International Journal of Electronics Communications and Electrical Engineering
ISSN : 2277-7040 Volume 3 Issue 7 (July 2013)
http://www.ijecee.com/ https://sites.google.com/site/ijeceejournal/

Analysis of Common DC Link in VSI fed Multi-motor Drives

Amit Biswal[1], Sai Ram Reddy Bhavanam[1], Dr. Umashankar S[1]

[1]School of Electrical Engineering, VIT University,
Vellore-632014, Tamil Nadu, India
amit.biswal2010@vit.ac.in ; umashankar.s@vit.ac.in

Abstract. VSI fed Induction Motor Drives forms the major part of Heavy Industries wherein the machine tools are supposed to possess varying speed. With increase in the number of machine tools in the industrial workshop, the number of induction motor drives increases. Size and space complexity involved with single huge motor limits its usage in the Industry where expansion in capacity is being planned. This necessitates the use of multi motor drives fed from Voltage Source Inverter connected to a common DC link. In this paper a multi-motor drive system has been simulated and simulation results were analyzed and compared based on the output waveforms of various performance parameters of an Induction Motor drive.

Keywords: Multi Motor Drives, Voltage Source Inverter, Induction Motor, Rectifier, Pulse Width Modulation

1 Introduction

Multi-motor drives are currently used in a number of applications in industrial plants. Few high end complex applications like paper mills, ironworks, caterpillar drives in large mining machines such as bucket wheel excavators which is used in open cast mining, etc depends heavily on the performance of multi-motor drives. For example, in big press rolling mills, where the space is limited for keeping a single huge motor, usually more than 1 motor of smaller size and rating is preferred. This multi-motor drives configuration is also preferred in industries because of its ability to provide planned expansion in plant production capacity. Using multi-motor drives, plant can rely upon single motor and later during expansion phase, more motors can be added up.

---

[2] The corresponding author.

Similar to controlled drives, controlled multi-motor drives are also fed from power converters. The type and topology of converted used in control depends heavily upon the type, power rating of the motor and the kind of multi motor drives used. Hence this necessitates the need to analyze the behavior of multi motor drives under different load conditions. This paper aims to simulate, study, analyze and compare the behavior of the multi-motor drives system.

This paper makes use of a system consisting of more than one Voltage Source Inverter (VSI) fed induction motor drive which has been simulated under different conditions of load on both the drives. Rest of the paper is organized as follows. '*Literature survey*' describes the various kinds of inverters which has been used for multi-motor drives and discusses various modulation techniques used to trigger IGBT gate terminals of the Inverters. '*Modeling and Simulation*' Section describes the model of the system and its various components which has been developed using SIMULINK. '*Results and Discussion*' section deals with the analysis and comparison of various output waveforms obtained from the four loading cases of the system and finally the paper is concluded.

2 Literature Survey

Voltage Source Inverter along with the squirrel cage induction motor forms the heart of the VSI fed Multi-motor drive system being analyzed in this paper. Voltage Source Inverters is a standalone inverter wherein the DC source being used has negligible impedance. In VSI, the DC source used provides a constant voltage as per its specified ratings. Voltage Source Inverters are driven by high frequency switches like MOSFET, IGBT, GTOs, etc. Various Pulse width modulation techniques are used to drive the inverter.

In [1], the authors have investigated a VSI fed Induction motor drive for fault tolerance capability using an analytical model. In this configuration, the induction motor was driven by a four switch inverter configuration.

In [2], the authors have modelled a multi-phase induction motor drive using MATLAB/Simulink. The modelled parameters were simulated under various load conditions and the performance parameters were observed. This model was based on the d-q axis equivalent circuit as presented by the authors.

In [3], the authors have presented a multi-motor drive system which uses a two-stage direct power converters using a single input bridge, the advantage of this system being the less or negligible usage of passive components in the drive system. The authors have proposed and successfully implemented the topology and its performance and feasibility has been evaluated in the corresponding paper.

In [4], the authors have presented the importance of controlling a drive and the concepts of speed synchronization have been discussed. In this paper, information related to load distribution and load sharing operations in multi-motor drives has been studied.

3 Modelling and Simulation

3.1. Components of the Multi-motor Drives System

Figure 1 represents the complete model of the multi-motor drive system. This model has been prepared and simulated using SIMULINK. The various subcomponents present in this system are:

a) 3 Phase AC Source

b) Diode Rectifier

c) VSI fed Induction Motor

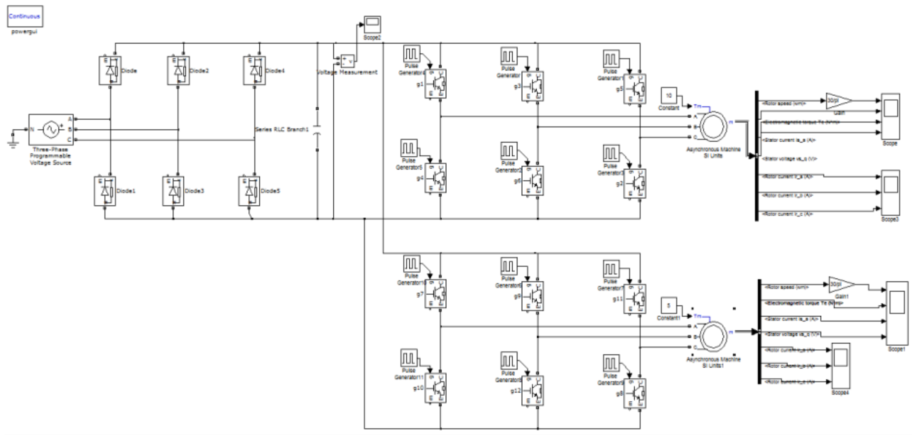

Fig.1. Simulink Model of the Complete Multi-motor Drive system

3.2. AC-DC converter

In this system Diode based AC-DC rectifier power converter has been used. The part of the complete model consisting of AC-DC Converter is shown in Fig.2. Appropriate Capacitance has been added to reduce the ripples coming out of the power converter after being rectified to DC from AC.

