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Analysis And Decrease of Electromagnetic Interference In Diode Bridge Rectifier

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ABSTRACT: Electromagnetic Interference (EMI) refers to the undesired radiated or conducted energy in some type of electrical systems. Semiconductors are applied in power electronic converters to increase efficiency (Mohan, Undeland and Robbins, 2003).But switching leads to generation of interference over a wide range of frequency and causes radio frequency interference (10KHz to 30MHz). EMI is an inevitable problem in modern power electronic circuits. Modeling and simulation of EMI is the first step in EMC evaluation to help power electronics designers get an estimate on the status of EMC in their designs. Modeling and simulation of diode bridge rectifier are studied in this paper from the EMC point of view. Simulation results demonstrated noncompliance behavior of this rectifier in terms of EMC standards. At the end, by using suitable filters, we can preclude or minimize any undesired effects to meet the standards of acceptable conditions.

***Keywords*:** Electromagnetic interference, LISN, Differential Mode, Common Mode, EMI filter, conducted emissions.

INTRODUCTION

Semiconductor devices, though, help reduce weight and volume of equipments; they can cause some unwanted effects such as Radio Frequency Interference (RFI) emission (Moy, 1989). EMC regulatory Compliance is a problem for manufacturers to bring their products to the market cost-effectively. Post-development modifications would be too costly; therefore it is important consider EMC standards prior to the design phase (Nave , 1986). Modeling and simulation is the most cost-effective way to analyze EMC considerations before developing the products. Most of the previous studies concerned the low frequency analysis of power electronics components (Henderson and Rose, 1994), (Kasikci, 2000). However, different types of power electronics converters are capable to be considered as EMI sources. They could propagate the EMI in both radiated and conducted forms. Line Impedance Stabilization Network (LISN) is required to measure and calculate the interference level (Nave, 1985). Interference spectrum measurement at the output of LISN will be introduced as the criteria of EMC evaluation (Williams, 2001), (Keisier, 1987).

National or international regulations are the references to the evaluation of equipments from the EMC point of view (Williams, 2001), (Keisier, 1987). This paper studies the interference spectrum and its reduction in the radio frequencies range. The simulation of a typical single-phase and three-phase diode rectifier was carried out using equivalent circuit approach with ORCAD 9.2 software, both with and without EMI filters. The simulation results have been compared with the regulatory limitations indicating noncompliance behavior of power electronic converters from EMC point of view.

SOURCE, PATH AND VICTIM OF EMI

Undesired voltage or current is called interference and what causes them is called interference source. In this paper diode bridge rectifier is the source of interference. Interference is either propagated by radiation around the interference source or by conduction through common cabling or wiring connections. In this study, only the conducted emissions in power electronics are considered. Equipments such as computers, receivers, amplifiers and industrial controllers which are negatively influenced by EMI are called victims. The common connections of elements, source lines and cabling provide paths for conducted noise or interference. Electromagnetic conducted interference has two components: differential mode and common mode (Fluke, 1991).

Differential mode conducted interference

This mode is related to the noise imposed on different lines of a test circuit by a noise source. Deduced current path is shown in Figure 1 (Fluke, 1991). The interference source, path impedances, differential mode current and load impedance are also shown in Figure 1.

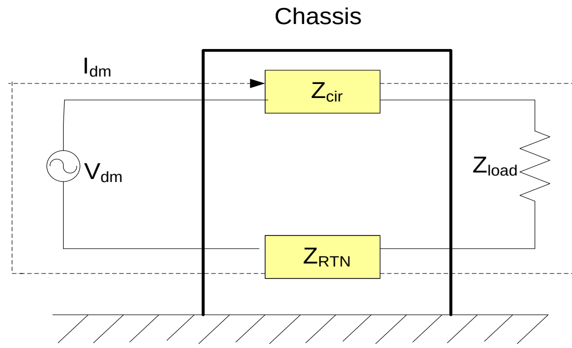

Figure 1. Differential mode conducted interference path

Common mode conducted interference

Noise or interference could appear and be imposed between the lines, cables or connections and common ground that is called common-mode interference. Any leakage current between load and common ground could be modeled by interference voltage source. Figure2 demonstrates the common mode interference source, currents, I_{cm1} , I_{cm2} and the related current paths (Fluke, 1991). The power electronic converters perform as the noise source between lines of the supply network.

