Design and Analysis of Front-End Rectifier For VSI Fed AC Drive For Different Loads

Muktha Eti[1], K V Nagalakshmi [2]
[1]Post Graduate, Department of Electrical and Electronics, The National Institute of Engineering, Mysuru, Karnataka
[2]Associate Professor, Department of Electronics and Communication, The National Institute of Engineering, Mysuru, Karnataka

Abstract-*This paper intends to show the effectiveness of soft switching control strategies for a Voltage Source Inverter based AC drive. The proposed system involves A Three Phase rectifier, dc link, Voltage Source Inverter and a PI controller. A Three-phase Rectifier section converts AC power the Three-phase AC power of variable voltage and variable into DC power with ripples. The filter section mitigates the ripples and produces the fixed DC from pulsating DC. The Inverter takes the DC power from the filter section and converts back to the three-phase AC power of variable voltage and frequency for a controlled operation. The Pulse Width Modulation produces the soft switching control strategy for the proposed system. The major focus of the work is on the mitigation of Total Harmonic Distortion (THD) of AC line current. An FFT analysis is carried out to determine the THD. The PI controllers played a major role in system regulation. An effort is made to reduce the reactive power consumption by active shaping of input current and hence power factor of AC input line current close to unity is achieved. The proposed system is carried out using MATLAB/SIMULINK. To validate the functionality of the concept, an experimental prototype is designed.*

Keywords-Voltage Source Inverter (VSI), Front End Rectifier (FER), DC-AC converter, LC filter, Total Harmonic Distortion (THD), Fast Fourier Transform (FFT), Proportional and Integral (PI)

I. INTRODUCTION

An AC drive is a device used to control the speed of an electrical motor in an energy-efficient way. The need for energy conservation in order to save the environment is a key driver in the development of speed control devices. and AC drives provide the optimum method of controlling the speed of electrical motors to match load demand.

An AC drive consisting of PWM Rectifier, DC-link and PWM inverter. PWM AC drives are most commonly used in industry because of excellent input power factor due to fixed DC bus voltage and hence, no motor cogging, higher efficiencies, and lower cost.

The current electric component of the choice to generate the voltage pulse is the insulated gate bipolar transistor (IGBT), used to build controlled rectifier and PWM inverter. The use of IGBT switches along with AC reactors is responsible for the power factor improvement. The PI controllers help to mitigate the THD.

II. PROPOSED SYSTEM

The Proposed AC drive system consisting of rectifier, DC-link, PWM inverter and PI controller. The output of the inverter is feeding an induction motor. A Three-phase Rectifier section converts AC power the Three-phase AC power of variable voltage and variable into DC power with ripples. The filter section mitigates the ripples and produces the fixed DC from pulsating DC. The Inverter takes the DC power from the filter section and converts back to the three-phase AC power of variable voltage and frequency for a controlled operation. A PI current controller is used for rectifier and a PI voltage controller is used for inverter section. The proposed system is shown in the Figure. 1

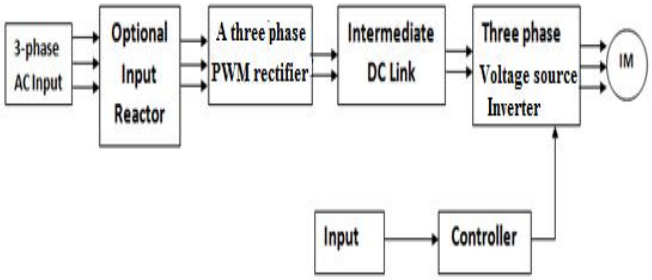


Fig.1 Proposed AC drive system

III. SIMULATION OF MODELS USING MATLAB/SIMULINK

The simulation of AC drive system is carried out using MATLAB/SIMULINK software.

