Power System Protection and Control
ISSN:1674-3415

EXPERIMENTAL FFT ANALYSIS OF VOLTAGES IN VARIABLE SPEED THREE-PHASE INDUCTION MOTOR DRIVE

Reddy Sudharshana K[1], Chandra Shekar S M[2], Prakash S Ari[3], A Ramachandran[4]

[1]Dept. of ECE, Vemana Institute of Technology, VTU, Bengaluru, India. reddy3690@gmail.com, https://orchid.org/ 0000-0001-8963-359X
[2]Dept. of ECE, Vemana Institute of Technology, VTU, Bengaluru, India, smcvit16@gmail.com, https://orchid.org/0009 0005 7619 0538:
[3]Dept. of ECE, Vemana Institute of Technology, VTU, Bengaluru, India, prakashsari2012sr@gmail.com, https://orcid.org/0009-0008-8593-8116
[4]Dept. of ECE, Vemana Institute of Technology, VTU, Bengaluru, India, arama1947@gmail.com, https://orcid.org/0009-0006-8434-0
*__Corresponding Author__: 1reddy3690@gmail.com

Received: 22/02/2026 **Revised**: 22/03/2026 **Accepted**: 27/04/2026

ABSTRACT:

Induction motor drives are widely used in variable speed applications due to their rugged and inherent benefits. Solid state components are used for industrial speed control of Induction motors uses sine modulation techniques. The advances in semiconductor technology and microcontrollers made the control easier for variable frequency applications. The control system involves generation of sine waves at various frequencies by changing input to the microcontroller. Since the carrier frequency is used in the control system the output voltage also contains in addition to fundamental and carrier frequency components due to inverter switching devices operating at fast switching frequencies. Hence, it is necessary to do the Fast Fourier analysis of voltages to identify the amplitude of various frequency components that exist in the phase and line voltages. The reason being other than the fundamental some of the higher order harmonic voltages result in opposite torque. The drive system has been run at frequencies of 30, 40, 50, 60 and 62.5Hz respectively, captured the phase and line voltages of the motor terminal output in bitmap and csv mode with mixed signal oscilloscope. By using the csv, the Fast Fourier Transform analysis done by Origin signal analysis software, which gives the results in frequency domain and has been validated from the mixed signal oscilloscope math function Fast Fourier Transform results.

Keywords*: Comma Separated Values, Fast Fourier Transform, Induction Motor, Pulse width modulation, Variable Frequency Drive.*

INTRODUCTION

The three phase Induction motor runs at 30, 40, 50, 60, and 62.5Hz at 370V DC voltage to the inverter. The above frequencies of operation the waveforms of phase voltage, line voltage and voltage across the snubber inductor are stored in the MSO as BMP and CSV format. The FFT analysis is done using Origin software for the phase and line voltage. Using math function at the MSO FFT done and compared with the Origin software. The detailed description is given in the following subdivision.

METHODOLOGY

The block diagram of the drive system for running the three-phase induction motor is shown Fig.1. The IM drives operate with V-F control system, a reference input is processed by converter to maintain voltage to frequency ratio with a constant airgap flux [1],[2]. The signal is buffered using the transistor for level shift the voltage. The level shifted voltage given to an 8-bit binary counter to get 8-bit address. The 8-bit microcontroller (unit sine curve is stored in the 1st 256 locations), is addressed (A0-A7) by the binary counter and the output is in digital form taken from appropriate terminals and fed to the 8-bit DAC. The DAC output is converted to analog form using OP-AMP. Further it is processed as per the block diagram shown in Fig.1 uses a variable drive system [3],[4], with inverter block. By increasing or decreasing the input voltage to the V-F converter the motor can be run at various frequencies and the terminal voltage at the motor terminals are stored [5],[7]. FFT analysis using math function at the MSO done and compared the results with FFT analysis by using Origin software and the

Power System Protection and Control
ISSN:1674-3415

detailed description is given in the following subdivision. The three phase induction motor runs at various frequencies of operation like 30, 40, 50, 60 and 62.5Hz. The terminal voltages of phase, line and voltage across Snubber inductor were stored in BMP and CSV format. The FFT is also done using math function for the phase voltage at the MSO and the value of the dBv is read and converted to voltage for comparing with Origin software results.

