SIMULATION OF FOUR SWITCH PWM AC CHOPPER FED SINGLE PHASE INDUCTION MOTOR

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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 IGBT, 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. FFT analysis for voltage and current is performed for the developed system. The harmonics are reduced by using LC filter at the output. It is proved that total harmonic distortion obtained from the developed circuit is less than that of phase controlled AC chopper system. Simulation results closely agree with the analytical predictions.

Keywords: AC Chopper, Total Harmonic Distortion, Pulse Width Modulation, Induction motor.

1. 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 choppers control the motor voltage by varying the duty cycle is discussed in [5]. The AC power is adjusted by a circuit which uses four switches and examines the fundamental character of the circuit [7]. A novel drive for single phase induction motor has an attractive feature that it effects both frequency and phase angle simultaneously [1].

2. 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

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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.

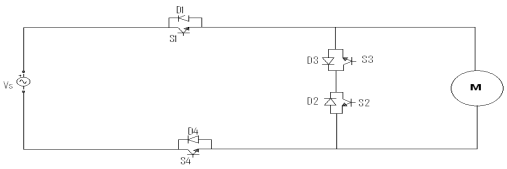

Fig.1. Circuit diagram of pulse width modulated AC Chopper.

When the source voltage is positive, switches S_3 and S_4 are turned on and S_2 is controlled by PWM. By turning S_1 on, current flows from source to the load.

Table 1 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.

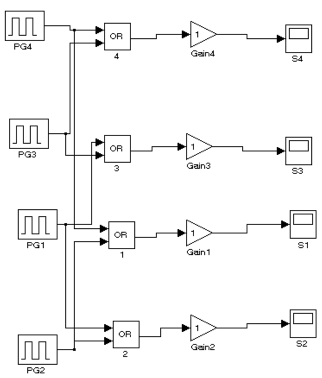

Fig.2. Pulse Generation circuit.

3. MODES OF OPERATION

The operation modes are divided in to three modes: 1. Active mode 2. Freewheeling mode 3. Dead time mode.

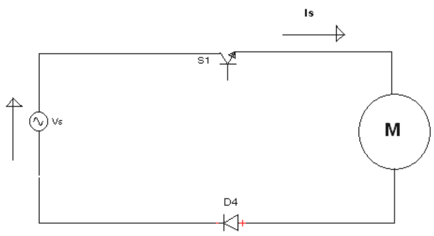

Fig.3. Equivalent circuit for Active Mode.

Fig.3 shows an 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. 4.

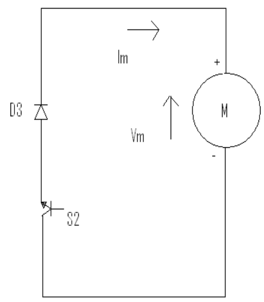

Fig.4. Equivalent circuit for Freewheeling Mode.

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.5 shows an equivalent circuit for dead time mode of the positive half cycle.

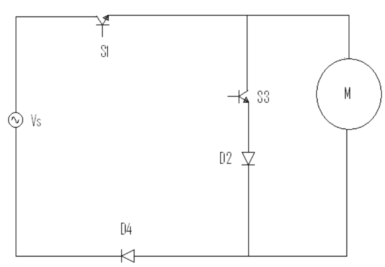

Fig.5. Equivalent circuit for Dead time Mode.

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.

4. SIMULATION RESULTS

The Performance of phase controlled AC Chopper is examined by simulation. Simulation is done using MATLAB and the results are presented. The AC Chopper simulation circuit is shown in Fig.6. The voltage and current are sensed and these signals are applied to the power measurement block. The power drawn is displayed. FFT analysis with pulse width 20%, 40%, 60% and 80% are shown in figures 7, 8, 9, and 10 respectively. Current drawn increases with the increase in pulse width. The variation of current with the pulse width is shown in Fig.11. The variation of power with the variation in pulse width is shown in Fig.12.

