# Simulation and Design of Closed Loop Controlled PFC Boost Converter with EMI Filter

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***Abstract****—This paper deals with the simulation and implementation of Boost Power Factor Correction (PFC) Converter along with Electro Magnetic Interference (EMI) Filter. The Boost Converter of PFC Circuit is analyzed, designed and simulated with resistive load. 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

Electromagnetic pollution of the power line introduced by power electronic systems include harmonic distortion due to non-linear 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] Because of rapid change in voltages and currents within a switching converter, power electronic equipment is a source of electromagnetic 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] The concept of inductor design is presented in[10] and soft switching techniques in PWM converters are given by.[11] In the literature mentioned above, the hardware implementation of boost converter using Atmel microcontroller is not available. In this paper, the hardware details of embedded microcontroller based boost converter are presented.

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## 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 Figure 1. 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,

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

Also,

$$V_L = L\,(I_2 – I_1)/T_{on} = L\,(\Delta I)/T_{on} \quad \dots (2)$$

From (1) and (2),

$$T_{on} = L\,(\Delta I)/V_d \quad \dots (3)$$

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,

$$V_L = (V_o – V_d) \quad \dots (4)$$

Also,

$$V_L = L\,(I_2 – I_1)/T_{off} = L\,(\Delta I)/T_{off} \quad \dots (5)$$

From (4) and (5).

$$T_{off} = L\,(\Delta I)/(V_o – V_d) \quad \dots (6)$$

From (3),

$$L(\Delta I) = T_{on} * V_d \quad \dots (7)$$

From (6)

$$L(\Delta I) = T_{off} * (V_o – V_d) \quad \dots (8)$$

From (7) and (8)

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

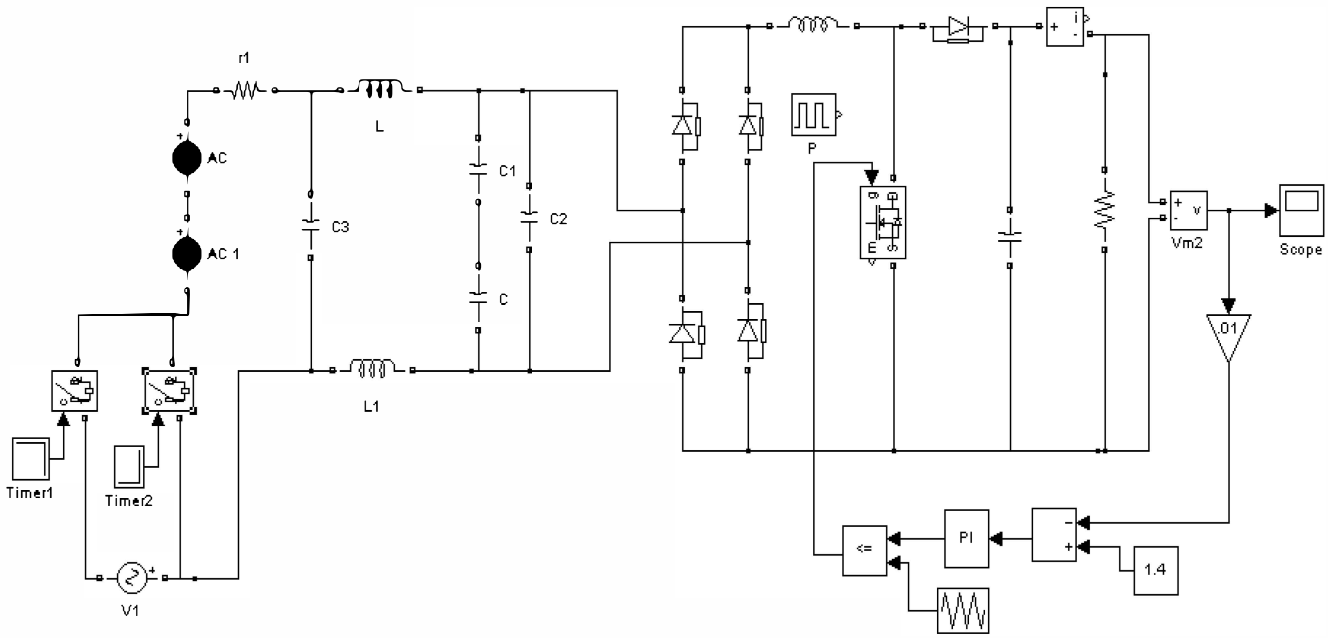


**FIG. 1:** CLOSED LOOP CONTROLLED BOOST CONVERTER

$$V_o = V_d/(1 - \alpha) \quad \dots (9)$$

Where $\alpha$ = 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.

The output voltage is greater than the input voltage. Boost converter is also called as step-up converter. 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.

