EXPERIMENTAL VERIFICATION OF FOUR SWITCH PWM AC CHOPPER FED SINGLE PHASE INDUCTION MOTOR

[1]M. NARENDRA KUMAR, [2]P. SUJATHA, [3]K.S.R. ANJANEYULU

[1]Research Scholar, Jntuh, Hyderabad, India
[2]Dept. Of Electrical Engg., Jntua College Of Engineering, Anantapur, India
[3]Jntua Anantapur, India

ABSTRACT

To improve the performance of motor drives, there is a need to improve the quality and reliability of the drive system. With the high power handling capability of the switching device, pulse width modulated AC chopper can be used in high power applications. AC chopper using pulse width modulation provides substantial advantages over conventional line commutated AC controllers. To alleviate the problems associated with the conventional AC voltage controllers, pulse width modulated AC chopper fed induction motor drive is developed and presented in this paper with an appropriate control circuit. The FFT analysis for voltage and current is performed for the developed system. The simulation is done using matlab and the hardware is implemented using an embedded microcontroller. The experimental results are compared with the simulation results.

Key Words: *AC Chopper, Total Harmonic Distortion, Pulse Width Modulation, Induction motor.*

I. INTRODUCTION

Single Phase Induction Machine (SPIM) is most widely used than other machines due to their advantages such as simplicity in construction, reliability in operation, lightness and cheapness. The speed control of such motors can be achieved by controlling the applied voltage on the motor by the use of power electronic devices. The AC line commutated phase angle control or integral cycle control with thyristor technology has been widely used in the voltage regulators. They suffer from several disadvantages such as retardation of firing angle, enormous harmonics in motor and supply current, discontinuity of power flow to the motor.

The symmetrical pulse width modulated control technique for AC chopper control by varying the duty cycle is discussed in [3]. The AC power is adjusted by a circuit which uses four switches and examines the fundamental character of the circuit [4]. A novel drive for single phase induction motor has an attractive feature that it effects both frequency and phase angle simultaneously [1].

Improved circuit of AC Chopper for single phase systems use only a single pulse width modulated switch. The advantages of this system are simple design requirements, easy implementation and high power capacity. Power factor improvement of AC chopper using symmetrical and asymmetrical pulse width modulation is discussed in [5] and [8]. A pulse width modulated buck boost AC chopper which solves commutation problem and gives good steady state performance is discussed in [6]. Optimal harmonic reduction in AC/AC chopper converter is discussed in [7]. Improved circuit of AC Chopper system is given in [8]. In the literature, there is no reference to the embedded implementation of AC Chopper system with phase controlled AC Chopper system. In this work, an attempt is made to implement the four switch PWM AC Chopper fed induction motor drive using an Atmel microcontroller.

II. Four Switch PWM AC Chopper

The circuit shown in Fig.1 is a PWM AC Chopper for single phase system. It consists of four switches. The series switches S_1 and S_4 are used to connect and disconnect the motor terminals to the supply. The series switches S_3 and S_2 provide a freewheeling path. A diode connected in anti-parallel with each parallel switch is used to complete the freewheeling current paths. Gating of these switches based on equal PWM technique or constant pulse width method is efficient and simple to implement.

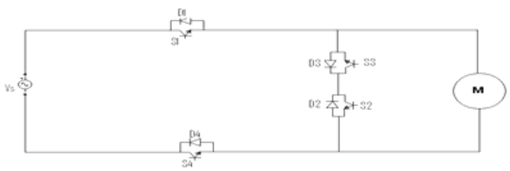

Fig.1 Circuit diagram of pulse width modulated AC Chopper.

When the source voltage is positive, switches S_3 and S_4 are turned on and S_2 is controlled by PWM. By turning S1 on, the current flows from source to the load.

Table1. Switching sequence

	S_1	S_2	S_3	S_4
Vs>0	PWM	PWM	ON	ON
Vs<0	ON	ON	PWM	PWM

When the source voltage is negative, switches S_1 and S_2 are turned on and switches S_3 and S_4 are controlled by PWM. The control method for positive and the negative period of the source is shown in Table 1.

The pulse generation circuit is shown in Fig 2. The generation of driving signals is accomplished by using the following control circuit.

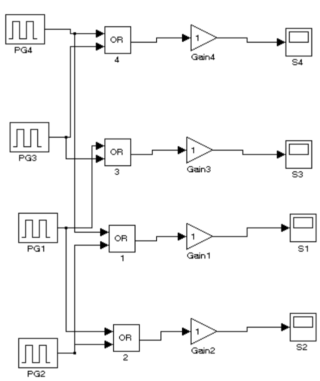

Fig.2 Pulse Generation circuit.

