Harmonic Reduction in Single Boost Converter Fed DC Motor with EMI Input Filter

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ABSTRACT

DC motor drive system supplied by AC/DC rectifier topology considered as a nonlinear load. It produces harmonic distortions and EMI noise effects in the power systems. In this paper deals with the reduction of supply current harmonics and EMI noise generated by the power electronics converter in the DC motor drive using FFT analysis. The single boost converter along with EMI input filter is proposed in this system to investigate the harmonic reduction in the DC motor drive. The single boost converter fed DC motor drive is modeled and simulated using MATLAB/Simulink software. The simulation results show better agreement with the proposed system.

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1. INTRODUCTION

Recent trends, increasing use of power electronic converter based loads like UPS, SMPS, rectifiers, inverters, motor drive systems, etc., in many applications due to deliver the power with maximum efficiency, minimum cost and weight in an integrated circuit. These loads are termed as a nonlinear load and cause an electrical noise pollution in the power system by injecting harmonics, EMI noises voltage distortions and associated power quality issues. EMI noise produced by power electronic converters is a serious problem in the connected and neighboring network due to the conducted EMI emissions. EMI filters are essentially required to reduce the electrical noise at considerable range. The EMC design of power converters is based on the EMI noise analysis and its propagation paths. Various research articles have been reported on the EMI analysis of power converters and SMPS using different filter topologies and techniques. The passive and active EMI filters are adopted for reducing the EMI noise levels and enhance the power factor.

The modeling and simulation approach gives a suitable design for building the final hardware prototypes because it is a difficult and time-consuming process. The EMI filters are introduced to minimize the undesirable electrical noises or disturbances in power lines; power supplies (SMPS) and power converters. The compensation of these harmonics and EMI noise effects has recently been attracting more interest to the power system engineers with suitable filtering techniques. The EMI filters are two types such as passive and active filters. The series type active filter is installed series with the nonlinear loads or harmonic generating loads and works as the harmonic compensation voltage source. The EMI input filter connected in series or parallel to the source.

The passive EMI filters improve the EMI noise attenuation without any complex control circuit. In [1]-[11] reported the closed loop controlled single stage PFC boost converter with EMI filter fed a resistive load. In this paper, the closed loop PI controlled single boost converter fed DC motor with input EMI filter has been introduced to reduce the harmonics.

2. EMI SOURCES AND FILTERS

The main sources of EMI generated in the power system due to power electronics converters and its associated loads i.e. nonlinear loads. The conducted emission caused by

a) Starting with AC/DC motors
b) Fluorescent bulbs/ ballasts
c) Light dimmers
d) Microwave ovens
e) Microprocessors
f) Computers
g) Switched mode power supplies (SMPS)

2.1. Need for EMI Input Filter

The aim of the EMI filter was to reduce the interference caused either conducted or radiated from the power circuit. AC to DC or DC to AC power supply circuits or systems may generate more electrical noise that cannot be filtered out by its internal filter. The problems associated with EMI noise can be resolved by introducing an additional EMI filter on the source side of the power supplies

a) Suppress the emission at the source end.
b) Provide the inactive coupling path.
c) Ensure the receiver less vulnerable to the emission.

2.2. EMI Filter Types

EMI filters usually two types, passive and active filters. Passive R, L and C electronic components which constitute the LC circuits. The unwanted EMI noise frequencies are greater than the normal signal frequencies. The EMI filter works by selectively blocking or shunting unwanted higher frequencies. The inductance of the EMI filter is used to allow the low frequency and block the high frequency. The capacitor in the EMI filter is used to bypass or shunt unwanted high-frequency noises. EMI filter takes an active part to attenuate the all undesirable noises in the power electronic device. The commonly used various filters are shown in Figure 2.1.a to d.

