ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

"HARMONIC REDUCTION IN AC DRIVES AND IT's WAVELET ANALYSIS"

Chetan Bhale[1], K.B. Porate[2]

Lecturer, Dept. of EE, Rajiv Gandhi College of Engineering and Research, Nagpur, India[1]

Professor, Dept. of EE, Priyadarshini College of Engineering, Nagpur, India[2]

ABSTRACT-: Variable speed AC drives are finding their place in all types of industrial and commercial loads. This work covers the current source converter technologies, including pulse width-modulated current-source inverters (CSIs) and in addition, this also addresses the present status of the direct converters & gives an overview of the commonly used modulation schemes for VFD systems. The proposed work flow is that to work with the simulation of three phase PWM Current Source Inverter fed Induction Motor (CSI-IM) drive systems using Matlab/Simulink simulation software. This work primarily presents a unified approach for generating pulse width-modulated patterns for three-phase current-source rectifiers and inverters (CSR/Is) that provides unconstrained selective harmonic elimination and fundamental current control. This conversion process generates harmonics in the motor current waveform. This project deals with the analysis of motor current harmonics using FFT analysis and use of filter for mitigating them for smooth operation of motor. The filter used for reduction of harmonics is passive filter. The filter is such it reduces only the 5^{th} & 7^{th} order harmonics. Thus the analysis of motor current harmonics is done firstly without filter & then it has been compared with the results after the addition of filter. It is found that the 5^{th} & 7^{th} order harmonics has reduced considerably. Also the project deals with study of signal in the form of motor current and performing Wavelet Analysis. The Wavelet Analysis is totally different approach than the FFT Analysis. Wavelet Analysis is done by two ways one by using wavelet programming & by using graphical method. Wavelet programming is done by using M-file where program is written for analysis of motor current with & without filter & then results are compared. The only focus of this research work is an improvement over existing techniques.

Keywords: Harmonics, Total harmonic distortion (THD), variable frequency drives (VFD), power factor, current source inverter (CSI), Fast Fourier Transform (FFT), Wavelet.

I. INTRODUCTION

The proposed work is based on current source inverter fed induction motor scheme. At the front end a current source rectifier is connected which converts the 6.6Kv ac voltage into dc by rectifying it. The inverter converts the dc voltage again into ac & then supplies to induction motor. As the switches used in the rectifier & inverter are GTO's & SCR's which requires triggering pulse. The triggering pulse is given by the discrete six pulse generator which is connected to the gate of both rectifier & inverter having six switching devices in each section. Due to the switching processes harmonics are produced in the system. The output of the inverter which is ac but not sinusoidal due to switching time taken by the switches & is in quazi square form which is the main cause of harmonics. As six switches are used the harmonics which are dangerous to the system are 5^{th} & 7^{th}. Thus main focus is to reduce this harmonic order. For doing so low pass filter is to be used so as to reduce this harmonics. An LC filter is used by selecting the values of inductor & capacitor. Thus it is a passive filter which is used in this scheme. The output of the induction motor is given to the bus - bar which shows the stator, rotor & mechanical quantities. As our main focus is on current on stator side we choose stator quantities from bus-bar. A scope is connected to observe the waveforms. The current waveform as a signal is analysed by using Wavelet. The Wavelet Toolbox is a collection of functions built on the MATLAB. It provides tools for the analysis and synthesis of signals and images, and tools for statistical applications, using wavelets and wavelet packets within the framework of MATLAB. The toolbox provides two categories of tools:

- Command line functions
- Graphical interactive tools

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

The first category of tools is made up of functions that you can call directly from the command line or from your own applications. Most of these functions are M-files, series of statements that implement specialized wavelet analysis or synthesis algorithms. Thus by writing program in M-file we can analysis the lower & higher frequency components of any signal.[4] [10]

II. METHODOLOGY

Adding a variable frequency drive (VFD) to a motor-driven system can offer potential energy savings in a system in which the loads vary with time. The operating speed of a motor connected to a VFD is varied by changing the frequency of the motor supply voltage. This allows continuous process speed control. Motor-driven systems are often designed to handle peak loads that have a safety factor. This often leads to energy inefficiency in systems that operate for extended periods at reduced load. The ability to adjust motor speed enables closer matching of motor output to load and often results in energy savings. The VFD basically consist of a rectifier section which converts the ac supply into dc, a dc choke which is used to smooth the dc output current & a inverter section which converts dc into ac supply which is fed to induction motor. The VFD consists of a switching devices such as Diodes ,IGBT ,GTO,SCR etc.[1]