III. MODES OF OPERATION

The operation of AC chopper is divided in to three modes (1) Active mode (2) Freewheeling mode (3) Dead time mode.

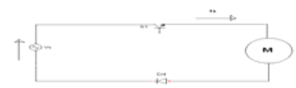

Fig.3a.Equivalent circuit for Active Mode.

Fig 3a shows the equivalent circuit for active mode of the positive half cycle. This represents the on state period of switches S_1 and S_4. When i_m >0, the motor current i_m flows through the switch S_1 and the body diode of the switch S_4.

The equivalent circuit of freewheeling mode for the positive half cycle is shown in Fig. 3b.

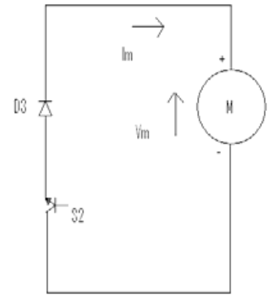

Fig.3b Equivalent circuit for Freewheeling Mode.

This mode represents the off- state periods of the switches S_1 and S_4. During this mode, the motor terminals are isolated from the supply and stator is short circuited.

During positive half cycle, S_2 and the body diode D_3 are conducting. The motor terminal voltage is zero and the current naturally decays through freewheeling switches.

Fig.3c shows an equivalent circuit for dead time mode of the positive half cycle.

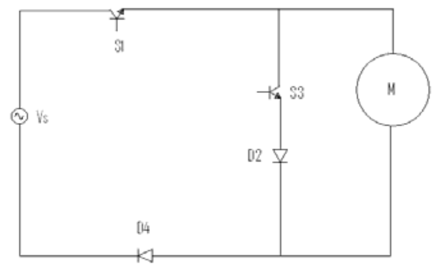

Fig.3c Equivalent circuit for Dead time Mode.

This mode is provided to avoid the voltage and current spikes. During the positive half cycle, switches S_2 and S_4 are turned on for safe commutation.

IV. SIMULATION RESULTS

The Performance of phase controlled AC Chopper is examined by simulation. The simulation is done using MATLAB and the results are presented. The AC Chopper simulation circuit is shown in Fig.4a. The voltage and current are sensed and these signals are applied to the power measurement block. The power drawn is displayed. Current waveforms with pulse width 10%, 20%, 30% and 40% are shown in figures 4b, 4c, 4d and 4e respectively. Current drawn by the motor increases with the increase in pulse width. The variation of current with the pulse width is shown in Fig.4f. The variation of power with the variation in pulse width is shown in Fig.4g.

Table 2 Parameters used for Simulation

V_s	**100V**
R	**10Ω**
L	**10 mH**
S_1 , S_2, S_3, S_4	**Switches**
C_1, C_2	**10µF**
R_1, R_2	**0.001Ω**

