International Journal of Control and Automation
Vol. 9, No. 7 (2016), pp.365-374
http//dx.doi.org/10.14257/ijca.2016.9.7.34

Harmonic Analysis in Power System using ZSI and Comparison with Conventional Inverter Techniques

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Abstract

Harmonics can appear due to non uniform condition or non-linearity in system. Harmonics out-turn distortion, losses and finally reduction in quality and efficiency. Distortion triggered by harmonic meters in term of % of THD (total harmonic distortion) which tie-up with distortion factor (unity for pure sine wave). Using MATLAB a circuit is sketch, for analyzing different harmonic effect in different fault condition, faults condition (with suitable parameter) imposed on system. By using ZS (Impedance source), VS (Voltage source) and CS (Current source) type inverters in design system contrast or similarity between results is analyzed.

***Keywords**: Power Quality, % THD (Total Harmonic Distortion), Impedanc Source, Current Source and Voltage Source Inverter*

1. Introduction

Power quality issues are in top priority while performance, losses and life of instrument calculated. The term quality may indicate by single factor like magnitude and/or quality of voltage, frequency, current *etc* or combinations of such factors. Combination of factors is justified as they are not independent of each-other, voltage tie-up with reactive (watt-less) whereas frequency with active (watt-full) power.

A Z-source inverter (ZSI) is a controllable, stable and performance wise optimal power inverter. It's a circuit performs conversion like CS and VS type inverter [1], a constant quantity as input in form of voltage or current reshape into alternating format. ZS inverter is X-shape model consist all general parameter R, L and C impedance network [2]. Impedance (X-shape) source is efficient means of power interchange between source and requirement in any form that is dc –dc, dc– ac, ac–dc, ac– ac [5]. ZS inverter is a technique performing both the steep function, which CS and VS inverter individually can't display, are buck (a step down mode) and boost (a step up mode) in same circuit [6]. Implementing such advantage of ZS inverter in power system PQ (power quality) problems like voltage sag and/or swell, load frequency control *etc* can address.

Distortion triggered by harmonics in system meter by % of THD [3]. THD value need to revise with various faults as the intensity and type of faults results non-identical distortion in quality.

2. Simulation Model and Results

This paper performs the simulation of various faults on various inverters fed system to analyze and compare the system performance at these conditions. Fault condition include LG, LL, LLL faults in which LG fault is very frequent and inverter topology involve are VS, CS and ZS type of Inverter.

ISSN: 2005-4297 IJCA

3. 3-ϕ VS Inverter Drive System:

