

TOTAL HARMONIC DISTORTION INVESTIGATION ON MULTI LEVEL INVERTER SYSTEMS

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Abstract: The proposed work deals with simulation and implementation of a multi level inverter fed adjustable speed drive system to analyze Total Harmonic Distortion (THD) of the inverter system. 3 level, 5 level, 7 level and 9 level inverter fed induction motor drive systems are modeled, simulated and successfully implemented in the Power Electronics laboratory. Simulation as well as experimental results of current THD and voltage THD are presented. FFT spectrums for the outputs are analyzed to study the reduction in harmonics of the system.

Keywords: THD, Cascaded inverter, Induction motor, Multilevel inverter, Matlab Simulink.

1. GENERAL

Multilevel inverters have become attractive in the power industries and are important for power electronics applications. It can be applied for improvement of the power quality such as in renewable energy sources, flexible AC transmission systems, uninterruptible power supplies and active power filters. In many applications especially for a transformerless battery energy storage system based on a cascaded multilevel inverter, it is used as a measure for voltage and frequency deviations. It results in the system with reduced size, weight, and cost of energy storage system. The proposed cascaded multilevel inverter generates lower voltage total harmonic distortion (THD) in comparison with conventional cascaded multilevel inverter. Simulations are carried out using Matlab Simulink to validate the hardware results of the proposed multilevel inverter

Harmonics play significant role in deteriorating power quality, called harmonic distortion. Harmonic distortion in electric distribution system is increasingly growing due to the widespread use of nonlinear loads. Large considerations of these loads have the potential to raise harmonic voltage and currents in an electrical distribution system to unacceptable high levels that can adversely affect the system. One of the biggest problems in the power quality aspects is the harmonic content in the electrical systems. Any periodic waveform can be shown to be the superposition of a fundamental and a set of harmonic components. The frequency of each harmonic component is the integral multiple of its fundamental frequency. The term harmonic is normally applied to waveform components that have frequencies other than fundamental frequency. A waveform that contains any components other than the fundamental frequency is non-sinusoidal and considered to be distorted.

The most frequently encountered harmonics in three-phase distribution networks are the odd orders. Harmonic amplitudes normally decrease as the frequency increases. Above order 50, harmonics are negligible and measurements are no longer meaningful. Sufficiently accurate measurements are obtained by measuring harmonics up to order 30. Utilities monitor harmonic orders 3, 5, 7, 11 and 13. Generally speaking, harmonic conditioning of the lowest orders (up to 13) is sufficient. Harmonics in the electric power system combine with the fundamental frequency to create distortion. The level of distortion is directly related to the frequencies and amplitudes of the harmonic current. The contribution of all harmonic frequency currents to the fundamental current is known as "Total Harmonic Distortion" or THD. The harmonics present in the output waveform of the inverter increase motor heating, causes electromagnetic interference and results in torque pulsations

2. SIMULATION RESULTS OF THD

FFT spectrums for the stator currents of 3-level, 5-level, 7-level and 9-level inverter fed induction motor drive systems are shown in Figures 1, 2, 3 and 4 respectively. The simulation and experimental results of current THDs are summarized in table 1 and the graphical representation of current THDs against inverter levels is shown in Figure 5. FFT spectrums for stator voltage of 3, 5, 7 and 9 level inverter fed drive systems are shown in Figures 6, 7, 8 and 9 respectively. The simulation and experimental values of voltage THDs are summarized in Table 2 and the graphical representation of voltage THDs against inverter levels is shown in Figure 10. From the comparative study of THDs it is concluded that in multilevel inverters, as the number of level increases, the synthesized output waveforms produces more steps, which produces staircase waveforms and reduces the magnitude of total harmonic distortion. In all the drive systems voltage harmonics are relatively more than current harmonics. Voltage waveform is a multi stepped waveform. Therefore it has more harmonics. The current is smoothened by using load inductance. Therefore the current harmonics will be lesser.