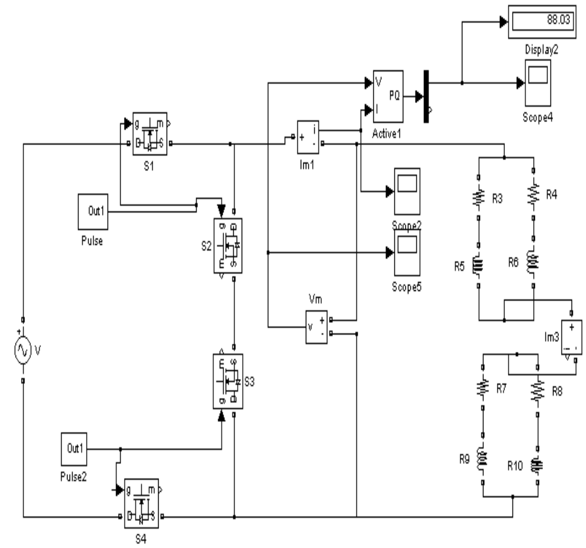

Fig. 4a AC Chopper circuit

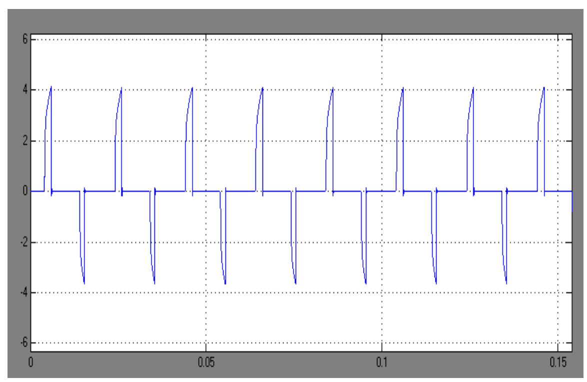

Fig. 4b current with 10 % pulse width

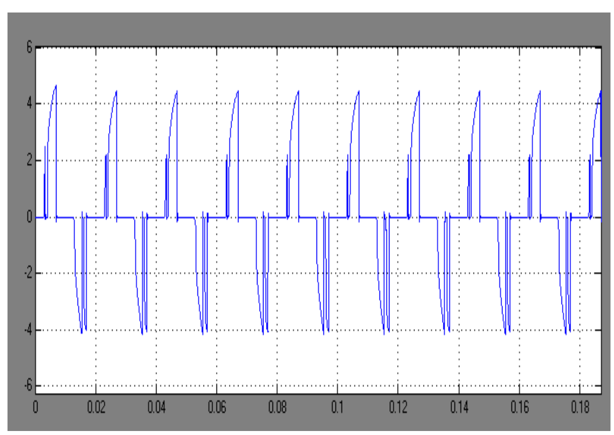

Fig. 4c current with 20 % pulse width

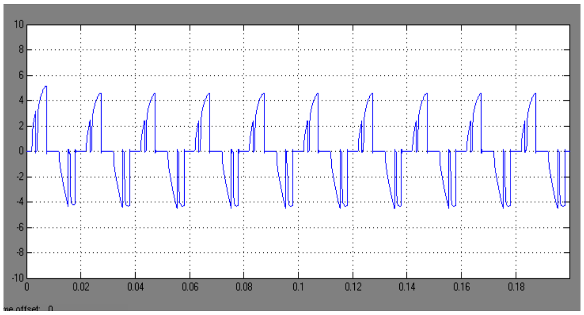

Fig. 4d current with 30 % pulse width

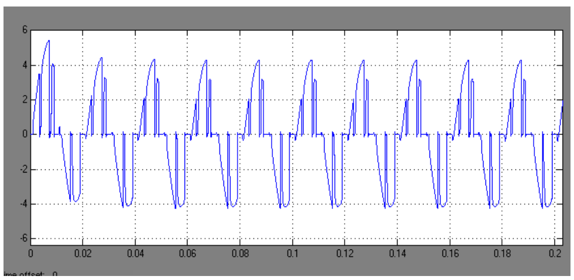

Fig. 4e current with 40 % pulse width

PULSE WIDTH %	CURRENT (AMP)	POWER(WATTS)
10	4.0	11.38
20	4.3	45.45
30	4.6	88.45
40	4.8	104.2

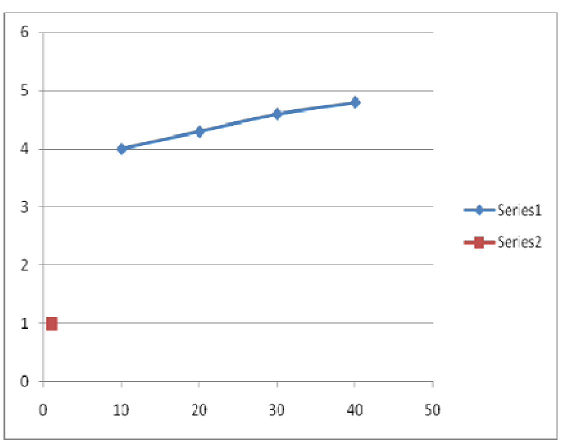

Fig.6f Output current V/S Pulse width

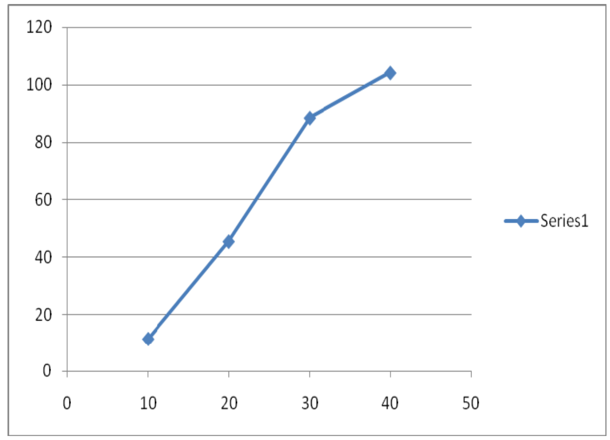

Fig. 6g Power V/S Pulse width AC chopper using 4 switch.