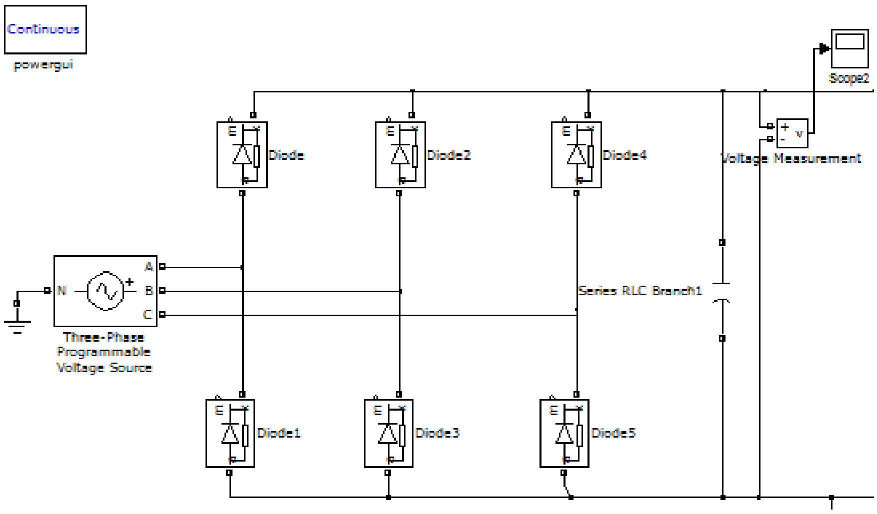

Fig.2. Part of the multi-motor drive system containing diode based full wave rectifier

3.3. Voltage Source Inverter fed Induction Motor Drive

Figure 3 shows the part of the System Simulink model containing VSI fed Induction Motor Drive. In this model, 6 pulses IGBT has been used, using which 3 phase square wave is being produced as shown in Fig.4. The Induction Motor ratings used in this system are as follows:

Rotor Type	: Squirrel Cage
Power Rating	: 5hp
Voltage Rating	: 460V, 50Hz
Rated RPM	: 1750 rpm

In the current simulation, the induction motor parameters being monitored are:

1. Rotor Speed (RPM)
2. Electromagnetic Torque (N-m)
3. Stator Current (A)
4. Stator Voltage (V)
5. Rotor Current of all 3 phases (A)

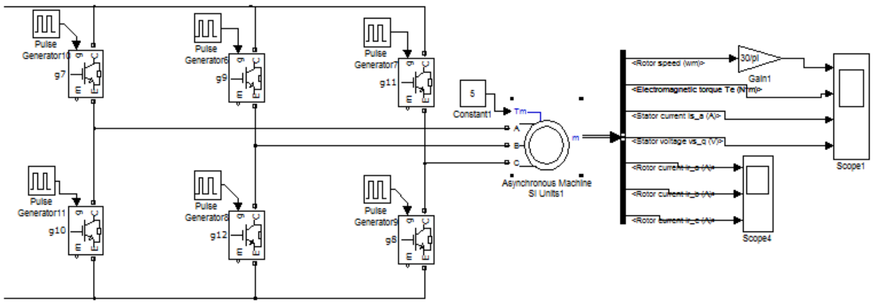

Fig.3. Part of the Multi-motor drive system consisting of VSI fed Induction Motor

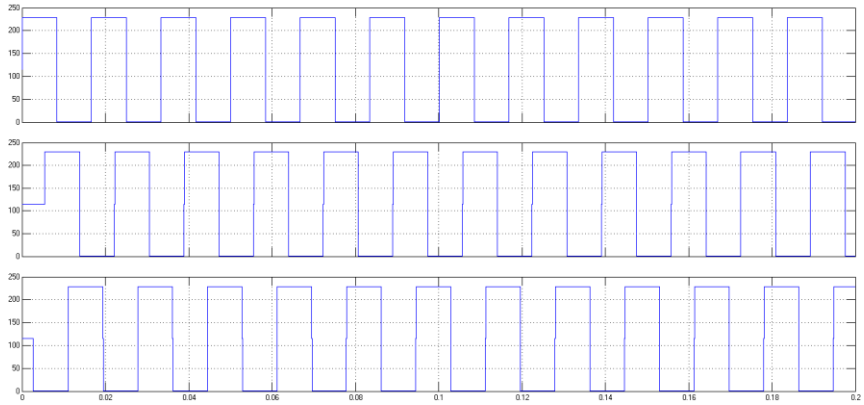

Fig.4. Output waveforms from the square wave inverter wherein each graph represents output from each phase

The graph shown in figure 4 represents the 3 phase square wave inverter output. Each graph represents each phase. It can be seen from the graph that the voltage waveforms are consist of a phase lag of 120^o with its preceding waveform.