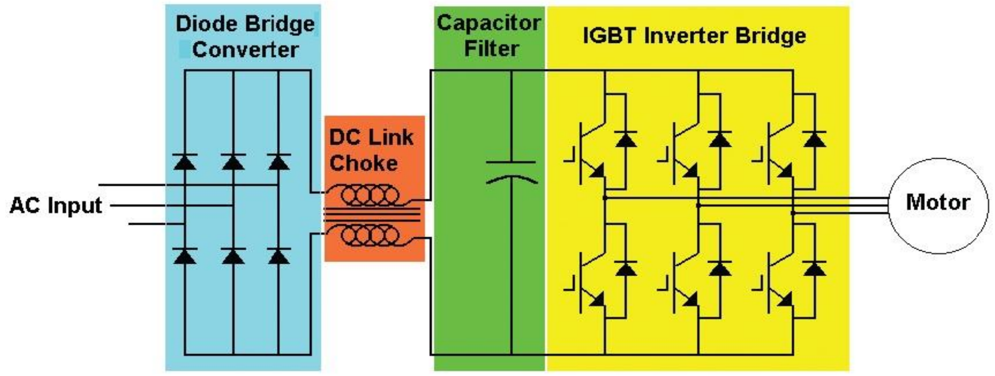

Fig.1: Generalized Variable Frequency Drive

A VFD can be divided into two main sections:

A. **Rectifier stage:** A full-wave, solid-state rectifier converts three-phase 50 Hz power from a standard 208, 460, 575 or higher utility supply to either fixed or adjustable DC voltage.

B. **Inverter stage:** Electronic switches power transistors or thyristor switch the rectified dc voltage on and off, and produce a current or voltage waveform at the desired new frequency. The amount of distortion depends on the design of the inverter and filter.

III. SYSTEM SIMULATION

The proposed work is based on current source inverter fed induction motor scheme. At the front end a current source rectifier is connected which converts the 6.6Kv ac voltage into dc by rectifying it. For smoothing this voltage before applying it to inverter a DC choke coil is used this removes the ripples. The inverter converts the dc voltage again into ac & then supplies to induction motor. As the switches used in the rectifier & inverter are GTO’s & SCR’s which requires triggering pulse. The triggering pulse is given by the discrete six pulse generator which is connected to the gate of both rectifier & inverter. Six switching devices in each section. Due to the switching processes harmonics are produced in the system. The output of the inverter which is ac but not sinusoidal due to switching time taken by the switches & is in quazi square form which is the main cause of harmonics. As six switches are used the harmonics which are dangerous to the system are 5^{th} & 7^{th}. Thus main focus is to reduce this harmonic order. For doing so low pass filter is to be used so as to reduce this harmonics. An LC filter is used by selecting the values of inductor & capacitor. Thus it is a passive filter which is used in this scheme. The output of the induction motor is given to the bus - bar which shows the stator, rotor & mechanical quantities. As our main focus is on current on stator side we choose stator quantities from bus-bar. A scope is connected to observe the waveforms. An FFT block is connected to the motor current of any one phase whose order of harmonic is to be found out. To this FFT block an FFT spectrum window is connected which displays the order of harmonics from 0 to 19th order of harmonic. Also a bar graph is displayed which shows the order of harmonics which is shown by the FFT spectrum. Thus the work is divided into two sections one before use of filter and after the use of filter. After running the simulation it is observed that the 5th & 7th harmonic components are reduced than that without filter which is shown by the FFT spectrum block. The signal is imported to workspace by performing wavelet programming & both the stator & rotor currents are analysed. [2] [3] [5]

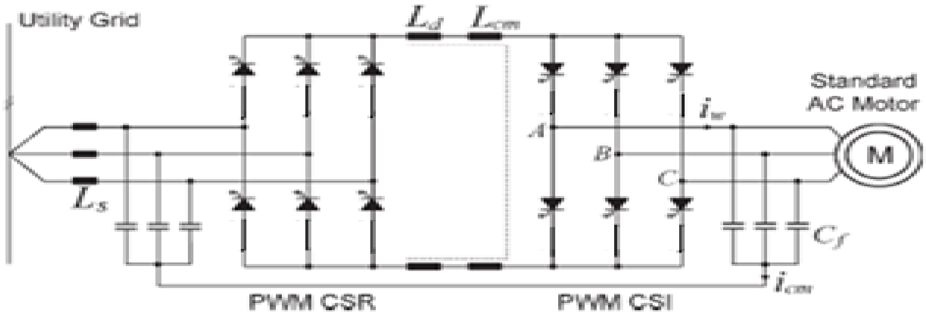

Fig.2: Simulation Diagram of CSI Fed Induction.