Table 2 Parameters used for Simulation

Vs	100V
R	10Ω
L	10 mH
S1 , S2, S3, S4	Switches
C1, C2	10µF
R1, R2	0.001Ω

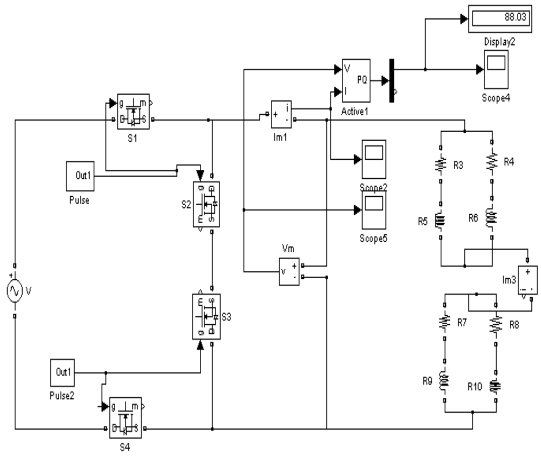

Fig.6. AC Chopper circuit diagram.

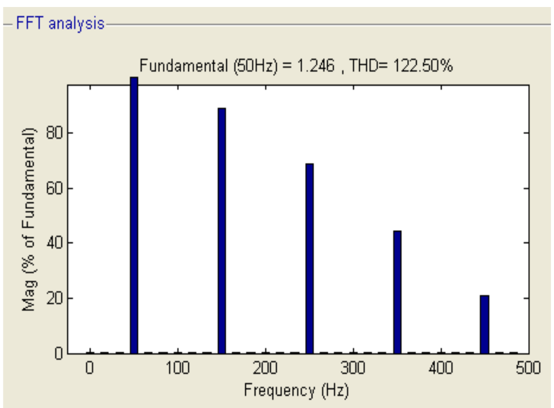

Fig.7. FFT analysis of input current at 20%Pulse width.

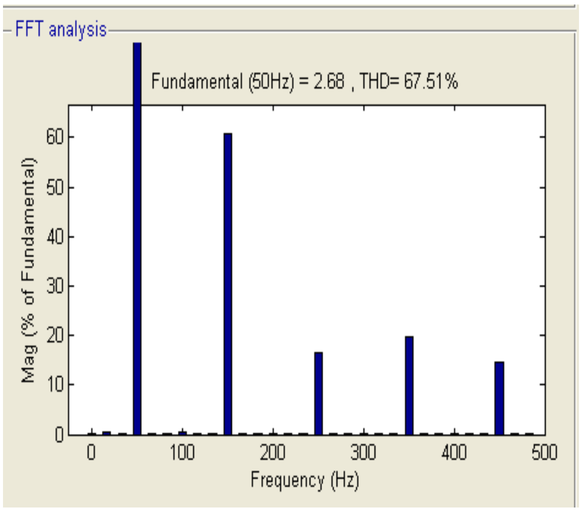

Fig.8. FFT analysis of input current at 40%Pulse width.

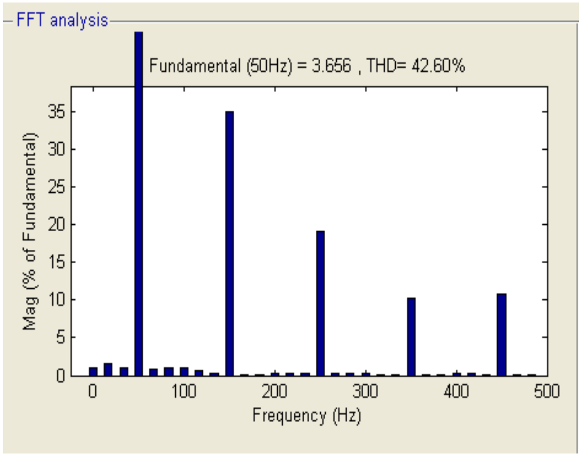

Fig.9. FFT analysis of input current at 60%Pulse width.

