

CLOSED LOOP CONTROLLED PFC BOOST CONVERTER FED DC DRIVE

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Abstract

This paper deals with the simulation and implementation of Boost Power Factor Correction (PFC) Converter fed DC drive. The Boost Converter Circuit is analyzed, designed and simulated with motor load. The circuit has advantages like reduced harmonics and improved power factor. Near unity power factor is obtained by using Boost PFC Converter with EMI Filter. The laboratory model is implemented and the experimental results are obtained. These experimental results are correlated with the simulation results.

Keywords: Power Factor Correction, Electro Magnetic Interference, diode, rectifier, boost converter.

I. INTRODUCTION

NOTATIONS:

$V_{in(nom)}$ Normal value of input voltage

$V_{in(Min)}$ Minimum value of input voltage

$V_{in(peak)}$ Maximum value of input voltage

f_s Switching Frequency

f_{line} Line frequency

P_o Output Power

$T_{ambient}$ Surrounding temperature

S Power MOSFET

C_x Input Capacitor of EMI Filter

C_y Output Capacitor of EMI Filter

L_c Inductor for Common Mode Noise

L_d Inductor for Differential Mode Noise

L_b Boost Inductor

D_p Power Diode

C_o Output capacitor

EMI Electro Magnetic Interference

PFC Power Factor Correction

Electromagnetic pollution of the power line introduced by power electronic systems include harmonic distortion due to nonlinear loads, typically, rectifiers [1]. So, various types of single phase PFC converter circuits to improve the AC current waveform have been developed and used [2] – [5]. A boost chopper circuit constructs the PFC converter

with a switching device in the DC side of the diode bridge rectifier circuit. Good characteristics such as a sinusoidal current waveform in phase with the AC line voltage and the constant DC voltage can be obtained from the PFC converter.

Electro Magnetic Interference is related with the disturbance caused due to electro magnetic waves to the operation of any electronic circuit. Because of rapid change in voltages and currents within a switching converter, power electronic equipment is a source of electro magnetic interference with other equipment as well as with its own proper operation. So, Electro Magnetic Interference Filter (EMI Filter) has to be used at the input of PFC converter. Literature [6] deals with design of Boost Power Factor Correction Converter using genetic algorithms. Conducted EMI analysis of boost PFC Converter is presented in [7]. A method for EMI study in PFC rectifier is given by [8]. EMI considerations in Power Electronic Converters are given by [9]. Concept of inductor design is presented in [10] and soft switching techniques in PWM converters are given by [11]. Single Phase PFC converter active clamping is proposed by Feng [12]. Single Phase boost rectifier system for wide range of load variations is given by Ghosh [13]. In the literature mentioned above, the hardware implementation of boost converter fed DC motor using Atmel microcontroller is not available. In this paper, the hardware details of embedded microcontroller based boost converter are presented.

II. BOOST POWER FACTOR CORRECTION CONVERTER

The thyristor for PFC converter with different firing angles will give less output power, more harmonics and less power factor as compared with Diode rectifier. Hence, the diode rectifier is used as a dc input source to the Boost converter as shown in Fig. 1.

The boost converter has V_d as the input voltage and V_o as the output voltage. Here, output voltage is greater than the input voltage. A large inductor L in series with the source voltage is essential. When the switch is on, the input current flows through the inductor and switch and the inductor stores the energy during this period. When the switch is off, the inductor current cannot die down instantaneously, this current is forced to flow through the diode and the load during this off period. As the current tends to decrease, polarity of the emf induced in L is reversed. As a result, a voltage across the load is the sum of supply voltage and inductor voltage and it is greater than the supply voltage.

The voltage impressed across the inductor during on-period is V_d . During this period, the current rises linearly from a minimum level I_1 to a maximum level I_2 . Therefore the voltage across inductor is,

$$V_L = V_d \quad (1)$$

Also,

$$V_L = L(I_2 - I_1) / T_{on} = L(DI) / T_{on} \quad (2)$$

From (1) and (2),

$$T_{on} = L(DI) / V_d \quad (3)$$

The voltage impressed across the inductor during off period is $(V_o - V_d)$ and the current drops linearly from the maximum level I_2 to the minimum level I_1 . Therefore the voltage across the inductor is,