Table: Induction Motor Specifications

Motor Supply Voltage	6600V
Horse Power Rating of Motor	200 HP
Supply Frequency	50 Hz
Stator resistance [Rs] , Stator inductance [Ls]	1.485Ω, 0.03027 H
Pole Pairs	2

IV.HARMONICS

Harmonics are the major problems in any industrial drives. They cause serious problems in the motor which is connected as a load fed from the VFD. The VFD is a current source inverter fed (CSI) .At the front end a current source rectifier is connected which converts the 6.6Kv ac voltage into dc by rectifying it. For smoothing this voltage before applying it to inverter a DC choke coil is used this removes the ripples. The inverter converts the dc voltage again into ac & then supplies to induction motor. As the switches used in the rectifier & inverter are GTO's & SCR's which requires triggering pulse. The triggering pulse is given by the discrete six pulse generator which is connected to the gate of both rectifier & inverter. Six switching devices in each section. Due to the switching processes harmonics are produced in the system. The output of the inverter which is ac but not sinusoidal due to switching time taken by the switches & is in quazi square form which is the main cause of harmonics. As six switches are used the harmonics which are dangerous to the system are 5th & 7th . Thus main focus is to reduce this harmonic order. For doing so low pass filter is to be used so as to reduce this harmonics. [5]

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

V. WAVELET ANALYSIS

Wavelet analysis represents the next logical step a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques miss, aspects like trends, breakdown points, discontinuities in higher derivatives, and self-similarity. Furthermore, because it affords a different view of data than those presented by traditional techniques, wavelet analysis can often compress or de-noise a signal without appreciable degradation. Thus by using wavelet i.e. time-scale analysis minute analysis of signal during the fault can be done. [10] [12]

VI. RESULTS

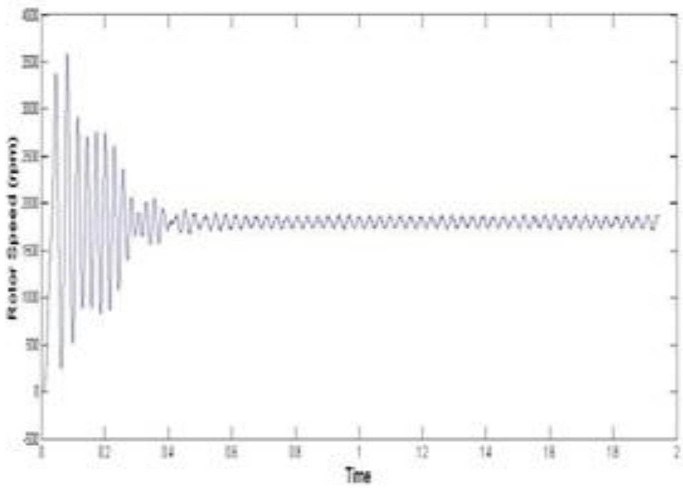

Fig.3: Motor speed without use of filter with ripple

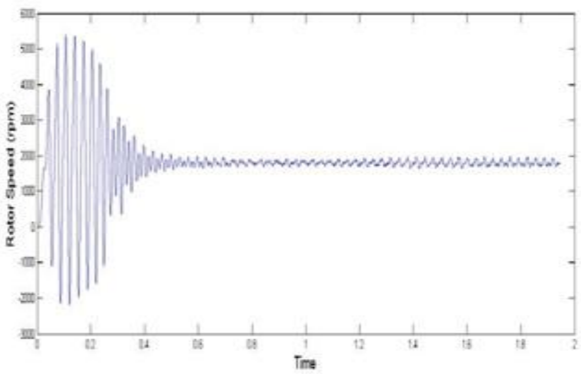

Fig.4: Thus we observe that when filter is used the ripples in the Speed is reduced .This is due to reduction in harmonics

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

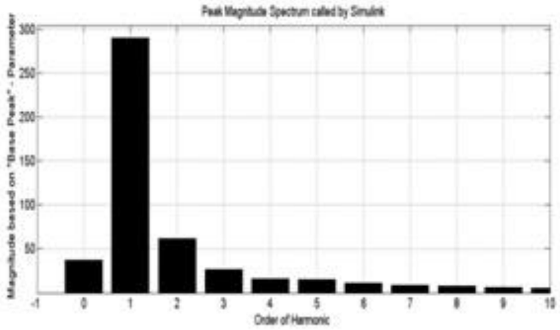

Fig.5: Bar-graph showing magnitude of harmonics without filter.