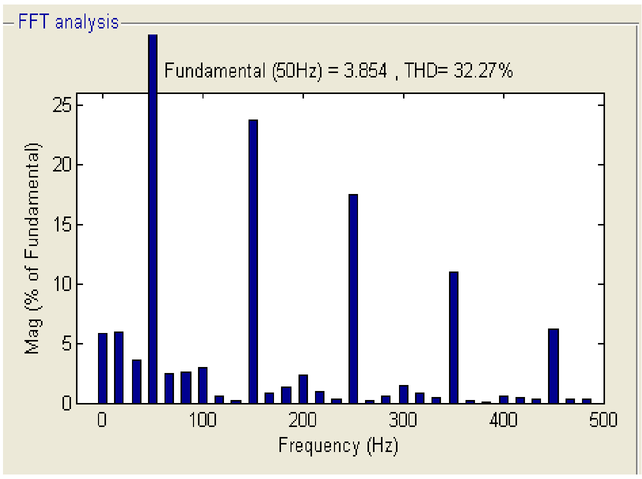

Fig.10. FFT analysis of input current at 60%Pulse width.

Table 3

Pulse Width %	Current (AMP) RMS	Voltage (V) RMS	Power (W)	THD
20	0.535	11.52	11.38	122
40	1.19	34.59	45.45	67.5
60	1.16	56.12	88.45	43.0
80	1.99	73.2	104.2	32.2

As shown in Table 3 variation of THD with Pulse width. THD increases with decrease in Pulse width.

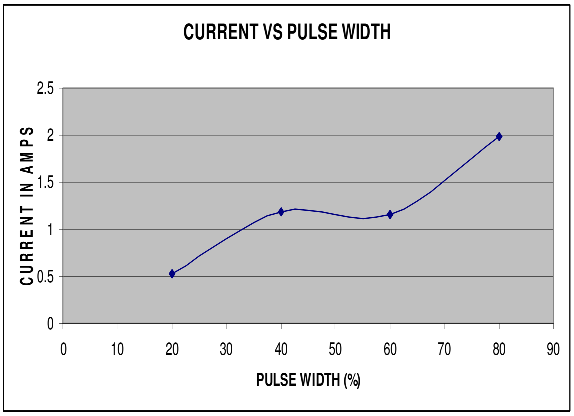

Fig.11. Output current V/S Pulse width.

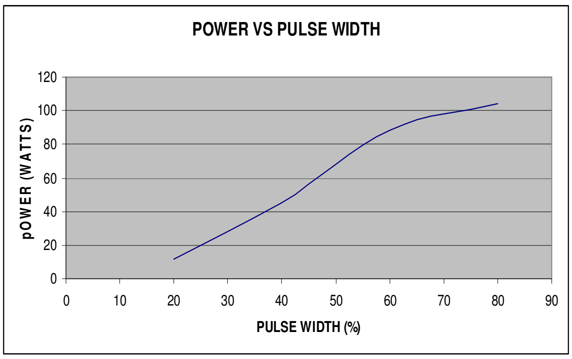

Fig.12. Power V/S Pulse width.

4.1. THD with Filter

The AC Chopper simulation circuit with Filter is shown in Fig.13. Current waveforms with pulse 20%, 40%, 60% and 80% are shown in figures 14, 16, 518 and 20 respectively. FFT analyses of AC Chopper output with Filter are shown in figures 15, 17, 19 and 21 respectively.