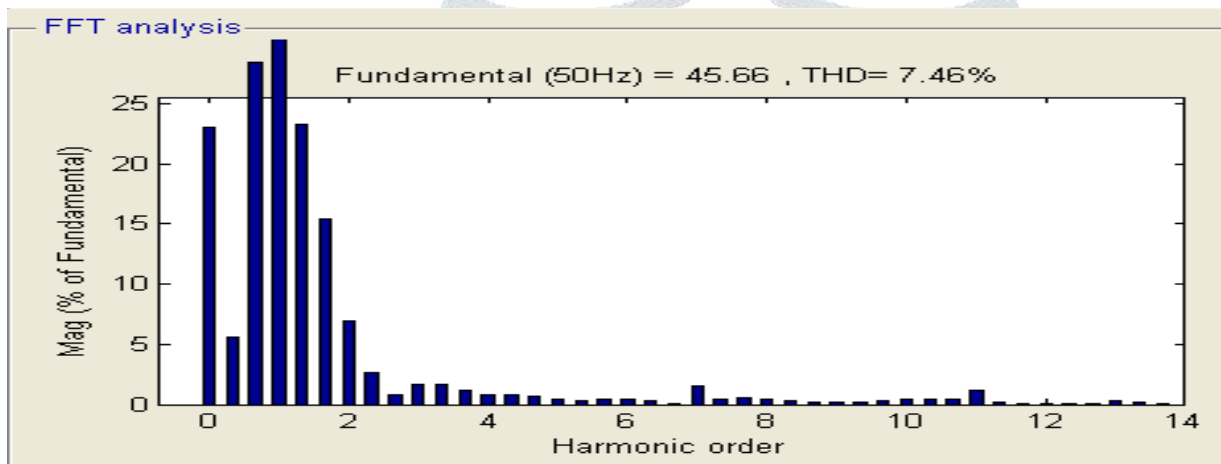


Figure 1. FFT Spectrum for stator current of 3-level inverter

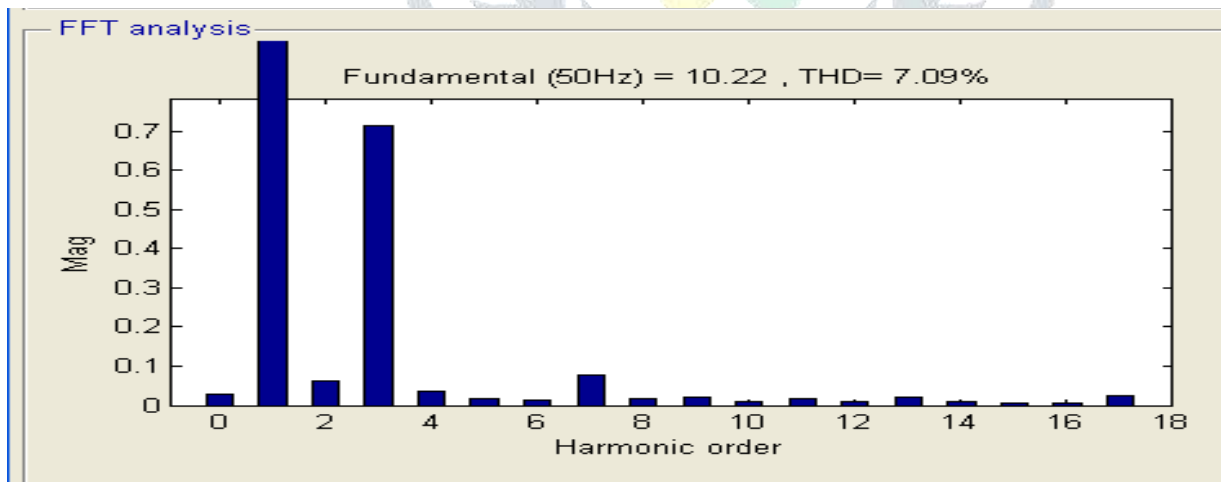


Figure 2. FFT Spectrum for stator current of 5-level inverter

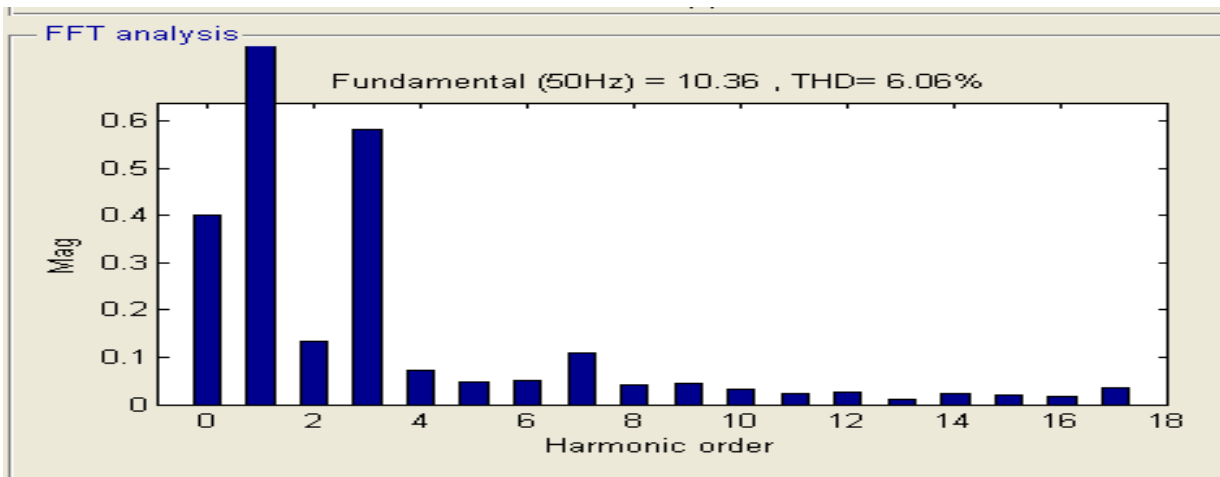


Figure 3. FFT Spectrum for stator current of 7-level inverter

