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Performance comparison of a VSI and a CSI using MATLAB/SIMULINK

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Abstract

Inverters are the devices which are used to create a single or multiple phase AC voltages from a DC supply source. A very large number of inverters exist for different applications such as for controlling speed motor drives and various industrial applications. Inverters falls in two categories which is voltage source inverter (VSI) and current source inverter (CSI). In this paper work simulation of three phase VSI and CSI is performed using Matlab/simulink. Comparison of THD in voltage and current waveform is studied and analyzed with motor load conditions.

1. Introduction

WITH the development of power electronic technology, the inverter has been widely applied in many fields. The inverter is therefore attracting attention of the researchers. An inverter is a contrary transformation device of a rectifier, whose function is to change AC into DC [5]. According to the property of the DC side power supply, the inverter is divided into the voltage-source inverter and the current-source inverter.

Voltage Source Inverter (VSI) has small or negligible impedance for dc source. In other words, a VSI has stiff dc voltage source at its input terminals. The easiest dc voltage source for a VSI may be a battery bank, which may consist of several cells in series-parallel combination. Solar photovoltaic cells can be another dc voltage source. An ac voltage supply, after rectification into dc will also passed as a dc voltage source. A voltage source is called stiff, if the source voltage magnitude does not depend on load connected to it. All voltage source inverters may be stiff voltage supply at the input.

Voltage source inverters can be described according to different criterions. They can be described according to number of phases they output. Accordingly they are Single-phase Voltage Source Inverter, Three-phase Voltage Source Inverter.

Thyristor-based current–source inverters (CSIs) have been traditionally used in high-power motor drives and utility power systems applications because of their topological and operational

Advantages [1], [2]. Due to the economical and reliable characteristics of the thyristors, the CSI topologies based on thyristors have performance merits such as simplicity, ruggedness, cost effectiveness, and very low switching losses [3], [4]. Due to all these features, the thyristor-based CSIs have been, so far, the favorable power converter topology in high-power applications, with available switching devices at high−power rating. However, the thyristor-based CSI has intrinsic drawbacks because the thyristors cannot be turned off by the gating signals. Therefore, external devices and circuits are required to turn the thyristors off by applying reverse-biased voltages, as well as transfer reactive energies of inductive loads after turning off the thyristors. Typical forced commutated thyristor-based CSIs are the auto sequentially commutated inverters (ASCIs) based on commutation circuits with six ac capacitors and six high-power diodes.

2. Modelling

Three-phase bridge inverters are widely used for ac motor drives and general-purpose ac supplies. Fig. 1 shows the inverter circuit, and Fig. 2 explains the fabrication of the out- put voltage waves in square-wave, or six-step, mode of operation. The circuit consists of three half-bridges, which are mutually phase-shifted by 2π√3 angle to generate the three-phase voltage waves. The input de supply is usually obtained from a single-phase or three-phase utility power supply through a diode-bridge rectifier and *LC* or C filter, as shown. The square-wave phase voltages with respect to the fictitious de center tap can be expressed by Fourier series as

$$Vao = \frac{2Vd}{\pi}[\cos\omega t - \frac{1}{3}\cos 3\omega t + \frac{1}{5}\cos 5\omega t - ....](2.1)$$

$$\text{Vbo} = \frac{2Vd}{\pi}[\cos(\omega t - \frac{2\pi}{3}) - \frac{1}{3}\cos 3(\omega t - \frac{2\pi}{3}) + \frac{1}{5}\cos 5(\omega t - \frac{2\pi}{3}) - ......](2.2)$$

$$\text{Vco} = \frac{2Vd}{\pi}[\cos(\omega t + \frac{2\pi}{3}) - \frac{1}{3}\cos 3(\omega t + \frac{2\pi}{3}) + \frac{1}{5}\cos 5(\omega t + \frac{2\pi}{3}) - .....](2.3)$$

Where V_d = dc supply voltage.