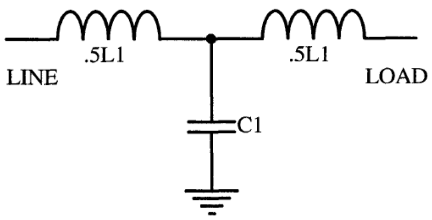

Figure 2.1.a. T Filter

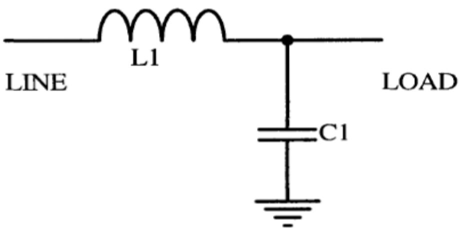

Figure 2.1.b. L Filter

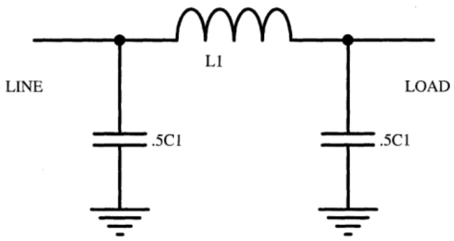

Figure 2.1.c. π Filter

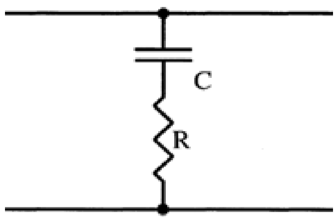

Figure 2.1.d. RC Filter

Common solutions to meet the EMC standards in power converters are using EMI filters. The filters are designed and validated with converter realization. The filtering techniques are invariably achieving the further EMI reductions necessary to satisfy EMC standards. It is desirable to implement cost-effective suppression methods in order to reduce the filtering characterization before designing and implementing the filter. Many filtering solutions based on passive and active network approaches have been introduced to attenuate conducted EMI. Presently the CM and DM filters are designed together with discriminating CM and DM noises for better performance [4-6].

Passive EMI filters are bulky in size and require multi-stage LC circuits to achieve significant high-frequency noise reduction. This results in higher cost and larger size of the power converter. A typical passive EMI filter designed for the suppression of Common Mode (CM) is shown in Figure 2.2.

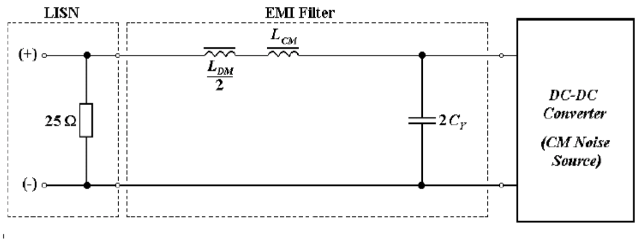

Figure 2.2. Equivalent circuit for CM

3. SINGLE BOOST CONVERTER CIRCUIT

The conventional schematic diagram of a single boost converter circuit is shown in Figure 3.1. Boost converter where the output voltage is greater than the input voltage. The boost converter is also literally known as a 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 zero instantaneously; this current is forced to flow through the diode and the load during this off period. As the current tends to decrease, the polarity of emf induced in L_1 is reversed. As a result, the voltage across a load is the sum of supply voltage and inductor voltage and it is greater than the supply voltage. The main drawback of the single inductor boost converter is it could not avoid some natural power loss because of its structural arrangement with rectifier circuit on the source side.

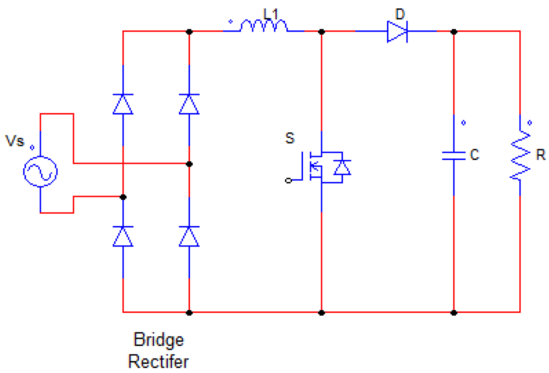

Figure 3.1. Single Boost converter Circuit

DC output voltage expression of the boost converter is given in (1) $V_o = \frac{V_s}{1-D}$, where, D – Duty ratio or

cycle = D = $\frac{T_{on}}{T}$, T = T_{on} +T_{off}

T – Total time period

V_s – Source voltage
V_o – Output voltage
T_{on} – On time
T_{off} – Off time
T – Total time period

The range of duty cycle is $0 < D < 1$ and the output voltage is greater than the input voltage i.e. $V_o > V_s$. The overall block diagram of proposed system is shown in Figure 3.2.