4 Results and Discussion

In this multi-motor drive system, the behavior of induction motor drives are being evaluated for 4 possible cases of induction motor load. The 4 possible cases being

1. Zero Load Torque on both Drives
2. Equal Non-Zero Load Torque on both drives
3. Unequal Non-zero load torque on both drives

4. Unequal Load Torque with Zero load on one of the drives

Simulation results of each case have been put forward in the upcoming sub-sections:

4.1. Case 1: Zero Load Torque on Both Drives

In this case, both the Induction Motor is being driven under unloaded condition. The waveforms of the common DC link are shown in Fig.5. As can be seen in the graph, there exists a ripple in the output waveforms. This is because of the limitation of non-industrial loads, wherein use of huge capacitor bank is not recommended. In this case, a capacitance of 800mF is being used.

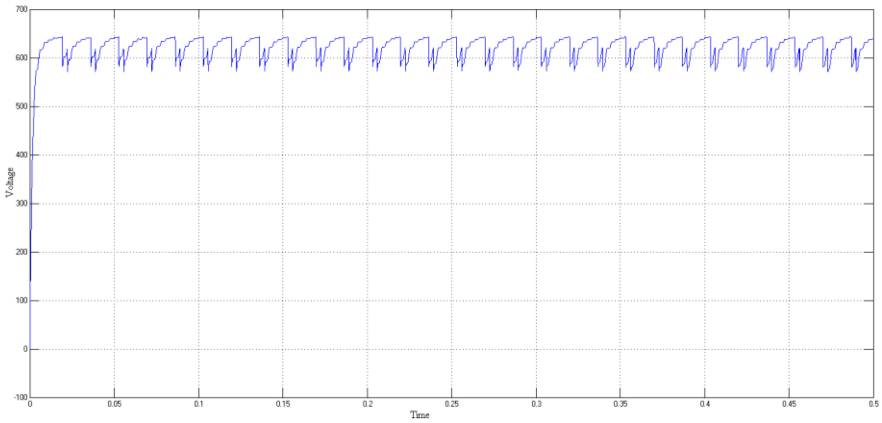

Fig.5. DC Link waveform

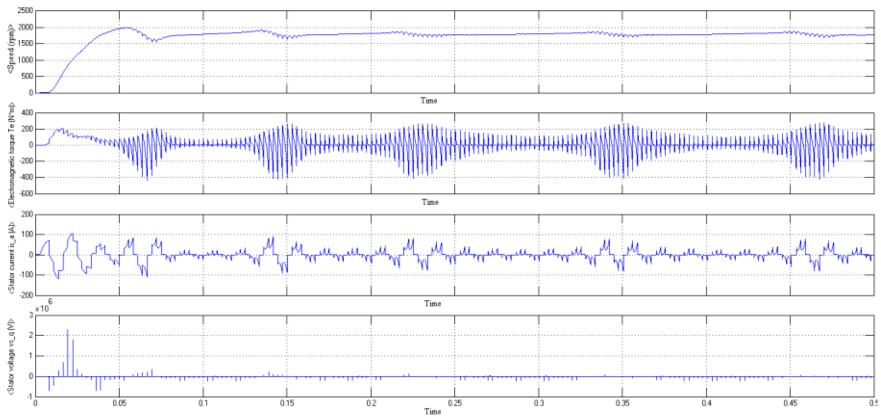

Fig.6. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the first drive

International Journal of Electronics Communications and Electrical Engineering
ISSN : 2277-7040 Volume 3 Issue 7 (July 2013)
http://www.ijecee.com/ https://sites.google.com/site/ijeceejournal/

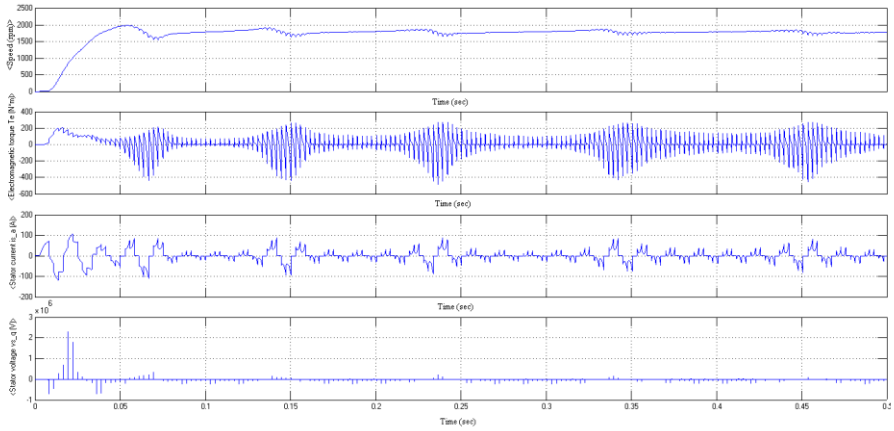

Fig.7. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the second drive

Fig.6 and Fig.7 are the waveforms demonstrating various performance parameters of first and second induction motor drives. On comparing both graphs, we can observe that the change existing is negligible or Nil. Hence it can be inferred that on unloaded condition, both the drive behave in a similar way.