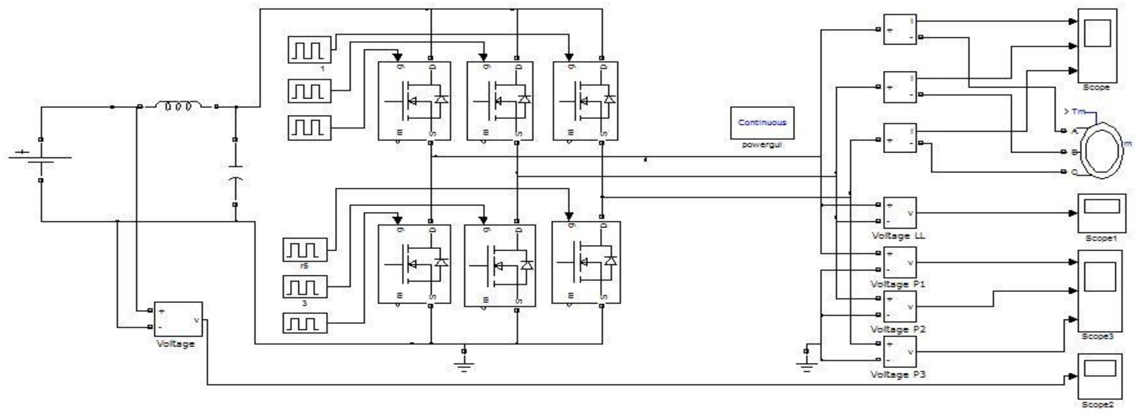

Figure 1.1. Matlab Model of 3-ϕ VS Inverter IM Drive System

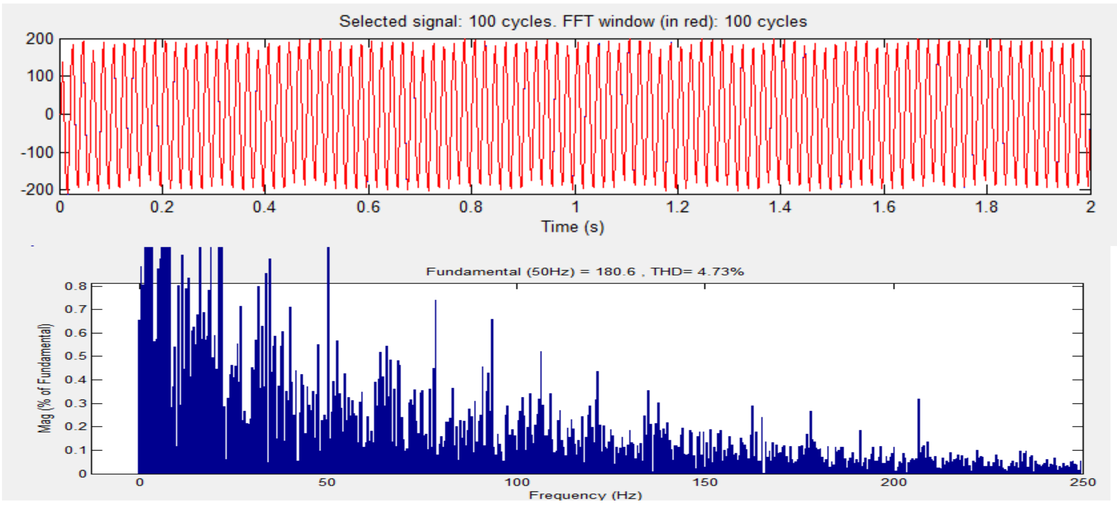

Figure 1.2. Current of Phase A And % THD by FFT

Figure 1.2 shows waveform of current and % THD of phase A which can be obtain from FFT window of Power GUI [3]. Current obtain is sinusoidal and % THD obtain is 4.73% under normal condition.

VS Inverter Subjected to LG Fault-

Using the setting of fault block in simulink a LG Fault is introduced.

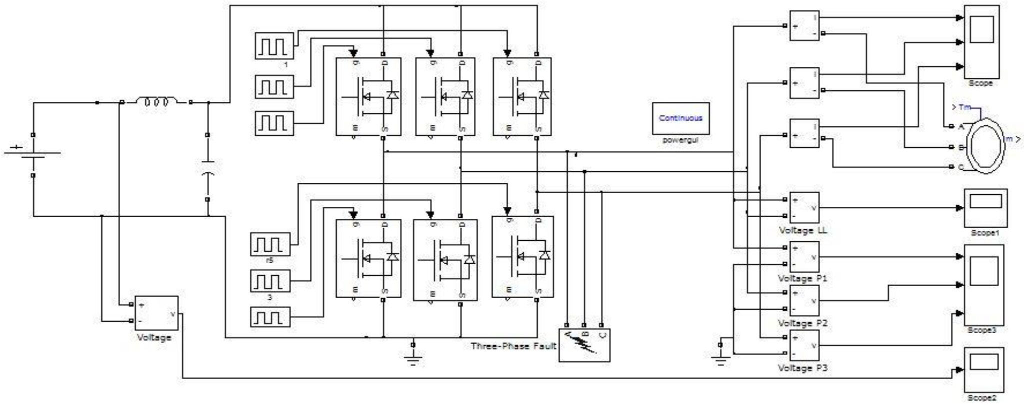

Figure 1.3. Matlab Model VS Inverter Fed System with LG Fault

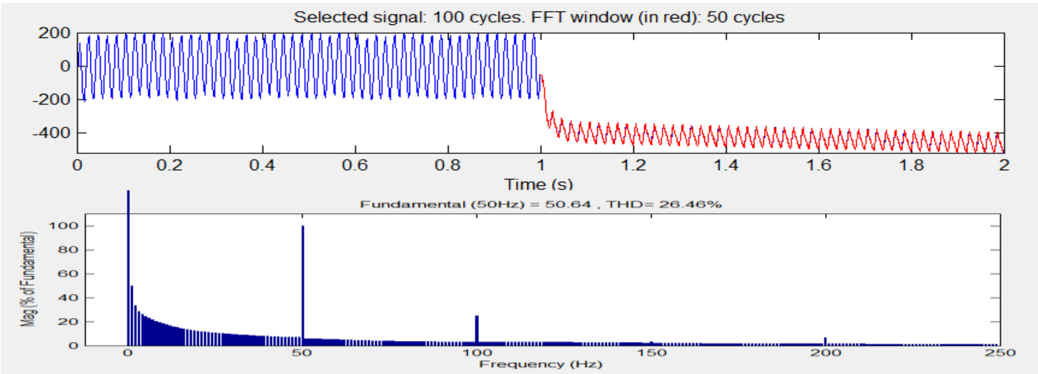

Figure 1.4. Current & % THD of Phase a under LG Fault

Figure 1.4 presents current and & % THD during LG fault at phase A. When LG fault triggered/occurred current waveform show oscillation with small magnitude and – ve in sign. FFT window displays % THD at 26.46% & current at -500 ampere.

