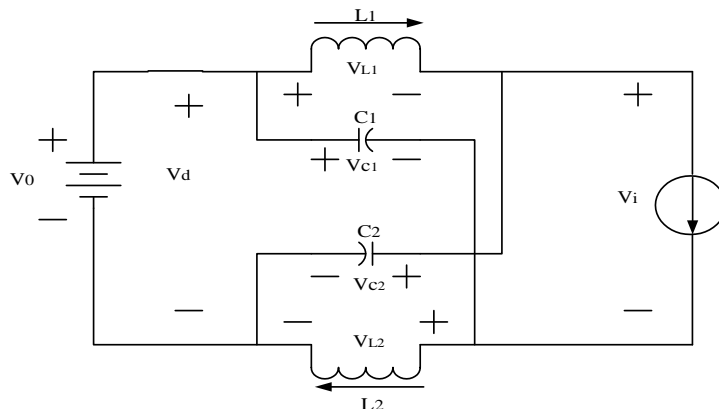


Fig.5.4 Equivalent circuit of the ZSI when the inverter bridge is in one of the eight non shoot-through switching states

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Now consider inverter bridge is in one of the eight non shoot-through states for an interval of T_1 , during the switching cycle, T . From the equivalent circuit. Fig. 1.6

$$V_L = V_0 - V_c$$

$$V_d = V_0$$

$$V_i = V_c - V_L = 2V_c - V_0$$

Where $T = T_0 + T_1$ and V_0 is the dc source voltage

The average voltage of inductors

$$V_L = \frac{T_0 \cdot V_c + T_1(V_0 - V_c)}{T} = 0$$

By simplified this equation

$$\frac{V_c}{V_0} = \frac{T_1}{(T_1 - T_0)}$$

Similarly, the average dc-link voltage across the inverter bridge can be found as follows:-

$$V_i = V_i = \frac{T_0 \cdot 0 + T_1(2V_c - V_0)}{T} = \frac{T_1}{(T_1 - T_0)} V_c = V_c$$

The peak dc-link voltage across the inverter bridge is

$$V_i = V_c - V_L = 2V_c - V_0 = \frac{T_1}{(T_1 - T_0)} V_0 = B V_0$$

Where

$$B = \frac{T_1}{(T_1 - T_0)} = \frac{1}{(1 - 2T_0/T_1)} \geq 1,$$

B is the boost factor resulting from the shoot-through zero state. The peak dc-link voltage is the equivalent dc-link voltage of the inverter. On the other side, the output peak phase voltage from the inverter can be expressed as,

$$V_{ac} = M \cdot \frac{V_i}{2}$$

Where M is the modulation index.

$$V_{ac} = M \cdot B \cdot \frac{V_0}{2}$$

For the traditional V-source PWM inverter, we have the well known relationship:

$$V_{ac} = M \cdot \frac{V_0}{2}$$

Buck-boost factor B_B

$$B_B = M \cdot B = (0 \sim \infty)$$

Capacitor voltage can expressed as,

$$V_{c1} = V_{c2} = V_c = \frac{1 - (T_0/T)}{(1 - 2(T_0/T))} V_0$$

The buck-boost factor is determined by the modulation index and boost factor. The boost factor can be controlled by duty cycle (i.e., interval ratio) of the shoot-through zero state over the non shoot-through states of the inverter PWM.

Advantages of Z-source Inverter

1. Secures the function of increasing and decreasing of the voltage in the one step energy processing. (lower costs and decreasing losses)
2. Resistant to short circuits on branches and to opening of the circuits.
3. Improve resistant to failure switching and EMI distortions.
4. Relatively simple start-up (lowered current and voltage surges).
5. Provide ride-through during voltage sags without any additional circuits.
6. Improve power factor reduce harmonic current and common-mode voltage.
7. Provides a low-cost, reliable and highly efficient single stage for buck and boost conversions.
8. Has low or no in-rush current compared to VSI.

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VI. CONTROL METHODS

There are number of control methods to control Impedance source inverter, mainly there are three control methods for impedance source inverter.