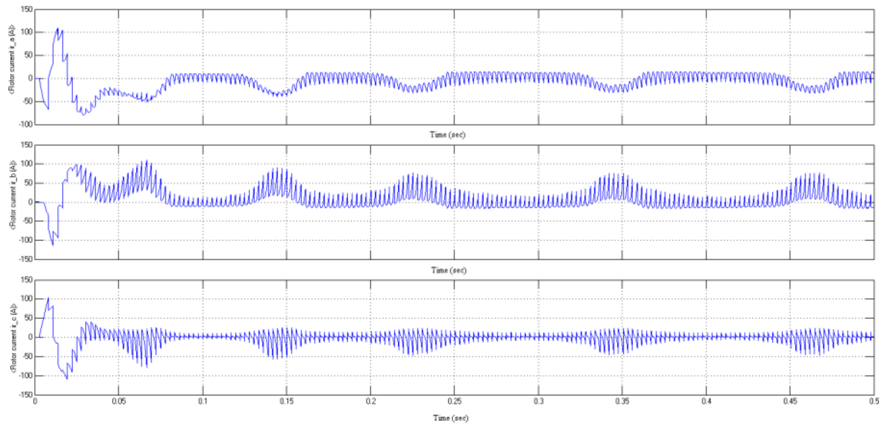

Fig.8. Rotor Current in first drive

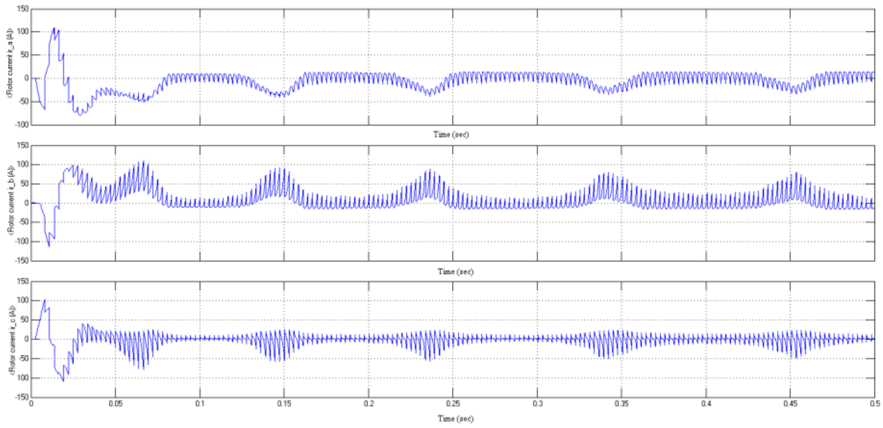

Fig.9. Rotor Current in second drive

Fig.8 and Fig.9 shows the corresponding rotor current waveforms in first and second drive. On observing the graph we find the difference is negligible or nil. This infers that on unloaded condition, the rotor currents of both the drives are similar.

4.2 Case 2: Equal Non-Zero Load Torque on Both Drives

In this case, an equal load torque of 5 Nm is applied on both the induction motors. The observations made have been put forward in the form of graphs.

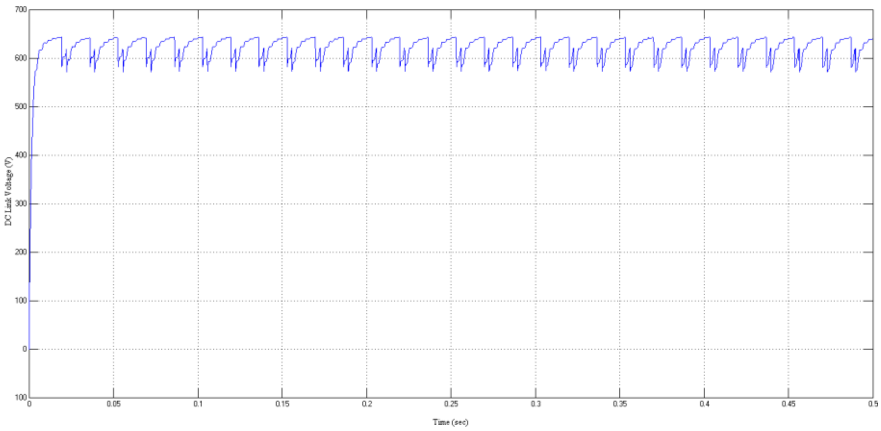

Fig.10. DC Link waveform

International Journal of Electronics Communications and Electrical Engineering
ISSN : 2277-7040 Volume 3 Issue 7 (July 2013)
http://www.ijecee.com/ https://sites.google.com/site/ijeceejournal/