The line voltages can therefore be constructed from Equations (2.4)-(2.6)

$$Vab = Vao - Vbo$$

$$= \frac{(2\sqrt{3}Vd)}{\pi}[\cos(\omega t + \frac{\pi}{6}) + 0 - \frac{1}{5}\cos 5(\omega t + \frac{\pi}{6}) - \frac{1}{7}\cos 7(\omega t + \frac{\pi}{6}) - ....](2.4)$$

$$Vbc = Vbo - Vco$$

$$= \frac{(2\sqrt{3}Vd)}{\pi}[\cos(\omega t - \frac{\pi}{2}) + 0 - \frac{1}{5}\cos 5(\omega t - \frac{\pi}{2}) - \frac{1}{7}\cos 7(\omega t - \frac{\pi}{2}) + ...]...(2.5)$$

$$Vca = Vco - Vao$$

$$= \frac{(2\sqrt{3}Vd)}{\pi}[\cos(\omega t + \frac{5\pi}{6}) + 0 - \frac{1}{5}\cos 5(\omega t + \frac{5\pi}{6}) - \frac{1}{7}\cos 7(\omega t + \frac{5\pi}{6}) + ...].(2.6)$$

Note that the line fundamental voltage amplitude is √3 times that of the phase voltage, and there is a leading phase-shift angle of π/6.

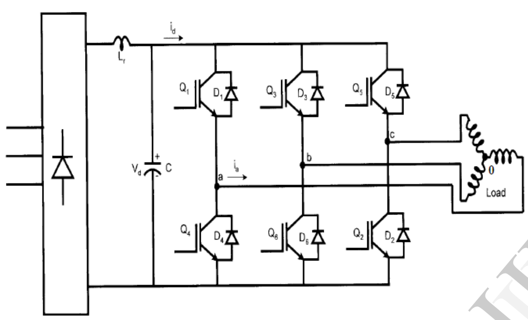
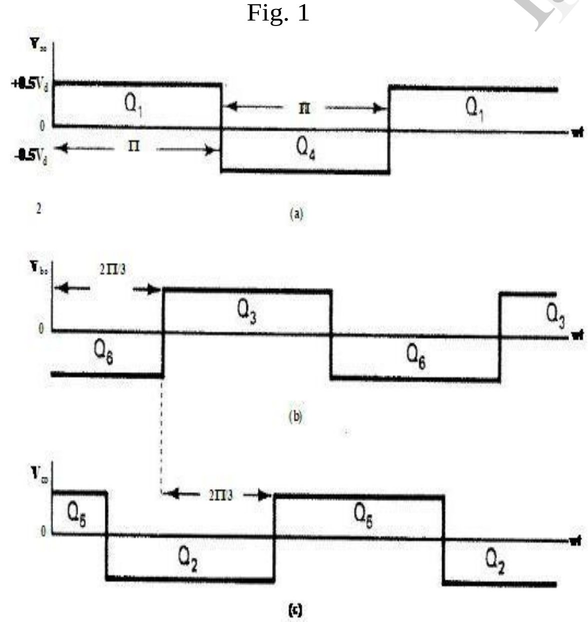