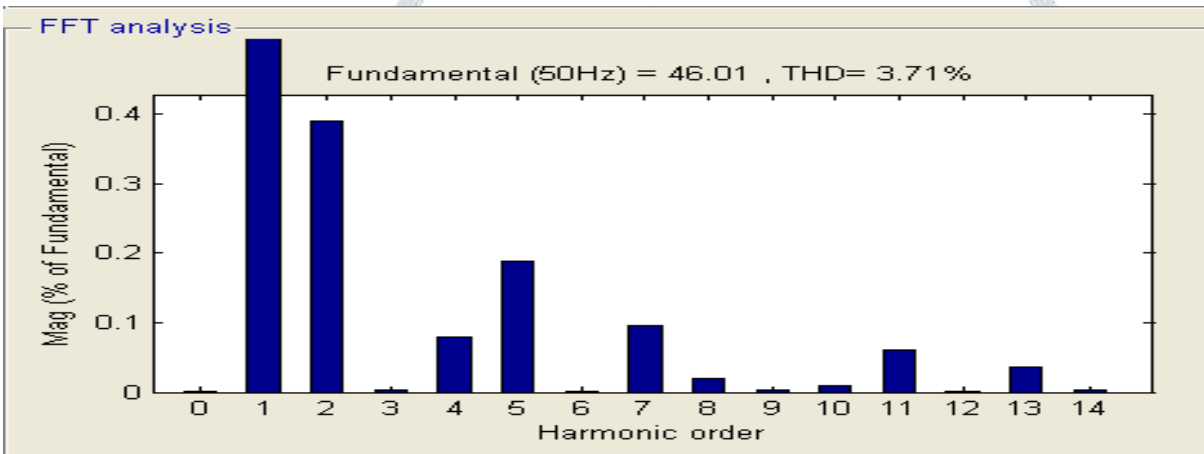


Figure 4. FFT Spectrum for stator current of 9-level inverter

Table 1. Simulation and experimental values of Current THD

Sl No	Inverter level	Simulation THD _i (%)	Experimental THD _i (%)
1	3 level	7.46	7.03
2	5 level	7.09	6.64
3	7 level	6.06	5.67
4	9 level	3.71	3.58

