EMC MODEL FOR MODERN POWER ELECTRONIC SYSTEMS FOR HARMONICS, LOSSES & EMI ELIMINATION AND POWER QUALITY IMPROVEMENT

Abhijit Dey[1], Shashwatee Paul[2], Nariseti Ramya Krishna[3], Nandini Peela[4]
[1, 2, 3, 4]M.Tech(RF & Microwave), Dept. of Electronics & Communication , Gitam University, Andhra Pradesh, INDIA,
abhijitdey.mtech@gmail.com**, **shashwatee.paul@gmail.com**, **ramya.nariseti@gmail.com**, **peelanandini1@gmail.com

Abstract

Electromagnetic compatibility of power electronic systems becomes an engineering discipline and it should be considered at the beginning stage of a design. Thus, a power electronics design becomes more complex and challenging and it requires a good communication between EMI and Power electronics experts. Three major issues in designing a power electronic system are Losses, EMI and Harmonics. These issues affect system cost, size, efficiency and quality and it is a tradeoff between these factors when we design a power converter, filter. In this paper the EMC model is discussed which should be considered while designing the power electronics systems. The design considerations in this paper help us to remove losses, harmonics & EMI elimination and power quality improvement of Power systems.

Index Terms: *Converter, EMI, EMC, Filter, Harmonics*

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1. INTRODUCTION

Power Electronics can be split into a Power and an Electronic circuit. The power circuit converts an unregulated input power from AC or DC type to a regulated AC or DC voltage or current and delivers it to a load. The electronic circuit controls the converter by measuring the input and output voltages and/or currents and generates signals for the power circuit. In a power electronic system, the flow of electric energy is controlled based on a load demand. In a power electronic system, line and EMI filters are important sections of a system.

Main aims in modern power electronic systems are to deliver the power with maximum efficiency, minimum cost and weight in an integrated circuit. Power electronics has a significant role in different industries when power processing is required such as in computers, telecommunications, motor drives, cars and alternative energy systems.

In power converters, efficiency is a main concern. Power circuits consist of capacitors, magnetic elements and transistors in switched mode. Resistors and power switches in linear modes are not used in most power circuits due to significant losses generated by current through these components which decrease the efficiency and cause thermal problems. In power electronics high voltages and high currents are processed by fast switching to reduce losses which are significant sources of electromagnetic noise and it cause additional costs. Main EMI research targets in power electronics are:

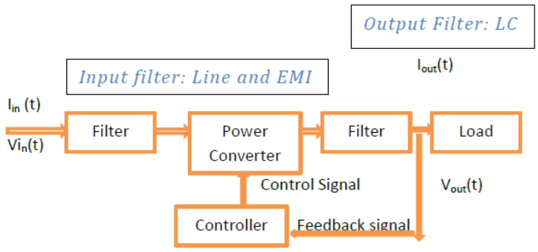

Fig -1: Basic Model of Power Electronics

- Analysis of electromagnetic emissions by measurements, modeling and simulations.
- Development active EMI filters in high power converters to suppress EMI noise.

How to reduce harmonics?
Increasing switching frequency can reduce low order harmonics and improve quality of output voltage or for a same quality, it reduces the size of low pass filter (L&C components); but the switching losses are increased. Thus it is a tradeoff between quality and losses.

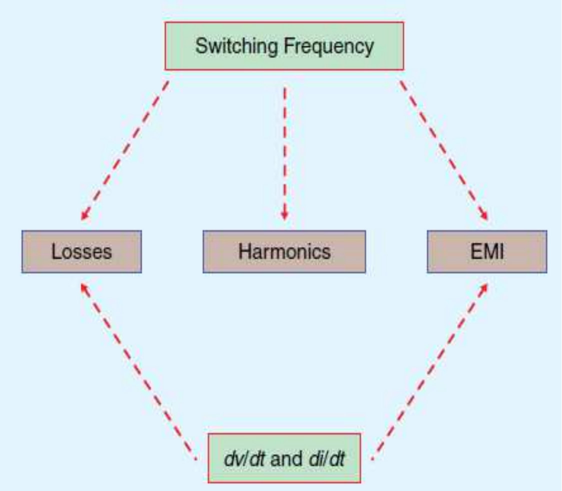

Fig -2: Relationship between losses, harmonics, EMI

In a power converter, increasing losses decreases the efficiency of the system and increases junction temperature of power switches which may damage them if heat is not transferred to ambient. Thus, the system may need a heat sink to transfer heat from junction into ambient which increases cost, size and weight of the power converter. A main part of total losses is the switching loss which depends on switching times and switching frequency. Fig.3 shows two waveforms with different switching times. The switching loss can be reduced by decreasing the switching time, but fast switching increases dv/dt and di/dt which affects EMI noise.