VS Inverter Subjected to LL Fault –

Using LL Fault setting in Fault Block the circuit in Figure 1.3 is shows Matlab model of system with LL fault

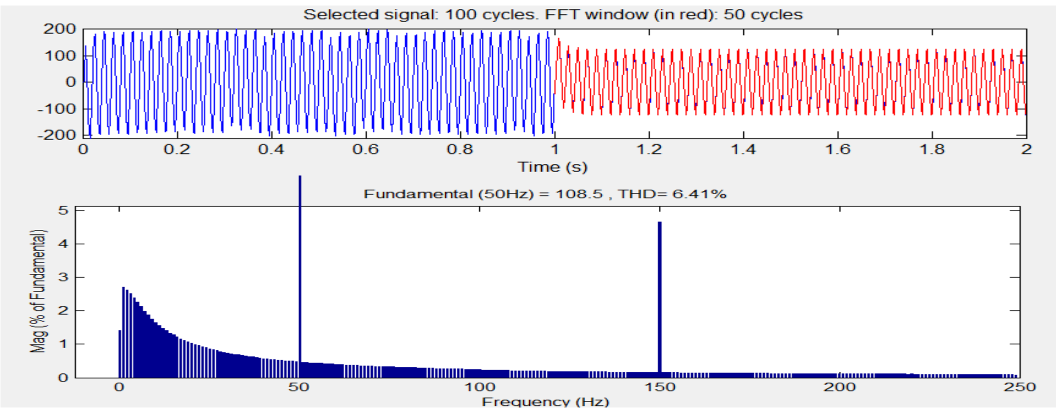

Figure 1.5. Current & %THD of Phase A When System under LL Fault

Under LL fault condition current magnitude of oscillation reduces up to value of 120 A & %TDS obtain is 6.41%.

VS Inverter Subjected to Three phase fault-

Figure 1.3 gives the simulation system under LLL Fault it the fault setting change to 3 phase fault.

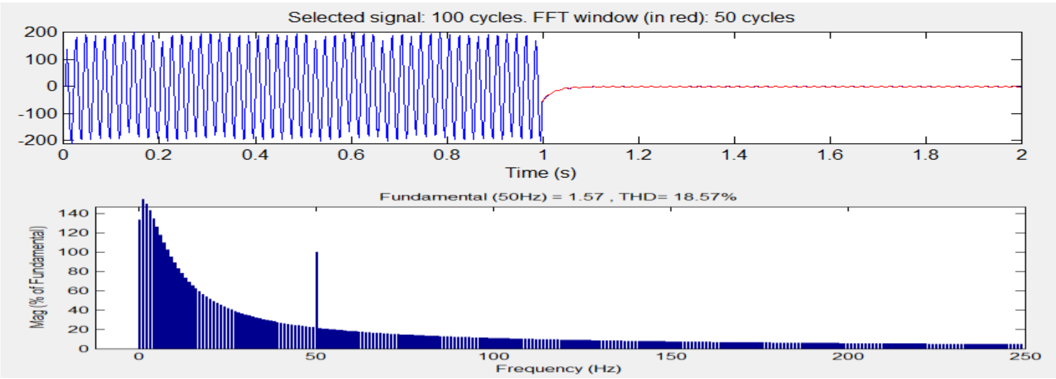

Figure 1.6. Current & %TDS of System under LLL Fault

3ϕ Fault or Dead Short Circuit Fault results zero current through fault resistance but the high current passes in line. Figure 1.6 indicates current reduces to zero at incident of LLL fault and % TDS to 18.57% value.

Table 1. Study of VS Inverter System

Conditions	THD %	Current
	Phase A	Phase A
Without Fault	4.73	200
LG Fault	26.46	-500
LL Fault	6.41	120
LLL Fault	18.57	0

Table 1. VS Inverter System Current & %TDS Data under Operating and Fault Condition