- 1) Simple boost control method
- 2) Maximum boost control method
- 3) Maximum constant boost control method

Simple boost control method

In the simple boost control method there are two lines used to control the shoot-through states, as shown in figure. In this fig. 6.1 we can see that when upper or lower envelope compare with triangular waveform and if it is greater or lower respectively at that time circuit turns into shoot-through state.

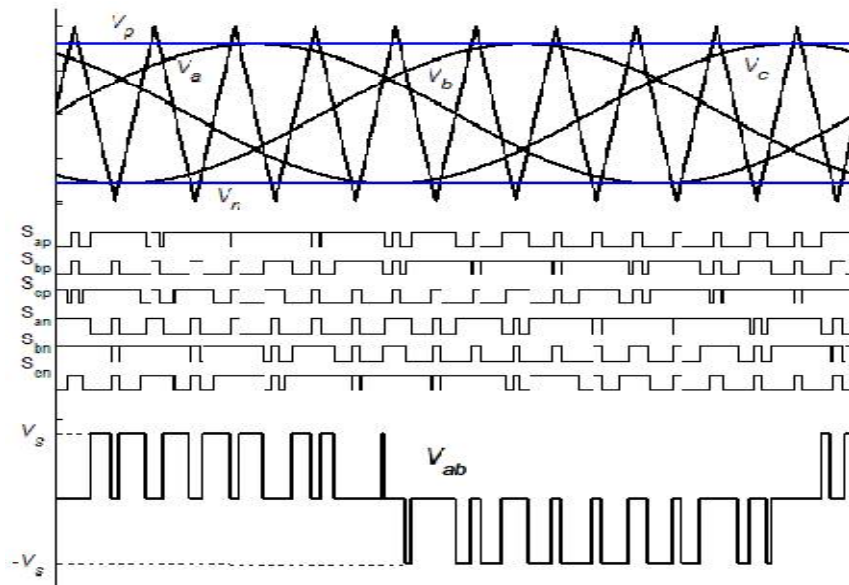


Fig.6.1 Simple Boost Control method

In 3-phase Z-source inverter, one additional parameter is introduced, namely the Boost Factor (B), which modifies the AC output voltage equation of traditional 3-phase PWM inverter as following.

$$\hat{V}_{out} = BM \frac{V_0}{2} \tag{1}$$

\hat{V}_{out} = Maximum sinusoidal inverter output voltage

B = Boost factor

M = Modulation Index

V0 = DC Input voltage

If we replace BM with G, then we may rewrite equation as,

$$\hat{V}_{out} = G \frac{V_0}{2} \tag{2}$$

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Where G is the inverter gain,

$$G=BM \tag{3}$$

It can be seen that has same form with that of the traditional VSI, i.e..

$$\hat{V}_{out} = M \frac{V_0}{2} \tag{4}$$

Where boost factor is obtain by introducing shoot through of minimally one pare of the inverter arm for a short period of time which called Shoot-through time.

$$B = \frac{T_1}{(T_1-T_0)} = \frac{1}{(1-2T_0/T_1)} = \frac{1}{1-2D_0}$$

(5)

Where: T0 = Shoot Through Time

T = Switching Period

D0 = Shoot through Duty Ratio

In the simple boost control method, the modulation index (M) and the shoot-through duty ratio (D0) are interdependence each other. The relation between these two parameters is expressed above. We can see from the equation that shoot-through duty ratio (D0) decreases with increasing modulation index (M).

$$D_0 = 1-M \tag{6}$$

From (3) and (5)

$$G = BM = \frac{M}{1-2D_0}$$

(7)

Since D0 = 1-M, thus

$$G = \frac{M}{1-2D_0} = \frac{M}{1-2(1-M)} = \frac{M}{2M-1}$$

(8)

Equation (8) infers that the inverter gain (G) can be controlled by adjusting modulation index (M). If we rearrange (1) in the original PWM output voltage equation form, we get

$$\hat{V}_{out} = BM \frac{V_0}{2} \tag{9}$$

BV0 should be the input voltage of the traditional VSI which in the case of Z-source is the voltage applied to inverter bridge.