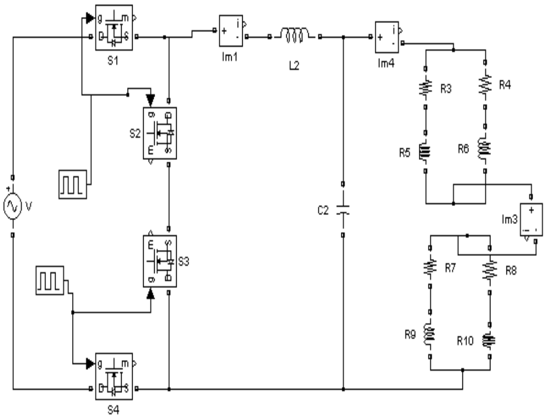

Fig.13. Circuit diagram with filter

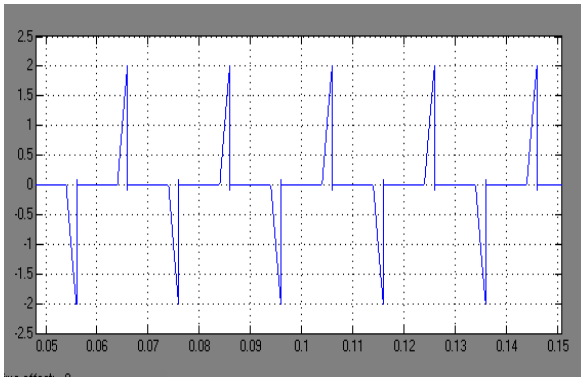

Fig.14. Output current with 20% pulse width

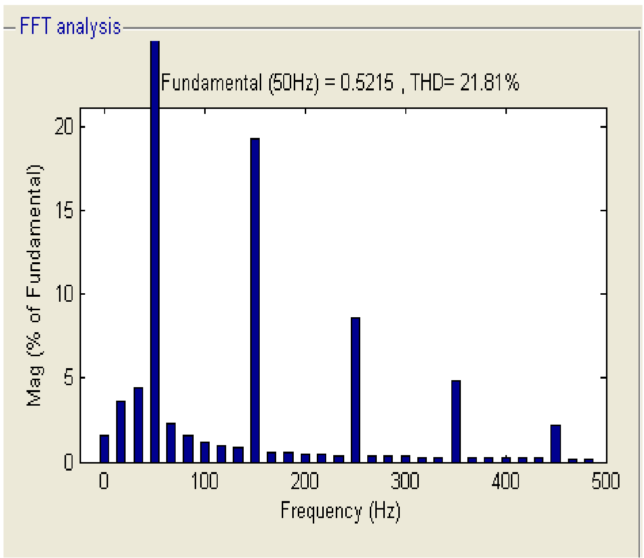

Fig.15. FFT analysis of current with 20% pulse width

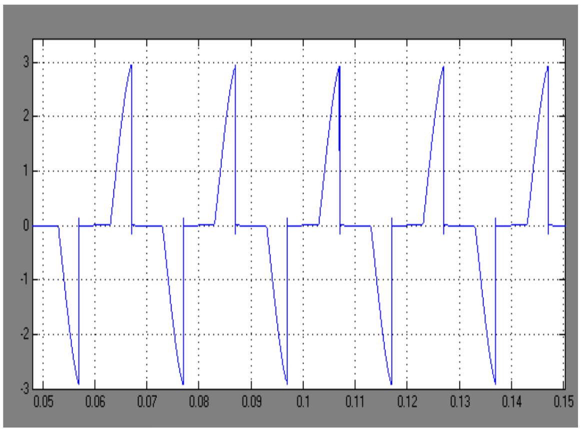

Fig.16. Output current with 40% pulse width

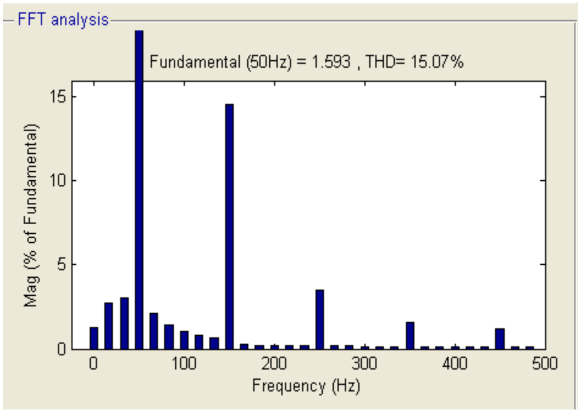

Fig.17. FFT analysis of current with 40% pulse width

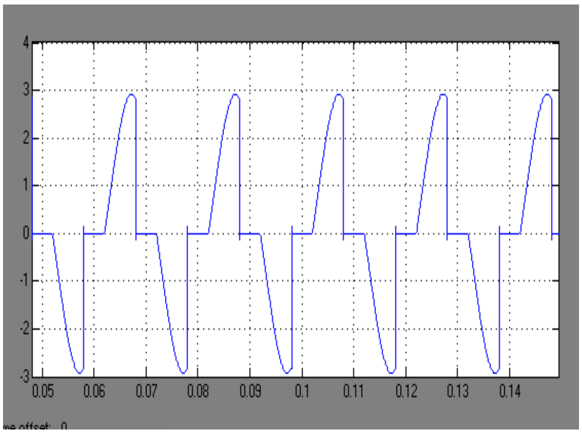

Fig.18. Output current with 60% pulse width

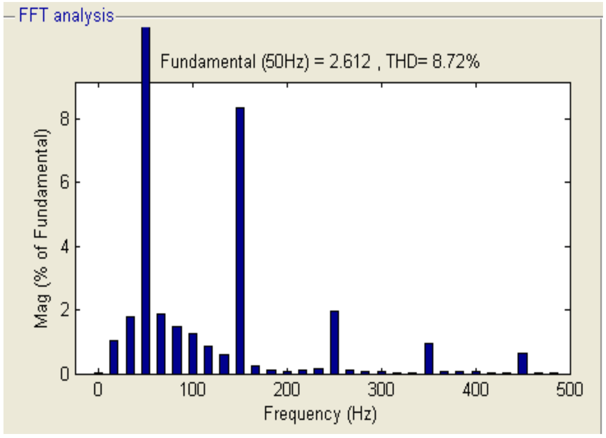

Fig.19. FFT analysis of current with 60% pulse width

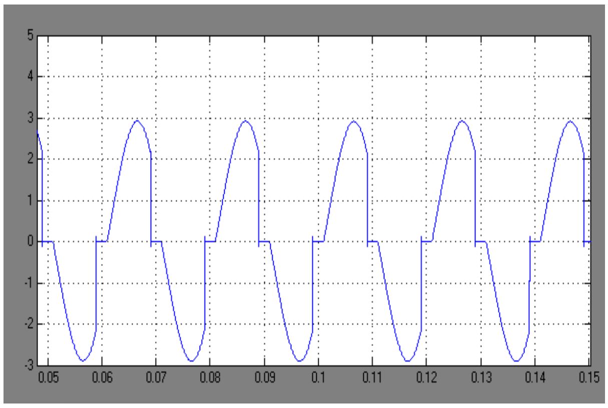

Fig.20. Output current with 80% pulse width

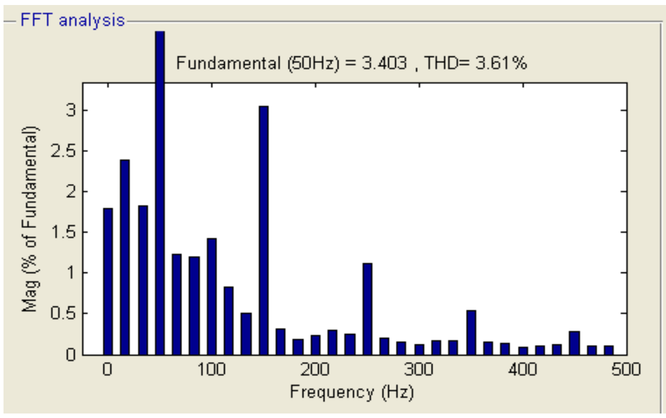

Fig.21. FFT analysis of current with 80% pulse width

Table 4

PULSE WIDTH %	THD WITHOUT FILTER	THD WITH FILTER
20	122	21.18
40	67.5	15.07
60	43.0	8.72
80	32.2	3.61

As shown in Table 4 THD variation at different pulse width with and without filter. THD is reduced by using LC filter. It can be seen that the THD with filter is 10% of the THD without filter.

5. CONCLUSION

The circuit for the pulse width modulated AC Chopper is presented and the results are obtained by simulation. The simulation results show that THD of output voltage and current in this system is less than that of phase controlled chopper circuit. The heating of the motor is reduced due to the reduction in THD. Hence the performance of drive system is improved.

The simulation results 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. There is a great reduction in the harmonics by using LC filter.

6. REFERENCES

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