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# Comparison Between Multilevel Inverter's To Drive Control & THD

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***Abstract:*** **The object of this paper is to compare the three level three legs multilevel inverter with five level three legs multilevel inverter to control induction motor & reduce the Total harmonic distortion. The conventional two level inverter is not producing the high ac output voltage & also increases the higher torque pulsation, ripple factor, higher total harmonic distortion. The high AC output voltage, less torque pulsation, less ripple factor, less total harmonic distortion is achieve with the help of multilevel inverter. Filter is also play a vital role in reduction of Total harmonic distortion. Second order low pass filter & LC filter are used in this project. Sinusoidal Pulse Width Modulation Control scheme is proposed for 3 & 5 level 3 legs multilevel inverter. The simulation results shows that as level increases the efficiency of the system is also increases.**

***Keywords:*** **Induction motor, 3 level & 5 level multilevel inverter, THD, MOSFET, filter, Damping factor.**

## I. INTRODUCTION

In industry there is a demand of high power & less total harmonic distortion. The conventional inverter is a electronic appliance which converts dc to ac having low power, higher torque pulsation, ripple factor, higher total harmonic distortion. In 1975 multilevel inverter was designed and become a option for high power, less total harmonic distortion. The multilevel inverter consist of power semiconductor switches, dc source & capacitor to get high power. Advantages of multilevel inverter are as(1)Reducing Total harmonic distortion,(2)Increasing the power,(3)Motor will not be damaged because stress of drive is reduced. There are so many practical importance of multilevel inverter are present for example Traction of train, Propulsion of ship.

In the past Induction Motor mostly used for constant speed. Induction Motor Play a vital role in Industry, they are low cost, reliable, rugged. In the Industry there are so many application that required variable speed, in the early times, DC motor is widely used for variable speed application. In the last century Mechanical gear system was used to produce variable speed. Presently with the help of control system & power electronics it is easy to obtain the variable speed & control of motor is become easy & replace the older method.

Now multilevel inverter is used to control the motor in place of Mechanical gear system.

## II. NEUTRAL POINT CLAMPED MLI

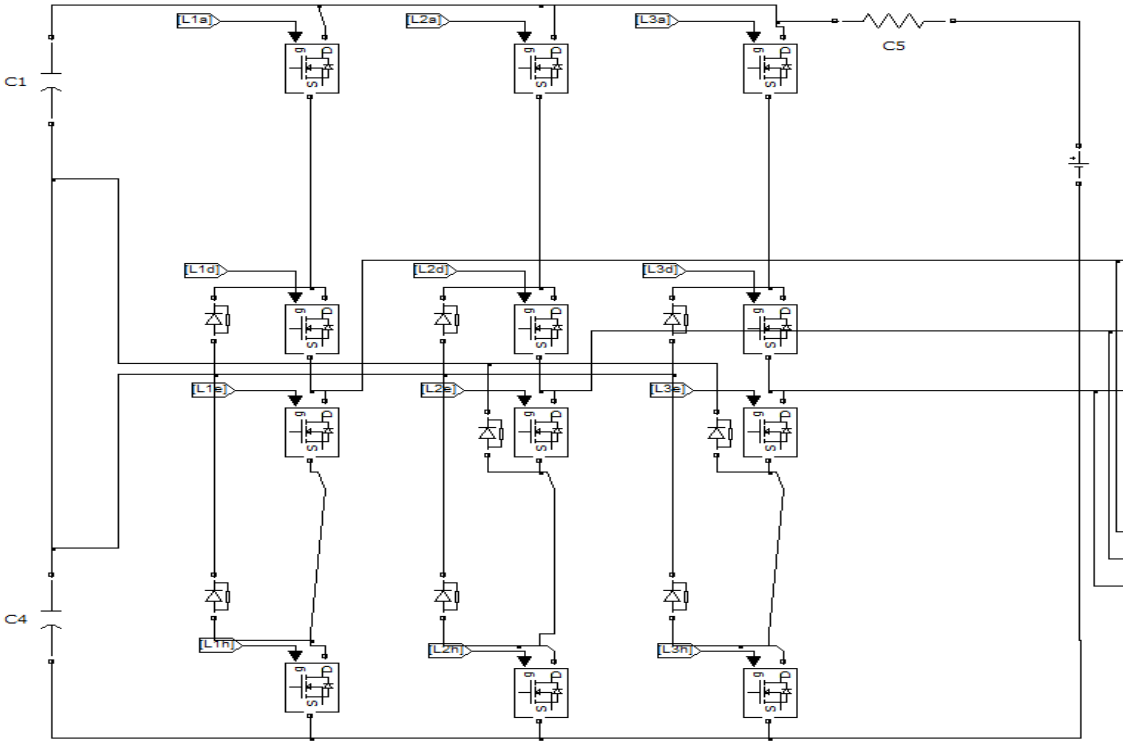
**3 level Neutral Point Clamped MLI-**The diagram of three level three legs Neutral Point Clamped inverter as shown in the Fig.(1),Each leg has four MOSFET, two capacitors, two clamping diodes. To obtain a staircase output, first consider only one arm of multilevel inverter. From the Table (1) it is clear that at every stage only 2 MOSFET are ON STATE & others are OFF.

**5 level Neutral Point Clamped MLI** -The diagram of five level three legs Neutral Point Clamped Multilevel inverter as shown in Fig(5).Each leg has eight MOSFET, four capacitors, six clamping diodes. To obtain a staircase output, first consider only one arm of multilevel inverter.

From the Table (2) it is clear that at every stage only 4 MOSFET are ON STATE & others are OFF. Clamping diodes plays a very important role to maintain a voltage. In Neutral Point Clamped Multilevel inverter a load is taken from the middle. Induction motor is a load of the multilevel inverter.

**Table (1) Operation of 3 level Neutral Point Clamped Multilevel inverter.**

| Output voltage=Va | MOSFET STATE | | | |
|---|---|---|---|---|
| | M1 | M2 | M'1 | M'2 |
| Va=V1 | 1 | 1 | 0 | 0 |
| Va=V2 | 0 | 1 | 1 | 0 |
| Va=V3 | 0 | 0 | 1 | 1 |




**Fig(1) 3 level 3 legs Multilevel inverter using Neutral point clamped inverter.**

**Table (2) Operation of Neutral Point Clamped Multilevel inverter**

| Output voltage=Va | MOSFET STATE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | M1 | M2 | M3 | M4 | M'1 | M'2 | M'3 | M'4 |
| Va=4Vdc | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Va=3Vdc | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| Va=2Vdc | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| Va=Vdc | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| Va=0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

1 show the ON state & O show OFF state.