Say

$$BV_0 = V_{inv}$$

(10)

It can be from Fig. That Vinv is the voltage stress of the inverter's devices.

From (3) and (8)

$$B = 2G-1 \tag{11}$$

Substitute (11) to (10) the voltage stress across the devices is

$$V_{inv} = (2G-1) V_0 = \frac{1}{2M-1} V_0 \tag{12}$$

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VII. SIMULATION AND RESULTS

In this section impedance source inverter is used to convert DC to AC. Simple boost control technique is used in this converter. For both R and RL load simulation done in this section.

Simulation of Z-source inverter with SBC method for R Load

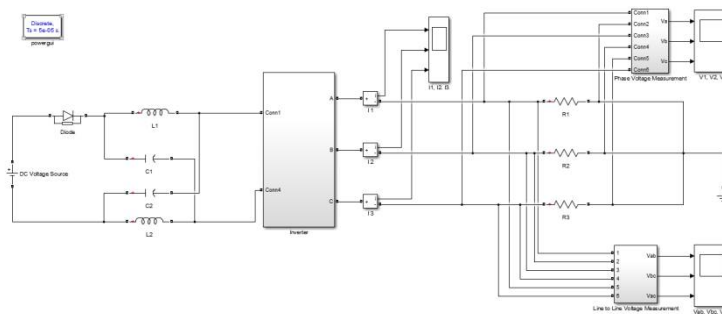


Fig. 7.1 Power Circuit of 3 Phase Inverter

Fig. 7.1 shows the power circuit of 3 phase inverter with R load. In this in impedance source inverter includes two inductor two capacitors. By using ammeter and voltmeter we measure line to line voltage, phase voltage and line current measure.

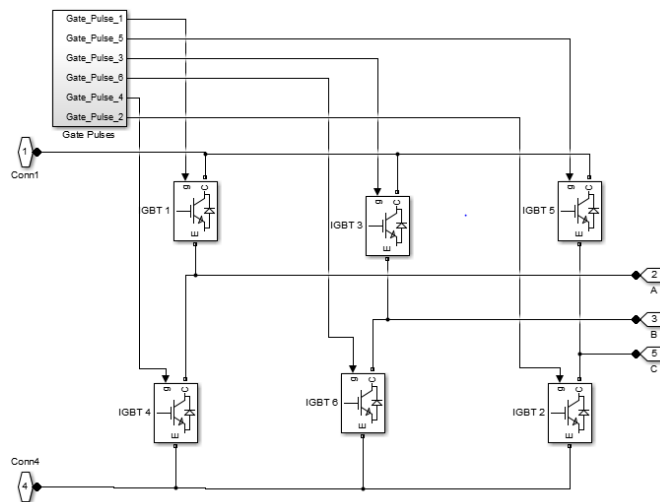


Fig. 7.2 Subsystem of Three phase Inverter

Fig. 7.2 shows the subsystem of three phase inverter. In this IGBT is used as a switch. By using Simple boost control technique we generate the six switches.

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Waveform & THD of Line to Line Voltage.