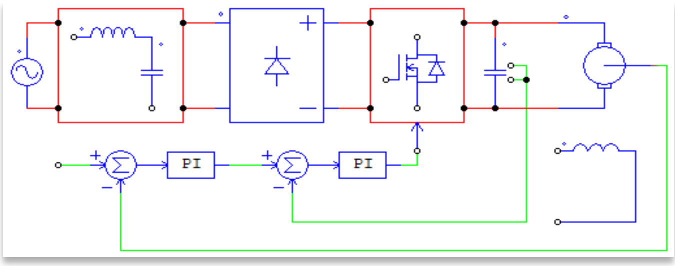

Figure 3.2. Overall Block diagram of Proposed system

4. SIMULATION RESULT

The simulation of single boost converter fed DC Motor without EMI filter was carried out using MATLAB/Simulink. Simulink model of single boost converter fed DC motor without input EMI filter is shown in Figure 4.1 and PI controlled DC motor with input EMI filter is shown in 4.2. The speed response of DC motor is shown in Figure 4.3 and the torque response of DC motor is shown in Figure 4.4. The spectrum analysis of THD in single boost converter fed DC motor without EMI filter is shown in Figure 4.5.

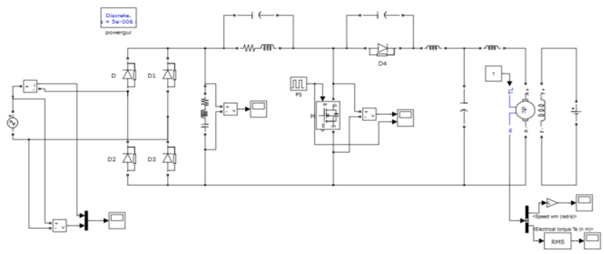

Figure 4.1. Simulink model of Single boost converter fed DC motor without EMI filter

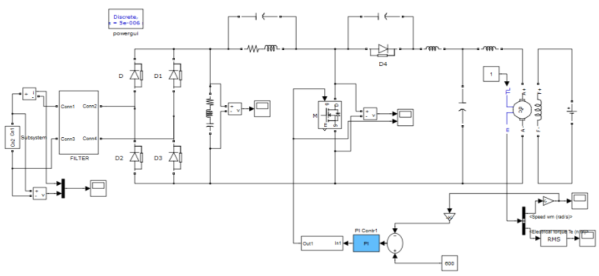

Figure 4.2. Simulink model of PI controlled Single boost converter fed DC motor with EMI filter

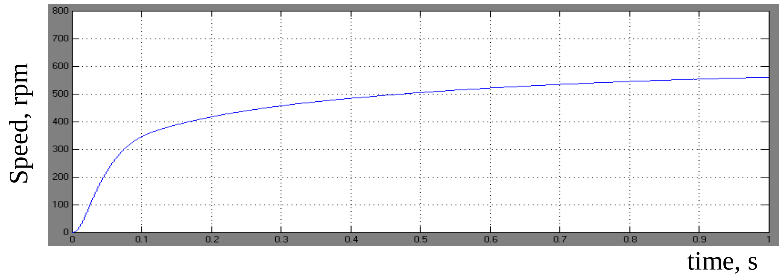

Figure 4.3. Speed response of DC motor without EMI filter

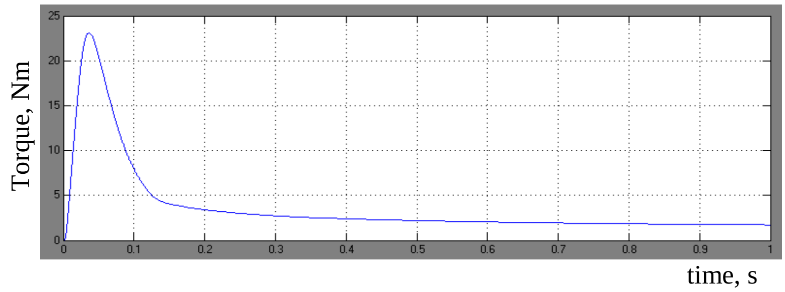

Figure 4.4. Torque response of DC motor without EMI filter

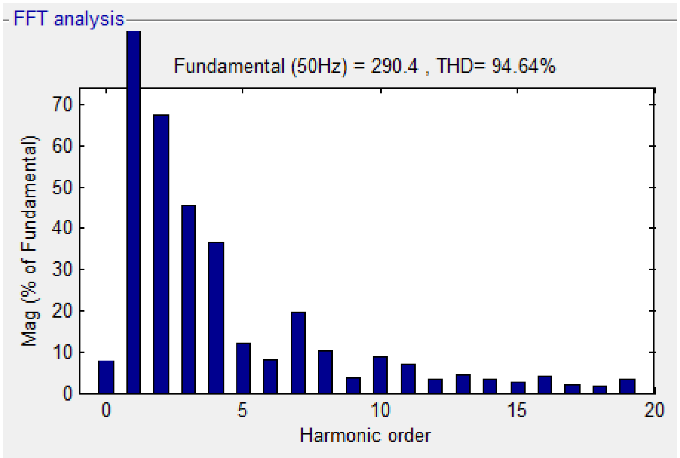

Figure 4.5. Frequency spectrum of THD in Single Boost converter fed DC motor without EMI filter

