Conducted EMI Analysis of a Three-Phase PWM Rectifier

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\textbf{Abstract.} Because of the strict electromagnetic interference (EMI) regulation, noises generated from high switching frequency converters need to be analyzed and suppressed by some methods. EMI noises in power converters are generally frequency related. This paper investigates the mechanisms of conducted EMI emissions associated with the typical three phases PWM rectifier system using frequency domain method. A simplified method for the calculation of Common-mode (DM) electromagnetic interference caused by the three-phase PWM rectifier is presented. Frequency domain noise current source has been represented first. The dominant high-frequency differential-mode current paths are identified later, the modeling principle of the paths has been explained at the same time, and this allows the noise spectrum to be predicted from knowledge of the component values. Theoretical predictions of EMI noises are verified by simulations in saber software through time domain and frequency domain analysis.

\textbf{Keywords:} PWM, EMI, modeling, differential-mode, frequency-domain.

1 Introduction

Main aims in modern power electronic systems are to deliver the power with maximum efficiency, minimum cost and weight in an integrated circuit [1]. Power electronics plays an important part in different industries when power processing is required such as in motor drives, cars and alternative energy systems. In power electronics, however, high du/dt and high di/dt are processed by fast switching to reduce loss which becomes primary sources of EMI.

Whereas, in the conventional design methodology, electromagnetic compatibility (EMC) issues are solved with “band-aid” methods by adding cumbersome and costly passive filters after a prototype is built. These traditional remedies usually have significant impact on the cost and the time-to-market for the products. To avoid such approaches after the development, it is necessary to take EMI into account at early design stage. How to predict EMI is thus becoming the major subject in recent power electronics researches. in recent years, the main EMI researches in power electronics focus on analysis of electromagnetic emissions by measurements, modeling and simulations [2-5].
This paper analyzed and explained the mechanisms giving rise to DM conducted interference in PWM rectifier systems. A simplified frequency domain model for noise prediction is presented here together with time domain simulations using the Saber package to determine the high-frequency current paths and sources. The Saber model, which includes high-frequency effects not normally considered by MATLAB or PSIM, proves to be an excellent tool for very detailed investigation of the high-frequency currents.

2 Noise Source Modeling

The topology of three-phase Voltage Source Rectifier (VSR) is shown in Figure 1. For simplified analysis, the proposed modeling method is based on the following basic assumptions: (1) The switching pattern is considered to be perfectly periodic. This is a pessimistic assumption, since the random changes in the period would decrease the EMI spectrum average [6]. (2) The power supplied in this system is three-phase smooth pure sine-wave source voltage; (3) The inductances used as unsaturated filters in net side are linear; (4) The switching device represented by equivalent loss resistor of the actual switch are in series with the ideal switch device [7].

![Fig. 1. The topology of the VSR](image)

![Fig. 2. Frequency domain circuit and noise current source representation](image)

DM disturbances are considered to be caused by sudden changes (di/dt) of load current flowing through inductive paths and will be modeled by current sources. The switching noise source can be considered as a trapezoidal pulse train, although the actual waveform will have different current rise and fall times, it is reasonable to assume the \( t_r = t_f \). The frequency domain representation of the DM noise current can then be expressed in (1) [8].

\[
I_{dm} = 2Id \frac{\sin(n\pi d)}{n\pi d} \frac{\sin(n\pi / T)}{n\pi / T}
\]

Where \( d \) is the duty cycle, \( T \) is the inverter switching period, \( I \) is the current amplitude, and \( n \) is the harmonic order.

3 The Equivalent Circuit of the DM EMI

According to the requirement of the GJB152A-97 EMI measurement standard, we can access the stable network impedance circuit (LISN) in circuit. The LISN which used in