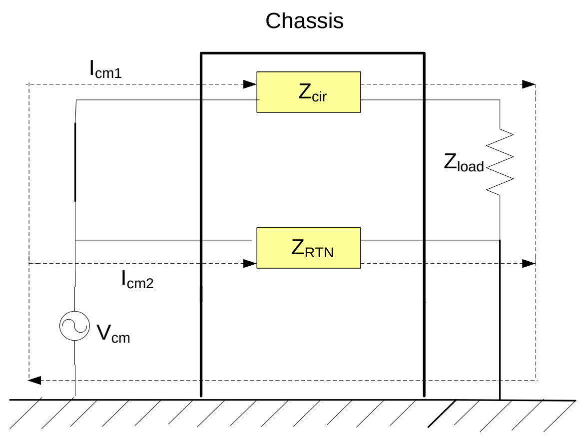

Figure 2. Common mode conducted interference paths

ELECTROMAGNETIC COMPATIBILITY REGULATION

Electrical equipments especially static power electronic converters are being used more and more these days. As mentioned before, power electronics converters are considered as a significant source of electromagnetic interference and have corrupting effects on the electric networks (Moy, 1989). High levels of pollution reduce the quality of power resulting from various disturbances in electric networks. Some of the residential, commercial and especially medical consumers, on the other hand, are so sensitive to power system disturbances including voltage and frequency variations. The best solution to reduce corruption and improve power quality is to assure compliance with the national or international EMC regulations.

CISPR, IEC, FCC and VDE are among the most famous organizations in Europe, USA and Germany being responsible to determine and publish the most important EMC regulations. IEC and VDE requirement and limitations on conducted emission are shown in Figure 3. and Figure 4 (Williams, 2001), (Fluke, 1991). For different groups of consumers different classes of regulations could be complied. Class A for typical consumers and class B with more severe limitations for specific consumers. The two classes are shown in Figure 3. and Figure 4. The limited frequency ranges of IEC and VDE are different. They range from 150 kHz to 30 MHz and from 10 kHz to 30 MHz in IEC and VDE, respectively. Conforming to regulations is evaluated through comparing the calculated conducted interference level in the mentioned frequency range with the stated requirements in EMC regulations. In united European community, compliance with regulations is mandatory and products must have certified labels to confirm the fulfillment of requirements (Keisier, 1987).

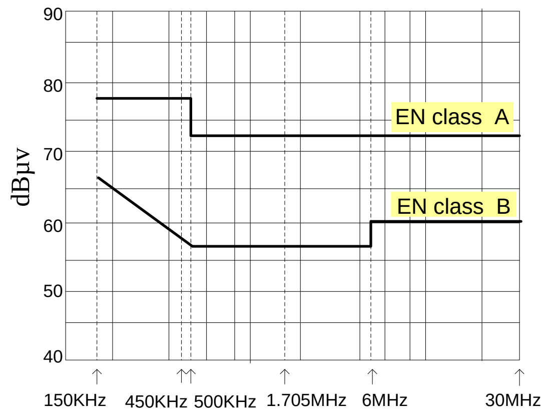

Figure 3. IEC conducted emission limits

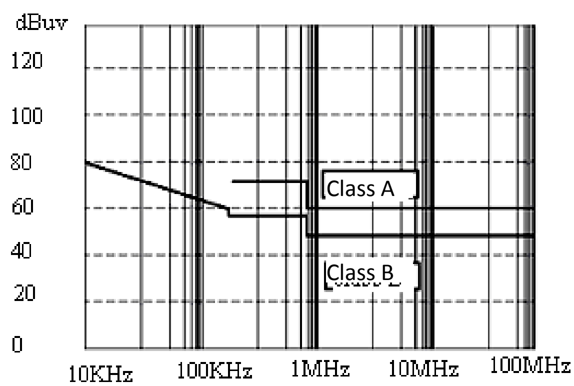

Figure 4. VDE conducted emission limits

ELECTROMAGNETIC CONDUCTED INTERFERENCE MEASUREMENT

Line Impedance Stabilization Network (LISN)