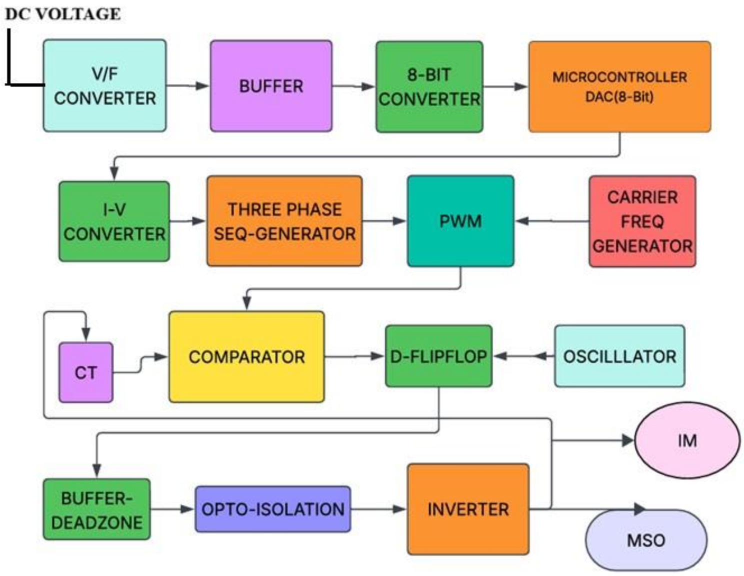

Fig.1 Induction motor variable-speed drive system block diagram.

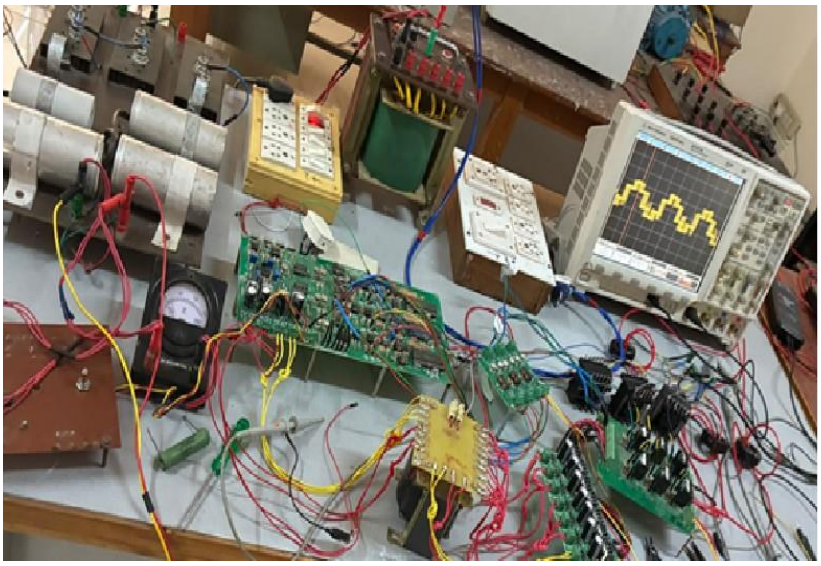

Fig. 2. Experimental Test Setup.

A. 30HZ OPERATION.

The experimental test setup shown in Fig. 2 operating the IM with a DC supply voltage of 370V is applied to the Inverter bridge, and the IM terminal voltages are stored in the BMP format, as shown in Fig. 2.1(a). Subsequently, in CSV format the phase, line voltages are logged. Using the Origin signal analysis software, FFT was performed (MSO 20ms/div). The following Fig.2.1(b) shows the FFT results in the frequency domain. From Fig. 2.1(b) shows the Fundamental frequency of 30Hz with an amplitude of 102V and subsequent higher order harmonics [6] are shown in TABLE-1.

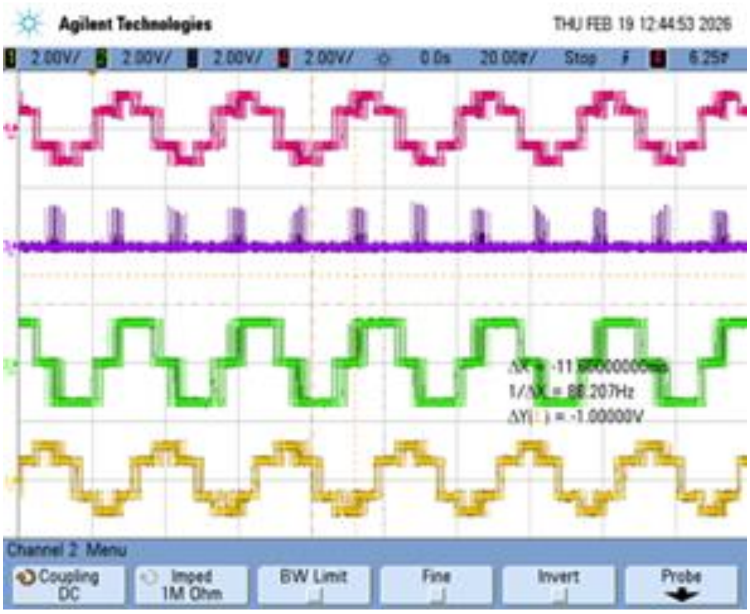

Fig. 2.1(a). Ch1: Phase voltage, 200:1, Ch2: line voltage, 250:1, Ch3: across inductor voltage, 25:1, Ch4: Phase voltage, 200:1.