## III. PROPOSED CONTROL METHOD

**Sinusoidal Pulse Width Modulation for 3 level MLI:** In sinusoidal pulse width modulation, a triangular carrier wave is compared with a desired frequency of sinusoidal reference wave. Comparator is used to compare the carrier & reference waves. Comparator output is high when triangular wave magnitude is lower than the sinusoidal reference wave.

For 3 level Neutral Point Clamped inverter one sinusoidal reference wave is compared with two triangular wave as shown in Fig.(2).

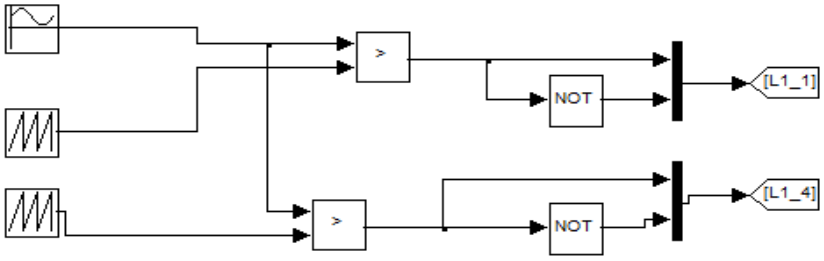



**Fig.(2) Simulink model of Sinusoidal PWM for 3 level inverter.**

**Sinusoidal Pulse Width Modulation for 5 level MLI:** For five level Neutral Point Clamped inverter one sinusoidal reference wave is compared with four triangular wave as shown in Fig.(3).

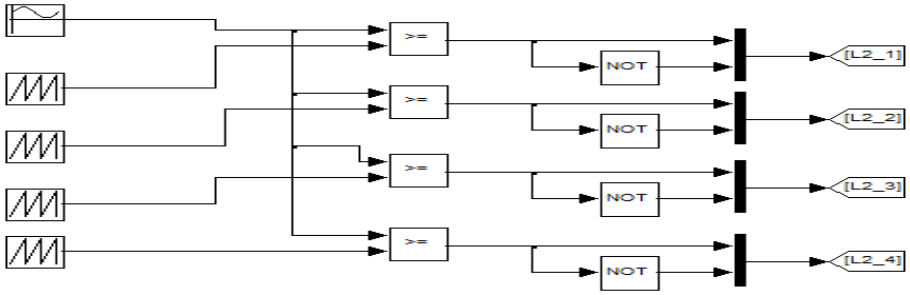



**Fig.(3 ) Simulink model of Sinusoidal PWM for 5 level inverter.**

## IV. INDUCTION MOTOR

An induction motor is also called as a asynchronous motor, it is a AC electric motor. In rotor there is a electric current, needed to obtained a torque which is produced by electromagnetic induction of the stator winding. An induction motor rotor classified in two types:

(1) Wound.

(2) Squirrel cage. Squirrel cage of three phase induction motor are rugged, reliable & economical that's why they are mostly used in industry. For house hold application that is for small loads like fans, Single phase induction motor are widely used.

**Table (3) Parameter of Induction motor**

| | |
|---|---|
| Induction motor | 15:5.4HP (4KW), 400volt,50Hz,1430 Rpm |
| Mechanical input | Torque |
| Rotor type | Squirrel cage |
| Reference frame | Rotor |

## V. FILTER

Electronic filters are called as analog circuits & filters are used to remove unwanted noise from the desired signals. There are different types of filter are present are as follow:

(1) Active filter.

(2) Passive filter.

(3) Hybrid filter.

Second order low pass filter-Two RC filters are connected in cascaded is called second order low pass filter. Hybrid Filter-It is also called LC filter. Two conductive foil layers are present in hybrid filter. From these two layers, one layer is sandwiched between the multilevel inverter & induction motor is called the main foil. Another layer is linked to a neutral potential & capacitance is formed between the layers.

## VI. SIMULINK MODEL

As per the proposed topology & proposed control method the Simulink model has been developed are shown below, the 3 level 3 legs Multilevel inverter with second order low pass filter & 5 level 3 legs Multilevel inverter with second order low pass filter are shown below.