LISN is an industrial element offered by standards to be placed between the supply and power electronics converter including load as an interface to make the measurement of conducted interference possible (Williams, 2001). The stated situation is shown in Figure 5 (Nave, 1985). LISN should have the following characteristics to satisfy measurement conditions (Nave, 1985). 1-Providing a low impedance path to transfer power from source to power electronics converter and load. 2-Providing a low impedance path from interference source, (diode bridge rectifier in here), to measurement port.

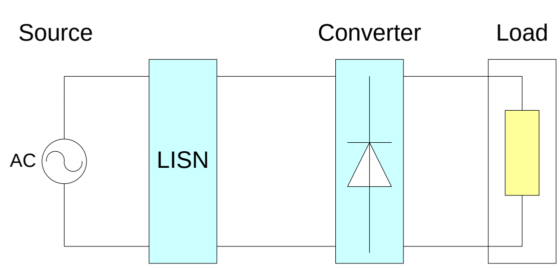

Figure 5. LISN placement to measure conducted interference

LISN topology

The common topology for LISN is shown in Figure 6 (Williams, 2001). LISN elements quantity based on the common topology are classified as shown in Table I (Williams, 2001).

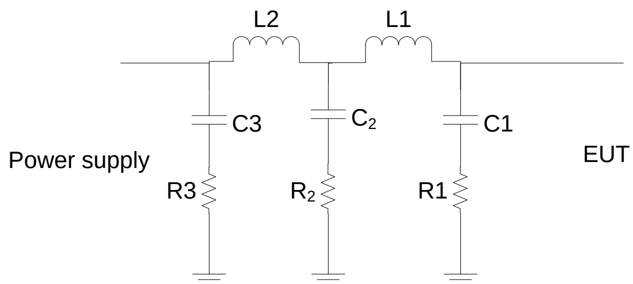

Figure 6. LISN common topology

Table 1. LISN Elements Quantity

L1	L2	C1	C2
50μH	250μH	250nF	8 μF
C3	R1	R2	R3
4 μF	50Ω	5 Ω	10 Ω

Variation of the signal level versus frequency at the LISN output is the interference spectrum. The electromagnetic compatibility of a device can be evaluated by comparison of its interference spectrum with the standard limitations. The level of signal at the output of LISN in the frequency range of 10 kHz up to 30 MHz or 150 kHz up to 30 MHz is criteria of compatibility and should meet the standard limitations. In practice, the LISN output is connected to a spectrum analyzer and interference measurement is carried out. But for modeling and simulation purposes, the LISN output spectrum must be calculated using appropriate software.

SIMULATION OF EMI DUE TO DIODE RECTIFIER

Orcad 9.2 is the verified and conventional software for electrical and electronic circuits simulations. This software is used to analyze and calculate the conducted interference spectrum in this study. Non-ideal behavior of resistors, capacitors and inductors are taken into account in the simulations. The simulation results are presented in the following sections.

Single Phase Diode Rectifier EMI Simulation

The single-phase diode bridge rectifiers have industrial applications. Sample of such equipment including source, LISN, converter and load in accordance with the block placement of Figure 5. is shown in Figure 7. Common and typical parameters of the simulated circuit are presented in Table 2. and Figure8 illustrates the simulation results, which is the variation of V(R1) at LISN output versus frequency.