$$V_L = (V_o - V_d) \quad (4)$$

Also,

$$V_L = L(I_2 - I_1) / T_{off} = L(I) / T_{off} \quad (5)$$

From (4) and (5),

$$T_{off} = L(DI) / (V_o - V_d) \quad (6)$$

$$\text{From (3), } L(DI) = T_{on} * V_d \quad (7)$$

$$\text{From (6) } L(DI) = T_{off} * (V_o - V_d) \quad (8)$$

From (7) and (8)

$$T_{on} * V_d = T_{off} * (V_o - V_d)$$

$$\text{Or } V_o = (T_{on} + T_{off}) * V_d / T_{off}$$

$$\text{Or } V_o = T * V_d / T_{off}$$

$$\text{Or } V_o = V_d / (1 - a) \quad (9)$$

Where a = delay angle of the boost converter. As firing angle increase from 0 to 1, the output voltage ideally increases from V_d to infinity. Hence, the output voltage is boosted.

III. ELECTRO MAGNETIC INTERFERENCE FILTER

The Electro Magnetic Interference is transmitted in two forms: radiated and conducted. The switching converters supplied by the power lines generate conducted noise into the power lines that is usually several orders of magnitude higher than the radiated noise into free space. Metal cabinets used for housing power converters reduce the radiated component of the electromagnetic interference.

Conducted noise consists of two categories commonly known as the differential mode and the common mode. The differential mode noise is a current or a voltage measured between the lines of the source, that is line to line voltage. The common mode noise is a voltage or a current measured between the power lines and ground, that is line to ground voltage.

An EMI filter is needed to reduce the differential mode and common mode noises. The filter comprises of inductors and capacitors as shown in Fig. 1a.

IV. SIMULATION RESULTS

The boost converter system is simulated using Matlab simulink. The A.C. source with EMI filter is shown in Fig. 1a. Noise is injected by using an additional source of higher frequency connected in series. Distorted input voltage is shown in Fig. 1b. The voltage waveform after EMI filter is shown in Fig. 1c. The circuit diagram of open loop system with disturbance is shown in Fig. 2a. Rotor speed curve is shown in Fig. 2b. The circuit of closed loop system is shown in Fig. 3a. Driving pulses for the MOSFET are shown in Fig. 3b. Error signal is shown in Fig. 3c. From the response of closed loop system, it can be seen that the speed reaches the set value.

