EMI Analysis on Dual Boost Power Factor Correction Converter

M.Gopinath [1]

Professor, Dr.N.G.P Institute Of Technology, Coimbatore, India.[1]

Abstract— *This paper discuses the reduced of common mode electromagnetic interference (EMI) and improved efficiency of proposed PFC converter. By designing the necessary techniques and methodology, the overall Power Factor (PF) can be improved to the expectation. Performance comparisons are analyzed between conventional Boost PFC converter and double boost PFC converter. Experiment results are given to validate the efficiency analysis and EMI model building.*

Keywords*-Dual boost PFC rectifier, power factor correction (PFC), single phase rectifier, boost converter.*

I. INTRODUCTION

In the world today, dc power supplies are extensively used inside most of electrical and electronic appliances such as in computers, monitors, televisions, audio sets and others. The high power non linear loads (such as static power converter, arc furnace, adjustable speed drives etc) and low power loads (such as fax machine, computer, etc) produce voltage fluctuations, harmonic currents and an imbalance in network system which results into low power factor operation of the power system [1]. Many power factor correction (PFC) circuits are used for realizing high power quality in the systems. In order to reduce energy consumption in the systems, the efficiency of PFC circuits must be increased. On the other hand, system reliability is also important to avoid any interruption of data communications. Therefore, PFC circuits should achieve both high efficiency and high reliability. Innovation and optimization of power factor correction (PFC) technology would be an important method to achieve higher efficiency and low electromagnetic interference (EMI) power supplies. Traditional Boost PFC in Fig.01 cannot avoid some natural power loss because of the drawbacks of their structures with full-wave rectifier in the input. Recently, a new PFC family called Bridgeless PFC (BLPFC) family/ dual boost PFC has been proposed to realize high efficiency PFC converters by more or less eliminating the ac rectifier of traditional Boost PFC [1~3]. However, whether all the members belonging to BLPFC family have high efficiency is doubtful, besides many researchers have shown that some of the BLPFC topologies have bad EMI performance due to their circuit structures [4~5]. In this paper, a systematic review of BLPFC family is presented; common mode (CM) EMI performances are analyzed comparing with conventional Boost PFC. Simulation and experiment results shows that low EMI and high efficiency PFC can be realized by a certain BLPFC/Dual boost topology.

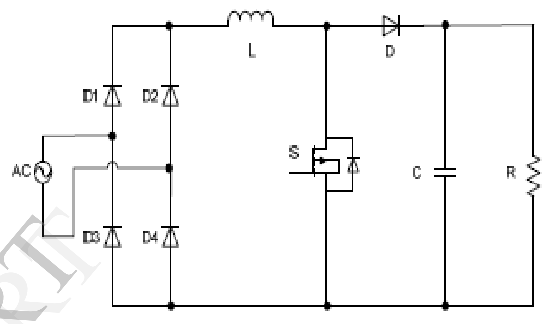

Fig.01. Conventional Boost PFC

II. REVIEW OF DUAL BOOST PFC CONVERTERS

To reduce the common-mode noise of the bridgeless PFC boost rectifier the topology of the bridgeless PFC boost rectifier needs to be modified to always provide a low frequency (LF) path between the ac source and the positive or negative terminal of the output [10-12]. In Fig. 2, in addition to diodes D3 and D4, which are slow recovery diodes, a second inductor is also added, resulting in two dc/dc boost circuits, one for each half-line cycle. During a positive half line cycle, the first dc/dc boost circuit, LB1 -D1 –S2 is active through diode D4, which connects the ac source to the output ground. During a negative half-line cycle, the second dc/dc boost circuit, LB2 -D2-S1, is active through diode D3, which connects the ac source to the output ground. It should be noted that switches S1 and S2, in both bridgeless PFC boost rectifiers can be driven with the same PWM signal, which significantly simplifies the implementation of the control circuit. In Fig. 2, there are two Boost circuits in the BLPFC [8~9]. One can expect higher efficiency than Boost PFC with

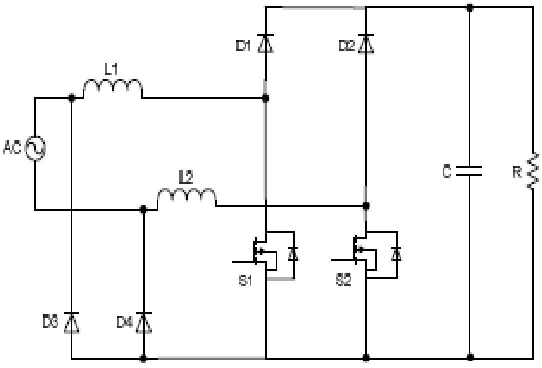

Fig.02. Dual Boost PFC

the same reason as Dual Boost PFC. And its EMI will be lower than Boost PFC, because not only the low frequency diodes D3 and D4 connect the output ground to the ac source but the symmetric Boost inductors operate as a CM filter which can be expected to achieve higher CM EMI reduction.