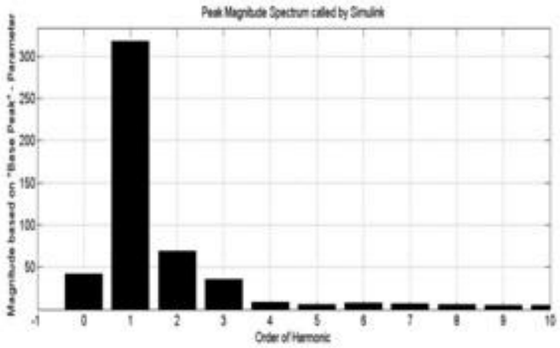

Fig.6: Bar-graph showing magnitude of harmonics with filter.

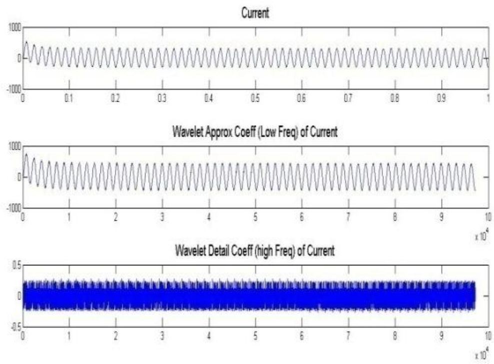

Fig.7: The waveform shows the low & high frequency component of stator current of phase A without use of filter. The higher frequency components are present.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

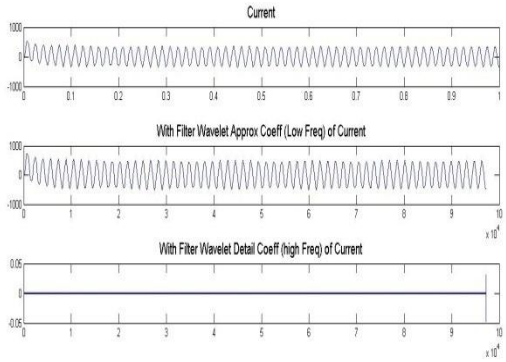

Fig.8: The waveform shows the low & high frequency component of stator current of phase A with use of filter. The higher frequency components are present.

.

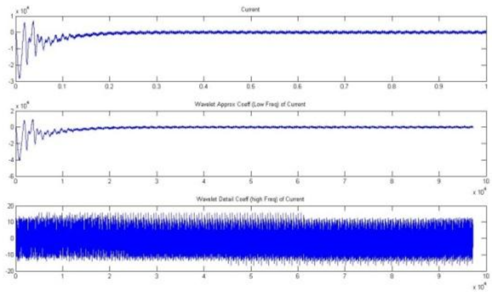

Fig.9: The waveform shows the low & high frequency component of rotor current of phase A without filter. The higher frequency components are present.

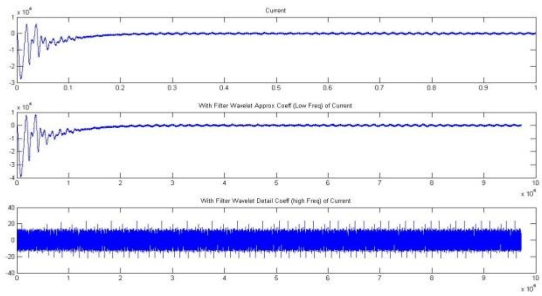

Fig.10: The waveform shows the low & high frequency component of rotor current of phase A without filter. The higher frequency components are present with lesser magnitude**.**

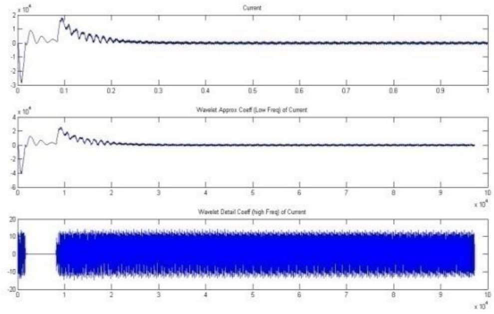

Fig.11: The waveform shows the low & high frequency component of rotor current of phase A without filter when three phase fault occurred. .