Fig. 1



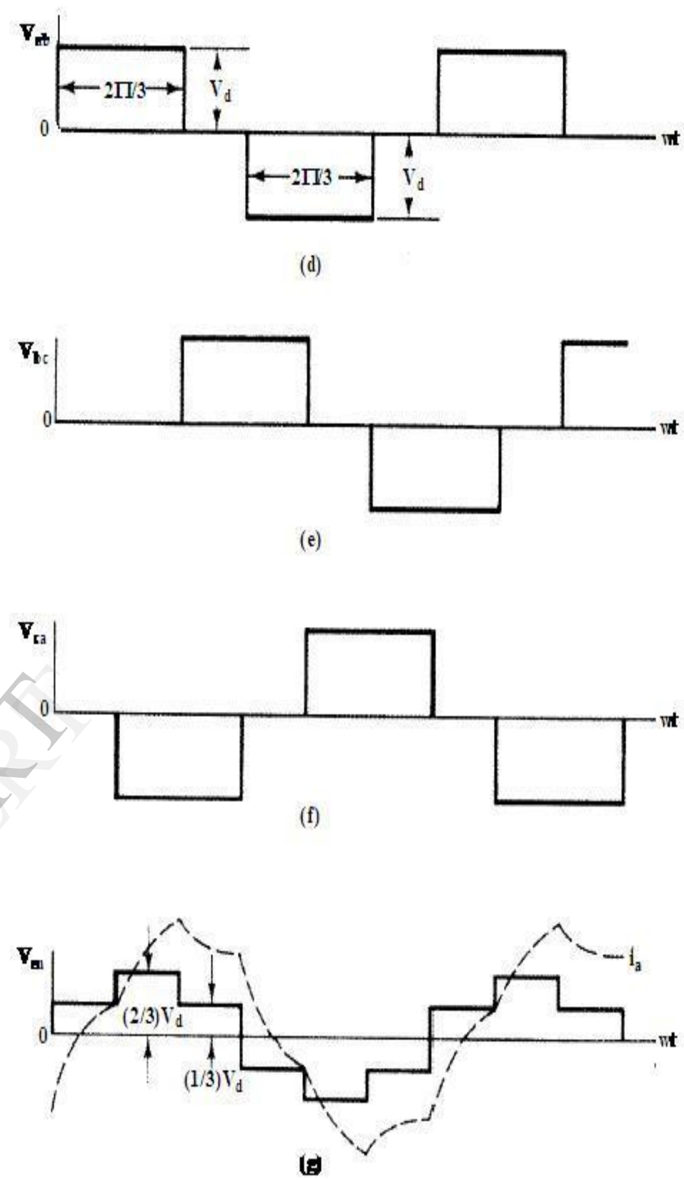


Fig. 2

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Fig. 3 shows topology for Three Phase Current source inverter.

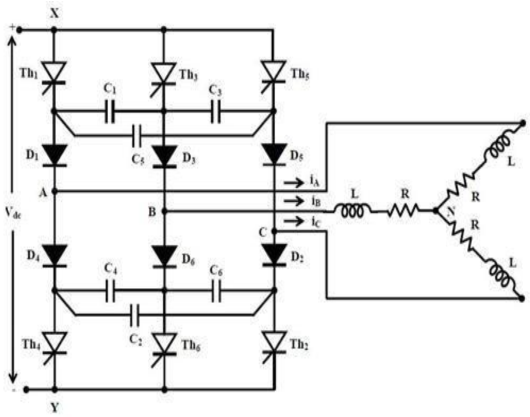

Fig.3 Three Phase Current source inverter.

The output current (phase) waveforms are shown in Fig. 3. In this circuit, six thyristors, two in each of three arms, are used, as in a three-phase VSI. Also, six diodes, each one in series with the respective thyristor, are needed here, as used for single-phase CSI. Six capacitors, three each in two (top and bottom) halves, are used for commutation. It may be noted that six capacitors are equal, i.e. $C_1 = C_2 = \dots = C_6 = C$. The diodes are needed in CSI, so as to prevent the capacitors from discharging into the load.