where the Origin results and MSO results in volts are shown in detail for the phase voltages. Fig. 2.1(c) shows the Fundamental frequency of the line voltage at 30Hz with an amplitude of 176V and subsequent higher order harmonics are shown in Table-II, where the Origin and MSO results in Volts are shown in detail for the line voltages.

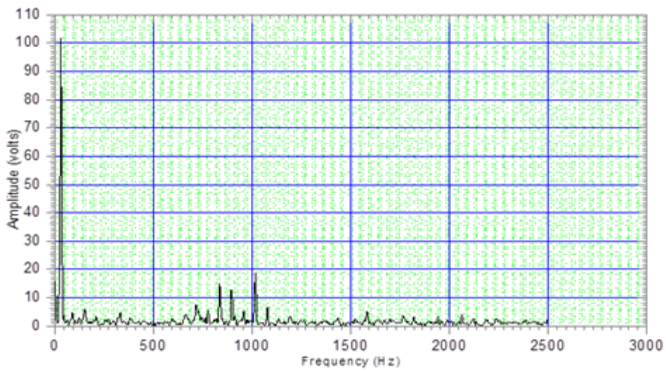

Fig. 2.1(b) FFT of phase voltage, 20msec/div.

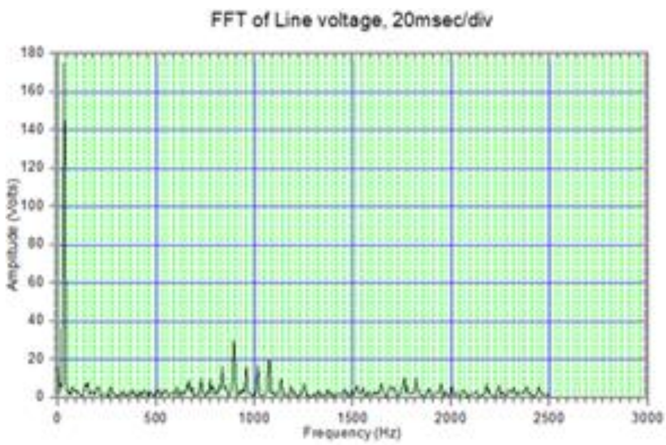

Fig. 2.1(c) FFT of Line voltage, 20msec/div.

DOI: 10.46121/pspc.54.3.02

Power System Protection and Control
ISSN:1674-3415

B. 40HZ OPERATION

By running the IM at 40Hz with a DC supply voltage of 370V given to the inverter bridge and storing the IM terminal voltages as shown in Fig.2.2(a) in the BMP format. Subsequently, in CSV format phase, line voltages are logged. Using the Origin software, the FFT was performed (MSO 20ms/div.).

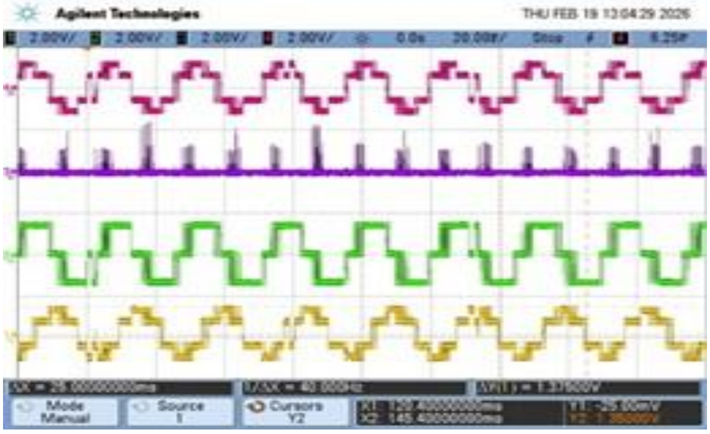

Fig. 2.2(a) Ch1: Phase voltage, 200:1, Ch2: line voltage, 250:1, Ch3: across inductor voltage, 25:1, Ch4: Phase voltage, 200:1.