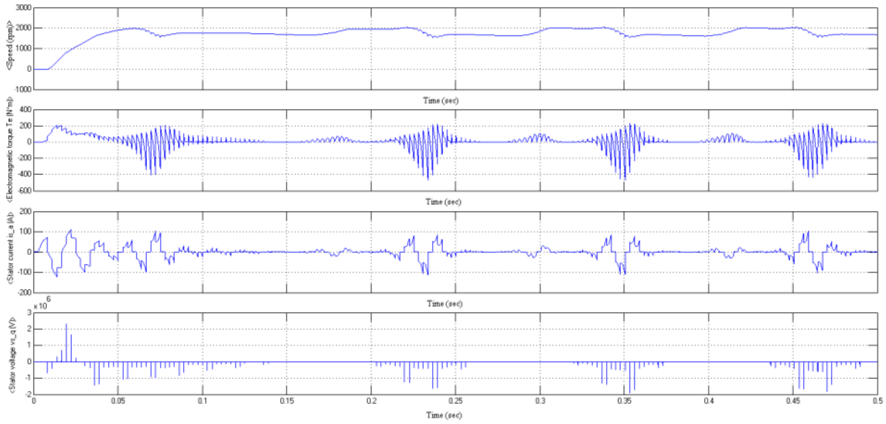

Fig.11. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the first drive

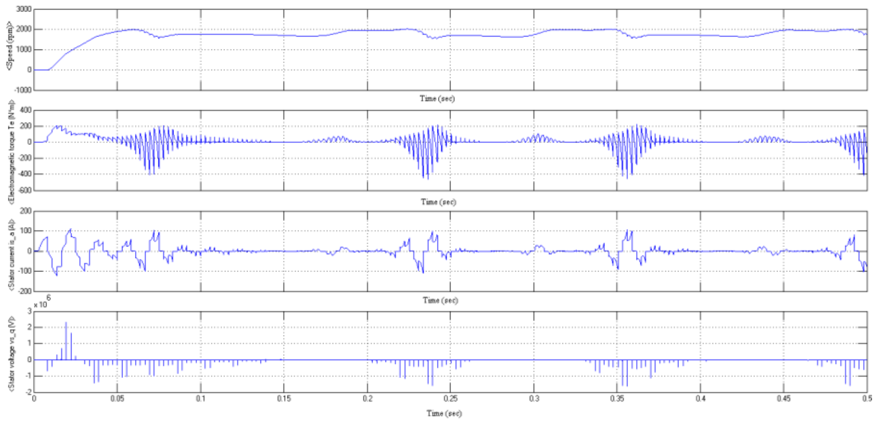

Fig.12. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the second drive

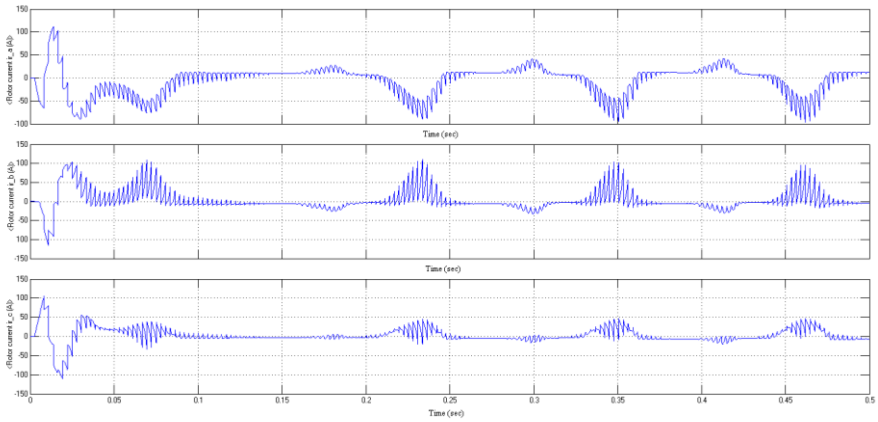

Fig.13. Rotor Current in first drive

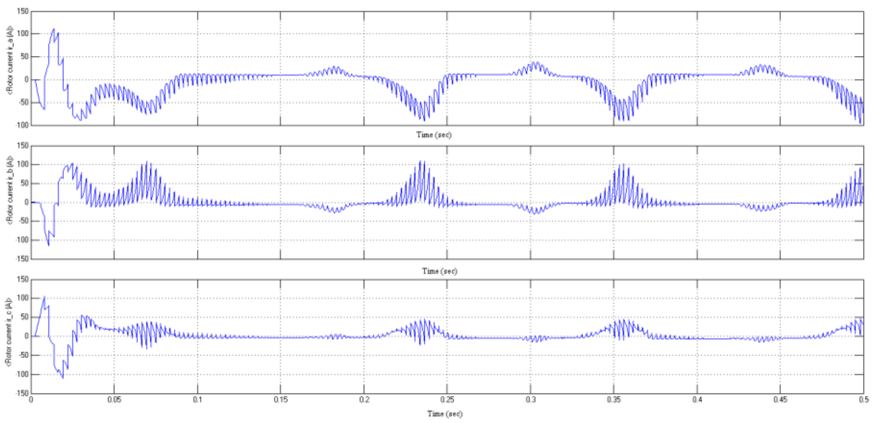

Fig.14. Current for second drive

On comparing graph present in Fig.11 with fig.12 and comparing Fig.13 with fig.14, it is found that the performance of both the drives under equally loaded conditions are almost similar.