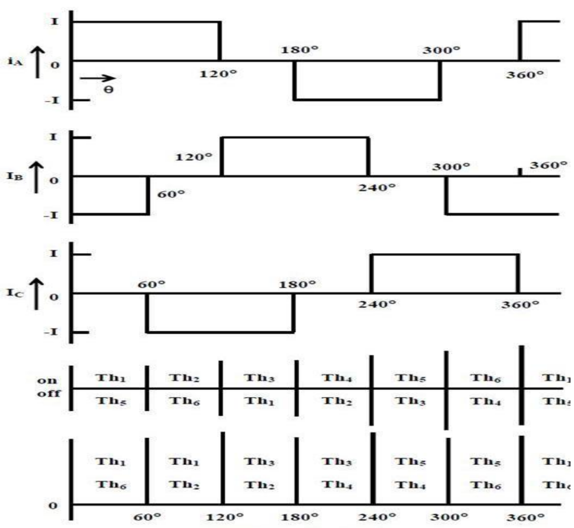

Fig. 4 output current (phase) waveforms

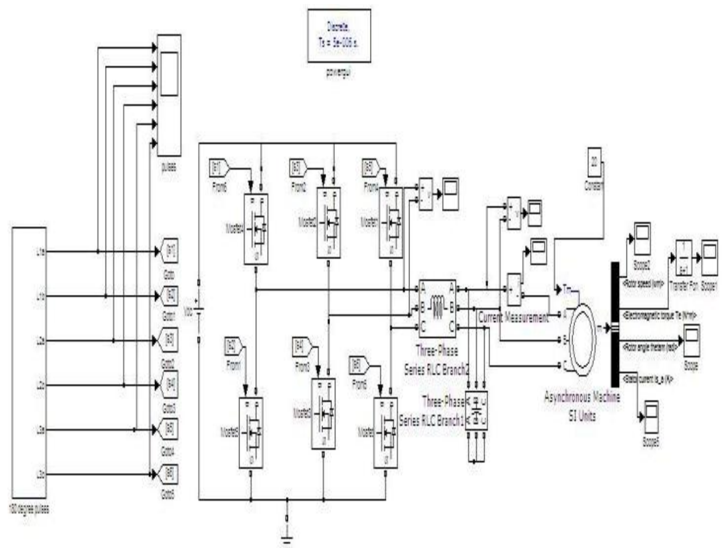

Fig.5 MATLAB Modal of VSI

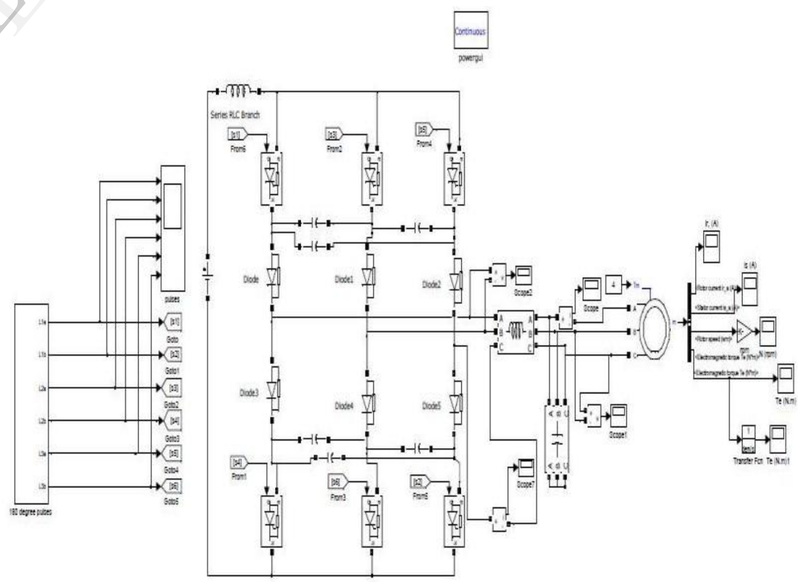

Fig.6 MATLAB Model of CSI

3. Simulation and Results

Current Source Inverter (CSI)

Fig 7 shows the waveform of line voltage before filter with motor load.

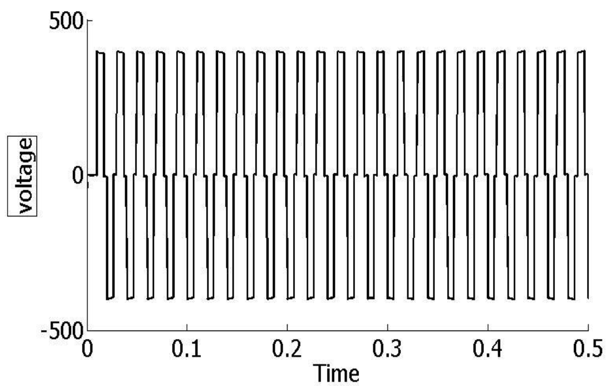

Fig. 7 Line Voltage before filter with motor load

Fig 8 shows the waveform of line voltage after filter with motor load.