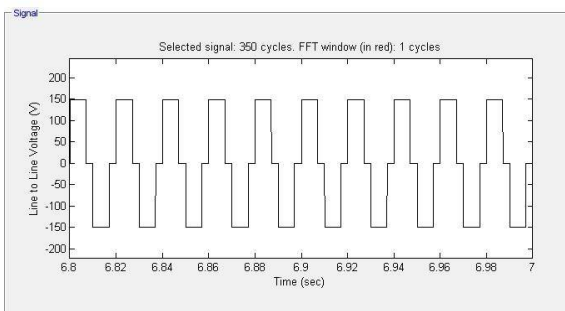


Fig. 7.3(b) THD of Line to Line Voltage

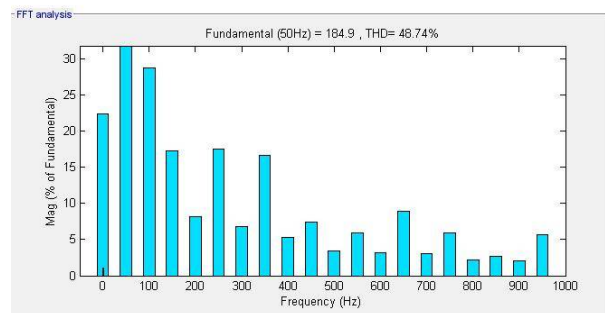


Fig. 7.3(a) Line to Line Voltage Waveform

Fig. 7.3(a) and Fig. 7.3(b) shows the Line to Line Voltage Waveform and THD of Line to Line Voltage respectively. By using voltmeter we measure line to line voltage and by using THD analysis we measure the THD of Line to Line voltage.

Waveform & THD of Line Current

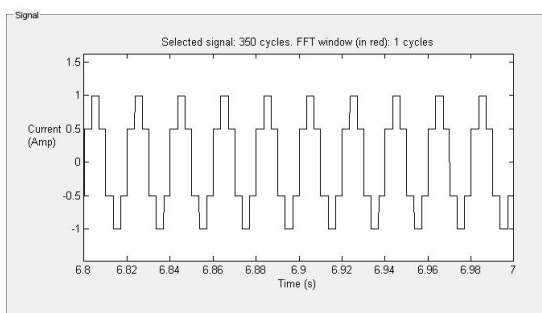


Fig 7.4(a) Line Current Waveform

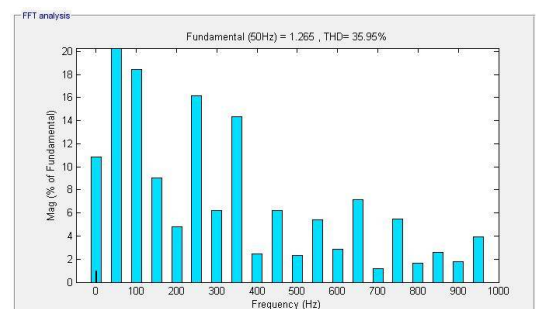


Fig. 7.4(a) THD of Line Current

Fig. 7.4(a) and Fig. 7.4(b) shows the Line Current Waveform and THD of Line Current respectively. By using ammeter we measure line current and by using THD analysis we measure the THD of Line Current.

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Waveform THD of Phase Voltage

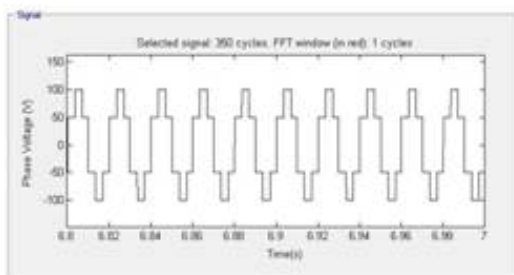


Fig 7.5(a) Phase Voltage Waveform

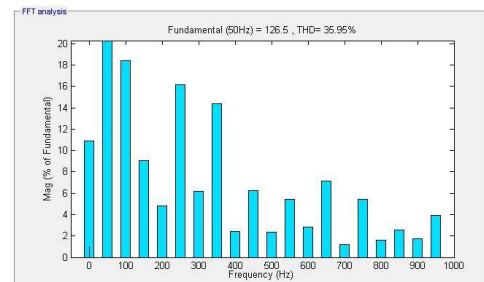


Fig. 7.5(b) THD of Phase Voltage

Fig. 7.5(a) and Fig. 7.5(b) shows the Phase Voltage Waveform and THD of Phase Voltage. By using voltmeter we measure Phase voltage and by using THD analysis we measure the THD of Phase Voltage.