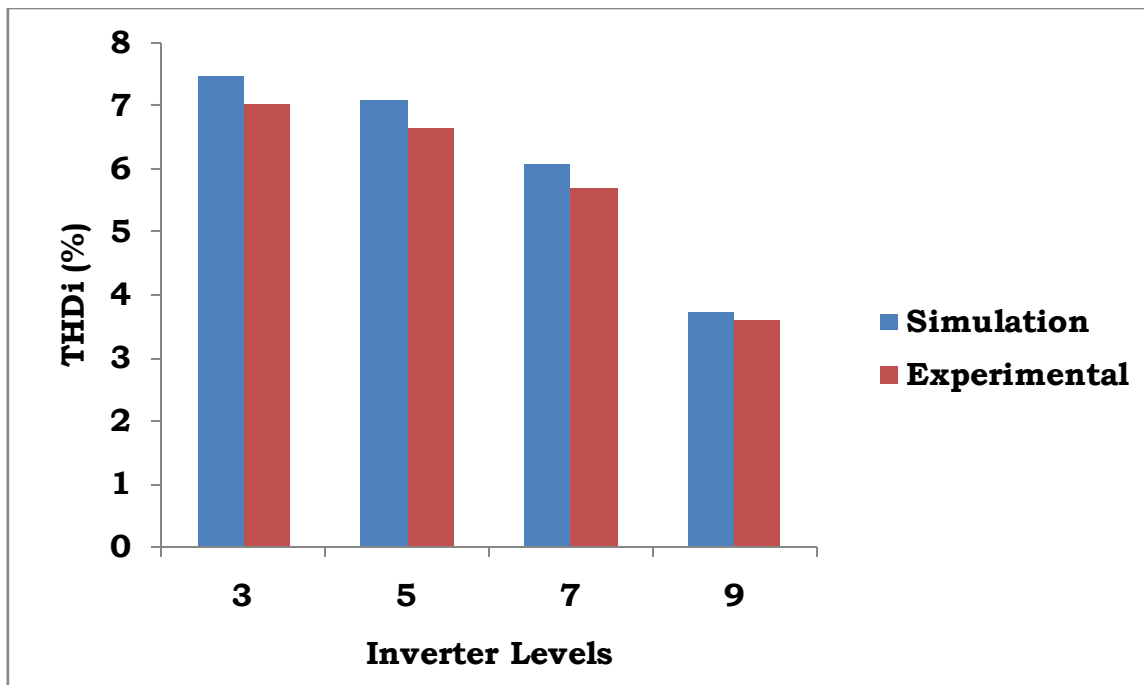


Figure 5. Simulation and experimental THDi Vs Inverter levels

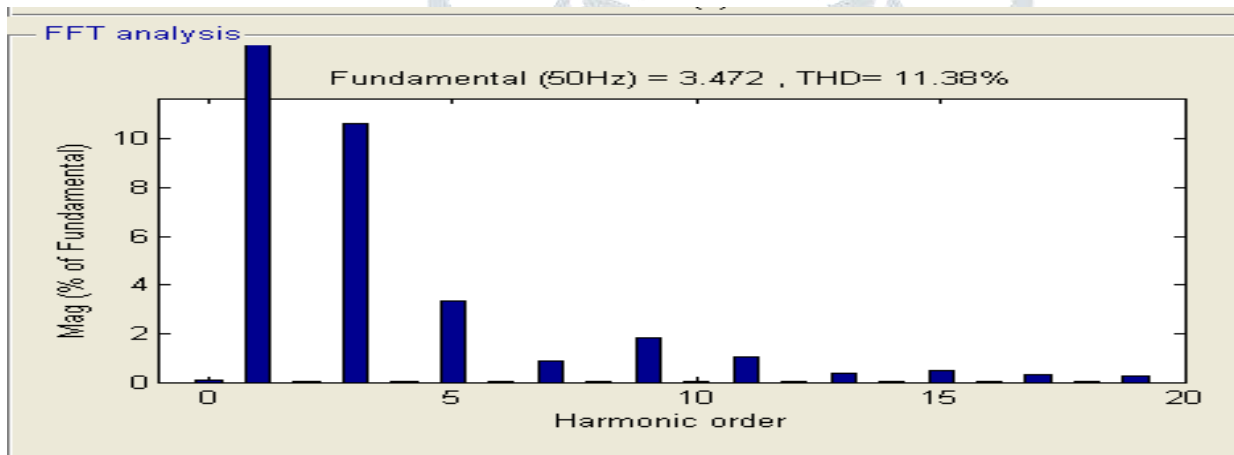


Figure 6. FFT Spectrum for stator voltage of 3-level inverter

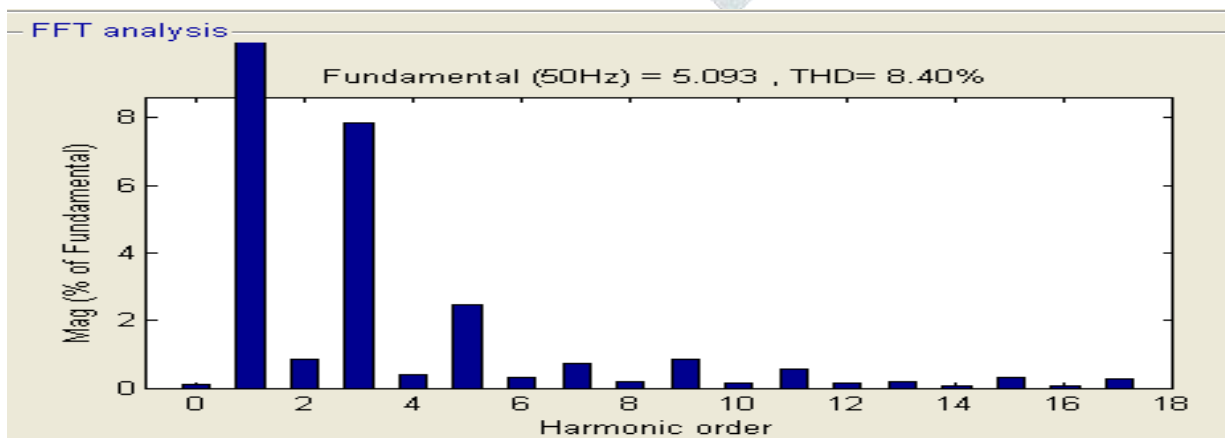


Figure 7. FFT Spectrum for stator voltage of 5-level inverter

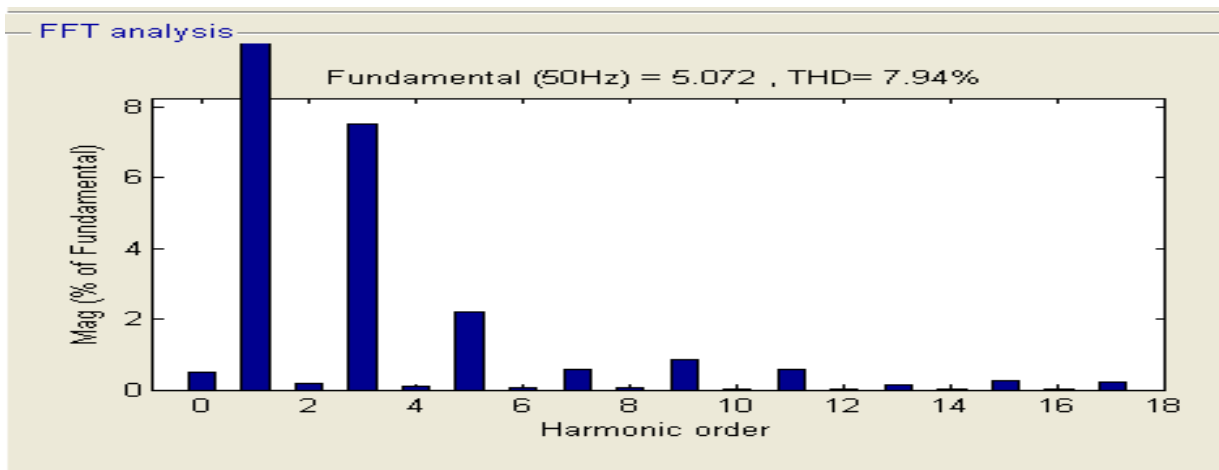


Figure 8. FFT Spectrum for stator voltage of 7-level inverter

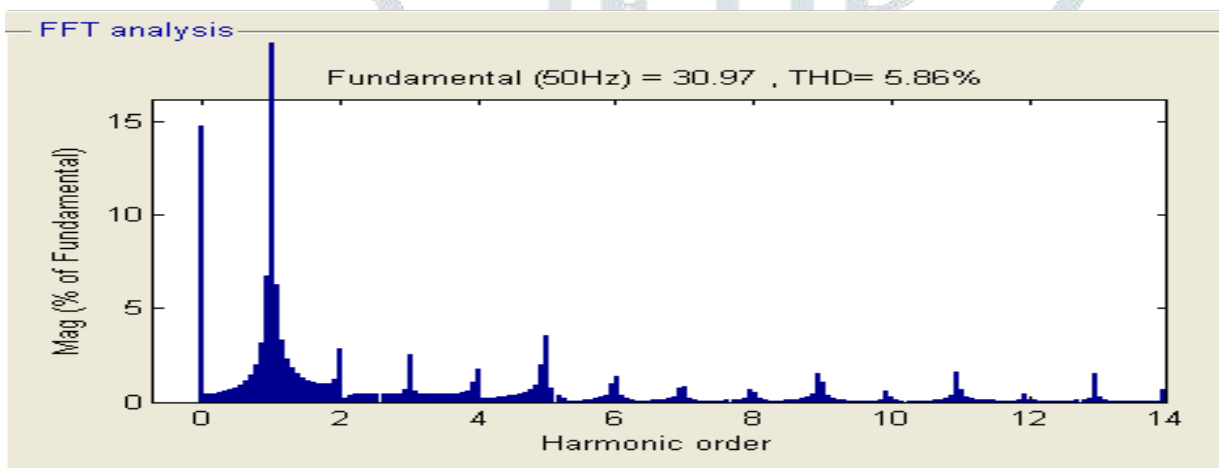