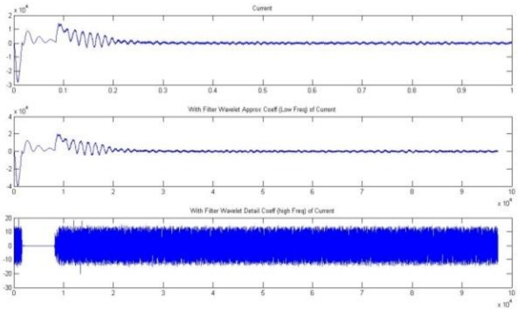

Fig.12: The waveform shows the low & high frequency component of rotor current of phase A with filter when three phase fault occurred.

.

VII. CONCLUSION

The simulation of CSI fed Induction Motor drive caused harmonics in the motor current. This harmonics are the by-product of switching devices used in rectifier & inverter section. From all the harmonic orders 5^{th} & 7^{th} harmonic cause problem as we use 6 pulse rectifier & Inverter Sections. For the reduction of harmonics we have used LC filter with typical values of inductor & Capacitor. Thus reduction in the 5^{th} & 7^{th} harmonics components is done by passive filter. By doing wavelet

programming we found out that the higher frequency harmonics are eliminated after use of filter also the exact time of fault occurrence in the rotor current.

REFERENCES

1. K. H. J. Chong and R. D. Klug, “High power medium voltage drives,” in *Proc. Power Con, vol. 1, pp. 658–664. Nov. 21–24, 2004*.
2. Bin Wu, S.B.Dewan and G.R.Slemon, ”PWMCSI Inverter Induction Motor Drives", IEEE Trans. IA, Vol. 28, NO. 1, pp. 64-71,Jan 1992.
3. P. M. Espelage, J. M. Nowak, " Symmetrical GTO current source inverter for wide speed range control of 2300 to 4160 volt, :350 tp 7000hp, induction motors," IEEE IAS Annual Meeting, pp302-307, 1988.
4. M.Salo and H.Tuusa, “A vector-controlled PWM current-source-inverter fed induction motor drive with a new stator current control method,” *IEEE Trans. Ind. Electron.*, vol. 52, no. 2, pp. 523–531, Apr. 2005.
5. H. Karshenas, H. Kojori, and S. Dewan, “Generalized techniques of selective harmonic elimination and current control in current source inverters/ converters,” *IEEE Trans. Power Electron., vol. 10, pp. 566–573,*Sept. 1995.
6. B.Wu, G. R. Slemon, and S. B. Dewan,“Stability analysis of GTO-CSI induction machine drive using constant rotor frequency control,” in *Proc. 6th Int. Conf. Elect. Machines and Drives*, pp. 576–581,1993.
7. J. Espinoza and G. Joos, “On-line generation of gating signals for current source converter topologies,” *ISIE*, pp. 674–678, 1993.
8. B. E. H. Benbouzid, “A review of induction motors signature analysis as a medium for faults detection”, *IEEE Trans. Industrial Electronics,*vol. 47, no. 5 pp. 984 – 993, Oct. 2000.
9. Y. Xiao, B. Wu, S. Rizzo and R. Sotuden, “A Novel Power Factor Control Scheme for High Power GTO Current Source Converter”, Conference Record IEEE- IAS, pp. 865-869, 1996.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

10. Meyer, Y. *Wavelets: their past and their future, Progress in Wavelet Analysis and its Applications*. Gif-sur-Yvette, pp 9-18, 1993.
11. Morlet, J.; Arens, G.; Fourgeau, E. and Giard, D. Wave propagation and sampling theory, Part1: Complex signal land scattering in multilayer media. *Journal of Geophysics,* 47: 203-221, 1982.
12. I. Daubechies. Ten Lectures on Wavelets. Society for Industrial and Applied Mathematics ISBN 0-89871-274-2,1992.

BIOGRAPHY

Chetan Bhale received the Engineer Degree in Electrical Engineering from Rashtrasant Tukdoji Maharaj Nagpur University (RTMNU), Nagpur, India, in 2009. He then got an M.Tech degree in Industrial Drives and Control (IDC) Electrical Engineering in 2012. Since 2012 he has been a lecturer with the department of Electrical Engineering, RGCER Nagpur (India).

K.B.Porate, Master of Engineering **(**M.E.) in Electrical power system from Govt. college of Engineering Amravati, Maharashtra, India. Currently, working as Assistant Professor in the Department of Electrical Engineering, Priyadarshini college of Engineering, Nagpur, India. He has 25 years experience in the field of teaching and research. His research interest in power system and electrical drives. He has published around 35 papers in reputed Journals and International conferences. He is member of Institutions of Engineers, ISTE and IEEE. He has submitted his PhD thesis to RTMNU Nagpur University, Nagpur (India).