A. Simulation model of AC drive without controller for inductive load

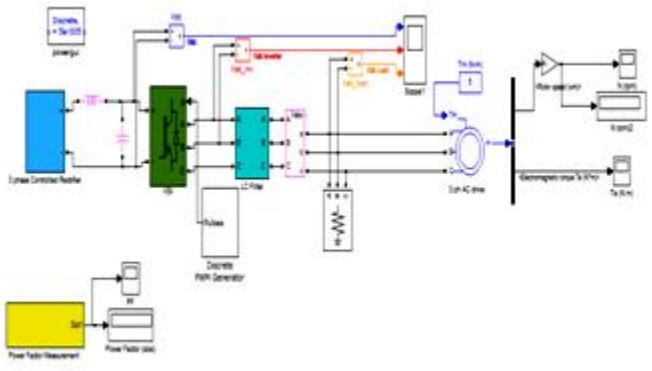


Fig. 2 Simulation model of AC drive without using PI controller

B. Simulation model of AC drive with controller for inductive load

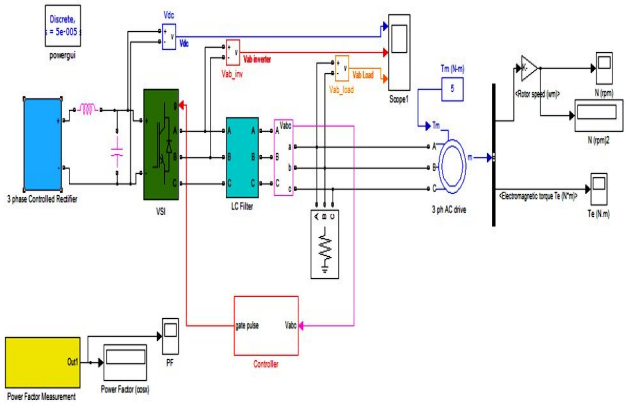


Fig. 3 Simulation model of AC drive with using PI controller

C. Simulation model of AC drive without controller for resistive load

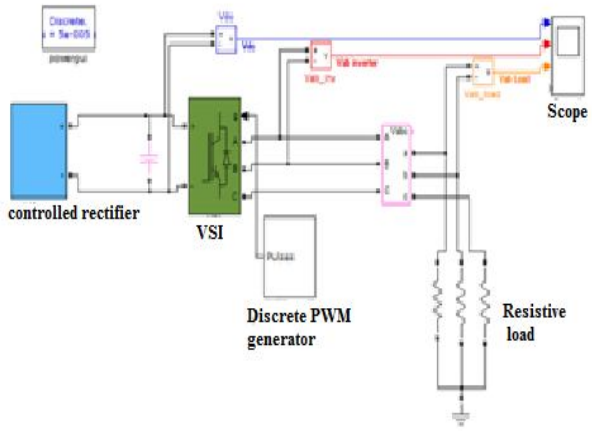


Fig. 4 Simulation model of AC drive for resistive load

An Ac drive is operated for resistive load by providing small AC input voltage. The high frequency filter element is not considered after the inverter. The result being the square wave output feeding a resistive load, and hence the harmonics of the line voltage will be comparatively high.

IV. HARDWARE IMPLEMENTATION

A prototype model of the AC drive system is built to validate the concept. Figure 4 shows the prototype model of Ac drive system. A step-down autotransformer provides dc voltage (5-15V) to 8051 microcontroller. Buffer is the one that provides electrical impedance transformation from one circuit to another, with the aim of preventing the signal source from being affected by whatever currents or voltages.

Driver provides the necessary voltage to drive the gate of IGBT. Voltage regulator provides precise voltages (5V/ 15V) to 8051 microcontroller, buffer and driver Ic's.