Fig. 2.2(b) shows the phase voltage Fundamental frequency at 40Hz with an amplitude of 100V, and subsequent higher order harmonic are shown in Table-I, where the Origin and MSO results in Volts are shown in detail for the phase voltages.

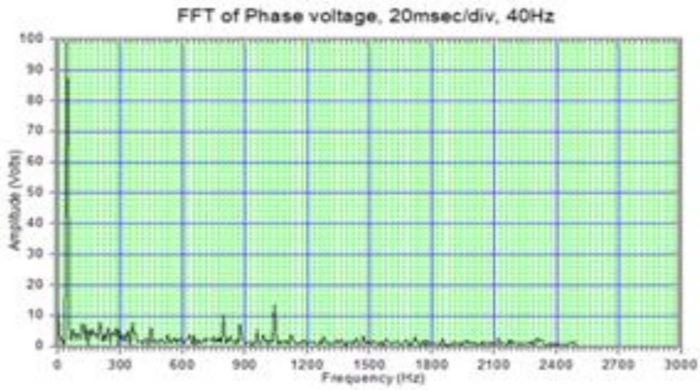

Fig. 2.2(b) FFT of Phase voltage, 20msec/div.

Fig. 2.2(c) shows the line voltage Fundamental frequency at 40Hz with an amplitude of 178V, and subsequent higher order harmonics are shown in Table-II, where the Origin and MSO results in Volts are shown in detail for the line voltages.

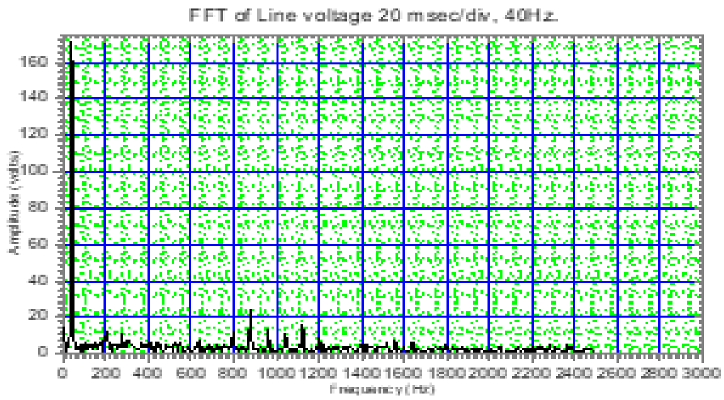

Fig. 2.2(c) FFT of line voltage, 20msec/div.

DOI: 10.46121/pspc.54.3.02

C. 50HZ OPERATION

By running the IM at 50Hz with a DC supply voltage of 370V given to the inverter bridge and storing the IM terminal voltages as shown in Fig. 2.3(a) in the BMP format. Subsequently, in CSV format the phase, line voltages are logged. Using the Origin software, the FFT was performed.

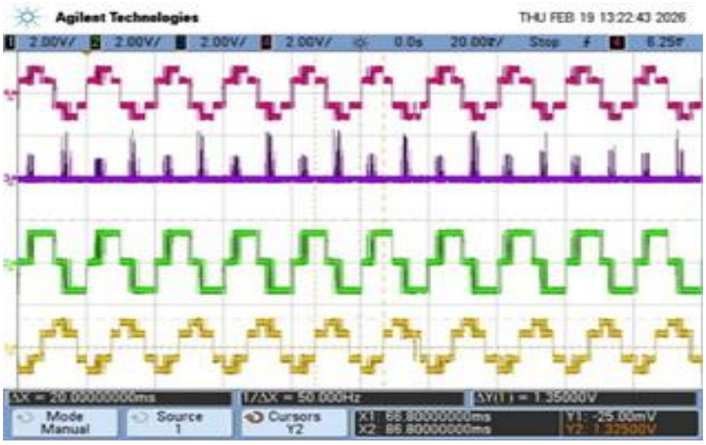

Fig. 2.3(a) Ch1: Phase voltage, 200:1, Ch2: line voltage, 250:1, Ch3: across inductor voltage, 25:1, Ch4: Phase voltage, 200:1.

Fig. 2.3(b) shows the FFT of phase voltage Fundamental frequency of 50Hz with an amplitude of 105V, and the subsequent higher order harmonics are shown in Table-I, where the Origin and MSO results in Volts are shown in detail for the phase voltages.