4. System with Current Source (CS) Inverter

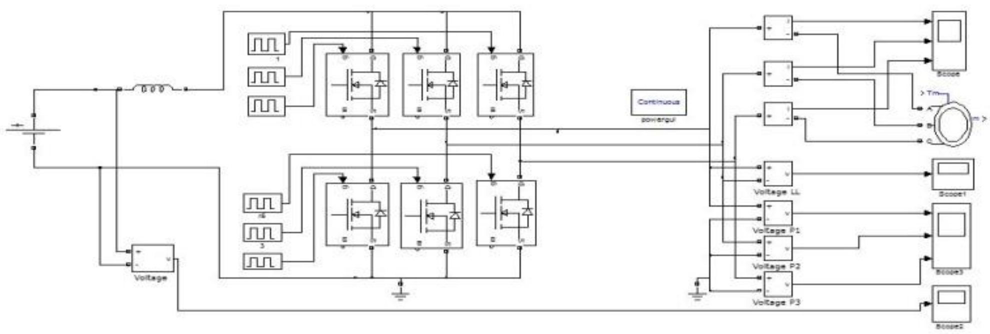

Figure 2.1. Matlab model of Current Source (CS) Fed system

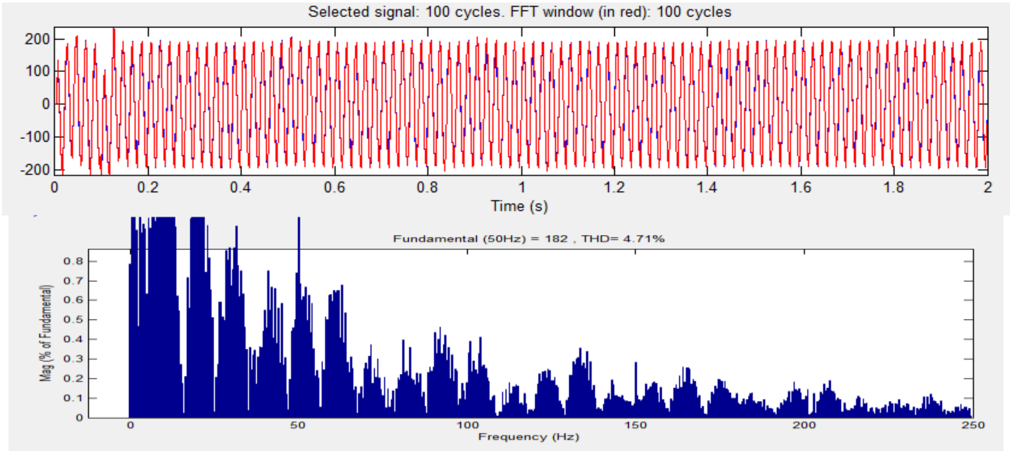

Figure 2.2. Current & %THD of Phase a of CS Inverter under No Fault

Figure 2.2 display the normal condition current waveform and its THD using FFT analysis of phase A and its value is 4.71% THD.

CS Inverter Subjected to LG Fault-

CS Inverter model is added with fault bock and setting is done for line to ground fault.