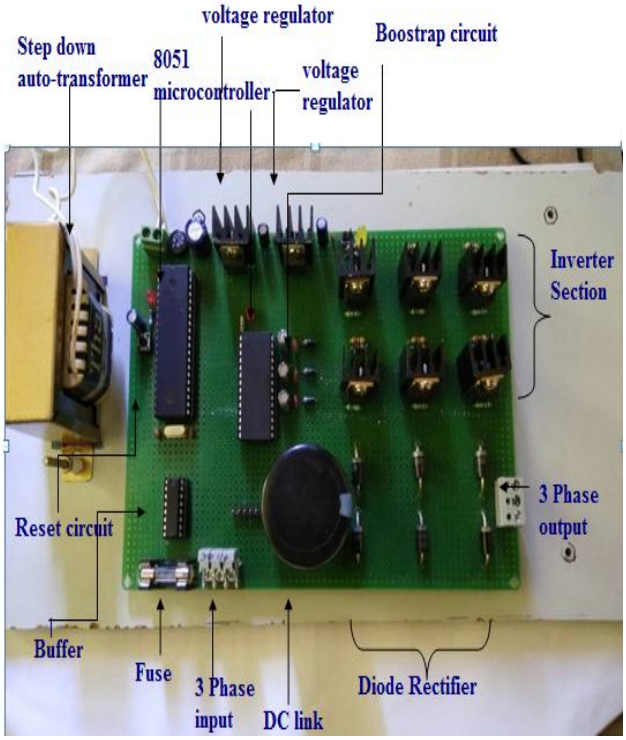
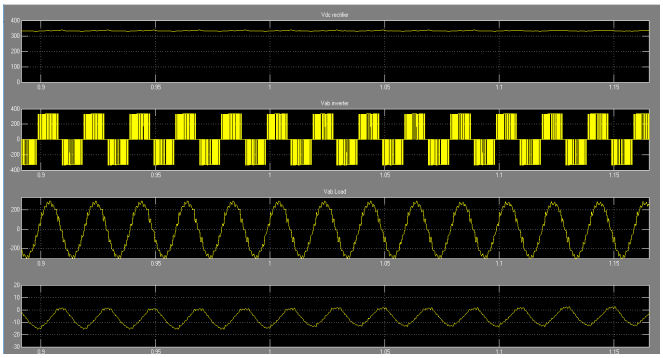


Fig. 5 Hardware prototype of Ac drive system without controller

V. RESULTS

For inductive load

A. Simulation results of AC drive without PI controller



a) Vdc rectifier, b) Vab inverter, c) Vab load d) Line current

Fig. 6 Output Voltages of AC drive without PI controller

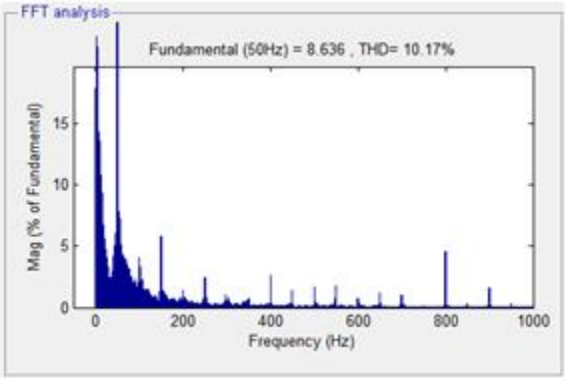
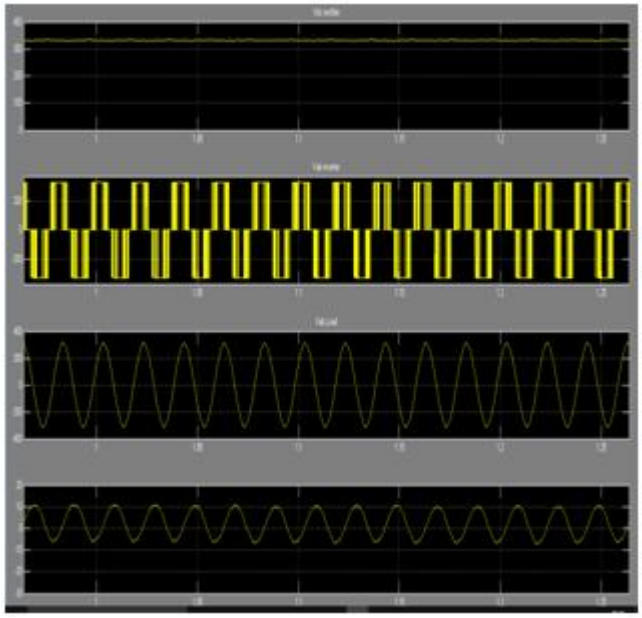