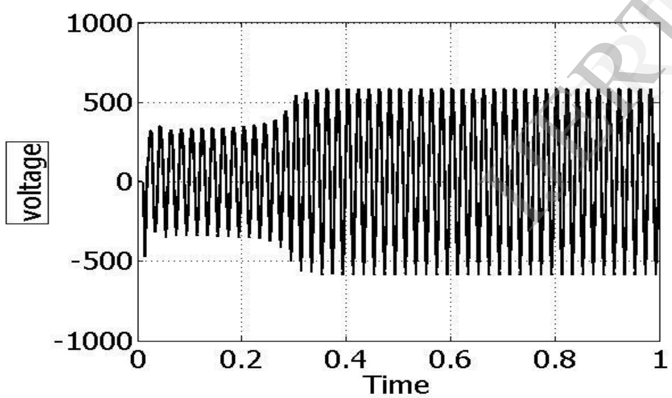

Fig. 8 Line Voltage after filter with motor load

Fig 9 and Fig 10 shows the FFT analysis of VSI with motor load before filter and after filter. THD before filter is 31.01% and after filter is 3.24%

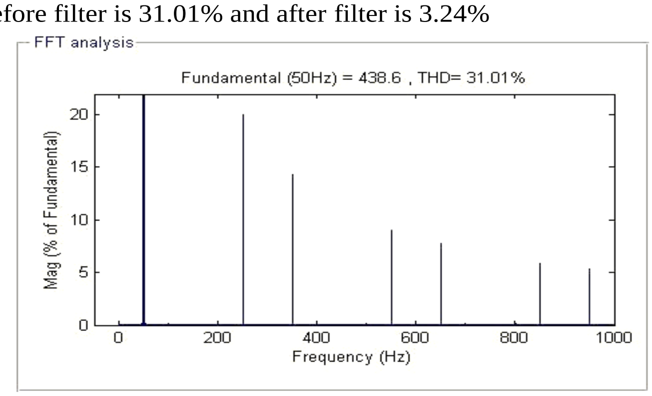

Fig. 9 FFT analysis before filter

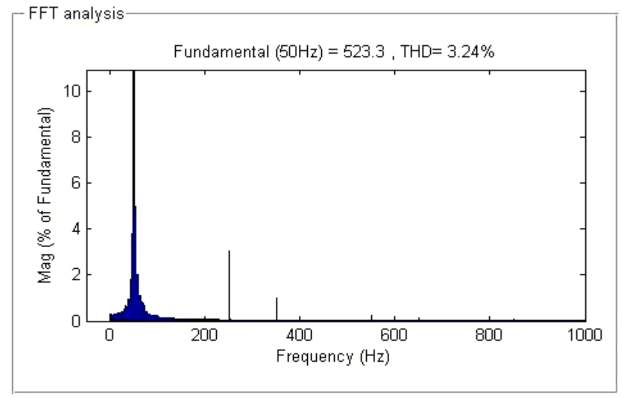

Fig. 10 FFT analysis after filter

Current Source Inverter (CSI)

Fig 11 shows the waveform of line voltage before filter with motor load.

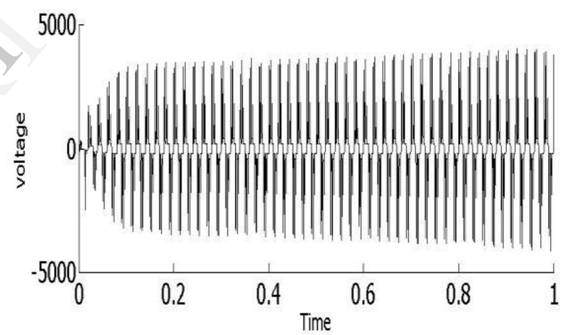

Fig. 11 Line voltage before filter

Fig 12 shows the waveform of line current before filter with motor load.