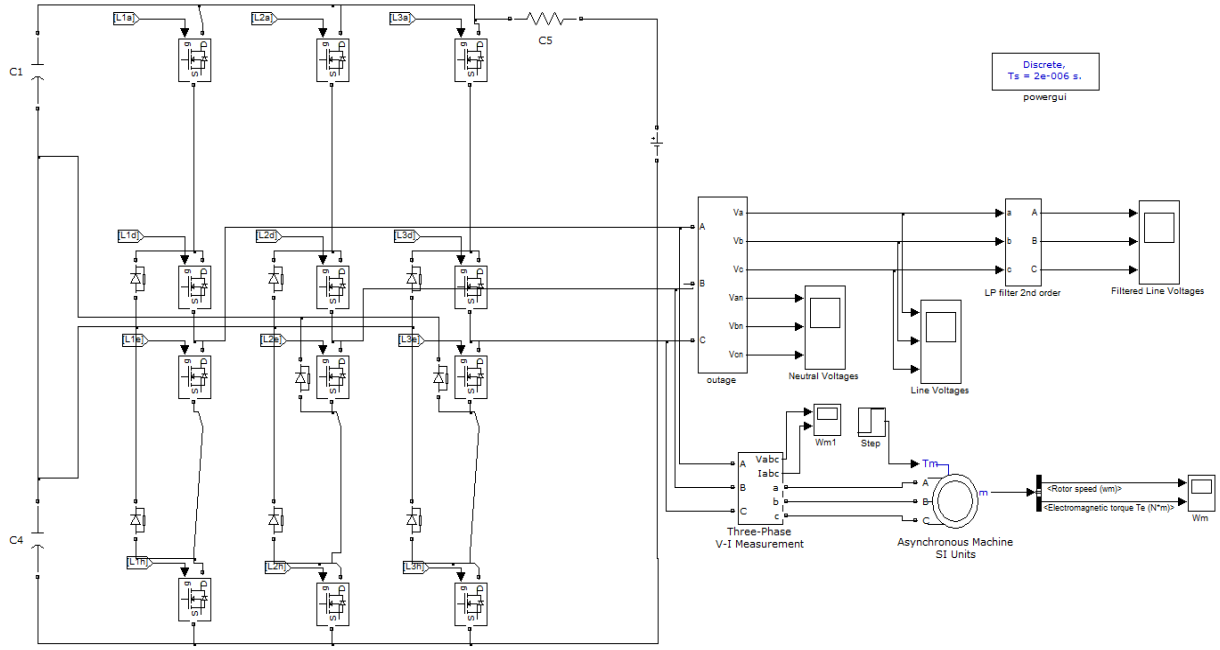



**Fig. (4) 3 level 3 legs multilevel inverter with second order low pass filter.**

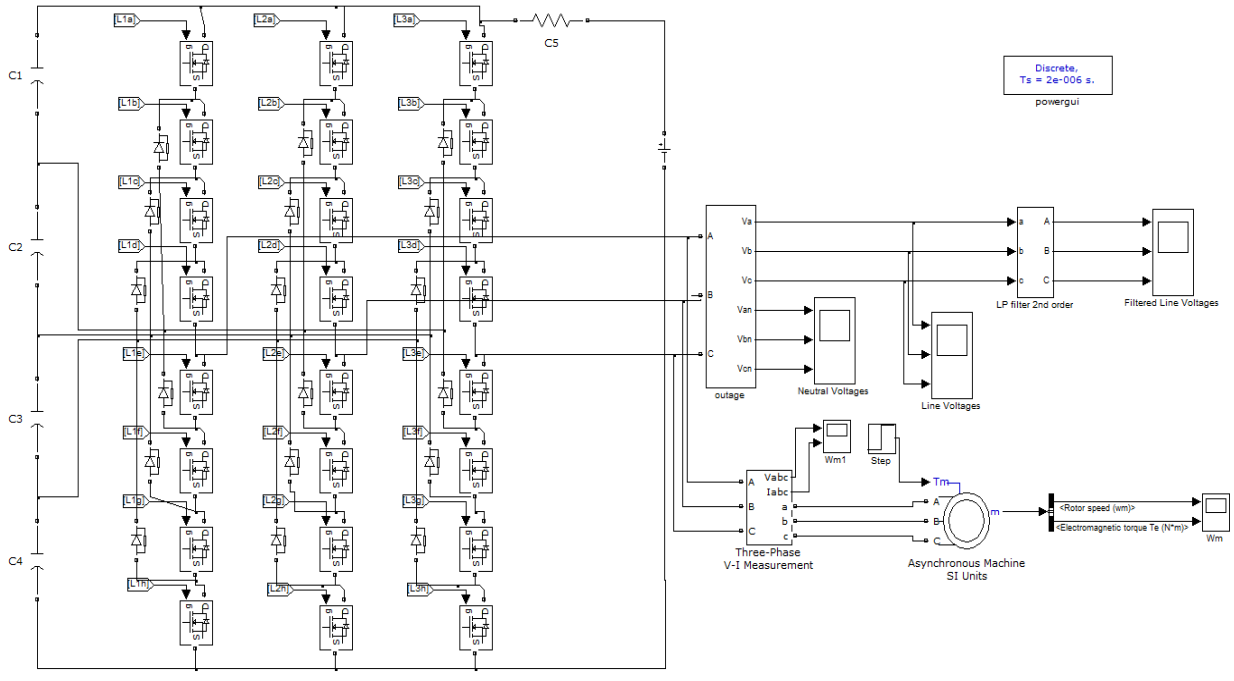



**Fig. (5) 5 level 3 legs multilevel inverter with second order low pass filter.**

## VII. RESULT AND DISCUSSION (CASE STUDIES)

**Case 1- FFT analysis of line voltage & THD without filter.**

When 3 level 3 legs MLI has been used to control drive without filter, its THD is very high as shown below.

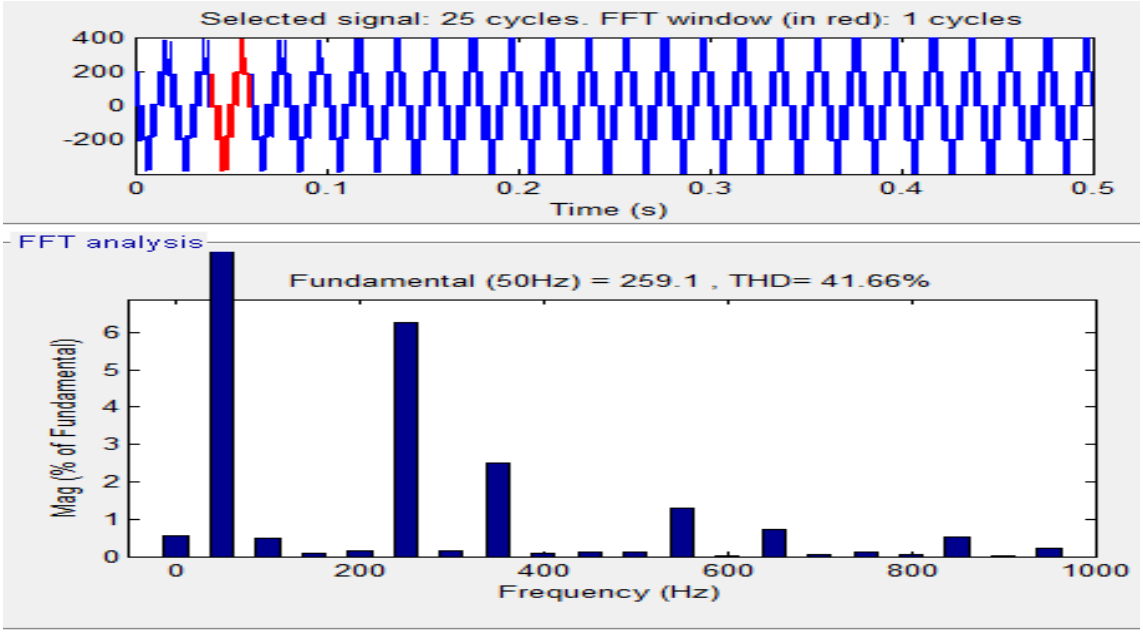



**Fig. (6) FFT analysis of line voltage and Total Harmonic Distortion for 3 level MLI without filter.**

From the Fig. (6) it is seen that the Total Harmonic Distortion of line voltage for 3 level MLI without filter is 41.66 % that is very high.