Fig. 7 THD without PI controller

B. Simulation results of AC drive with PI controller



a) Vdc rectifier, b) Vab inverter, c) Vab load d) Ia Line current

Fig. 8 Output Voltages of AC DRIVE with PI controller

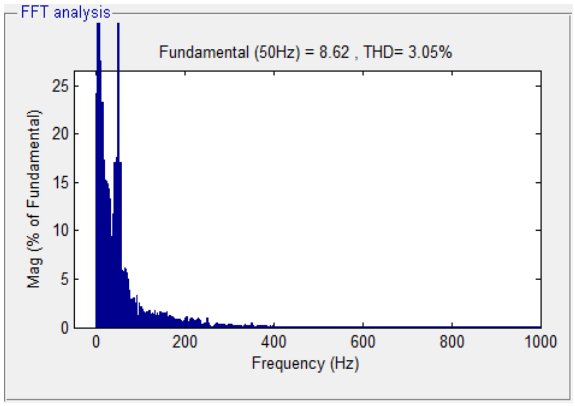


Fig. 9 THD with PI controller

- **For resistive load**

C. Simulation results of AC drive without PI controller

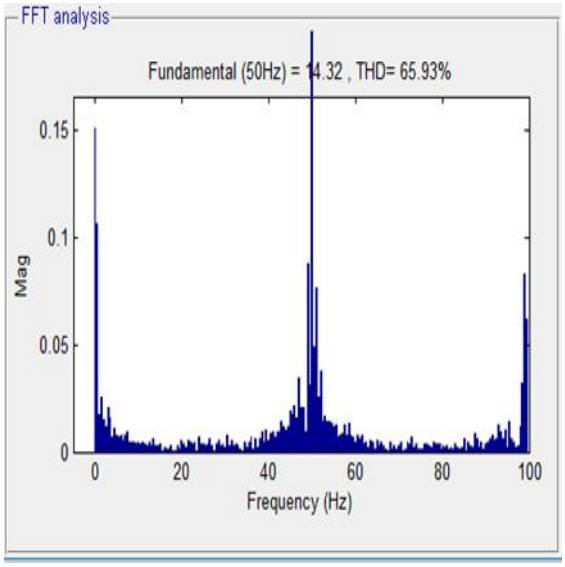


Fig. 10 THD without PI controller

D. Experimental results of AC drive

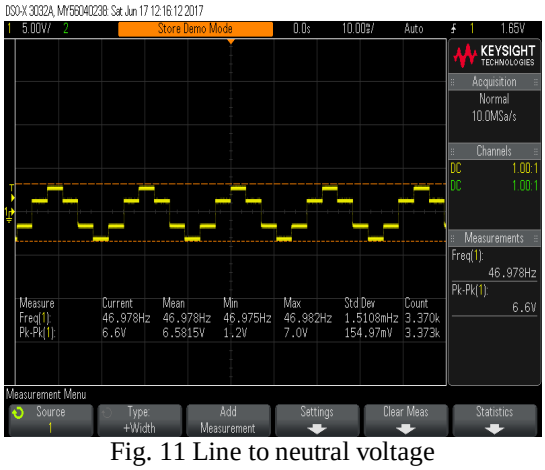


Fig. 11 Line to neutral voltage

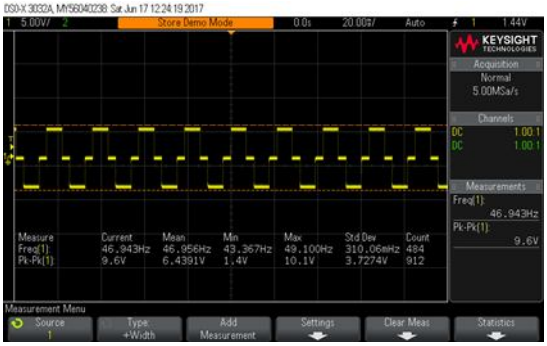


Fig 12. Line to Line voltage

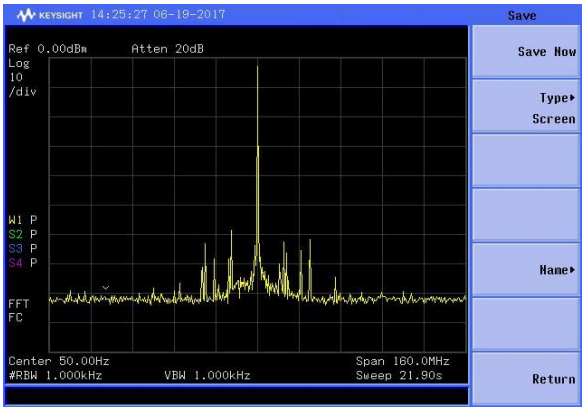
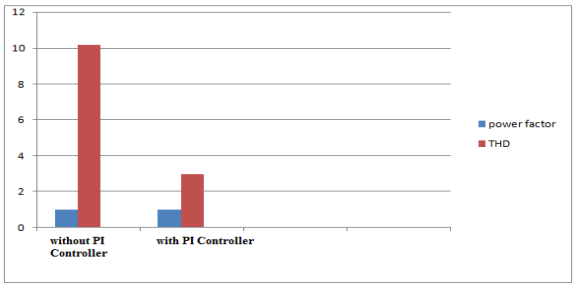
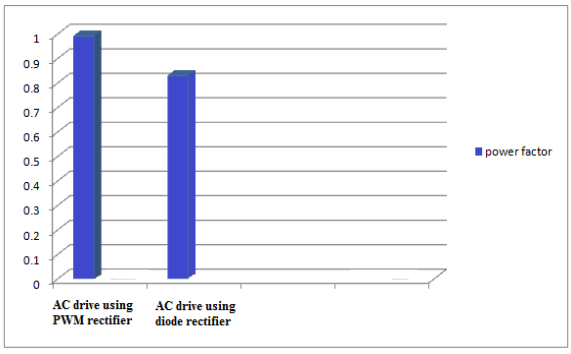


Fig.13 THD spectrum without PI controller

E. Comparison of AC drive with PI and without PI controller



F. Comparison of AC drive with PWM rectifier and diode rectifier



VI. CONCLUSION

In this paper, an effort is made to reduce the reactive power consumption by active shaping of input current and power factor near to unity is achieved.. The major concern with the converters is the content of harmonics. In this work, the THD is reduced to 3.05%. The spectrum of harmonics for a three phase star connected resistive load is observed for the experimental prototype and is