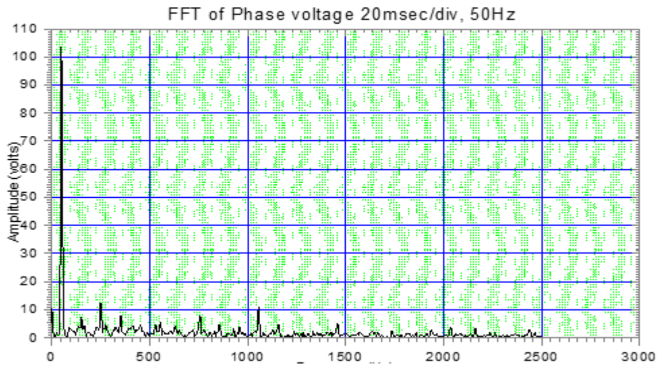

Fig. 2.3(b) FFT of Phase voltage, 20ms/div.

Fig. 2.3(c) shows the FFT of line voltage Fundamental frequency at 50Hz with an amplitude of 175V, and subsequent higher order harmonic are shown in Table-II, where the Origin and MSO results in Volts are shown in detail for the line voltages.

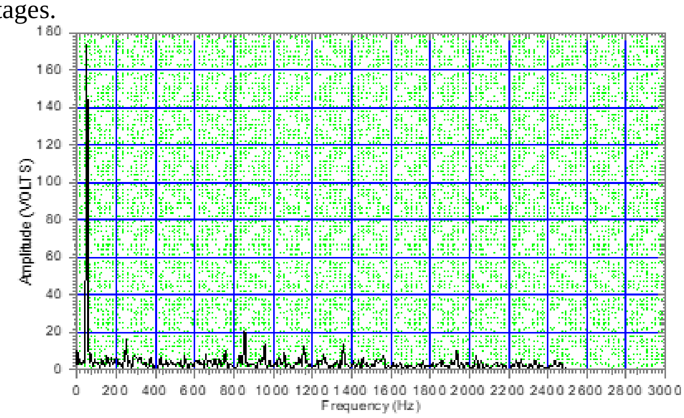

Fig. 2.3(c) FFT of line voltage, 20msec/div.

DOI: 10.46121/pspc.54.3.02

ISSN:1674-3415

D. 60HZ OPERATION

By running the IM at 60Hz with a DC supply voltage of 370V given to the inverter bridge and storing the IM terminal voltages as shown in Fig. 2.4(a) in the BMP format. Subsequently, in CSV format the phase, line voltages are logged. Using the origin tool, the FFT was performed.

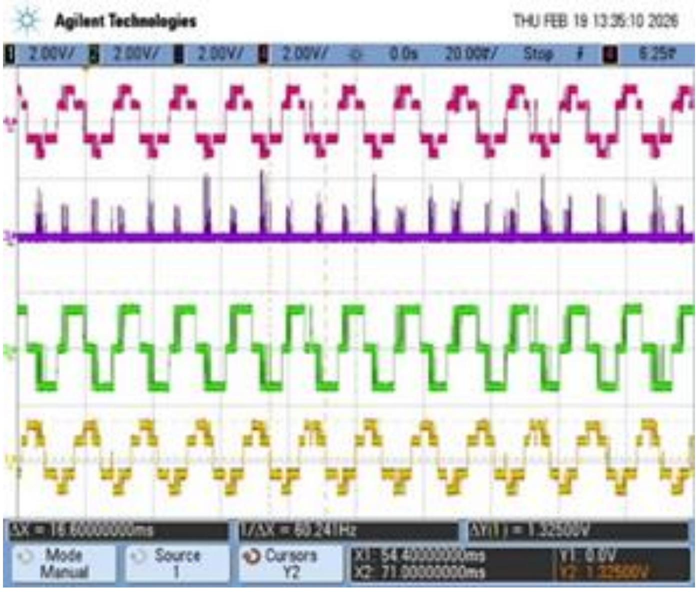

Fig.2.4(a) Ch1: Phase voltage, 200:1, Ch2: line voltage, 250:1, Ch3: across inductor voltage, 25:1, Ch4: Phase voltage, 200:1.

Fig. 2.4(b) shows the FFT of phase voltage with Fundamental frequency of 60Hz with an amplitude of 100V, and the subsequent higher order harmonic are shown in Table-I, where the Origin and MSO results in Volts are shown in detail for the phase voltages.