## 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.

## IV. SIMULATION RESULTS

The boost converter system is simulated using Matlab simulink. The A.C. source with EMI filter is shown in Figure 2. Noise is injected by using an additional source of higher frequency connected in series. Distorted input voltage is shown in Figure 3(a). The voltage waveform after EMI filter is shown in Figure 3(b). Driving pulses for the MOSFET are shown in Figure 3(c). The output voltage of open loop system with disturbance is shown in Figure 3(d). The circuit of closed loop system is shown in Figure 1. Driving pulses for the MOSFET are shown in Figure 3(e). Error signal is shown in Figure 3(f). The output voltage of closed loop system is shown in Figure 3(g). From the response of closed loop system, it can be seen that the output voltage reduces to the set value.

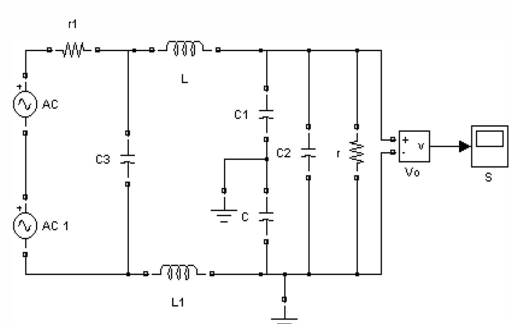


**FIG. 2:** EMI FILTER CIRCUIT

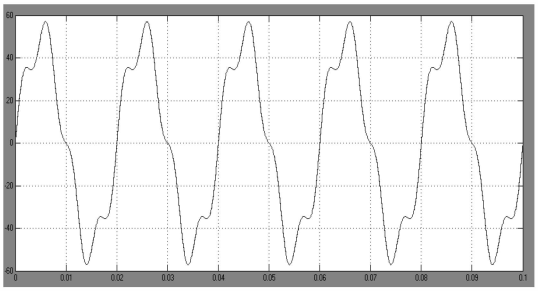

**FIG. 3(A):** INPUT VOLTAGE BEFORE EMI FILTER

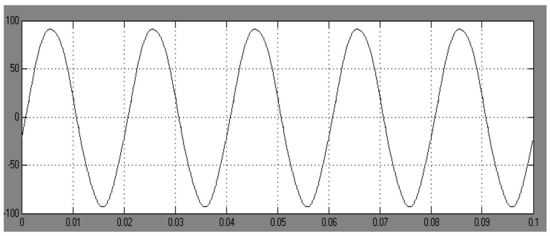

**FIG. 3(B):** VOLTAGE AFTER EMI FILTER

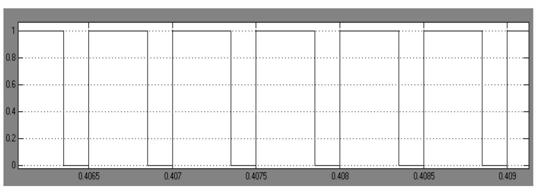

**FIG. 3(C):** DRIVING PULSES FOR MOSFET

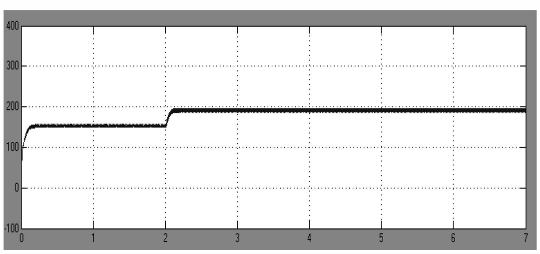

**FIG. 3(D):** OUTPUT VOLTAGE WITH DISTURBANCE

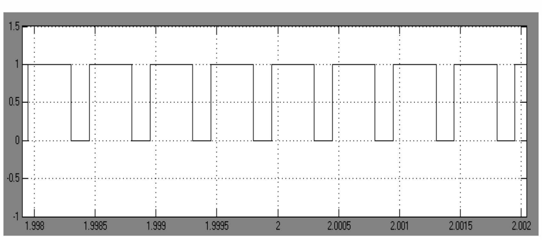

**FIG. 3(E):** DRIVING PULSES OF MOSFET

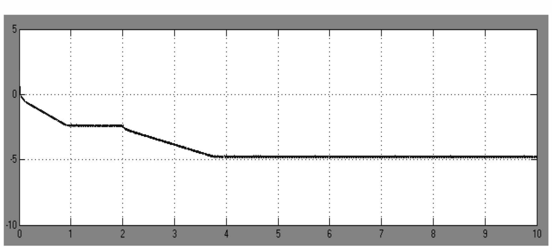

**FIG. 3(F):** ERROR SIGNAL FOR CLOSED LOOP SYSTEM

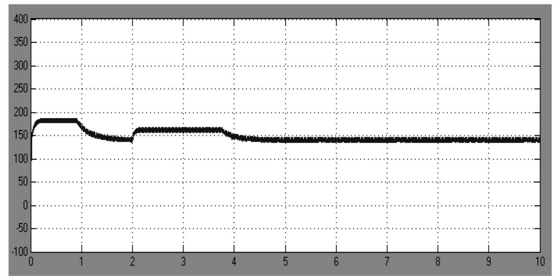

**FIG. 3 (G):** OUTPUT VOLTAGE WITH CLOSED LOOP SYSTEM

## V. EXPERIMENTAL RESULTS

The boost converter is fabricated and tested with R load. The control circuit is shown in Figure 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.