4.3. Case 3: Unequal Non-Zero Load Torque on Both Drives

In this case, unequal load torque has been applied on each of the induction motor drive. The first Induction motor has been provided with a load torque of 10 N-m and the second induction motor has been provided with a load torque of 5 N-m. The corresponding waveforms obtained are given below:

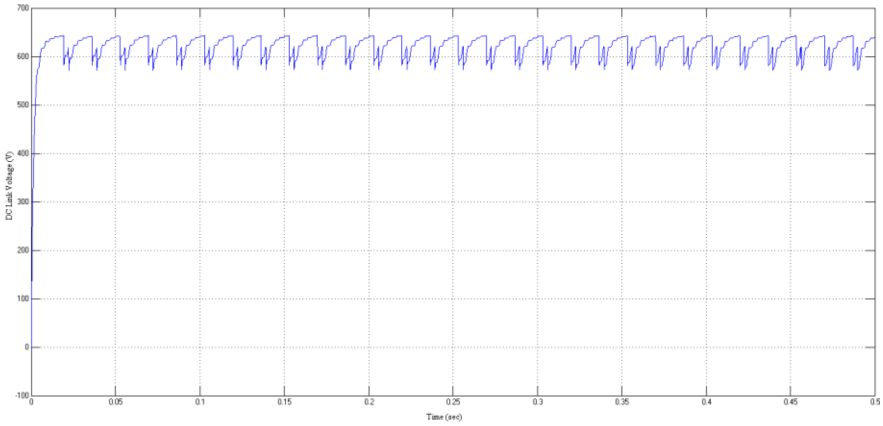

Fig.15. DC Link waveform

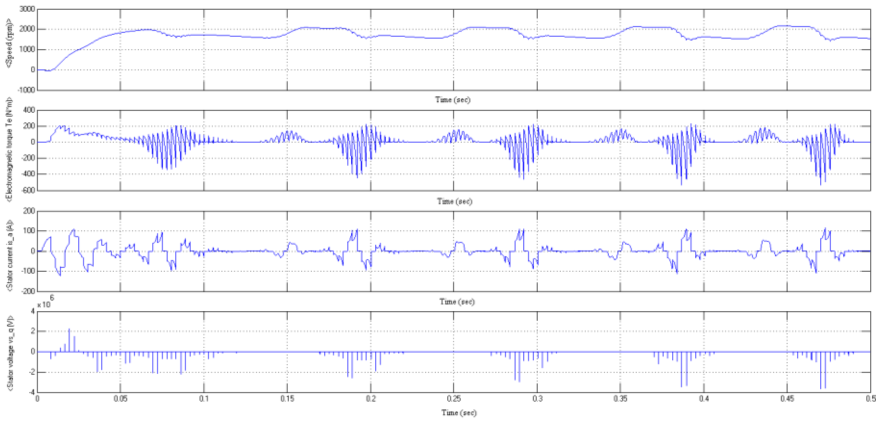

Fig.16. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the first drive

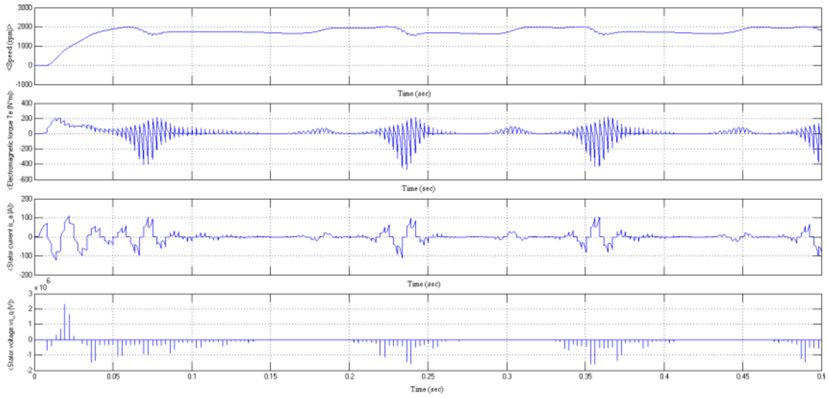

Fig.17. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the first drive

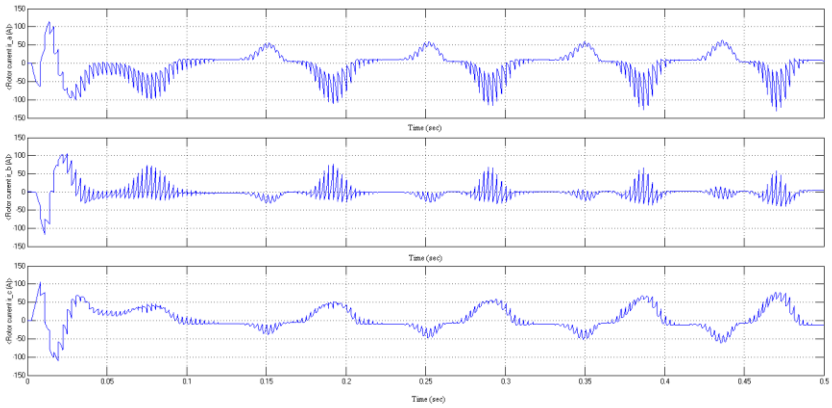

Fig.18. Rotor current in first drive

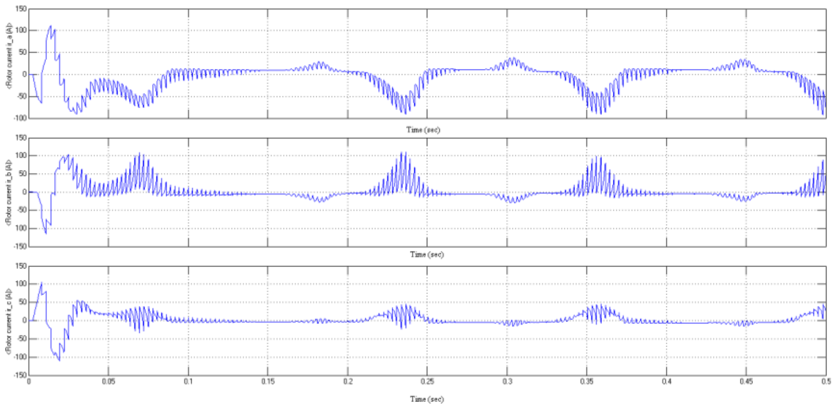

Fig.19. Current in second drive

International Journal of Electronics Communications and Electrical Engineering
ISSN : 2277-7040 Volume 3 Issue 7 (July 2013)
http://www.ijecee.com/ https://sites.google.com/site/ijeceejournal/