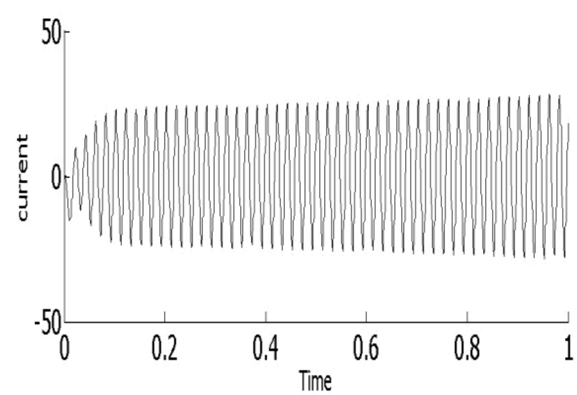

Fig. 12 Line current before filter

Fig 13 shows the waveform of line voltage after filter with motor load.

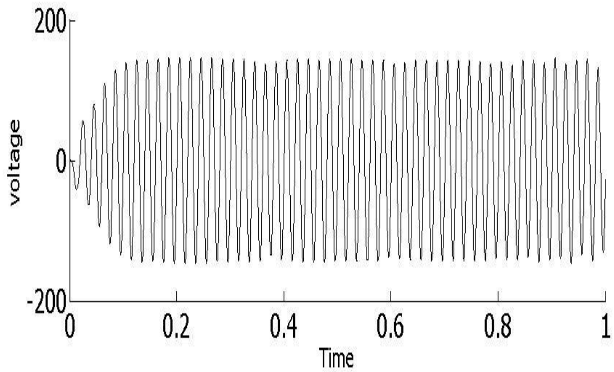

Fig. 13 Line voltage after filter

Fig 14 shows the waveform of line current after filter with motor load.

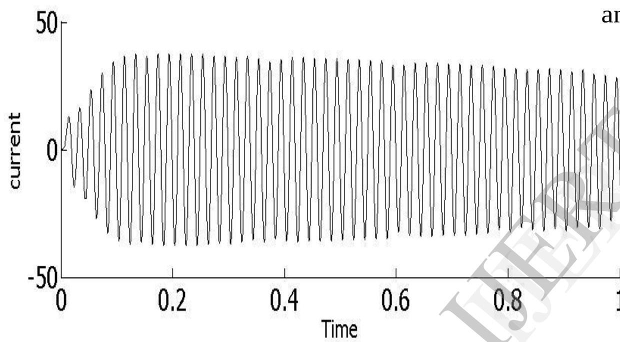

Fig. 14 Line current after filter

Fig 15 and Fig 16 shows the FFT analysis of Line voltage and current of CSI with motor load before filter. THD of line voltage before filter is 113.61% and current is 16.51%