Figure 9. FFT Spectrum for stator voltage of 9-level inverter

Table 2. Simulation and experimental values of voltage THD

Sl No	Inverter level	Simulation THDv (%)	Experimental THDv (%)
1	3 level	11.38	10.77
2	5 level	8.40	7.81
3	7 level	7.94	7.12
4	9 level	5.86	4.91

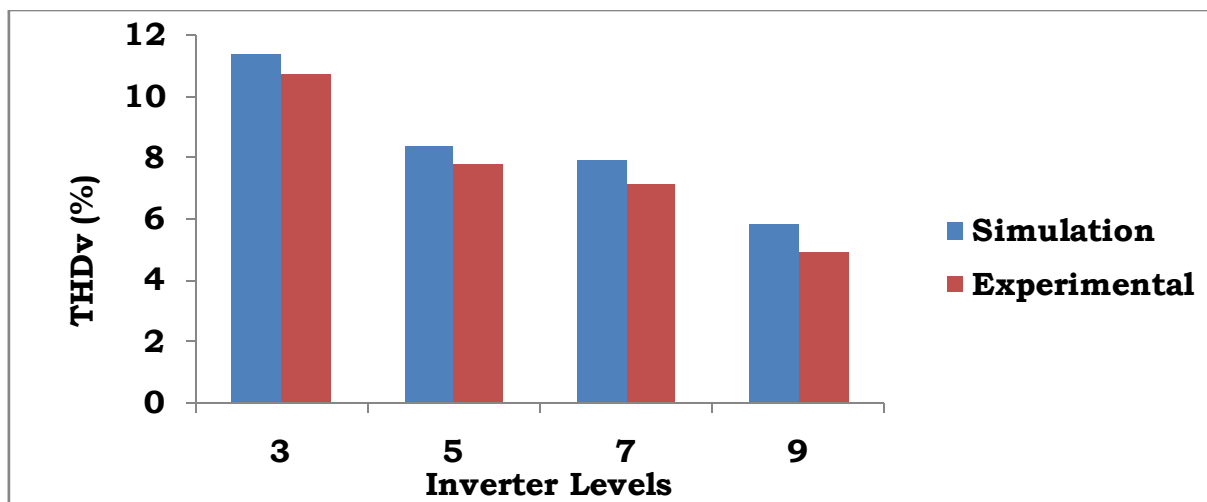


Figure 10. Simulation and experimental THDv Vs Inverter levels

3. CONCLUSION

In this paper simulation and implementation of a multi level inverter fed adjustable speed drive systems are studied to analyze the Total Harmonic Distortion (THD) of the inverter system. 3 level, 5 level, 7 level and 9 level inverter fed induction motor drive systems are modeled, simulated and successfully implemented. Simulation as well as experimental results of current THD and voltage THD are presented. FFT spectrums for the outputs are analyzed to study the reduction in harmonics of the system.

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