REGULATION OF OUTPUT VOLTAGE IN BOOST POWER FACTOR CORRECTION CONVERTER WITH ELECTRO MAGNETIC INTERFERENCE FILTER

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Abstract: *This paper deals with the closed loop control of a Boost Power Factor Correction (PFC) Converter with Electro Magnetic Interference (EMI) Filter to regulate the output voltage for the source side and load side disturbances. Circuit model for closed loop controlled boost power factor correction converter is developed. A controller is used to regulate the output voltage. The converter is simulated for resistive load. Using the proposed control scheme, the improved power factor at the line side of the converter and regulated output voltage on the load side of the converter are obtained.*

Key words: *Power Factor Correction, Electro Magnetic Interference, Boost Converter, regulation, disturbance*

1. Introduction

Various types of single-phase PFC converter circuits have been developed and used to improve the ac current waveform [1-4]. The PFC converter is constructed by use of a boost chopper circuit with a switching device in the dc side of the diode bridge rectifier circuit. A sinusoidal current waveform in phase with the ac line voltage and the constant dc voltage can be obtained from PFC converter.

Reference [5] discusses the design of Power Factor Correction Boost Converter using genetic algorithms. Digital Power Factor Correction Control Strategy optimized for DSP is given by [6]. Soft switched high power factor boost converter with IGBTs is given by [7].

Electro Magnetic Interference is related with the disturbance caused by electro magnetic waves in 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. So, Electro Magnetic Interference Filter (EMI Filter) has to be used at the input of PFC converter to minimize the interference [8-10].

The modeling and design of boost PFC converter with low common mode EMI is presented in [11]. The detail about mixed mode EMI noise is given by [12]. Modeling and characterization of PFC converter in the medium and high frequency ranges for predicting the conducted EMI is given by [13].

In this paper, the simulation work on closed loop control circuit for the Boost PFC Converter with EMI Filter is done to regulate the output voltage for source side and load side disturbances. The simulation results are presented in this paper.

2. Analysis of Boost Converter

Fig.1 shows the boost converter where the output voltage is greater than the input voltage. Boost converter is also called as step-up converter. A large inductor 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_b is reversed. As a result, voltage across the load is the sum of supply voltage and inductor voltage and it is greater than the supply voltage.

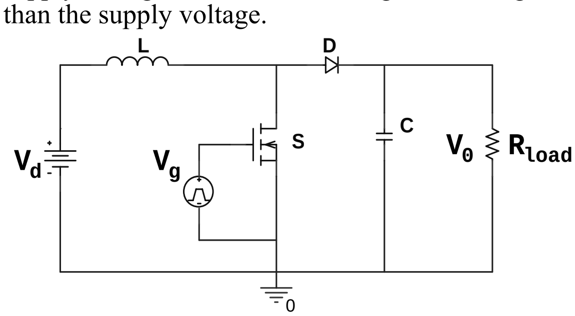

Fig.1. Boost Converter

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,

$V_L = V_d$ (1)

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

From (1) and (2),

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

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

$V_L = (V_0 – V_d)$ (4)

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

From (4) and (5),

$T_{off} = L (\Delta I) / (V_0 – V_d)$ (6)

From (3),

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

From (6),

$L (\Delta I) = T_{off} * (V_0 – V_d)$ (8)

From (7) and (8)

$T_{on} * V_d = T_{off} * (V_0 – V_d)$

Or $V_0 = (T_{on} + T_{off}) * V_d / T_{off}$

Or $V_0 = T * V_d / T_{off}$

Or $V_0 = V_d / (1 - \alpha)$ (9)

where α = delay angle of the boost converter. As firing angle increases from 0 to 1, the output voltage will be from V_d to infinity. Hence, the output voltage is boosted.

3. Boost Power Factor Correction (PFC) Converter

Fig.2 shows the Boost Power Factor Correction converter. It comprises of a diode rectifier, boost inductor, switching device, boost diode and boost output capacitor.

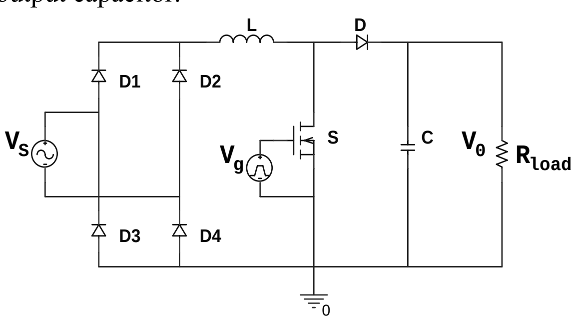

Fig.2. Boost PFC Converter

The specifications of the proposed Boost PFC converter are

AC input Voltage=V_s=230 V
DC output Voltage=V_0=400 V
Output Power=P_{out}=500 W
Switching Frequency=F_s=100 KHz
Efficiency=η=85%

The designed values of the boost inductor L and the output capacitor C are L=1 mH; C=880µF.