Contrary to Case 1 and Case 2, this case gives a complete different result. On comparing Fig.16 with Fig.17 and comparing Fig.18 with Fig.19, we can observe a major difference in the performance of both the drives. It can inferred that the fluctuations are more in case of heavily loaded induction motor compared to the induction motor which is lightly loaded.

4.4. Case 4: Unequal Load Torque with Zero Load on One Drive

In this case unequal load has been given on each of the induction motor drive but with a constraint that one of the Induction Motor is given zero load, i.e. under unloaded condition.

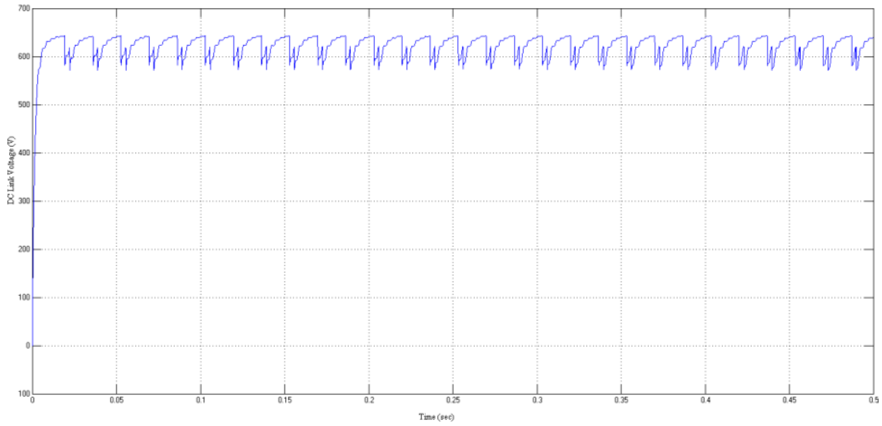

Fig.20. DC Link waveform

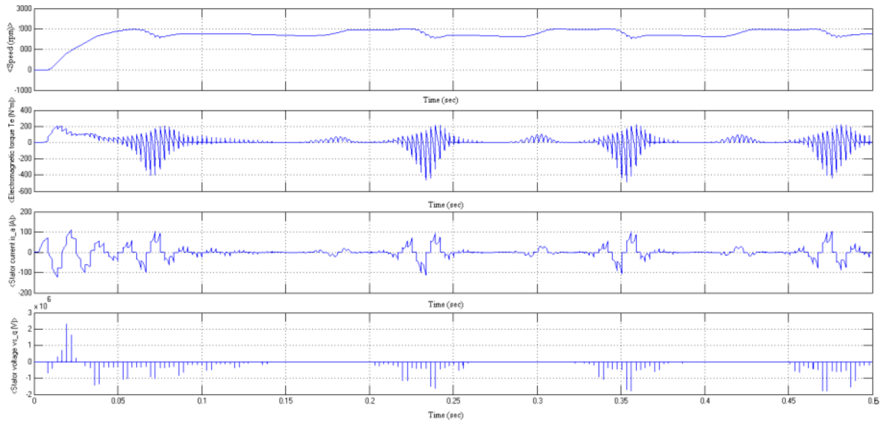

Fig.21. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the first drive

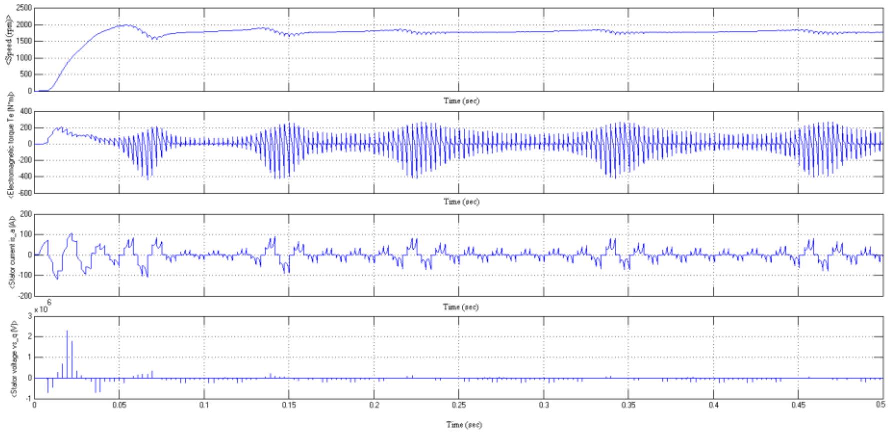

Fig.22. Rotor Speed, Electromagnetic Torque, Stator Current and Stator Voltage waveforms of the second drive