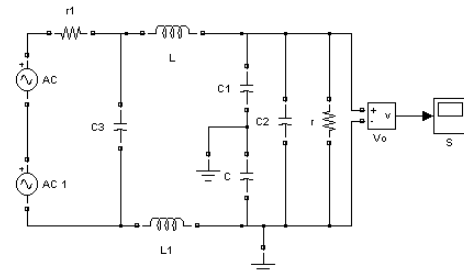


Fig. 1a. EMI Filter Circuit

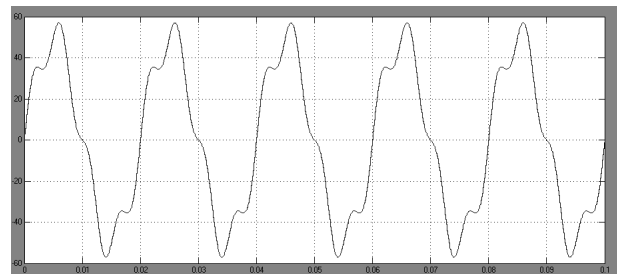


Fig. 1b. Input Voltage before EMI filter

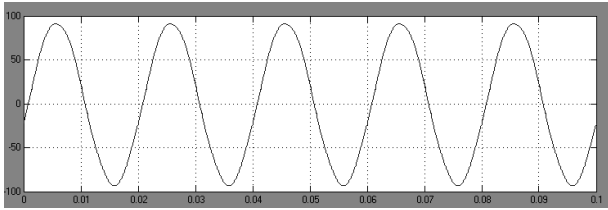


Fig. 1c. Voltage after EMI Filter

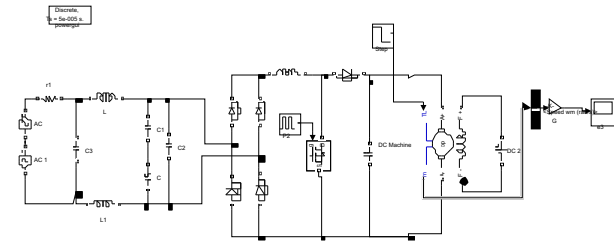


Fig. 2a. Simulation circuit of open loop system

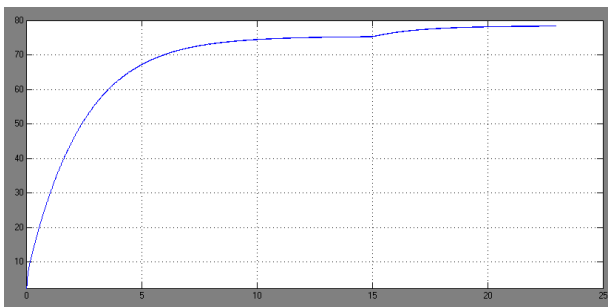


Fig. 2b. Rotor speed (RAD/Sec) with disturbance in open loop system

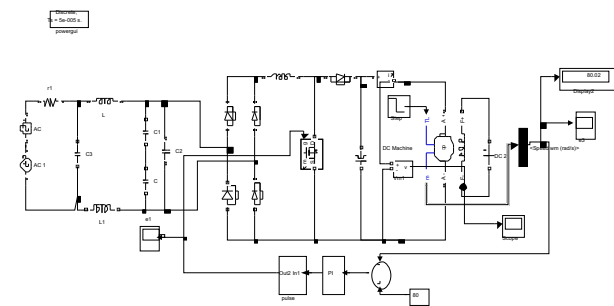


Fig. 3a. Circuit diagram for closed loop system

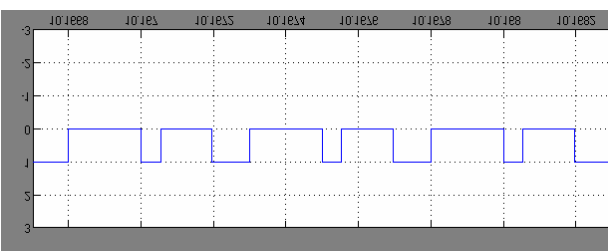


Fig. 3b. Output pulses

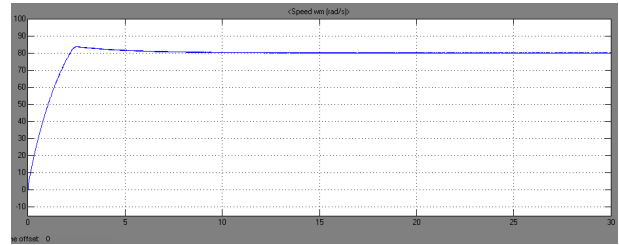


Fig. 3c. Rotor Speed (Rad/Sec) With Disturbance In Closed Loop System

V. EXPERIMENTAL RESULTS

The boost converter is fabricated and tested with DC motor load. The top view of the hardware is shown in Fig. 4. The control pulses are generated using the Microcontroller 89C2051. These pulses are amplified to 10 V using the driver IC IR 2110. The output of the driver chip is applied to the gate of the MOSFET.

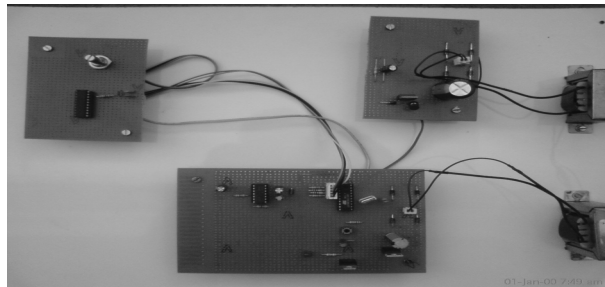


Fig. 4. Hardware of the Boost Converter

The experimental results are obtained and they are presented here. The oscillogram for driving pulses is shown in Fig. 5. The oscillogram of voltage across MOSFET is shown in Fig. 6. The output of the boost converter is shown in Fig. 7