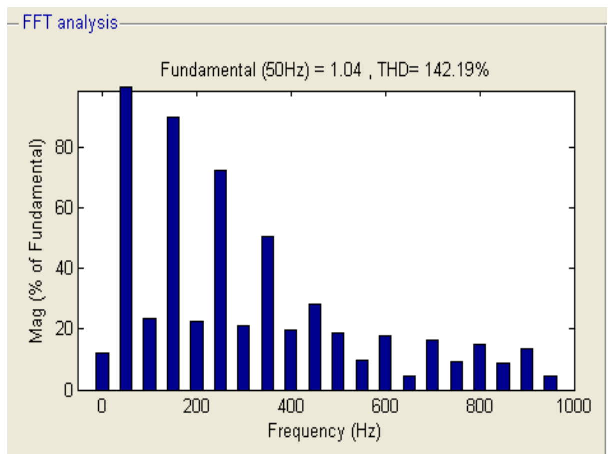

Fig. 6h FFT analysis of current with 10 % pulse width

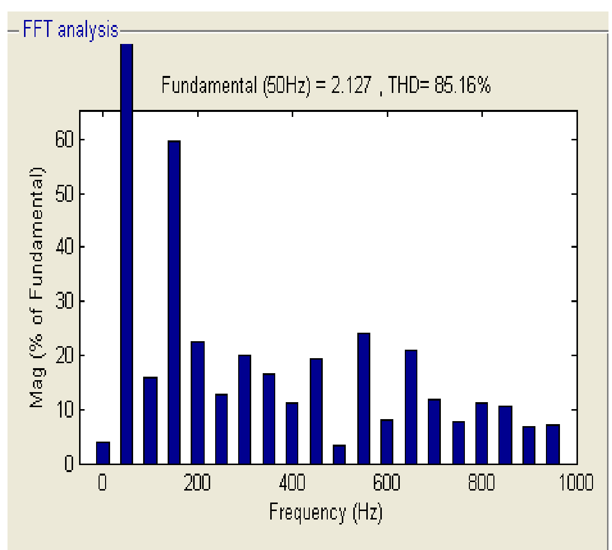

Fig.6i FFT analysis with 20% pulse width

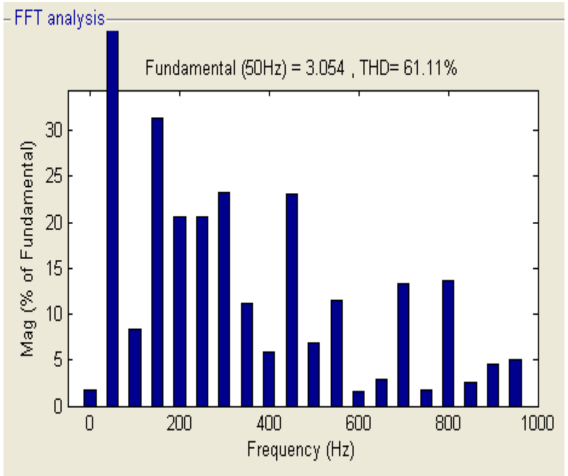

Fig.6j FFT analysis with 30% pulse width

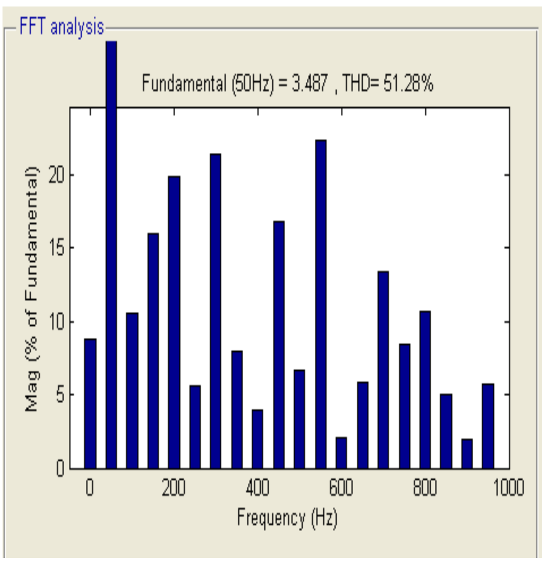

Fig.6k FFT analysis with 40% pulse width

V. EXPERIMENTAL RESULTS

The pulses needed by the AC Chopper are developed using the microcontroller 89C2892051. Hardware implementation of AC chopper fed drive is shown in Fig. 7a. The hardware consists of ZCD, driver circuit and the power circuit. AC input voltage is shown in Fig 7c. These pulses are generated by using Atmel microcontroller. They are amplified by using a driver amplifier. The amplified pulses are applied to the MOSFET of the AC chopper. Output voltage of AC chopper is shown in Fig 7d.