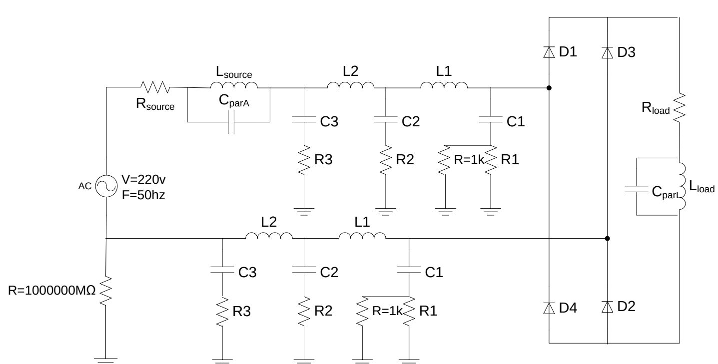

Figure 7. Simulation diagram of Single-phase diode bridge rectifiers

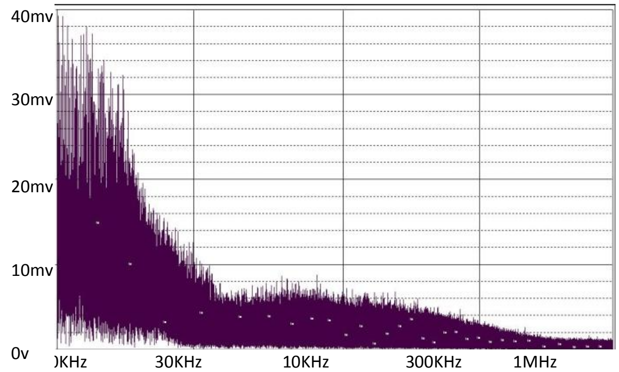

Figure 8. EMI simulation results of a Single-phase diode bridge rectifiers

Table 2. Typical Quantity for simulation elements

C_{parL}	2pF	input voltage	220V
$R_{sourceA}$	1mΩ	Frequency	50Hz
L_{source}	100nH	R_{load}	10mΩ
C_{parA}	2pF	L_{load}	50mH

Converting the results to dBμv makes it possible to compare them with standard requirements. It is seen in this sample that the level of conducted interference due to converter is not tolerable according to the regulations in Figure 3 and Figure 4. The maximum amplitude of conducted interference in rectifier is 39.177mv which is equal to 91.86dBμv. As a consequence this converter with the mentioned parameters does not comply with the regulations. It is possible to repeat the simulation with the other parameters. the performance may improve with just a few of them, but for the rest the results may become worse.

Three-phase Diode Bridge rectifiers EMI simulation

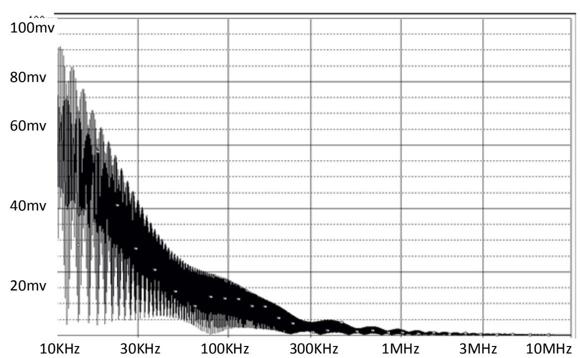

Figure 9. EMI simulation results of a Three-phase diode bridge rectifiers

The maximum amplitude of conducted interference in three-phase diode bridge rectifier is 91.18mv which is equal to 99.198dBμv. As a consequence this converter with the mentioned parameters does not conform to the regulations.

SIMULATION OF EMI DUE TO DIODE RECTIFIER WITH EMI FILTER

Filtering Overview

The purpose of the EMI filter is to prevent the undesired electromagnetic energy from entering or exiting from the equipment, however, not without expense. This method uses EMI correcting filters that can be purchased in IC form or can be constructed via discrete components(by using a capacitor or inductor placed appropriately). EMI filters are single-section filters or several single-section filters cascaded together for more attenuation. It has been demonstrated that a two- section filter has less optimum weight than a single-section one; in spite of the fact that they both have identical filtering properties in design. The number of sections and configuration are not limited to this presentation. It is important to remember to isolate the input and output cables of the filter.