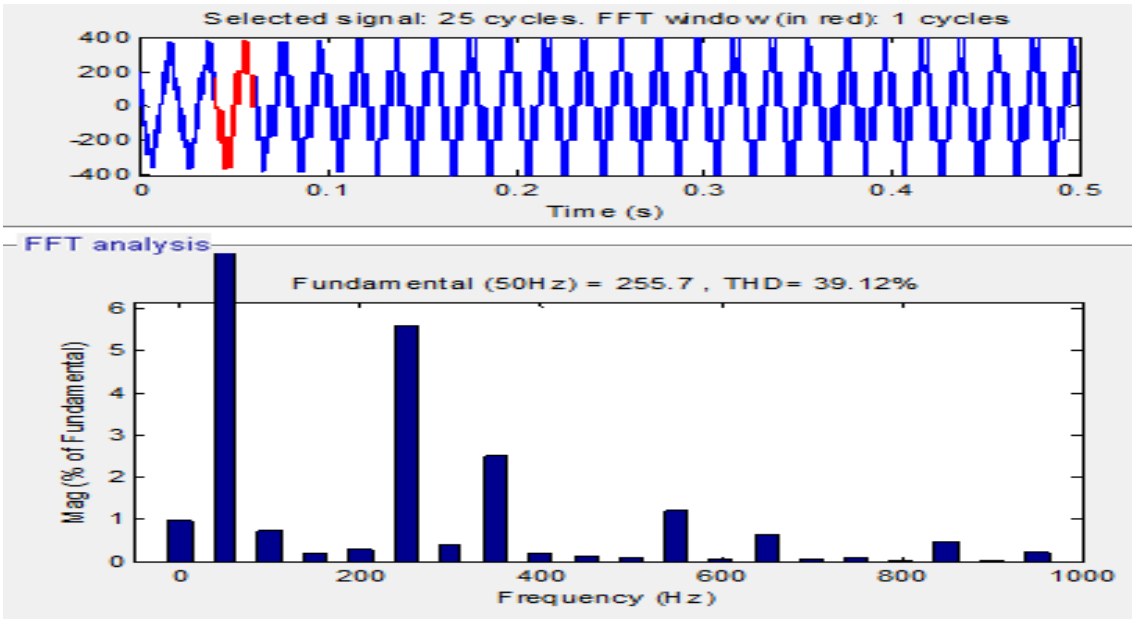



**Fig. (7) FFT analysis of line voltage and Total Harmonic Distortion for 5 level MLI without filter.**

From the Fig. (7) it is seen that the Total Harmonic Distortion of line voltage for 5 level MLI without filter is 39.12% that is very high but less than the Total Harmonic Distortion of line voltage for 3 level MLI without filter.

**Case 2-FFT analysis of line voltage & THD for 3 level MLI with Second Order LPF & different values of damping factor.**

When 3 level 3 legs MLI has been used to control drive with second order low pass filter & damping factor=0.707 that is for Under Damped, its THD is decrease as shown below.

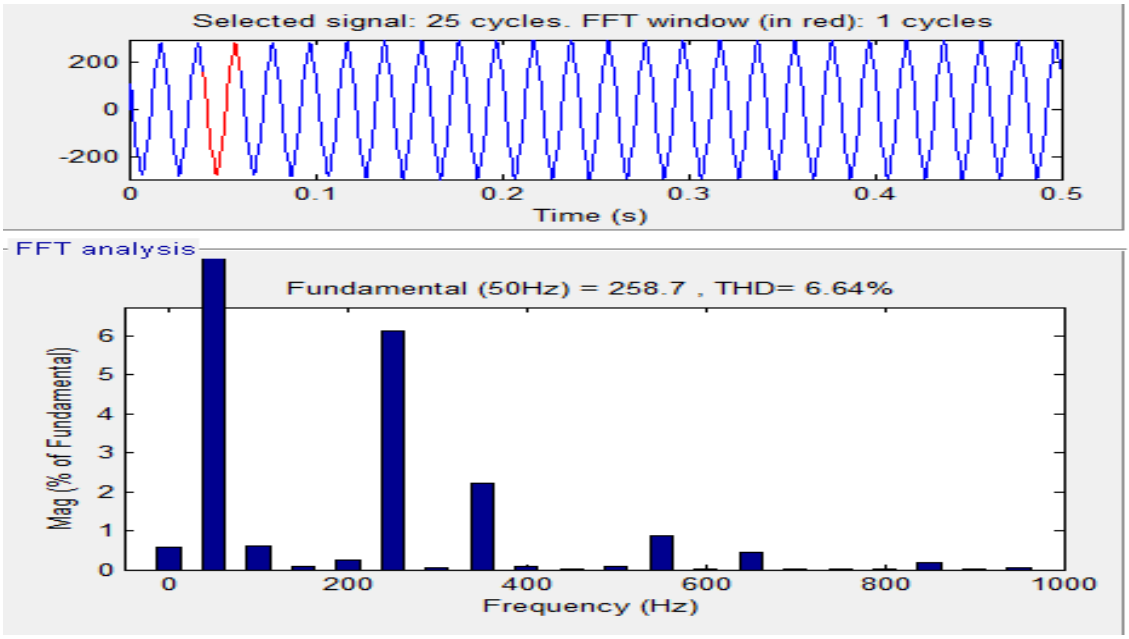



**Fig. (8) FFT analysis of line voltage and Total Harmonic Distortion for 3 level MLI with Second Order LPF & damping factor=0.707.**

From the Fig.(8) it is seen that the Total Harmonic Distortion of line voltage for 3 level MLI with second order low pass filter & damping factor=0.707 is 6.64 % that is less compare to THD without filter.

Increasing the value of damping factor from 0.707 to damping factor=0.85,gradually THD is decrease as shown below.

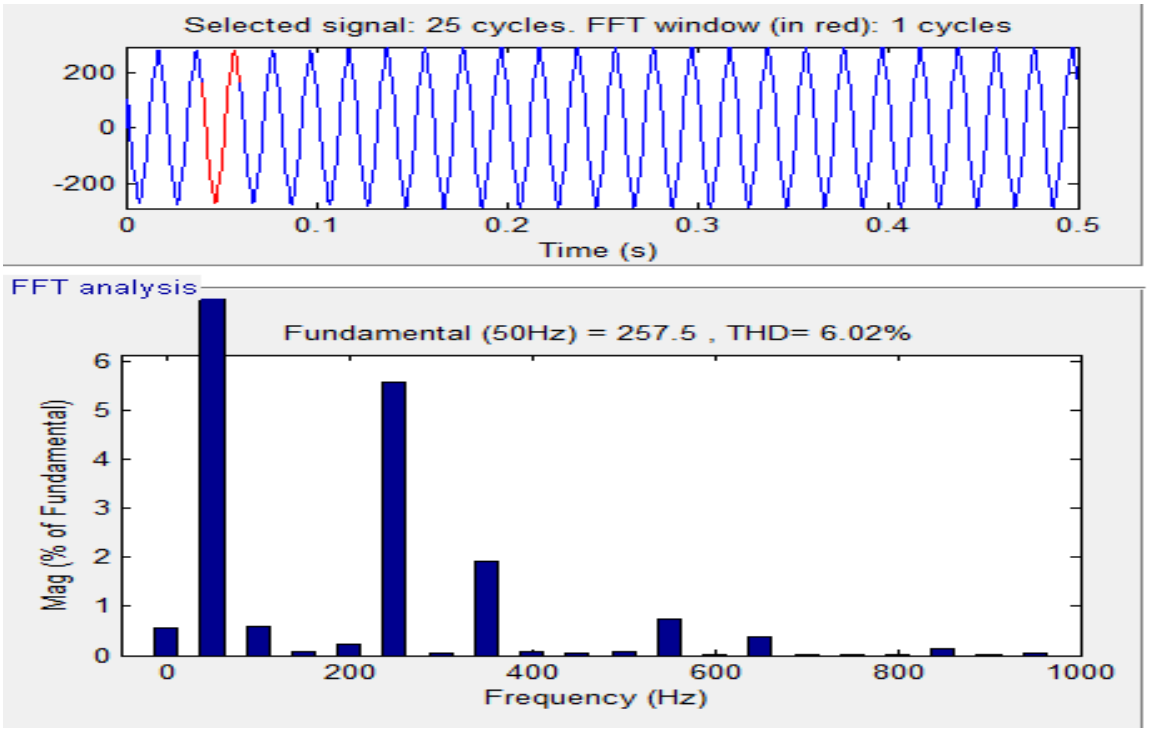



**Fig. (9) FFT analysis of line voltage and Total Harmonic Distortion for 3 level MLI with Second Order LPF & damping factor=0.85.**