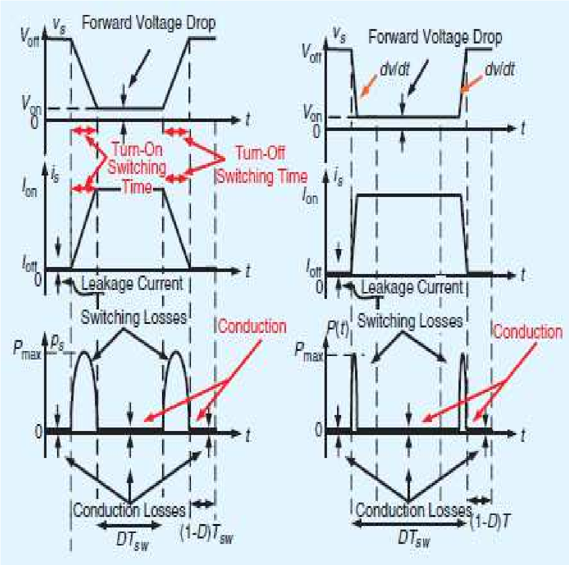

Fig -3: Voltage, current and power waveform of a switch at two different switching times.

2. PROPOSED MODEL

2.1. Converter Model

Any EMC analysis must account for the ground potential.Therefore,a power electronics converter, fed by a single phase or a DC power line, has to be considered as a quadrupole: two power access and a reference potential. Since the converter can be considered as an EMI generator, some sources have to be added to the conventional quadrupole representation. We chose to add current sources Therefore, the generic EMC model for a power converter is the one presented in Figure4. In Comparison with other work, it accounts for all necessary parameters, without any redundancy or approximation. Other representations using voltage source can also be used; they can be easily obtained from the proposed Norton scheme.

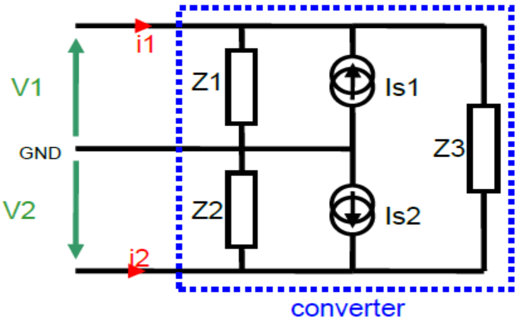

Fig -4: Model of converter

Three impedances and two current sources have thus to be identified on the whole frequency range of interest. To achieve this task, one possible solution is to measure the input voltage and currents for several operating conditions, obtained by varying line impedance. Any line impedance can be changed, either Common Mode, or Differential Mode. To be noticed that this change in power line impedance must not affect the switching behavior of the converter, in order the sources can be properly identified. Therefore, this method is more adapted for identifying a power converter rather than a switching cell, as proposed in [1]. Further works of [1] have indeed been oriented to power converter modeling [2].

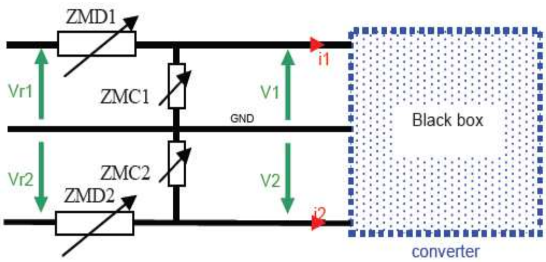

Fig -5: Line impedance variation for parameters identification.