4. Electro Magnetic Interference (EMI) Filter

The Electro Magnetic Interference is transmitted in two forms: radiation and conduction. 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.3.

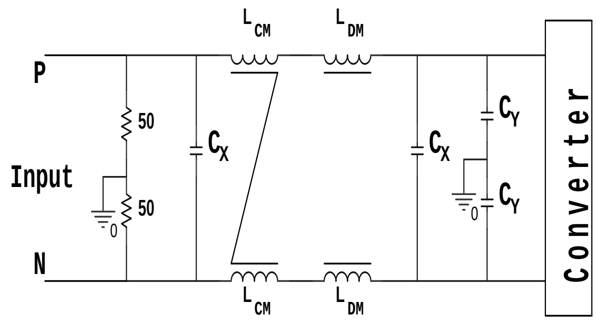

Fig.3. EMI Filter for Boost PFC Converter

In general, for any Boost Power Factor Correction Converters, the corner frequency for CM noise is 28 KHz and the corner frequency for DM noise is 20.5 KHz. The parameters for the EMI Filter i.e. inductance value L_{CM} for CM noise and inductance value L_{DM} for DM noise can be calculated as

For CM Noise,

$$f_{RCM} = \frac{1}{2\pi\sqrt{2 * C_Y * L_{CM}}} \quad (10)$$

Here, consider C_Y as 0.22µF, then

L_{CM} = 4.9 mH

The leakage inductance is in the range of 0.5% to 2% of the L_{CM} value, then

$L_{leakage}$ = 1% of L_{CM} (11)

Therefore, **$L_{leakage}$ = 49µH**

For DM Noise,

$$f_{RDM} = \frac{1}{2\pi\sqrt{2 * C_X * L_D}} \quad (12)$$

Here, consider C_X as 0.47µF, then

L_D = 128µH

$L_{DM} = (L_D – L_{leakage}) / 2$ (13)

Therefore, **L_{DM} = 40µH**

5. Results

Boost PFC Converter with EMI Filter for source side and load side disturbances with resistive load circuits are simulated using ORCAD PSPICE Software of Version 9.2.

The input voltage and input current waveforms are given in fig.4. Then, a source voltage disturbance is created by using a source. The input voltage and input current waveforms with disturbance are given in fig.5 and it can be seen that when the input voltage increases, the output voltage also increases in open loop system. A closed loop controller is designed and it is given in fig.6. The simulation results with the closed loop controller are given in fig.7.

Now, a load side voltage disturbance is created. The input voltage and input current waveforms are given in fig.8 and it can be seen that the output voltage decreases due to the load side disturbance in open loop system. The closed loop controller shown in fig.6 is connected to the circuit. The simulation results with the closed loop controller are given in fig.9.

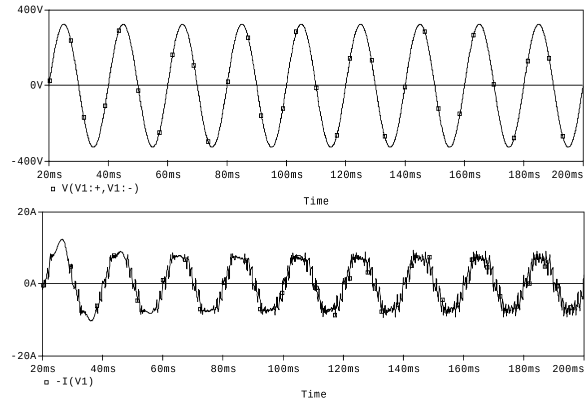

Fig.4. Input voltage and input current waveforms of Boost PFC Converter with EMI Filter