From the Fig.(9) it is seen that the Total Harmonic Distortion of line voltage for 3 level MLI with second order low pass filter & damping factor=0.85 is 6.02 %.

Increasing the value of damping factor from 0.85 to damping factor=1 that is for Critical Damped, gradually THD is improved as shown below.

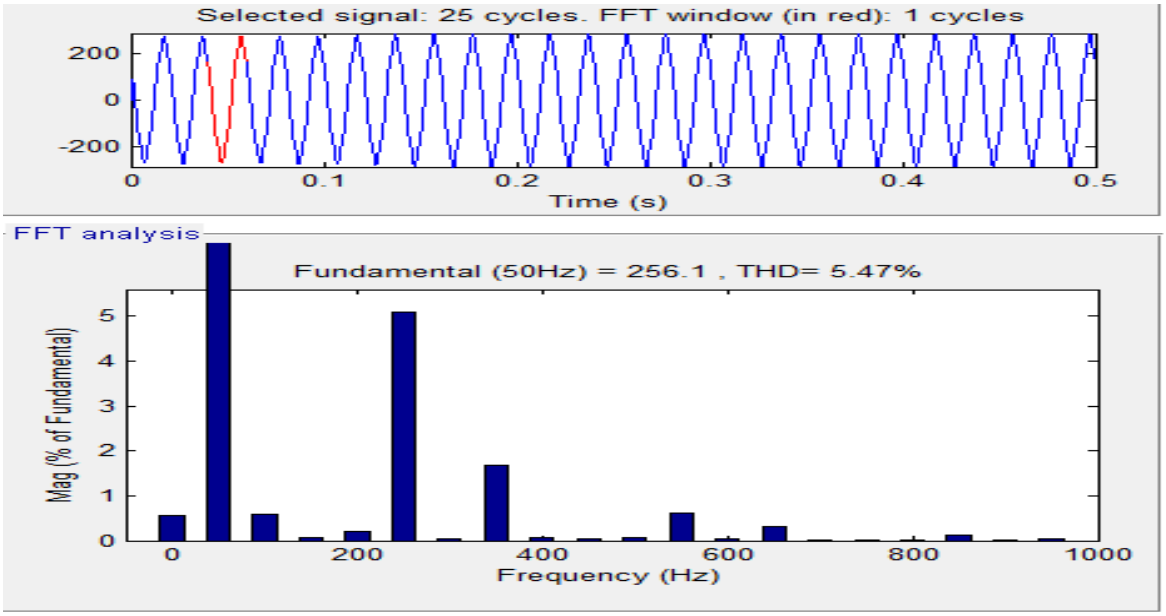



**Fig. (10) FFT analysis of line voltage and Total Harmonic Distortion for 3 level MLI with Second Order LPF & damping factor=1.**

From the Fig.(10) it is seen that the Total Harmonic Distortion of line voltage for 3 level MLI with second order low pass filter & damping factor=1 is 5.47 % .

Increasing the value of damping factor from 1 to damping factor=1.2 that is for Over Damped, gradually THD is decrease & improved the system performance as shown below.

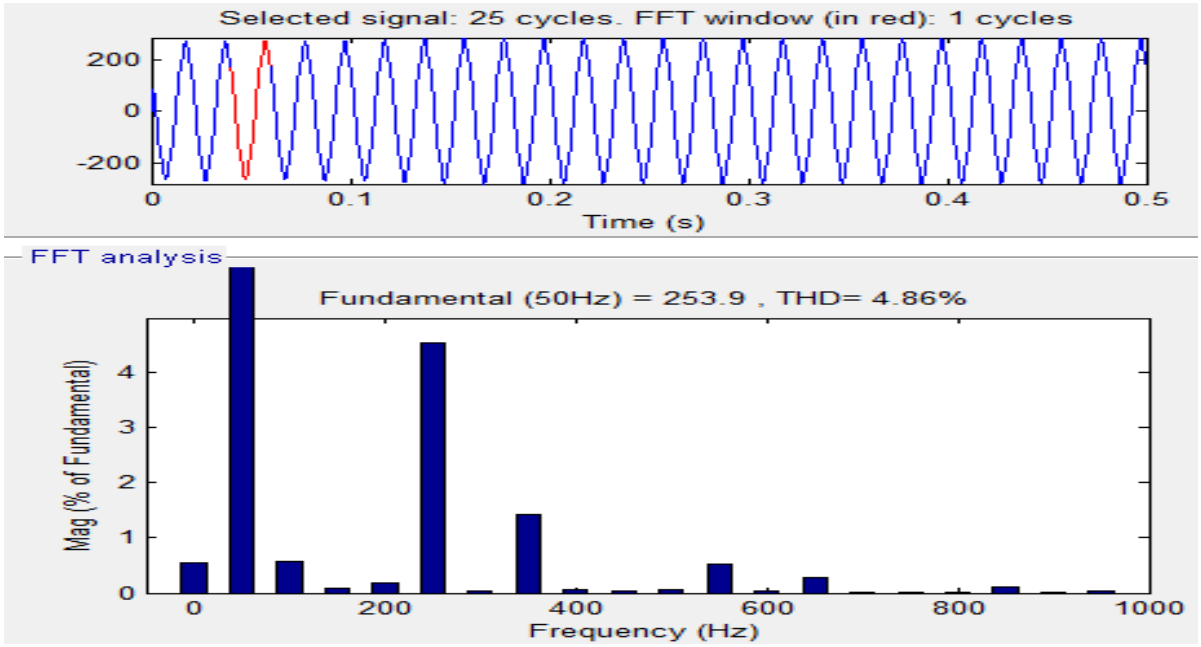



**Fig. (11) FFT analysis of line voltage and Total Harmonic Distortion for 3 level MLI with Second Order LPF & damping factor=1.2.**

From the Fig.(11) it is seen that the Total Harmonic Distortion of line voltage for 3 level MLI with second order low pass filter & damping factor=1.2 is 4.86 %.