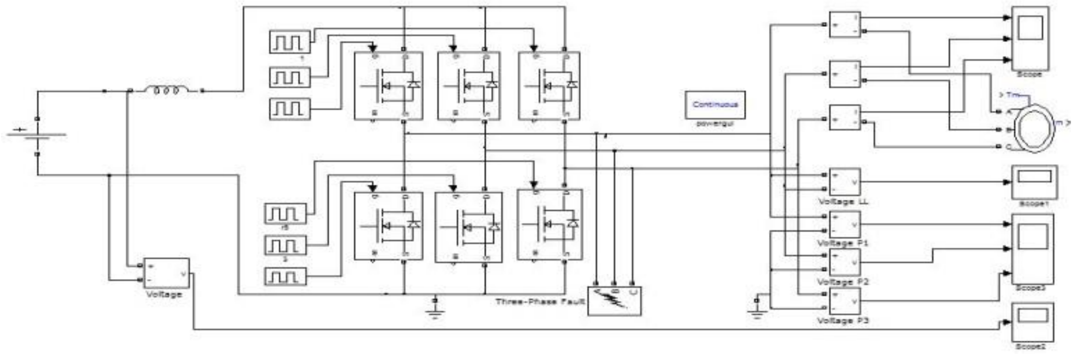

Figure 2.3. CS Inverter Fed System under LG Fault

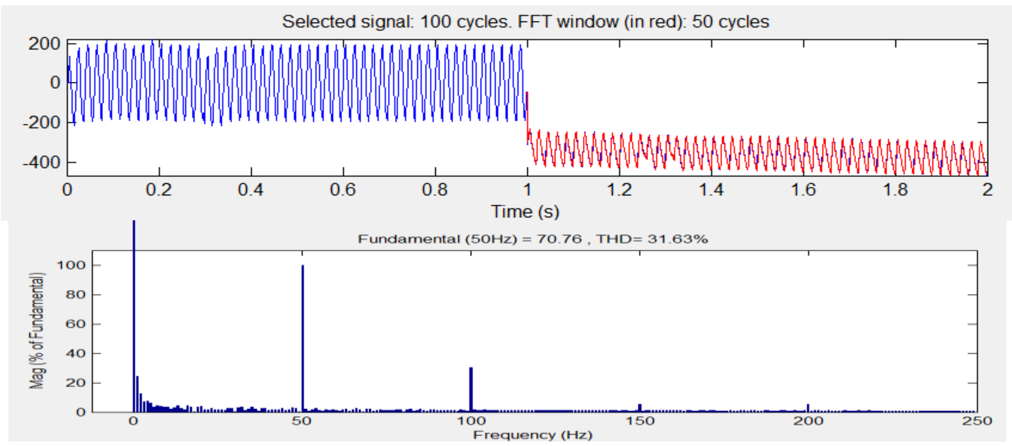

Figure 2.4. Current & %THD of Phase a of CS Inverter fed system under LG Fault Condition

Under LG Fault of CS inverter fed system negative current is observe. FFT block shows current value -500A & %THD 31.63.

CS Inverter Subjected to LL Fault-

Changing the Fault Setting of Figure 2.3 double line fault condition is imposed on CS inverter fed system

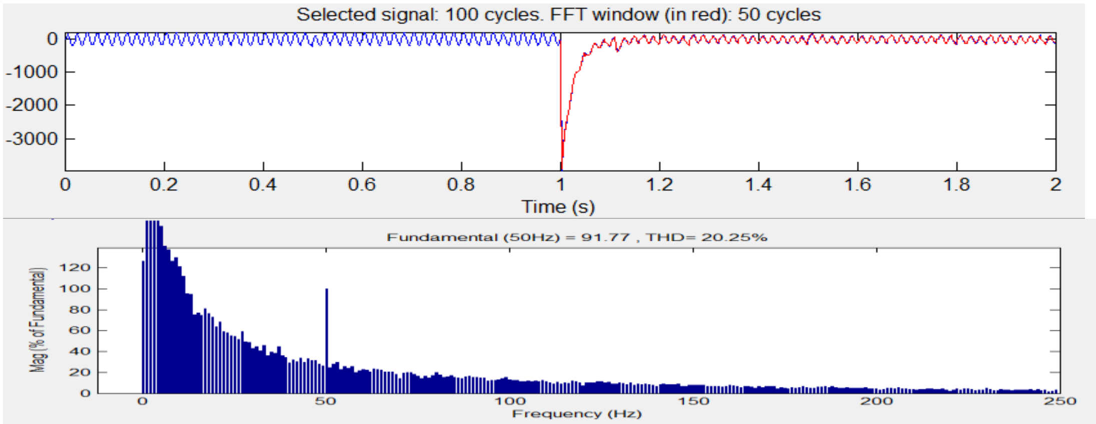

Figure 2.5. Current and its %THD of Phase A under LL Fault

Figure 2.5 display that when system is subjected to LL Fault at time 1 sec and current of phase A attain peak negative value and 20.25% is the THD obtain by FFT Analysis.

CS Inverter Subjected to LLL Fault -

The setting of fault block is change for LLL fault condition for FFT analysis.

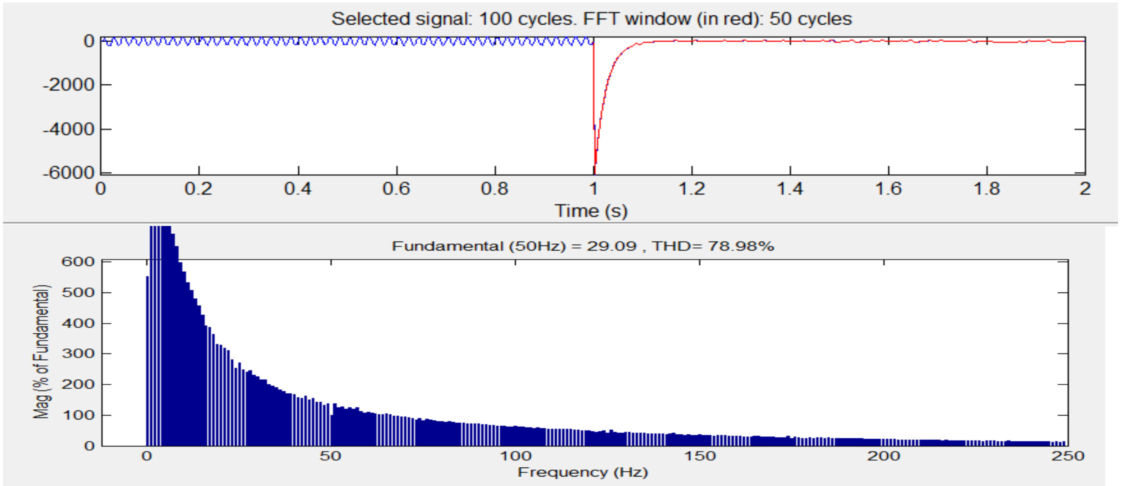

Figure 2.6. Current and % THD of Phase a under LLL Fault

Figure- 2.6 shows the waveform of current under LLL line fault condition and display % THD of 78.98% using FFT analysis. After the fault the current reduces to approx zero value.