2.2. Active Filters Model

Different approaches such as notch filter, (Newman et al., 2002), scalar control,[7] (Chandra et al., 2000), instantaneous reactive power theory,[5] (Furuhashi et al., 1990, Akagi et al., 2007),synchronous detection method[8], (Chen et al., 1993), synchronous d–q frame method,[10](Mendalek et al., 2003), flux-based control, [6](Bhattacharya et al., 1996), and closed loop PI, (Bhattacharya et al., 1996), internal model control, (Marconi et al., 2007), and sliding mode control,[12] (Saetieo et al., 1995), can be used to improve the active filter performance. Also, the direct power control method has found application in active filters, [8](Chen & Joós, 2008). Specific harmonics can be cancelled out in the grid using the selective harmonic elimination method [9](Lascu et al., 2007). In all cases, the goal is to design a simple but robust control system for the filter. Usually, the voltage-source is preferred over the current-source to implement the parallel active power filter since it has some advantages, [11](Routimo et al., 2007). Using higher voltages in the DC bus is desirable and can be achieved with a multilevel inverter [3](Lin & Yang, 2004). In this section it is used the voltage-source parallel topology, schematically shown in Fig. 6.

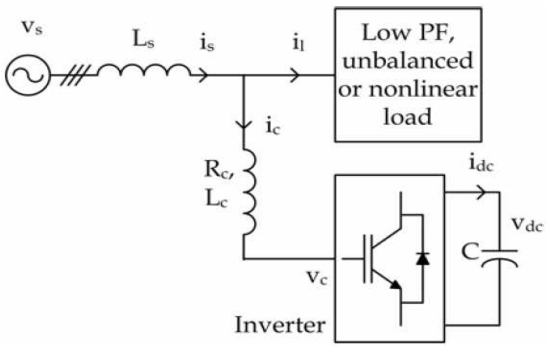

Fig -6: Connection Diagram of a voltage source active power filter.

The filter generates currents in the connection point in order to: 1- cancel/minimize the harmonic content in the AC system, 2- correct the power factor at fundamental frequency, 3- regulate the voltage magnitude, and 4- balance loads. So, the AC distribution system only carries the active fundamental component of the load current. Very different current control algorithms can be applied to the active filter, [5](Akagi, 2005).The current reference for the active filter connection node usually satisfies one of the two following strategies: 1- power factor correction, harmonic elimination, and load unbalance compensation or, 2- voltage regulation, harmonic elimination, and load unbalance compensation.

The voltage regulation strategy is a concurrent objective faced to the power factor compensation because the two depend on the reactive current. However, any control algorithm has enough flexibility to be configured, in real-time, to either objectives or for the two, in a weighted form. Even under the same compensation strategy, the filter can be controlled with different control algorithms. Two main approaches are common: voltage control, and current control. Both methods have advantages and weaknesses.

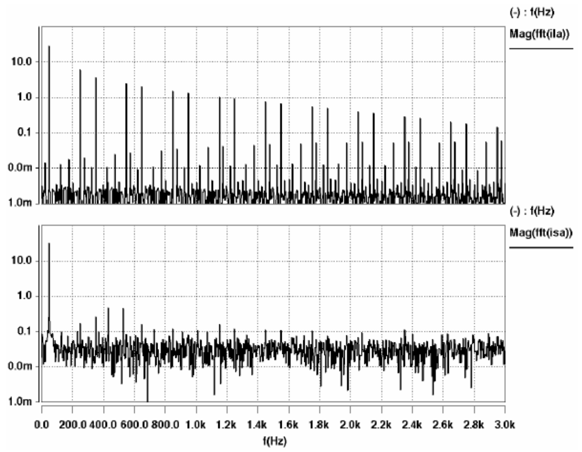

Fig -7: Harmonic spectrum of phase a non-linear load current (top) and AC source current (bottom), with the APF connected.

CONCLUSIONS

A compact EMC model for a power electronics converter, filter based on a black box approach, has been proposed, as well as the identification method. The difficulties of model identification have been studied in a simplified case. The obtained model is compact and allows very quick simulations, even if several converters are to be handled. It should thus be a good method to forecast EMI in embedded networks. The converter model and the active filter model is discussed which helps to improve the quality of power electronics systems.