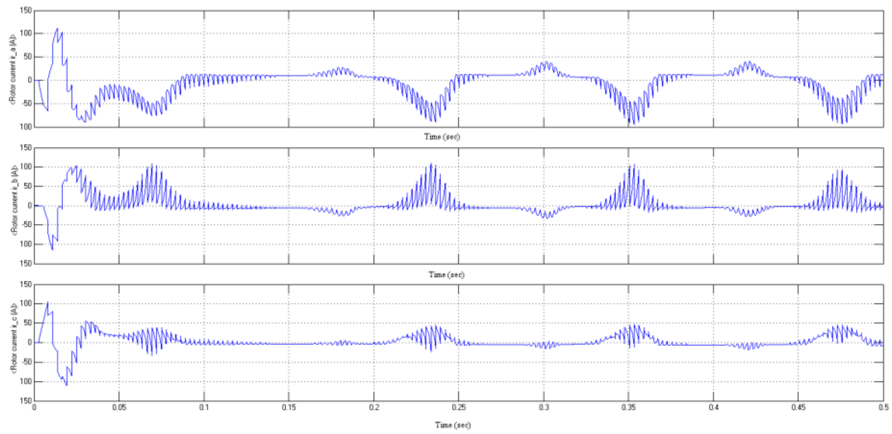

Fig.23. Rotor Current in first drive

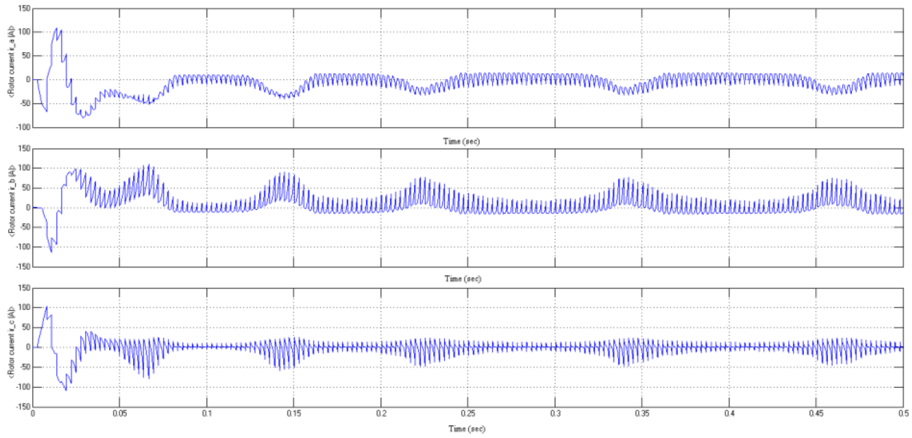

Fig.24. Rotor Current in second drive

On comparing with Fig.21 with Fig.22 and comparing Fig.23 with Fig.24, major differences can be observed in the waveforms of the key performance parameters.

Combining the 4 cases, the Simulation results can summarized and the inference can be tabulated as follows:

Table 1. Summary of Simulation Results and Inference

CASE	**INFERENCE (Comparison of Performance between both Drives)**
Zero Load Torque on both Drives	No difference in performance
Equal Non-Zero Load Torque on both drives	No difference in performance
Unequal Non-zero load torque on both drives	Change Observed in the performance parameters
Unequal Load Torque with Zero load on one of the drives	Change observed in the performance parameters

5 Conclusion

In this paper performance of VSI fed multi motor drives were investigated. The graphical analysis and SIMULINK model of the 3 phase voltage source inverter fed multi-motor drives was presented in this paper. Various waveforms representing drive performance were demonstrated and compared.

Acknowledgments. Authors acknowledge the support of *School of Electrical Engineering, VIT University* for providing a platform to carry out this project work under the aegis of its innovative *Project Based Learning* Program, which aims to make students learn by experimenting.

References

1. Klima, J.; Chomat, M.; Schreier, L., "Analytical investigation of voltage source inverter fed induction motor drive under fault conditions," Industrial Technology, 2002. IEEE ICIT '02. 2002 IEEE International Conference on, vol.1, no., pp.604-609 vol.1, 2002
2. Renukadevi, G.; Rajambal, K., "Generalized model of multi-phase induction motor drive using matlab/simulink," Innovative Smart Grid Technologies - India (ISGT India), 2011 IEEE PES , vol., no., pp.114,119, 1-3 Dec. 2011
3. Kumar, D.; Wheeler, P.W.; Clare, J.C.; Empringham, L., "A multi-drive system based on a two-stage matrix converter," Power Electronics and Motion Control Conference, 2008. EPE-PEMC 2008. 13th, vol., no., pp.207-212, 1-3 Sept. 2008
4. Jeftenić, B.; Bebić, M.; Štatkić, S., "Controlled multi-motor drives," Power Electronics, Electrical Drives, Automation and Motion, 2006. SPEEDAM 2006. International Symposium on, vol., no., pp.1392-1398, 23-26 May 2006
5. Kastha, D.K., "A novel starting strategy for three phase voltage-fed inverter induction motor drives under inverter fault conditions," Power Electronics, Drives and Energy Systems for Industrial Growth, 1996., Proceedings of the 1996 International Conference on , vol.1, no., pp.53,57 vol.1, 8-11 Jan 1996
6. Trabelsi, M.; Boussak, M.; Chaari, A., "High performance single and multiple faults diagnosis in voltage source inverter fed induction motor drives," Electrical Machines (ICEM), 2012 XXth International Conference on , vol., no., pp.1717,1723, 2-5 Sept. 2012