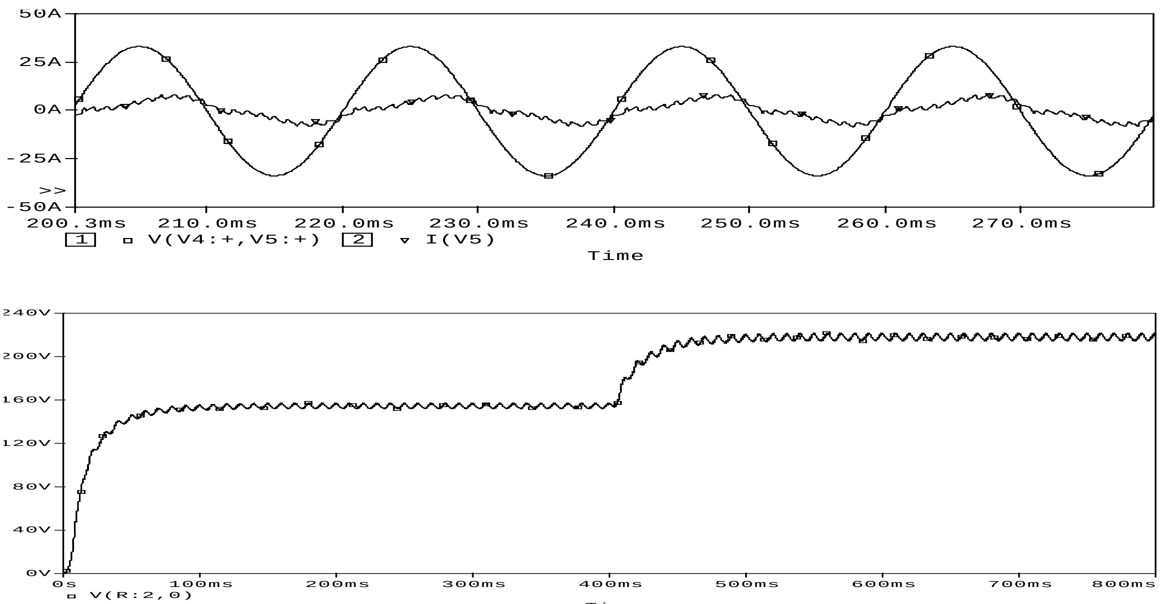

Fig.5. Input voltage and input current, output voltage waveforms of Boost PFC Converter with EMI Filter with source side disturbance in open loop

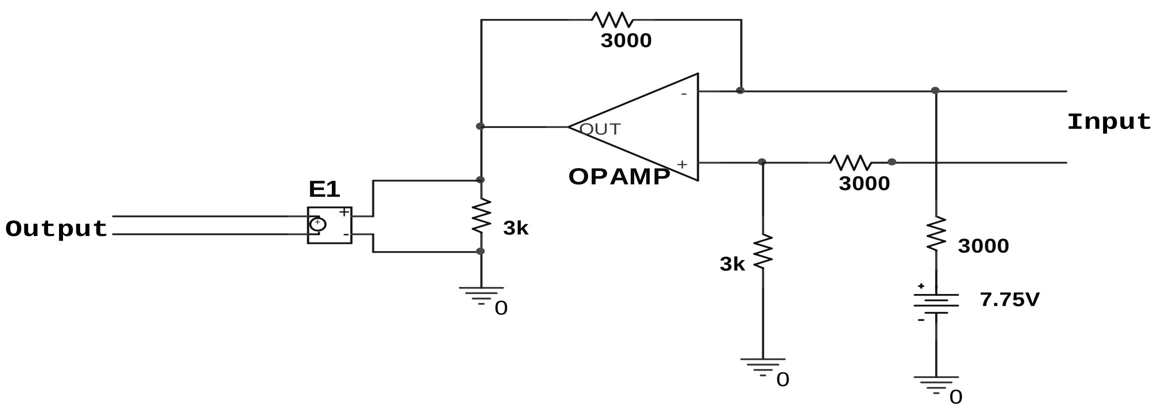

Fig.6. Closed loop controller

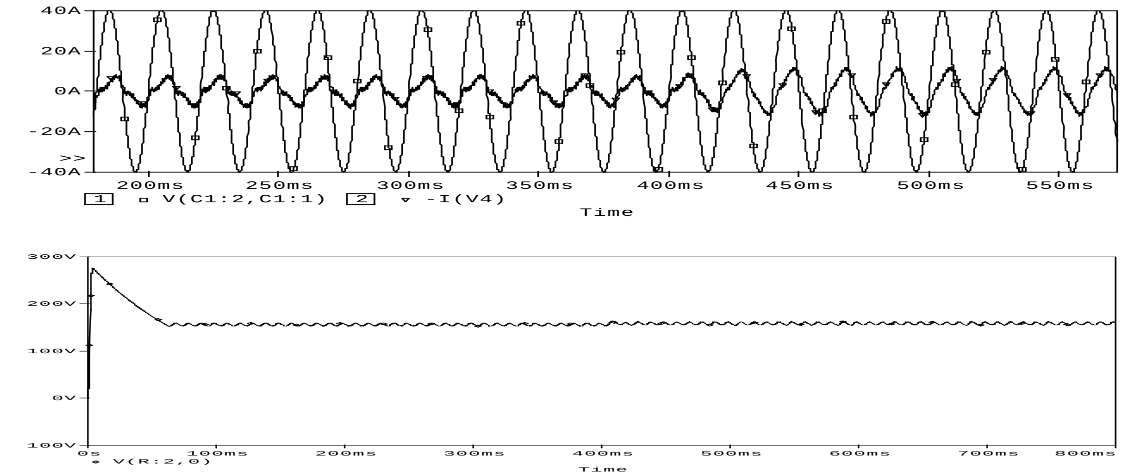

Fig.7. Input voltage and input current, output voltage waveforms of Boost PFC Converter with EMI Filter with source side disturbance with closed loop controller