**Case 3-FFT analysis of line voltage & THD for 5 level MLI with Second Order LPF & different values of damping factor.**

When 5 level 3 legs MLI has been used to control drive with second order low pass filter & damping factor=0.707,its THD is decrease as shown below.

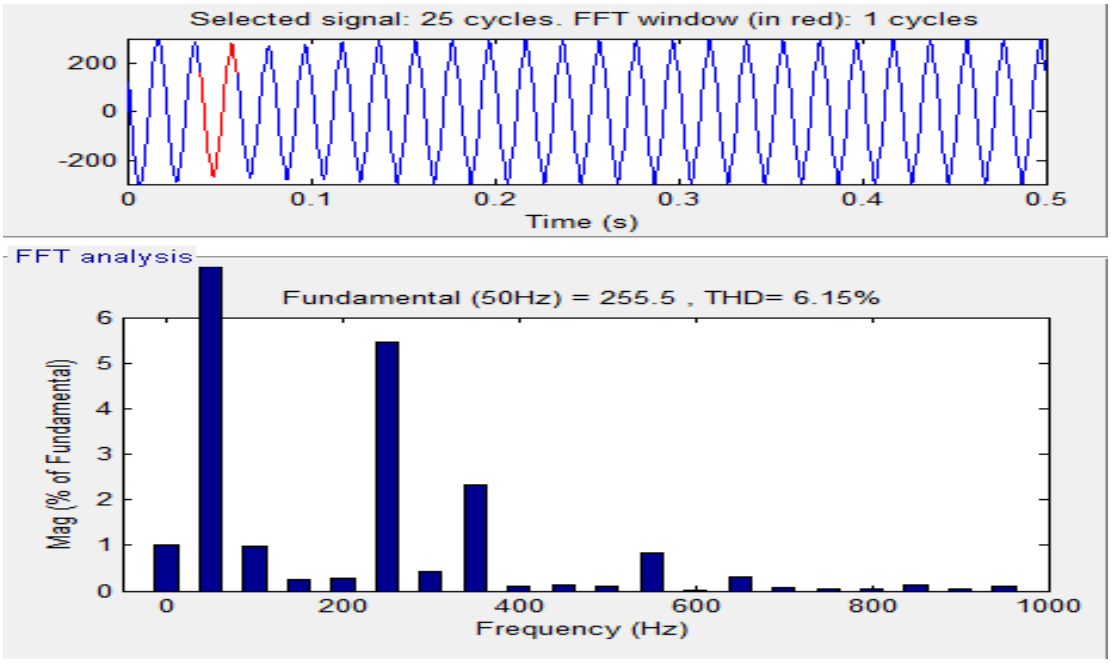



**Fig. (12) FFT analysis of line voltage and Total Harmonic Distortion for 5 Level MLI with Second Order LPF & damping factor=0.707.**

From the Fig.(12) it is seen that the Total Harmonic Distortion of line voltage for 5 level MLI with second order low pass filter & damping factor=0.707 is 6.15 % that is less compare to THD without filter.

Increasing the value of damping factor from 0.707 to damping factor=0.85 that is for Under damped, gradually THD is decrease & less than the THD for 3 level MLI for same condition as shown below.

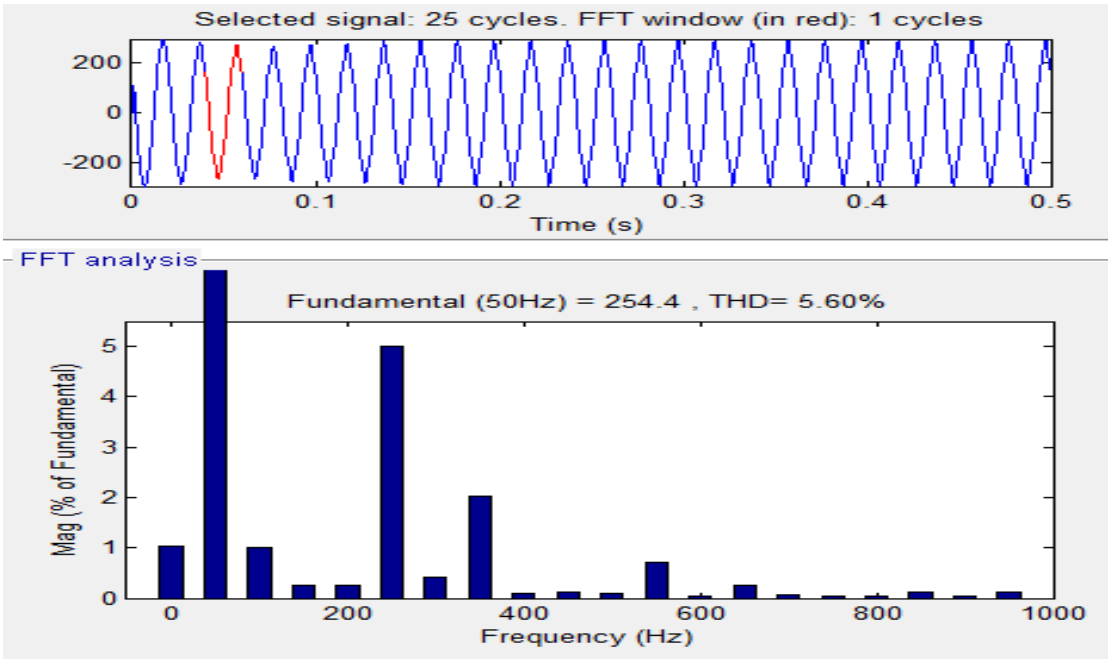



**Fig. (13) FFT analysis of line voltage and Total Harmonic Distortion for 5 level MLI with second order LPF & damping factor=0.85.**

From the Fig.(13) it is seen that the Total Harmonic Distortion of line voltage for 5 level MLI with second order low pass filter & damping factor=0.85 is 5.60 % .

Increasing the value of damping factor from 0.85 to damping factor=1 that is for Critical Damped, gradually THD is improved as shown below.