Simulation of Z-source inverter with SBC method for R-L Load

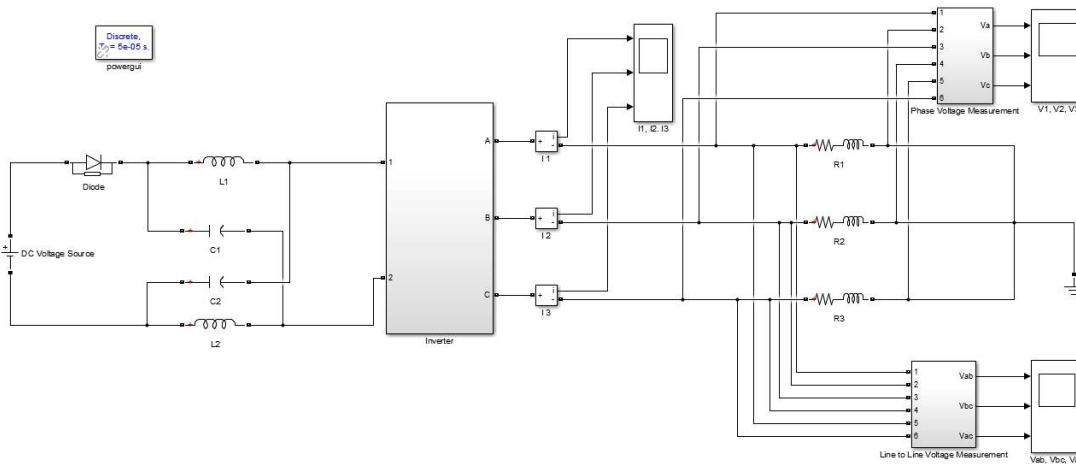


Fig. 7.6 Power circuit of Inverter 3 Phase Inverter

Fig. 7.9 shows the power circuit of 3 phase inverter with RL load. In this impedance source inverter includes two inductor two capacitors. By using ammeter and voltmeter we measure line to line voltage, phase voltage and line current measure.

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Waveform & THD of Line to Line Voltage

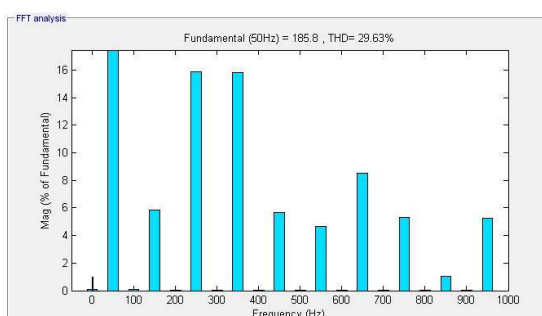


Fig. 7.7(a) Line to Line Voltage Waveform

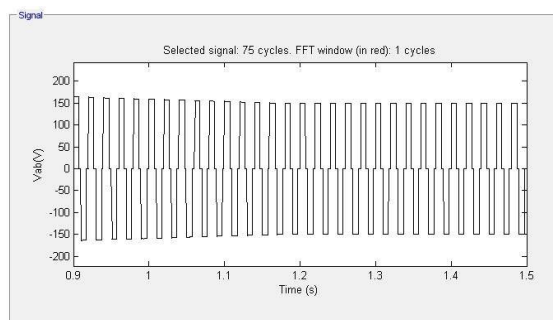


Fig. 7.7(b) THD of Line to Line Voltage

Fig. 7.7(a) and Fig. 7.7(b) shows the Line to Line Voltage Waveform and THD of Line to Line Voltage respectively. By using voltmeter we measure line to line voltage and by using THD analysis we measure the THD of Line to Line voltage.