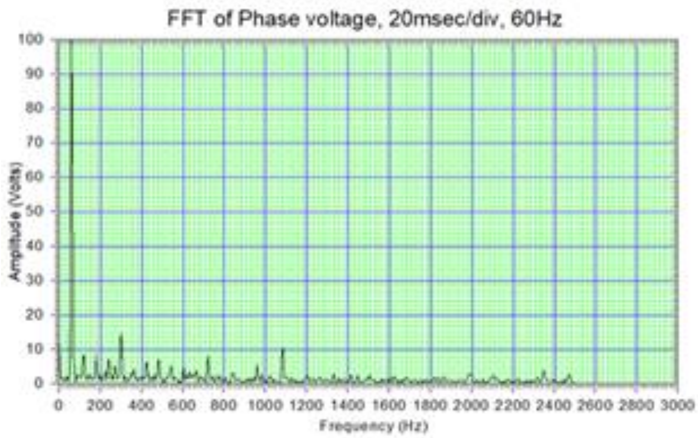

Fig. 2.4(b) FFT of Phase voltage, 20ms/div.

Fig. 2.4(c) shows the FFT of Line voltage with Fundamental frequency at 60Hz with an amplitude of 163V, subsequent higher order harmonics are shown in Table-II, where the Origin results and MSO results in Volts are shown in detail for the line voltages.

DOI: 10.46121/pspc.54.3.02

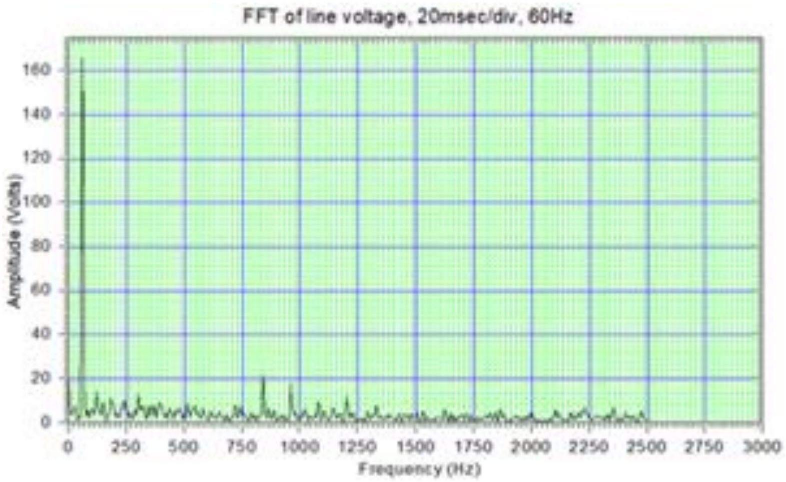

Fig. 2.4(c) FFT of line voltage, 20msec/div.

E. 62.5HZ OPERATION

By running the IM at 62.5Hz with a DC supply voltage of 370V given to the inverter bridge and storing the IM terminal voltages as shown in Fig. 2.5(a) in the BMP format. Subsequently, in CSV format the phase, line voltages are logged. Using the origin softwarel, the FFT was performed (MSO 20ms/div).

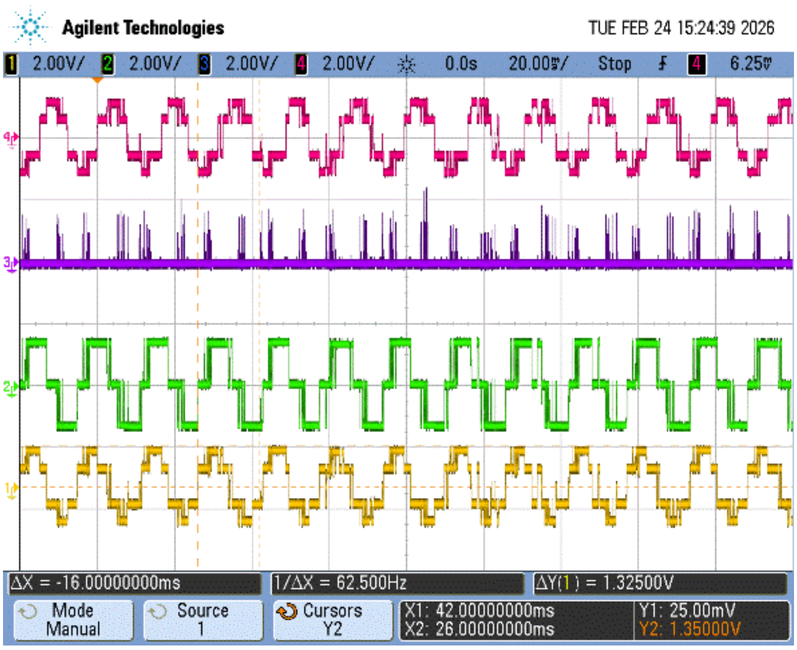

Fig. 2.5(a) Ch1: Phase voltage, 200:1, Ch2: line voltage, 250:1, Ch3: across inductor voltage, 25:1, Ch4: Phase voltage, 200:1.