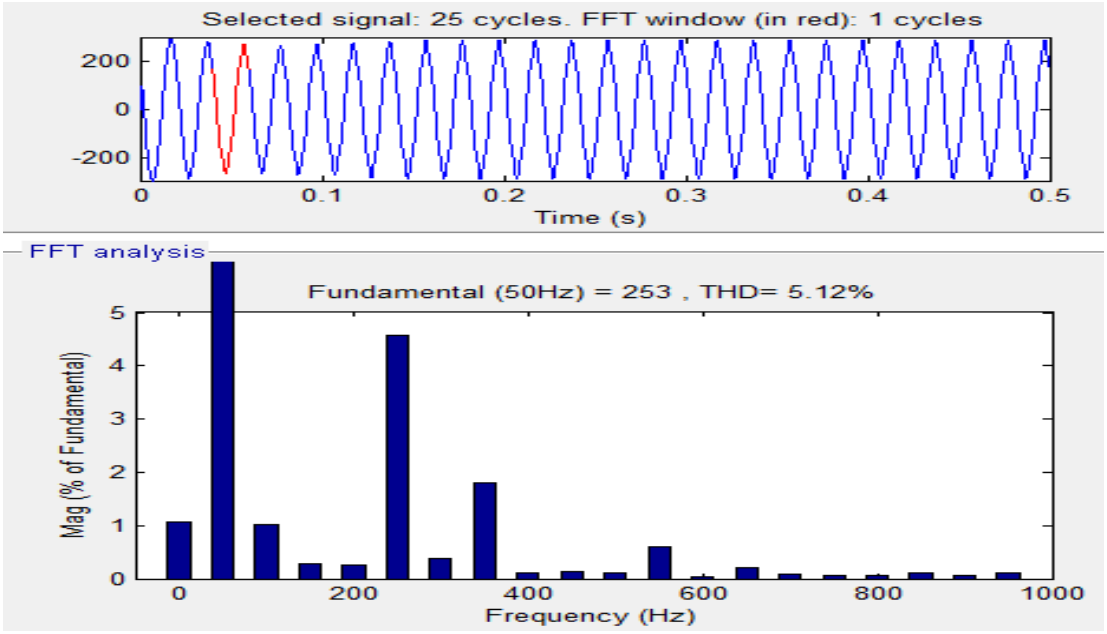



**Fig. (14) FFT analysis of line voltage and Total Harmonic Distortion for 5 level MLI with Second Order LPF & damping factor=1.**

From the Fig.(14) it is seen that the Total Harmonic Distortion of line voltage for 5 level MLI with second order low pass filter & damping factor=1 is 5.12 % .

Increasing the value of damping factor from 1 to damping factor=1.2 that is for Over Damped, gradually THD is decrease & efficiency is improved as shown below.

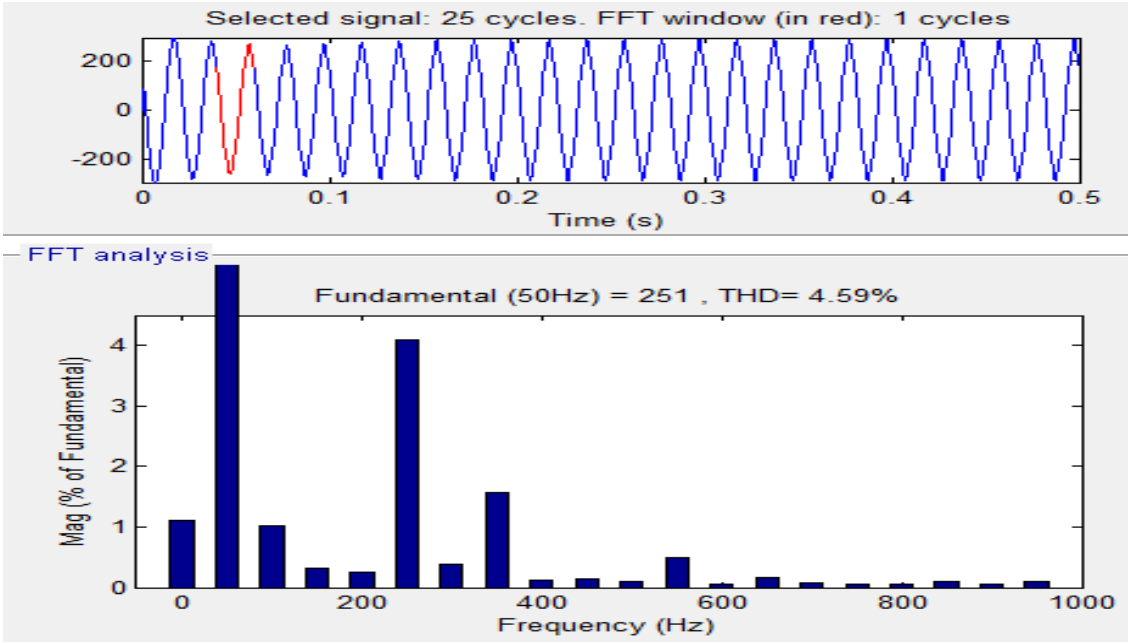



**Fig. (15) FFT analysis of line voltage and Total Harmonic Distortion for 5 level MLI with second order LPF & damping factor=1.2.**

From the Fig.(15) it is seen that the Total Harmonic Distortion of line voltage for 5 level MLI with second order low pass filter & damping factor=1.2 is 4.59 % .

**Case 4-FFT analysis of line voltage & THD with LC filter.**

When 3 level 3 legs MLI has been used to control drive with LC filter its THD is decrease but more than THD with second order LPF as shown below.