Waveform & THD of Line Current

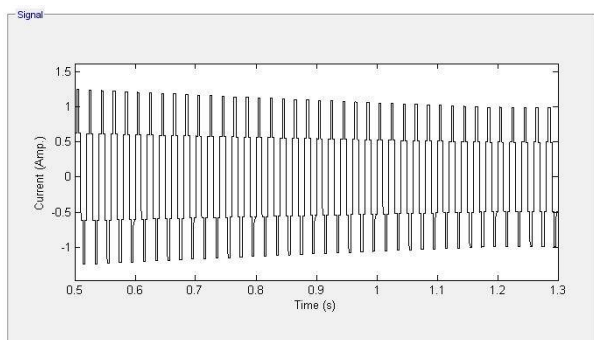


Fig. 7.8(a) Line Current Waveform

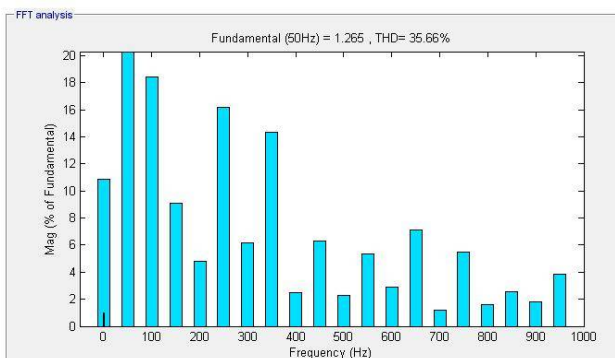


Fig. 7.8(b) THD of Line Current

Fig. 7.8(a) and Fig. 7.8(b) shows the Line Current Waveform and THD of Line Current respectively. By using ammeter we measure line current and by using THD analysis we measure the THD of Line Current.

Waveform THD of Phase Voltage

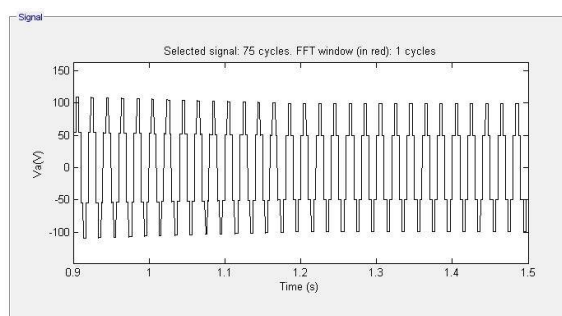


Fig. 7.9(a) Phase Voltage Waveform

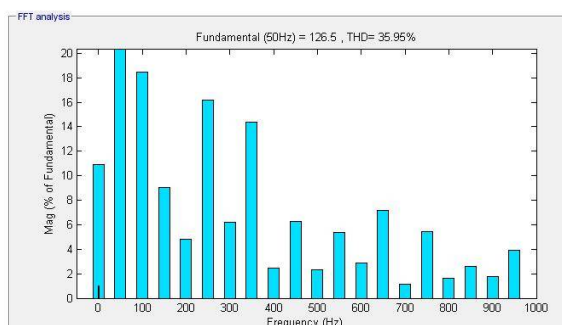


Fig. 7.9(b) THD of Phase Voltage

Fig. 7.9(a) and Fig. 7.9(b) shows the Phase Voltage Waveform and THD of Phase Voltage. By using voltmeter we measure Phase voltage and by using THD analysis we measure the THD of Phase Voltage.

Voltage and Current's THD for R Load and RL Load

Voltage and Current THD for R Load		Voltage and Current THD for RL Load	
Line Voltage V_{ab}	48.74 %	Line Voltage V_{ab}	29.63 %
Line Voltage V_{bc}	56.09 %	Line Voltage V_{bc}	32.09 %
Line Voltage V_{ca}	35.64 %	Line Voltage V_{ca}	32.10 %
Phase Voltage A	35.95 %	Phase Voltage A	30.43 %
Phase Voltage B	61.34 %	Phase Voltage B	30.41 %
Phase Voltage C	44.17 %	Phase Voltage C	32.98 %
Line current I_a	35.95 %	Line current I_a	29.99 %
Line current I_b	61.34%	Line Current I_b	29.97%
Line current I_c	44.17%	Line Current I_c	32.52%

Table 7.1 Voltage and Current THD for R and RL Load

Table 7.1 shows the Voltage and current THD for R and RL Load. In this measurement we measure the Line Voltage and phase voltage , Line current. In this we can see that we get less THD in RL load compare to R Load.

VIII. CONCLUSION

We Implemented the impedance source inverter by using simple boost control technique and get better result compare to traditional inverter Voltage Source Inverter and Current Source Inverter by THD analysis.

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