Table 2. Study of ZS Inverter System

Conditions	Harmonics	Current
	Phase A	Phase A
Without Fault	4.71	220
LG Fault	31.63	-500
LL Fault	20.25	200
LLL Fault	78.98	0

Table 2 shows the analysis on CSI fed IM drive, five fault condition and one healthy condition is compared with the help of output current of the inverter and the THD% is consider for harmonic analysis.

5. Impedance Source Inverter (ZSI)

Using special network arrangement the impedance source inverter is able to perform the effect like the Current Source and Voltage Source types of Inverter [4].

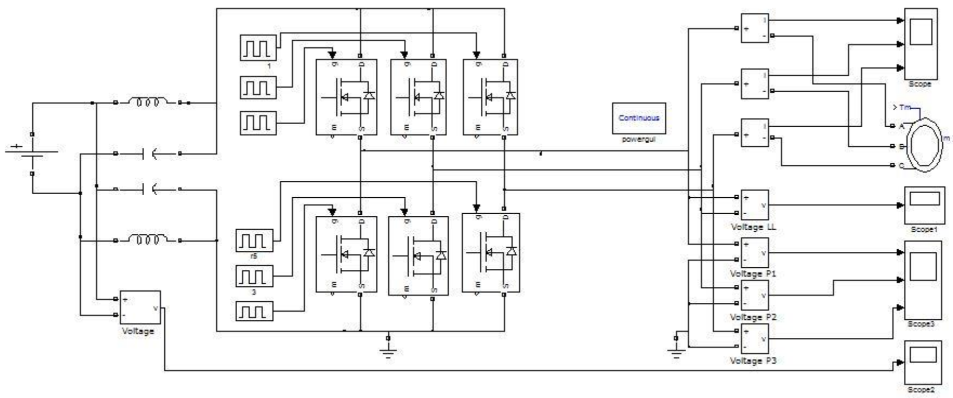

Figure 3.1. Matlab Model of 3ϕ ZS Inverter at Normal Condition

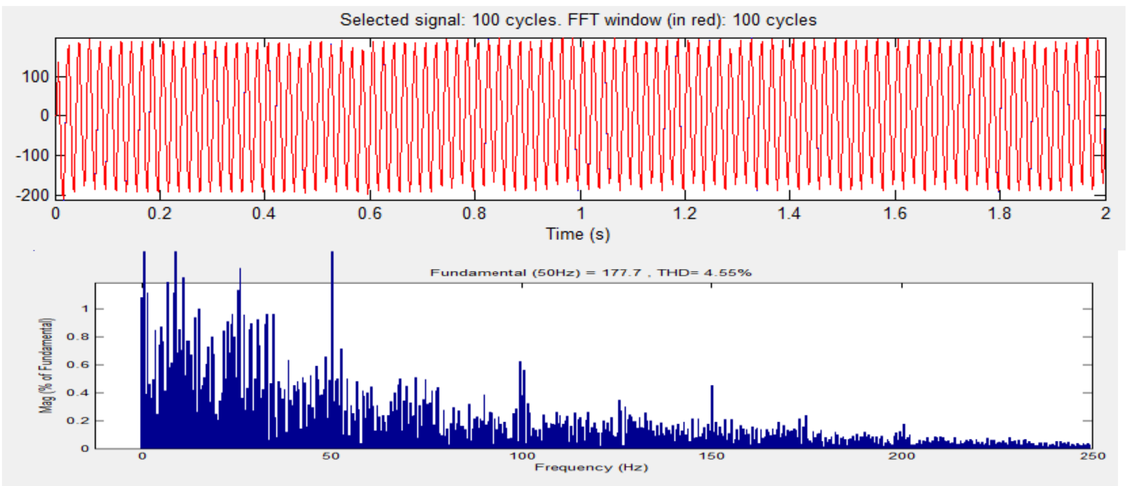

Figure 3.2. Current And % THD of Phase a Using ZSI under Normal Condition

Current wave is sinusoidal under no fault condition and THD % obtain is 4.55% .

ZS Inverter System Subjected to LG Fault-

A fault block is added in simulation model of ZS Inverter and fault setting are done to simulate single line to ground fault [5].