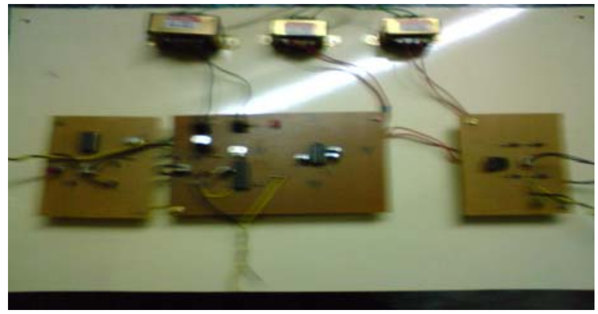

Fig.7a Hardware Implementation

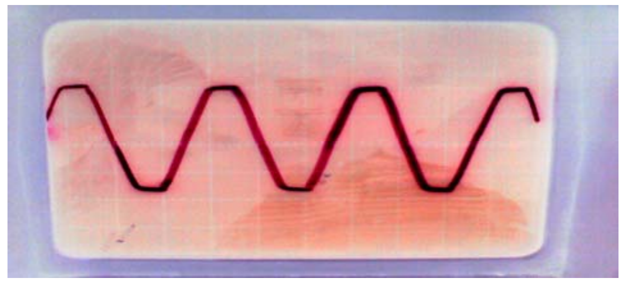

Fig.7b AC Input Voltage

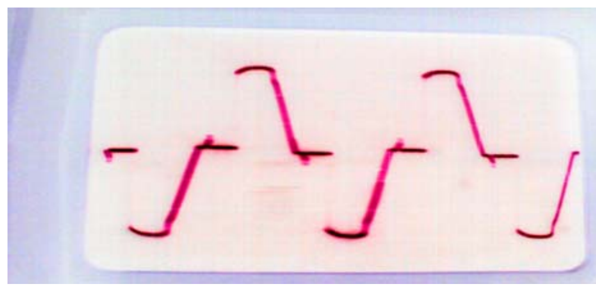

Fig. 7c Driving pulses

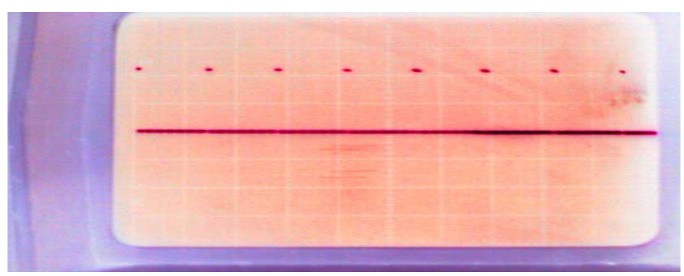

Fig. 7d Voltage across the Motor

VI. CONCLUSION

The circuit for the pulse width modulated AC Chopper is presented and the results are obtained by simulation and implementation. The simulation results show that THD of the output in this system is less than that of phase controlled chopper system. The heating of the motor is reduced due to the reduction in THD. Hence the performance of drive system is improved. The studies indicate that PWM AC Chopper is a viable alternative to the phase controlled converter for the control of induction motors. From the investigations, it is observed that the energy can be saved and harmonics can be reduced using PWM AC Chopper. The experimental results closely agree with the simulation results.

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AUTHOR BIOGRAPHY:

M. Narendra Kumar has obtained B.E. degree in Electrical Engg. from Gulbarga University, M.S. from BITS and M.Tech. from JNTU, Anantapur subsequently. Now he is pursuing his research in the area of Energy Management. He is working at Guru Nanak Engineering College, Hyderabad (A.P.) as a Professor in the Department of EEE.He is a life member of ISTE and Member of IEEE.

P.Sujatha, presently working as, Assoc. Professor, Department of Electrical and Electronics Engineering, J.N.T.U. College of Engineering, Anantapur,-515002, Andhra Pradesh, India. She completed her B.Tech degree in 1993 and M.Tech Degree with specialization in Electrical Power Systems in 2003 from J.N.T.U.College of Engineering, Anantapur, Andhra Pradesh, India. She has nearly 15 years of teaching experience and her areas of interest include Reliability Engineering with emphasis to Power Systems and Real time Energy Management. She is currently working towards her PhD in Electrical Engineering at Jawaharlal Nehru Technological University Anantapur.

K.S.R. Anjaneyulu, Professor of Electrical & Electronics Engineering is presently working as Director, Research & Development Cell, J.N.T.U, Anantapur, Andhra Pradesh, India. He has completed his B.Tech degree in February 1982, M.Tech Degree in February 1985 and Ph.D. in July 1999. He has 25 years of teaching experience and his research areas of interest include Power systems, FACTS devices, Energy management, Neuro-Fuzzy and Genetic Applications.