compared with simulation model. On comparison, the spectrum of harmonics is symmetrical about axis. The sinusoidal waveform contain less harmonic when compared to square wave (65.93%). The use of PWM rectifier helps to improve the power factor of AC input line current compared to Diode rectifier. The PI controller effectively mitigated the total harmonic distortion.

REFERENCES

[1] Modeling and Analysis of Active Front-End Induction Motor Drive for Reactive Power Compensation"- Pankaj Prabhakar Pandit University of Tennessee – Knoxville-2005.

[2] "Sensorless control strategies for three phase PWM rectifier" – M.Sc Mariosz Malinowski, Dr.Sc.Marian P Kazmier Kauski".

[3] "Design of three phase PWM voltage source inverter for photovoltaic application" - Bandana Bhutia, Dr. S. M. Ali, Narayan Tiadi, IJIREEICE Vol. 2, Issue 4, April 2014

[4] "High Power Factor Operation of a Three Phase Rectifier for an Adjustable-Speed Drive" - Hiralal M. Suryawanshi, Abhishek K. Kulwal, Madhuri A. Chaudhari, and Vijay B. Borghate, IEEE Trans. Ind. Electron., 2008, 55.

[5] Mahasweta Bhattacharya, "Improvement of power quality using PWM rectifiers

[6] Singh, B., Gairola, S., Singh, B.N., Chandra, A., Al-Haddad, K.:"Multipulse AC–DC converters for improving power quality": a review', IEEE Trans. Power Electron., 2008, 23, (1), pp. 260–281.