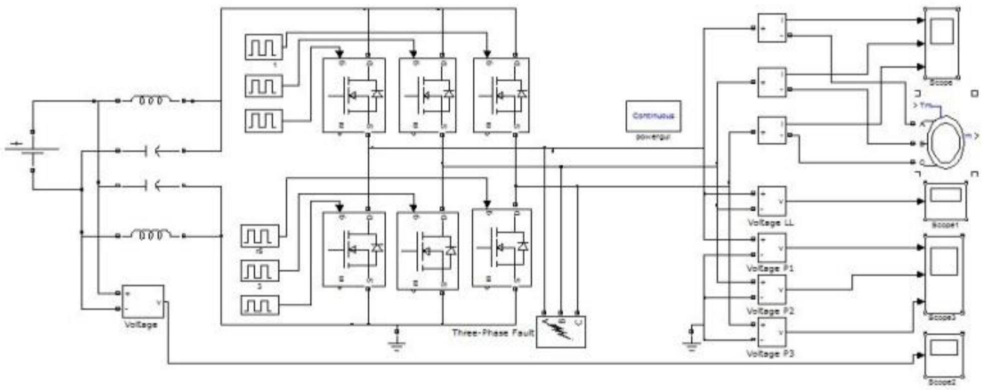

Figure 3.3. Simulation Model of ZS Inverter under LG (Line To Ground) Fault

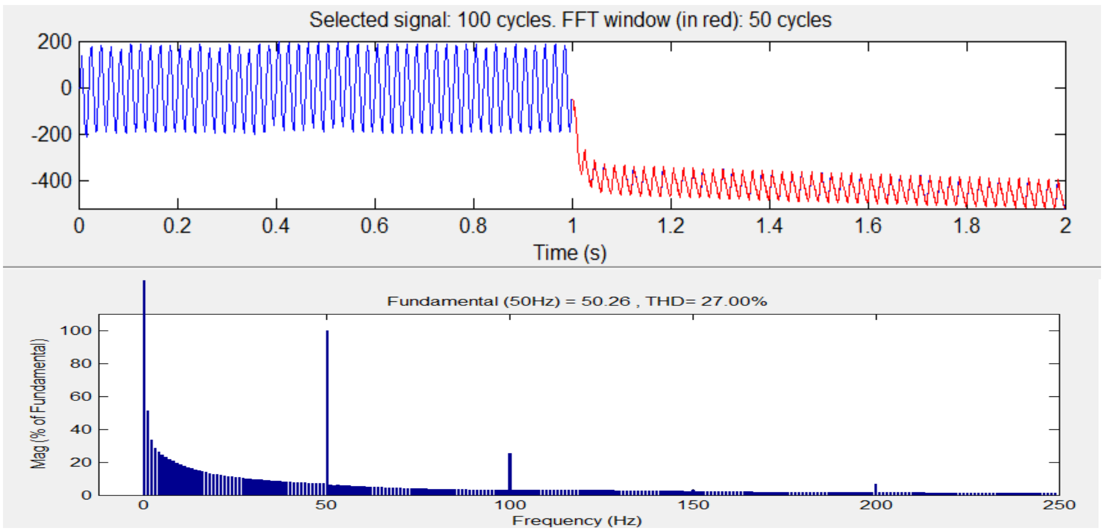

Figure 3.4. Current And % THD of Phase A During LG Fault

Figure 3.4 shows the waveform of current which becomes negative when subjected to fault and FFT analysis display 27 % THD under LG Fault [3].

ZS Inverter System Subjected to LL Fault-

Fault setting is change for double line and ground is disconnected for simulation of LL Fault condition.