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

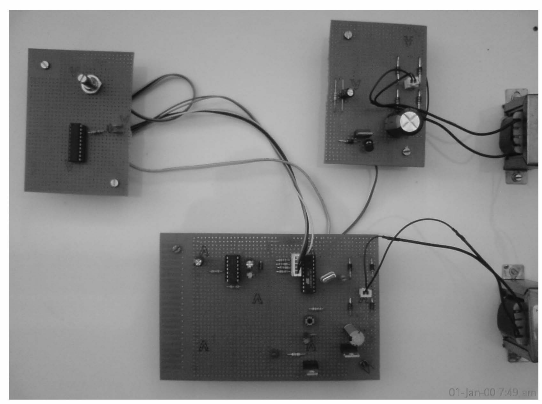

**FIG. 4:** HARDWARE OF THE BOOST CONVERTER

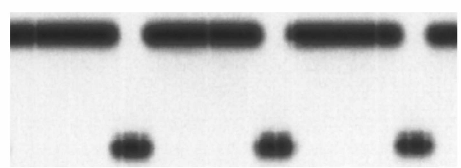

**FIG. 5:** DRIVING PULSES

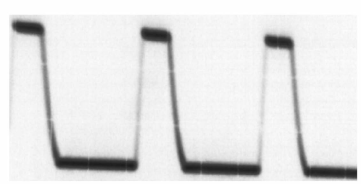

**FIG. 6:** VOLTAGE ACROSS S1

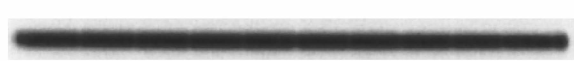

**FIG. 7:** OUTPUT VOLTAGE

If the converter is supplying all the reactive power demanded by the load, its output currents are expected to be higher than they would be in the case when only active power is injected. This calls for higher output apparent power ratings. However, if a lower source power factor is admissible, the converter output ratings and therefore its cost can be reduced. The proposed control strategy is supposed to be capable of generating any output imaginary power, that is, the source power factor may be set at any desired value. In case of choosing a particular value for the source power factor, the imaginary power reference q* should no longer be set to qload, but to the following value:[10]

$$q^* q_{\text{load}} - (P_{\text{load}} - p^*)\tan\phi^* \qquad \ldots (10)$$

Where, ϕ* is the source desired reference displacement angle (cosϕ* is the reference power factor).

Therefore, neglecting the harmonics, the apparent power of the converter should be:

$$S_{\text{conv}} = \sqrt{\left[q_{\text{load}} - (p_{\text{load}} - p^*)\tan\phi^*\right]^2 + p^{*2}} \qquad \ldots (11)$$

In the Figure 8 shows how the converter output apparent power can be determined for three different load power factor and considering the capacity of the solar cell (p*). In this figure the maximum admissible source power factor was considered equal to 0.92 (ϕ*≅23°≅0.40 rad). From this figure it is possible to see that if the load power factor is equal to unity the converter will have the same rating as its active power p*. However, if the load power factor is, for instance, equal to 0.80 and p* is 0.4 (in pu) the converter rating will have to be 0.63 (pu).

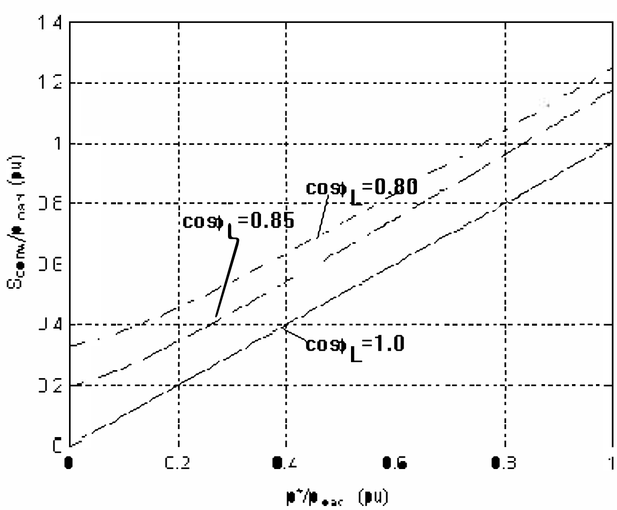


**FIG. 8:** IMPROVED POWER FACTOR OF CONVERTER OUTPUT (PU)

If the load currents contain harmonics, the converter can also supply them, with slight modifications in the control strategy. In this case, the converter will also operate as an active power filter, making the three-phase source currents nearly sinusoidal. The small high-frequency oscillations produced by the converter on the three-phase source currents can be easily filtered out by a small passive filter.

## V. CONCLUSION

The Boost Converter 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 power factor improvement. The laboratory model for boost converter with EMI filter is implemented. The circuit is tested with resistive load. The experimental results are presented in this paper. The experimental results closely agree with the simulation results.

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