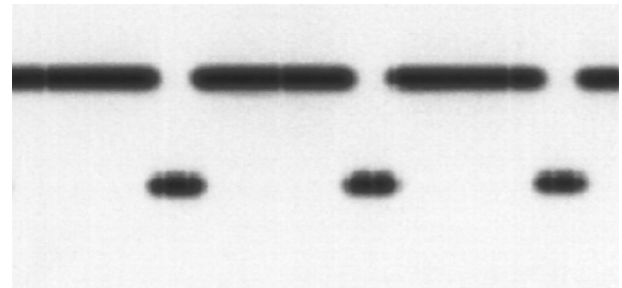


Fig. 5. Driving Pulses

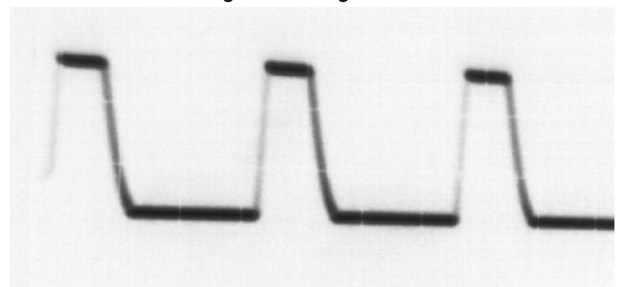


Fig. 6. Voltage Across S1

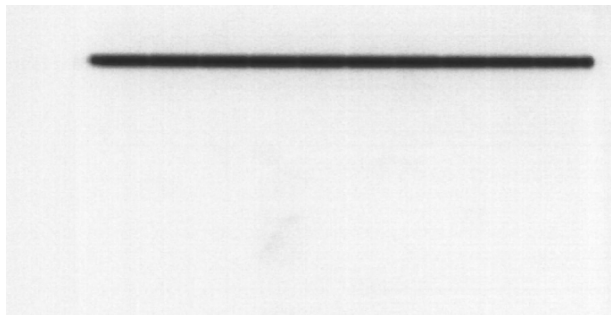


Fig. 7. Output Voltage

VII. CONCLUSION

The Boost Converter fed DC drive is analyzed, simulated and fabricated. The Boost Power Factor Correction (PFC) Converter along with the Electro Magnetic Interference (EMI) Filter is also simulated. From the simulation results, it is observed that the best power factor can be obtained by using Boost PFC Converter along with EMI Filter. The simulation studies prove that the Boost PFC Converter with EMI filter is a viable alternative for the control of DC motor. The laboratory model for boost converter with EMI filter is implemented. The circuit is tested with motor load. The experimental results are presented in this paper. The experimental results closely agree with the simulation results.

REFERENCES

- [1] W.Chew, P Evans and W Heffernan, 1991, "Inductor design concepts for high frequency applications", EPE FIRENZE, pp. 1.019-1-1.024.
- [2] Guichao Hua and F C Lee, 1993, "Soft switching techniques in PWM converters", IEEE IECON, pp. 637-643.
- [3] A W Zhang, M. T Zhang and F C Lee, 1997, "Conducted EMI analysis of a boost PFC Circuit", 1997, Proc. IEEE Applied Power Electronics conf., vol. 1, pp. 223-229.
- [4] J C Crebier, M Brunello and J P Ferrieux, 1999, "A new method for EMI study in PFC rectifiers", Proc. IEEE Power Electronics Spc. Conf., pp. 855-860.
- [5] L.Rossetto, P.Tenti and A. Zucato, 1999, "Electromagnetic Compatibility issue in industrial equipment", IEEE Ind. Applications, Mag., pp. 34-36.
- [6] J. Qian and F.C. Lee, "Charge pump power factor correction technologies part I and Part II", 2000, IEEE Trans. Power Electronics, vol. 15, pp. 121-139.

- [7] T. Ohnishi and M. Hojo, 2000, "Single phase PFC converter with switching pulse free chopper", 2000, Proc. Tokyo, Japan, pp. 1796-1801.
- [8] T. Ohnishi, 2000, "Binary controlled single phase PFC rectifier", Nagoya, Japan, pp. 2666 – 2671.
- [9] P Evans and W Heffernan, 2001, "Electromagnetic considerations in power electronic converters", , Proc. IEEE, vol. 89, No. 6, pp. 864-875.
- [10] T. Ohnishi and. M.Hojo, 2002, "Single phase PFC converter constructed by ac line voltage waveform detection", Proc. SPC , pp. 7-11.
- [11] S. Busquets – Monge, G. Soremekun, 2002, "Design of a boost power factor correction converter using genetic algorithms", proc. IEEE Applied Power Electronics Conf., vol. 2, pp. 1177-1182.
- [12] Bo Feng and Dehong Xu, 2005, "1-kW PFC converter with compound active clamping", IEEE transactions power electronics, pp. 324 – 330.
- [13] Ghosh and Narayanan, 2007, "A Single Phase Boost Rectifier System for Wide Range of Load Variations", IEEE transactions power electronics, pp. 470 – 476.



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