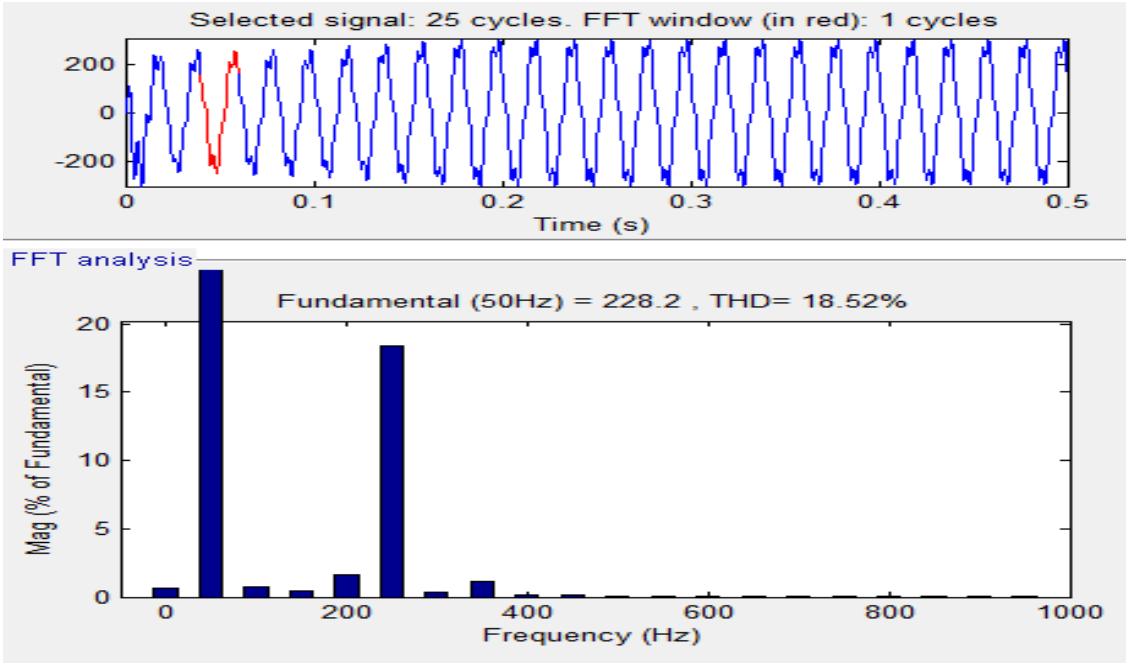



**Fig. (16) FFT analysis of line voltage and Total Harmonic Distortion for 3 level MLI with LC filter.**

From the Fig.(16) it is seen that the Total Harmonic Distortion of line voltage for 3 level MLI with LC filter is 18.62 % that is less compare to THD for 3 level MLI without filter.

When 5 level 3 legs MLI has been used to control drive with LC filter its THD is less than THD for 5 level MLI without filter but more than THD for 5 level MLI with second order LPF as shown below.

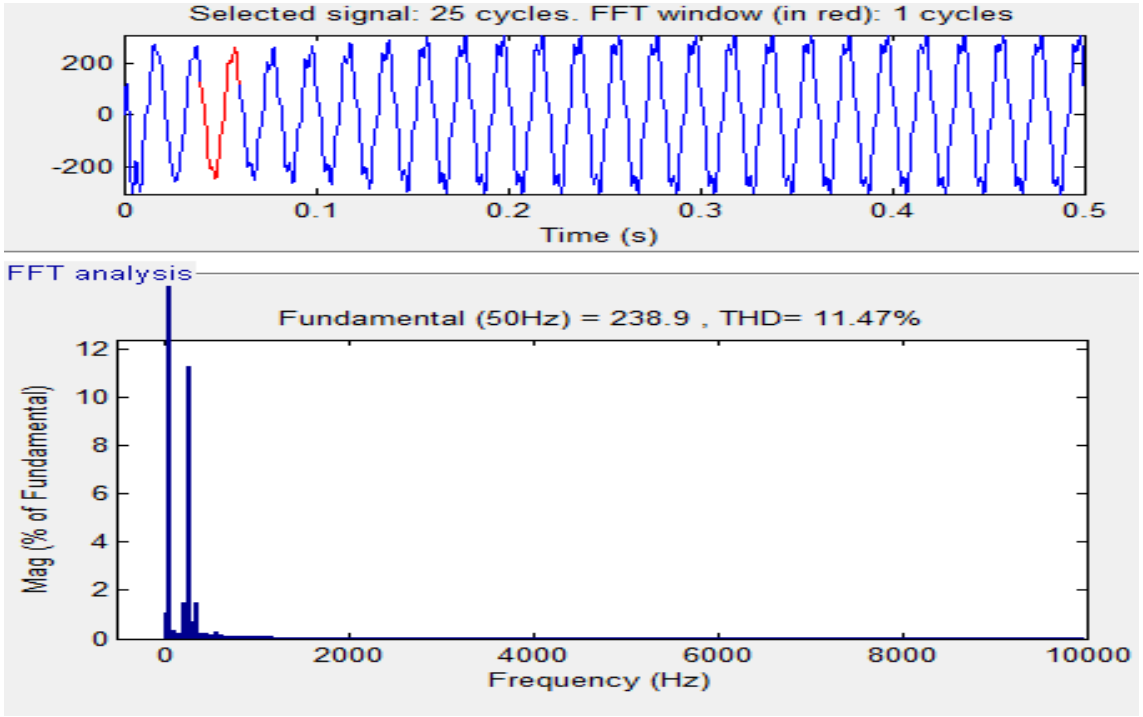



**Fig. (17) FFT analysis of line voltage and Total Harmonic Distortion for 5 level MLI with LC filter.**

From the Fig.(17) it is seen that the Total Harmonic Distortion of line voltage for 5 level MLI with LC filter is 11.47 % & that is less compare to THD for 3 level MLI with LC filter.

The Neutral Point Clamped Multilevel inverter scheme was simulated by the help of Matlab/simulink. Parameter used in this Model are as follow, f=50Hz,fs=4000Hz.Load is induction motor. Analysis of THD has done for line voltage using 3 level inverter & 5 level inverter.

**Table (4) Comparison Between THD Of Line Voltage**

| S.No. | THD without Filter in 3 level MLI. | THD without Filter in 5 level MLI. | THD for 3level MLI using LC filter. | THD for 5 level MLI using LC filter. | Damping factor (ζ). | THD for 3 level MLI using second order low pass filter. | THD for 5 level MLI using second order low pass filter. | Damping Condition. |
|---|---|---|---|---|---|---|---|---|
| 1 | 41.66% | 39.12% | 18.52% | 11.47% | ζ =0.1 | 10.56 % | 9.82 % | **Under damped, 0< ζ <1** |
| 2 | | | | | ζ =0.2 | 9.61 % | 8.92 % | |
| 3 | | | | | ζ =0.3 | 8.91 % | 8.24 % | |
| 4 | | | | | ζ =0.4 | 8.28 % | 7.65 % | |
| 5 | | | | | ζ =0.5 | 7.70 % | 7.11% | |
| 6 | | | | | ζ =0.6 | 7.16 % | 6.62 % | |
| 7 | | | | | ζ =0.707 | 6.64 % | 6.15 % | |
| 8 | | | | | ζ =0.85 | 6.02 % | 5.60 % | |
| 9 | | | | | ζ =0.9 | 5.83 % | 5.43 % | |
| 10 | | | | | ζ =1 | 5.47 % | 5.12 % | **Critical damped, ζ=1** |
| 11 | | | | | ζ =1.2 | 4.86 % | 4.59 % | **Over damped ζ>1** |

From the Table(4) it is seen that THD of line voltage for 5 level MLI using second order low pass filter is gives the better result.

## VIII. CONCLUSION

This paper analysis comparison between the 5-level MLI with 3 level MLI. Sinusoidal PWM control method is proposed for neutral point clamped MLI. It is seen from the simulation as the number of level increases, Total harmonic distortion is decreasing. The results shows that as level increases the efficiency of the system is also increases. The simulation results shows 5 level inverter is better than 3 level inverter for reducing THD & for increasing the efficiency. As the value of damping factor is increases THD is decreasing. Total harmonic distortion with second order low pass filter for 5 level inverter is less than Total harmonic distortion with LC filter & THD without filter for 3 level MLI.

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