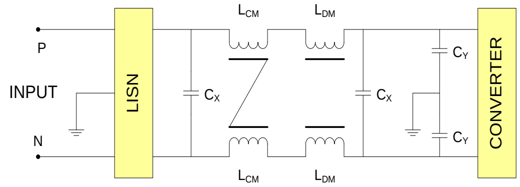

Figure 10. Proposed topology of EMI filter

Main harmonic filter should be rated for the switching frequency and its harmonics, i.e. it will absorb all harmonic multiples of the switching frequencies.

Determine filter component values L_{CM} and L_{DM} After determining the filter corner frequency, the filter component values can be calculated using the equations given below.

For CM Noise

$$f_{R,CM} = 1/(2\pi\sqrt{(2C_y * L_{CM})}) \quad (1)$$

$$L_{leakage} = 0.5\% to 2\% L_{CM} \quad (2)$$

For DM Noise,

$$f_{R,DM} = 1/(2\pi\sqrt{(2C_x * L_D)}) \quad (3)$$

$$L_{DM} = (L_D - L_{leakage})/2 \quad (4)$$

These capacitors and inductors are typically within the following values:

C_x = 0.1mF to 2mF
C_y = 2200pF to 33000pF

Single Phase Diode Rectifier EMI Simulation with Proposed Topology

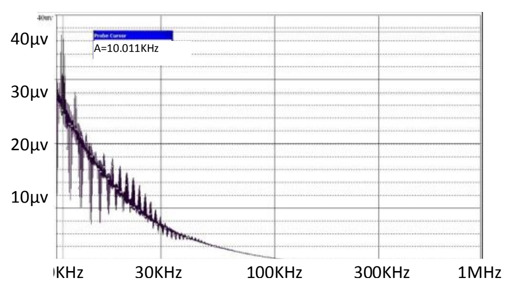

Figure 11. EMI si tion results of a Single-phase diode bridge rectifiers with EMI filter

The maximum amplitude of conducted interference in the single-phase diode bridge rectifier is 37.41µv which is equal to 31.46dBµv. As a consequence this converter with the mentioned parameters, attenuates more than 60dBµv and complies whit the regulations.

Three Phase Diode Rectifier EMI Simulation with Proposed Topology

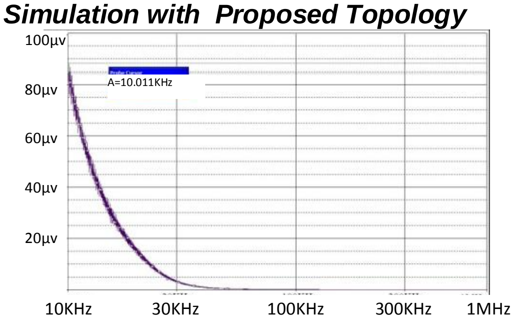

Figure 12. EMI simulation results of a three-phase diode bridge rectifiers with EMI filter

The maximum amplitude of conducted interference in this rectifier is 88.376μv which is equal to 38.92dBμv. As a consequence this rectifier with the mentioned parameters, attenuates more than 60dBμv and conform to the regulations.

CONCULSION

The appearance of electromagnetic interference due to the operation of diode bridge rectifier is introduced in this paper.Radiated and conducted interference coupling was introduced as the two major types of electromagnetic interference; however only the conducted type was studied in this paper.The Compatibility regulations and techniques of measuring conducted interference were explained. LISN, as an important part of measuring process, and its topology, parameters and impedance were described. Samples of two common power electronic diode rectifiers were considered and their EMI was simulated using orcad 9.2 software.The most important point of this study is that none of the mentioned rectifiers comply with the EMC standard regulations.It is necessary to apply hardware and software mechanisms to reduce the interference to the standard level. with design of suitable EMI filter and simulating the produced circuit, complied with the EMC standard regulations.

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