The speed response of a PI controlled DC motor with EMI filter is shown in Figure 4.6 and the PI controlled DC motor with EMI filter is shown in Figure 4.7. The spectrum analysis of THD in Single Boost converter fed DC motor with EMI filter is shown in Figure 4.8. It is interpreted that the speed and torque response of a PI controlled DC motor reaches a rated value in a smooth manner. The source current harmonic %THD has drastically decreased from 94.64% to 11.38%. The comparative results of PI controlled DC motor with and without EMI input filter is given in Table 1. Simulation parameter is given in Table 2.

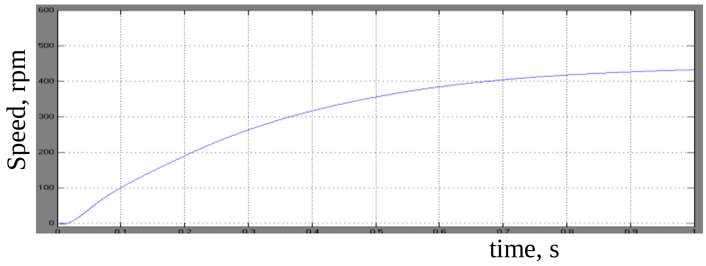

Figure 4.6. Speed response of a PI controlled DC motor with EMI filter

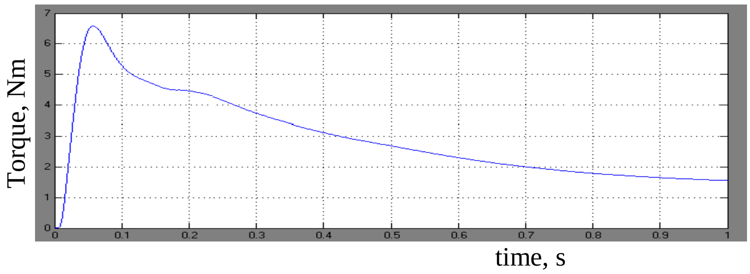

Figure 4.7. Torque response of a PI controlled DC motor with EMI filter

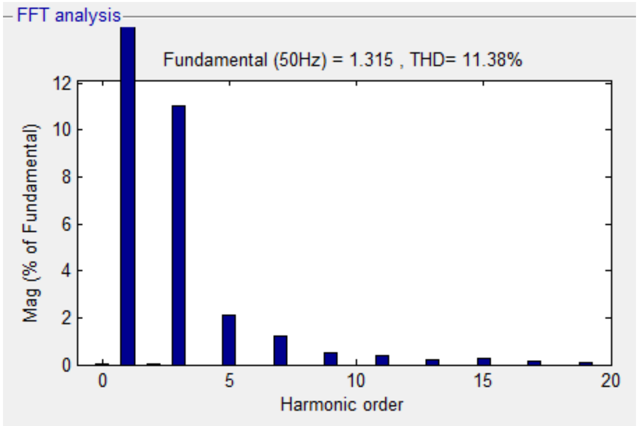

Figure 4.8. Frequency spectrum of THD in a PI controlled DC motor with EMI filter

Table 1 Comparison of THD Value With and Without EMI Filter

PI Controlled Single Boost Converter fed DC Motor	%THD
without EMI Filter	94.64%
with EMI Filter	11.38%

Table 2 Simulation Parameters

Parameters	Value
AC Supply	100V, 50Hz, Single Phase
DC Motor (Separately excited Shunt)	5HP, 1750 rpm, 240V, Filed: 150V
PI Controller	$K_p = 1$ $K_i = 0.5$
EMI Filter	R = 0.01Ω L = 0.8mH C = 1μF

5. CONCLUSION

The harmonic reduction using an EMI filter is discussed and demonstrated with help of PI controlled single boost converter supplied DC motor load. The simulation results of the single boost converter fed a DC motor load with and without EMI input filter are presented. The PI controller significantly reduces the source current harmonics in terms of %THD

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