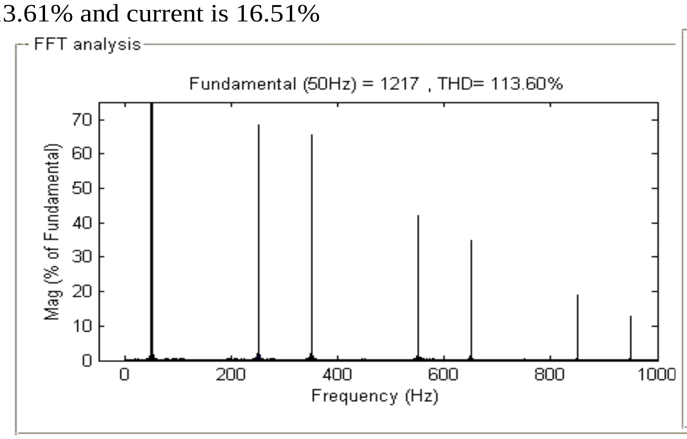

Fig. 15 FFT of Line voltage before filter

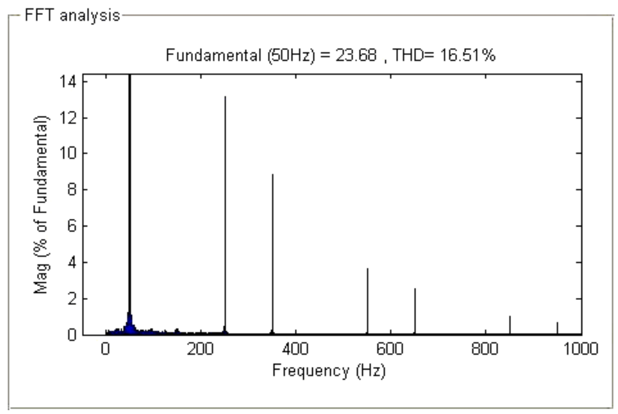

Fig. 16 FFT of Line current before filter

Fig 17 and Fig 18 shows the FFT analysis of Line voltage and current of CSI with motor load after filter. THD of line voltage after filter is 1.84% and current is 0.48%

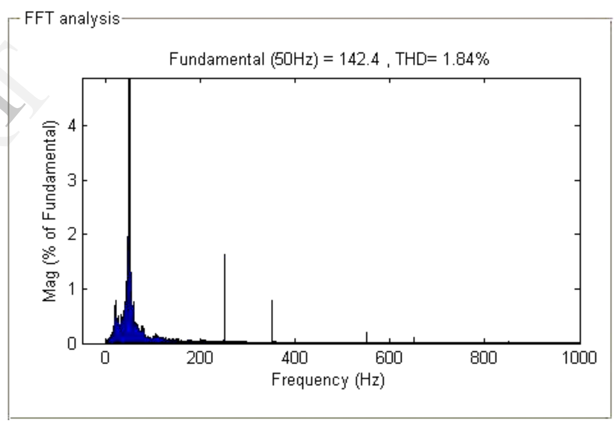

Fig. 17 FFT of Line voltage after filter

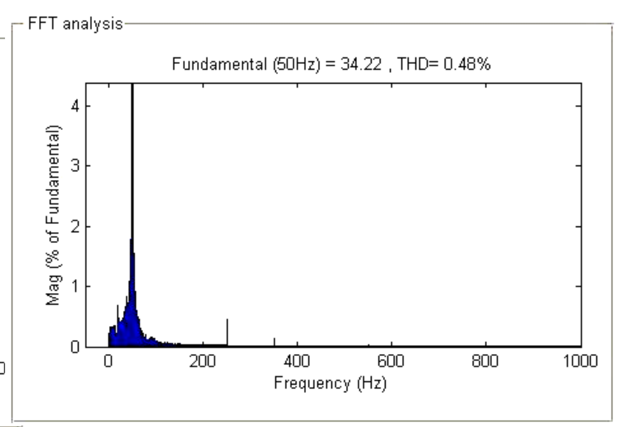

Fig. 18 FFT of Line current after filter

4. Comparison

S.No	Type of inverter	Type of Load	Filter parameter		Voltage THD (%)	Current THD (%)
			Inductor (mH)	Capacitor (μF)		
1	VSI	Motor Load	10	300	3.24	3.62
2	CSI	Motor Load	400	1000	1.84	0.48

5. Conclusion

Simulations of the Voltage source inverter (VSI) and Current source inverter (CSI) with motor loading condition are presented. Simulations have been done using Matlab/Simulink toolbox. The results with motor load are analyzed and THD comparison is done with different loads. Performance of both CSI and VSI is compared. Simulation results are shown to validate the performance of the system.

6. Refrances

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