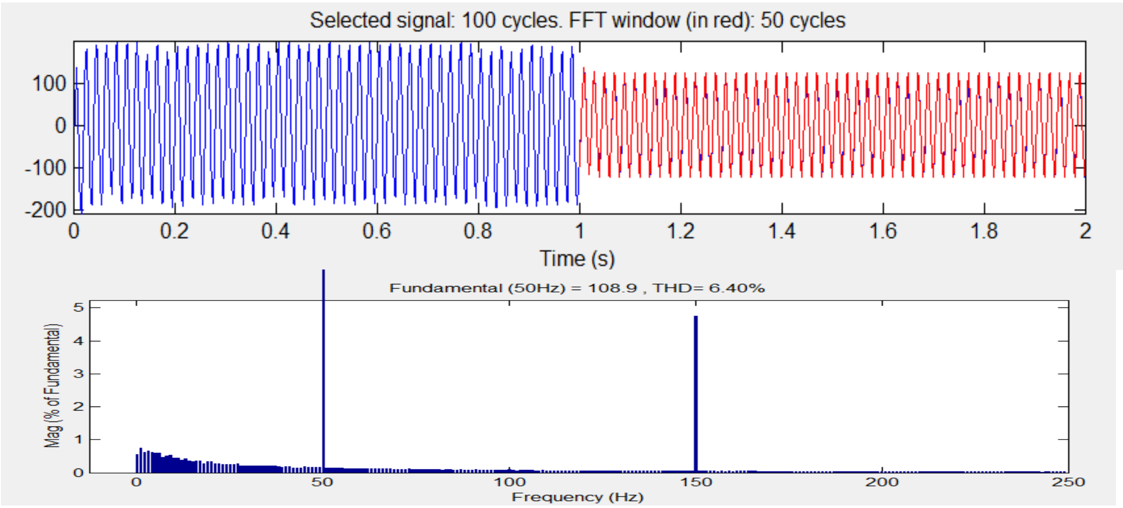

Figure 3.5. Current Waveform and % THD in LL Fault Condition

Figure 3.5 shows the waveform of current change to low magnitude when fault LL Fault is triggered and the % THD measured is 6.40%.

ZS Inverter System Subjected to LLL FAULT-

Fault setting change to simulate 3ϕ fault in ZS Inverter circuit.

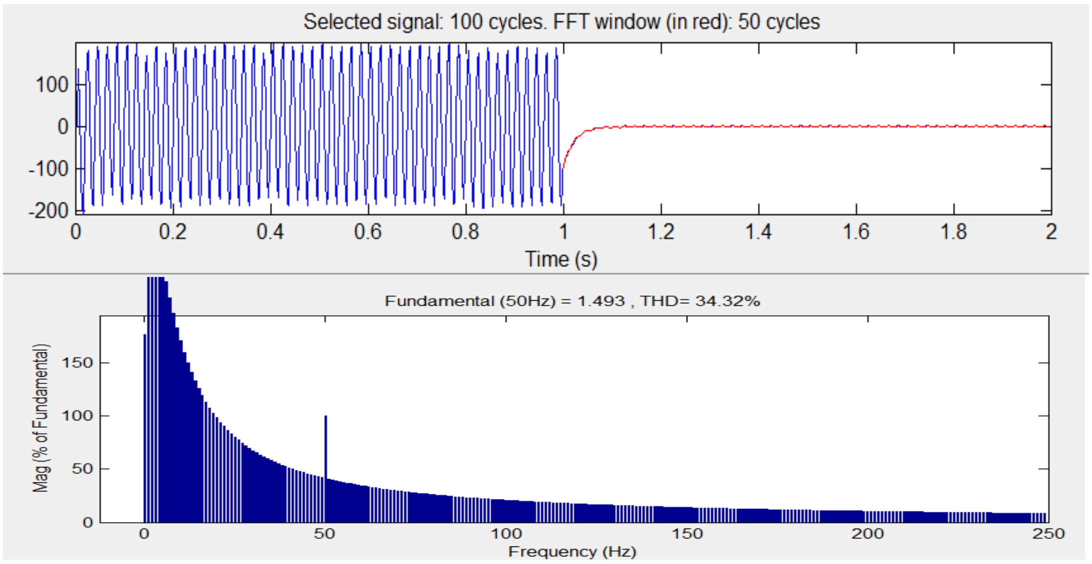

Figure 3.6.- Analysis of Healthy and Faulty Condition Using FFT For ZSI Fed IM Drive System

Figure 3.6 shows that the current under the 3ϕ fault or dead short circuit fault do not flow through the fault point so current value is zero at fault point. FFT analysis gives the % THD value 34.32%.

Table 3. ZS Inverter System Analysis

Conditions	% THD	Current
	Phase A	Phase A
Without Fault	4.54	200
LG Fault	27.00	-500
LL Fault	6.40	120
LLL Fault	34.32	0

Table 3-shows the analysis on ZSI fed IM drive, five fault condition and one healthy condition is compared with the help of output current of the inverter and the THD% is consider for harmonic analysis.

6. Conclusion

Classical power converter topologies still give satisfactory results and their performances are being improved by advanced control techniques. Unique buck and boost capability of the ZSC allows a wider input voltage range and eliminates the usage of DC/DC boost stage.

- Z-source inverter can boost–buck voltage minimizes component count, increase efficiency, and reduce cost.
- The Simulation studies proofs that fault current changes, which may cause breakdown of device. As of study, it is concluded that the output current also falls to negative value due to faulty conditions which is undesirable for the inverter operation.
- As we can found that in the line to ground fault for all three topologies of inverter having the higher negative current value, these current value are the three times of the current in other faults.
- For the distortion analysis the CSI fed IM drive in the short circuit case having the highest Total Harmonic Distortion.

In future, this study can be extended for analysis using the Fuzzy controller. To increase the performance multilevel inverter topology can be used.

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