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REFERENCES

[1] B. Revol, J. Roudet, J.L. Schanen, P.Loizelet, "EMI study of a three phase inverter-Fed Motor Drives", IEEE IAS 04, 2-7 octobre 2004, seattle
[2] Jin Meng, Weiming Ma, “Noise Source Lumped Circuit Modeling and Identification for Power Converters”, IEEE

Transactions on industrials electronics, vol. 53, no. 6, decenbre 2006

[3] Qian Liu, “Modular approach for Characterizing and Modeling Conducted EMI Emissions in Power Converters”, thesis of laboratory CPES-Virginia Tech, 2005

[4] Baisden, A.C.; Boroyevich, D.; Wang, F.; "EMI Terminal Modeling"IAS'08, Edmonton, Canada.

[5] Akagi, H. (2005). Active harmonic filters. Proceedings of the IEEE, vol. 93, nº 12, (Dec. 2005), pp. 2128-2141, ISSN 0018-9219

[6] Bhattacharya, S., Veltman, A., Divan, D.M. & Lorenz, R.D. (1996). Flux-based active filter controller IEEE Transactions on Industry Applications, vol. 32, nº 3, (May/June 1996), pp. 491-502, ISSN 0093-9994

[7] Chandra, A., Singh, B., Singh, B.N., Al-Haddad, K. (2000) An improved control algorithm ofshunt active filter for voltage regulation, harmonic elimination, power factor correction and balancing of nonlinear loads IEEE Transactions on Power Electronics, vol. 15, nº 3, (May/Jun. 2000), pp. 495-507, ISSN 0885-8993

[8] Chen, B.S., & Joós, G. (2008). Direct power control of active filters with averaged switching frequency regulation. IEEE Transactions on Power Electronics, vol. 23, nº 6, (Nov.2008), pp. 2729-2737, ISSN 0885-8993.

[9] Lascu, C., Asiminoaei, L., Boldea, I. & Blaabjerg, F. (2007). High performance current controller for selective harmonic compensation in active power filters. IEEE Transactions on Power Electronics, vol. 22, nº 5, (Sept. 2007), pp. 1826-1835, ISSN 0885-8993

[10] Mendalek, N., Al-Haddad, K., Fnaiech, F. & Dessaint, L.A. (2003). Nonlinear control technique to enhance dynamic performance of a shunt active power filter IEE Proceedings Electric Power Applications, vol. 150, nº 4, (July 2003), pp. 373-379, ISSN 1350-2352

[11] Routimo, M., Salo, M. & Tuusa, H. (2007). Comparison of voltage-source and current-source shunt active power filters IEEE Transactions on Power Electronics, vol. 22, nº 2, (March 2007), pp. 636-643, ISSN 0885-8993

[12] Saetieo, S., Devaraj, R. & Torrey, D.A. (1995). The design and implementation of a threephase active power filter based on sliding mode control. IEEE Transactions on Industry Applications, vol. 31, nº 5, (Sept./Oct. 1995), pp. 993-1000, ISSN 0093-9994.

BIOGRAPHIES

Abhijit Dey is currently pursuing his M.Tech in RF and Microwave Engg. From the Department of Electronics and Communication Engineering from Gitam Institute of Technology,GITAM University, A.P, India. Presently he is carrying out his project work on Differential GNSS from National Atmospheric Research Laboratory (NARL), Department of Space, and Govt. of India. He has completed his Bachelor of Engineering in Electronics and Communication from North Maharashtra University, Jalgaon, Maharashtra, India. He has already published many International Journals.

Shashwatee Paul is presently pursuing M.Tech in Electronics & Communication with specialization RF & Microwave Engg. From GITAM University, Visakhapatnam, India. She has done her B.Tech in Electronics and Communication Engineering from Rajiv Gandhi Technical University, M.P India.

Nariseti Ramya Krishna is presently pursuing M.Tech in Electronics & Communication with specialization RF & Microwave Engg. From GITAM University, Visakhapatnam, India She has done her B.Tech in Electronics and Communication Engineering from HI-Tech college of Engineering and Technology, A.P India.

Nandini Peela is presently pursuing M.Tech in Electronics & Communication with specialization RF & Microwave Engg. From GITAM University, Visakhapatnam, India