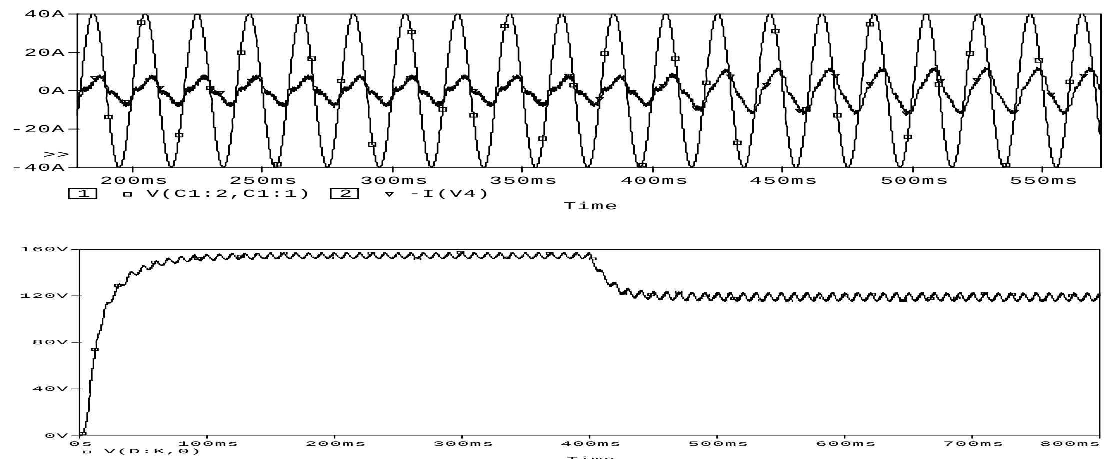

Fig.8. Input voltage and input current, output voltage waveforms of Boost PFC Converter with EMI Filter with load side disturbance in open loop

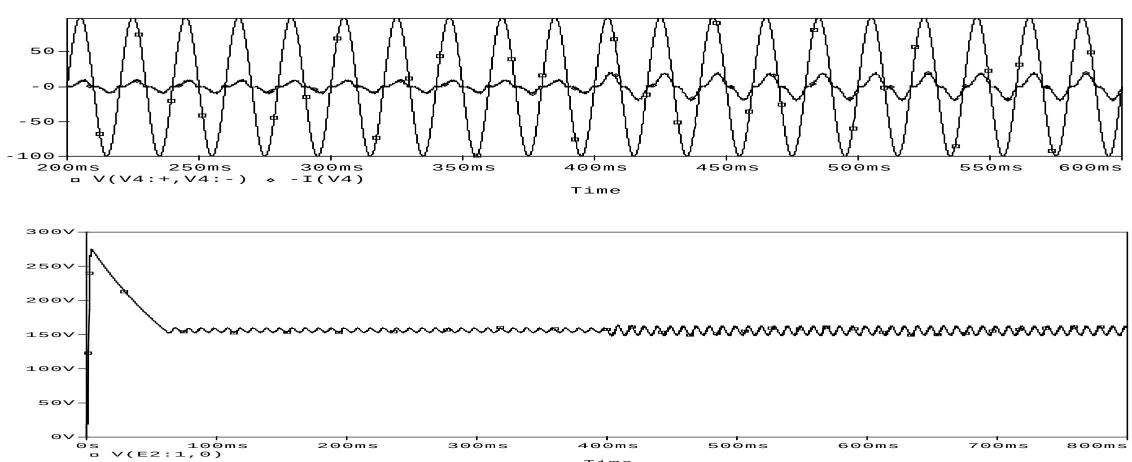

Fig.9. Input voltage and input current, output voltage waveforms of Boost PFC Converter with EMI Filter with load side disturbance with closed loop controller

From figures 7 and 9, it is observed that the output voltage is regulated i.e. maintained constant and the input power factor is improved using the proposed control circuit.

6. Conclusion

This paper has dealt with the closed loop control of a Boost Power Factor Correction (PFC) Converter along with Electro Magnetic Interference (EMI) Filter to regulate the output voltage for the source side disturbance and load side disturbance. The Boost PFC Converter along with EMI Filter is simulated in open loop for resistive load. A closed loop controller is proposed to regulate the output voltage for both the disturbances. Using the proposed control scheme, improved Power factor at the line side of the converter and regulated output voltage on the load side of the converter are obtained.

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