Fig 2.5(b) shows the Phase voltage FFT, with the fundamental frequency of 62.5Hz with an amplitude of 104V and carrier frequency voltage of 12V.

DOI: 10.46121/pspc.54.3.02

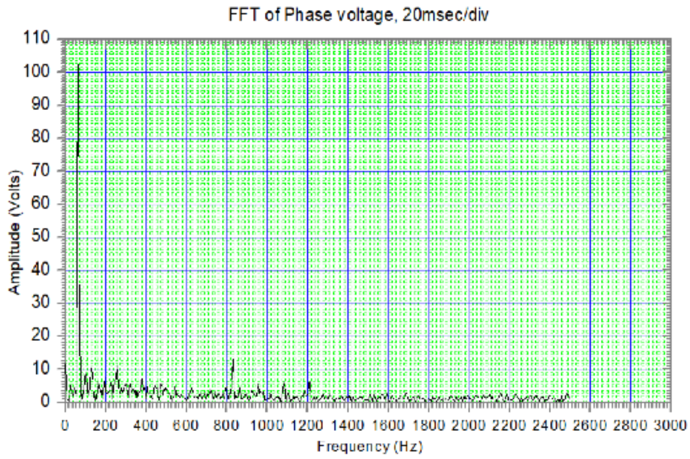

Fig. 2.5(b) FFT of Phase voltage, 20ms/div.

Fig. 2.5(c) shows the line voltage of Fundamental frequency at 62.5Hz with an amplitude of 175V and the higher harmonic frequencies of 850Hz and 1200Hz amplitude of 24V and 10V respectively.

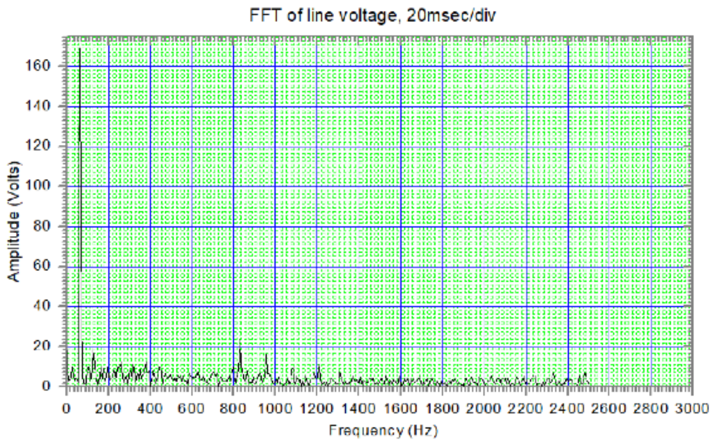

Fig. 2.5(c) FFT of line voltage, 20msec/div.

The carrier frequency amplitude of 18V. It is observed that the harmonic frequencies other than 1KHz are due to high voltage switching transients of power MOSFETs, whereas ~1KHz is due to the carrier frequency.

RESULTS

It is noted that by referring to headings 2.1 – 2.5 regarding the FFT results, other than the fundamental, that is higher order harmonics may give opposing / aiding torques to the motor [8]. Hence higher order harmonic voltage should be minimized for the drive system to operate favorably [9],[10]. The above FFT graphs will help to identify various harmonic-frequency voltage components at the inverter terminals. The MSO math function FFT results are given in dBv and this has been converted as voltage using the formulae.

V = 10dBV/20

Using the above formulae the voltage has been calculated for the 30-50Hz frequency of operation of the motor and validated with the Origin software voltages at the fundamental and higher order harmonic frequencies Which is shown in Table-I for phase voltages. Similarly, Table-II shows the line voltages. By observing Table-I and II the MSO results give ~40-50% more than the Origin Software results. It is to be noted that MSO and Origin might have been calibrated with different references. However, the results show uniformity.

DOI: 10.46121/pspc.54.3.02

TABLE-1: Comparison of Expt. Phase voltage FFT Origin vs MSO (math function) results (in volts).

Comparison of Expt. Phase voltage FFT Origin vs MSO (math function) results (in volts).						
Frequency of operation	**30Hz, Phase voltage**		**40Hz, Phase voltage**		**50Hz, Phase voltage**	
Frequency Components	Origin	MSO	Origin	MSO	Origin	MSO
Fundamental	102	140	105	158	105	149
5th harmonic	6	8.6	8	16	10	18.74
29th harmonic	20	30	18	27.3	12	20.5
1kHz-carrier	12	17.2	11	15	7.5	10.25
35th harmonic	12	18	12.5	18.7	11	13.7

TABLE-II: Comparison of Expt. Line voltage FFT results vs. MSO (math function) results (in volts).

Comparison of Expt. Line voltage FFT results vs. MSO (math function) results (in volts).						
Frequency of operation	**30Hz, Line voltage**		**40Hz, Line voltage**		**50Hz, Line voltage**	
Frequency Components	Origin	MSO	Origin	MSO	Origin	MSO
Fundamental	175	250	181	250	180	250
5th harmonic	9	14.5	11	21.67	12	24.3
29th harmonic	31	43	15	24.3	17	23.6
1kHz-carrier	17.5	28	18	23.6	13	21
35th harmonic	18	28	17.5	26.5	15	23.2

CONCLUSION

From Table -I and Table-II one can observe the results of MSO readings ~40-50% more than the Origin results. The higher order harmonic frequencies of phase and line voltages must be low, since some of the higher order harmonic may give negative torque to the motor which is not healthier and in addition the higher order harmonic voltages may produce heat rather than torque, and due to the heat, the insulation of the stator winding may deteriorate [7, 8]. Hence it is to be noted the higher order frequencies must be lower, since it produces EMI which may be disturbing the measuring and sensing instruments.

ACKNOWLEDGEMENT

The authors are thankful to the KRJS management for providing the facilities and funds to do the experimental and simulation work. The authors are also thankful to the Principal, Vice Principal and HoD of the ECE department for their cooperation and permission to conduct the project work. The authors are thankful to all the staff members of ECE department who have coordinated and supported directly or indirectly to do the project work. The authors are thankful to Mr. R. Narayanan B.E, M.S for suggesting the various circuit blocks of control system design and the testing methods and simulation of the experimental work.

REFERENCES

1. Akire Nabae, Kenichi Otsuka, H Uchino, R Kurosawa, “An approach to flux control of IM operated with variable frequency supply”, IEEE trans. industry applications, May 1990., issue 3, Vol. IA-16, PP.342-35
2. A Nabae, I. Takahashi, and H Akagi, “A new neutral-point clamped PWM inverter”, IEEE trans. IND. Applications, Sep/Oct 1981, Vol.IA-17, PP.518-523.
3. A Ramachandran, M Channa Reddy “Noval method of litigation of conducted EMI in PWM inverter fed IM adjustable speed drives”, IEEE international conference on Industrial Technology, 2006, ICIT-Dec 15-17, held at Mumbai, India.
4. G Narayan and V T Ranganathan “Synchronized PWM strategies based on space vector approach principles of waveform generation”, IEEE proceedings-Electric power applications, May 1999, Vol.146 No.3, PP.267-275.

5. P Srikant Verma and G Narayanan, “Space vector PWM as a modified form of PWM for simple analog or digital implementation”, IETE journal of research, Nov/Dec 2006, Vol.52 No.6, PP.435-444.
6. Prathibha S. Babu, “Harmonic Analysis of Inverter-Fed Induction Motor Drive System under Fault Conditions using FFT’, 2016, Indian Journal of Science and Technology, Volume: 9, Issue: Special Issue 1, Pages: 1-6.
7. Three-Phase Inverter-Fed Induction Motor Drives, by Narayanaswamy P R Iyer, Chapter First Online: 27 December 2024, In book: Inverters and AC Drives (pp.463-561).
8. Jai Ram, Alok Priyadarshi, Shravan Kumar Yadav, Saurav Suman. “Speed Control of 3 Phase Induction Motors using different PWM Techniques. 2025, IEEE 1st International Conference on Smart and Sustainable Developments in Electrical Engineering (SSDEE), 979-8-3315-4210-8/25.
9. Muhammad Usman Sardar, Toomas Vaimann, Lauri Kütt Ants Kallaste, Bilal Asad, Siddique Akbar and Karolina Kudelina. “Inverter-Fed Motor Drive System: A Systematic Analysis of Condition Monitoring and Practical Diagnostic Techniques”, Energies 2023, Vol., 16, 5628.
10. S Jyothirani, P Raghava Prasad, P Chanikya, P Pradeep Kumar, M Surya Bhargav, and S Mounika. “Simulation of Voltage Source Inverter Fed Induction Motor Drives”, International Research Journal of Engineering and Technology (IRJET) Apr 2024, Volume: 11 Issue: 04, e-ISSN: 2395-0056.