III. EMI MODEL BUILDING

If we take the Boost PFC as a noise source and consider the ac source as a load, it was proved that the EMI model of the Boost PFC converter equals to a high frequency pulse source [12]. In order to make a precise analysis, the EMI model is needed to be built. Take Dual -boost-circuit PFC as an example; since it's a symmetrical circuit for both positive and negative part of ac source, we only consider the positive ac period. Ignore the limited noise current flows through the body diode of S2 and L2 [12], analysis of generate the EMI model of the topology is showed in Fig.3.

- **Step 1**: Using the symmetrical operation structure to simplify the topology.
- **Step 2**: Because the output filter capacitor can be considered as a short circuit in high frequency, and the boost inductor can be considered as an open circuit, these two components can be ignored.
- **Step 3**: Simplify the semiconductor components. In high frequency domain, the fast diode can be simplified as a capacitor and the MOSFET can be considered as a pulse source.
- **Step 4**: Deduction of circuit using Thevenin's Theory.

As the result, the Two-boost-circuit BLPFC in the positive ac source can be equal to a pulse voltage source Veq in series with a capacitor Ceq.

$$Veq = -Vds \times C_{S1} \times C_{eq}^{-1} \qquad (1)$$

$$C_{eq} = C_{S1} + C_{S2} + C_b \qquad (2)$$

Where, CS1 and CS2 are the parasitic capacitances of MOSFETs, Cb is the capacitance between output ground and the power earth. Normally, Cb is 10 to 20 times bigger than CS1 and CS2 [11], so if there is any pulses voltage across it, it will bring a significant extra CM current flow through it and lead to CM EMI problems. However, from (1) and Fig. 3(c), one can find that Cb is connected directly between the source of the MOS (which connected to the neutral) and the earth. This will cause no pulses voltage draw on Cb, therefore the CM current of the circuit will be reduced.

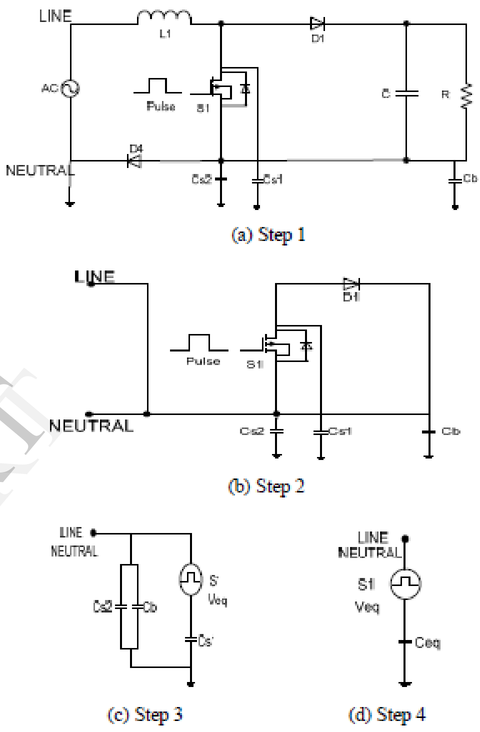

Fig.03. EMI model building for two-boost-circuit PFC

EMI model of this topology in the negative period of ac source is the almost the same as the former one in (1), but:

$$Veq = -Vds \times C_{S2} \times C_{eq}^{-1} \qquad (3)$$

Assuming CS1 =CS2 =CS, the EMI model for the whole ac period can be written as:

$$Veq = -Vds \times C_S \times C_{eq}^{-1} \qquad (4)$$

$$Ieq = -Vds \times \omega C_S \qquad (5)$$

Equation (4) shows that although the switching operation generates high frequency pulses inside the Two-boost-circuit PFC, they will not impact the voltage waveform between power ground and neutral. Because of the line frequency return diodes D3 and D4 in Fig. 02, the power ground is connected to the neutral for the whole ac period and all the pluses voltages go into the earth through the parasitic capacitances CS of the MOS, which gives a continuous and smooth waveform between power ground and the neutral. Equation (5) shows that the CM current will only flow through the parasitic capacitance of MOS.

IV. SIMULATION ANALYSIS

Simulation is done using Matlab Simulink and the results are presented. The conventional boost converter is shown in Fig.04.a.The corresponding AC input voltage and current waveforms are shown in Fig.04.b.

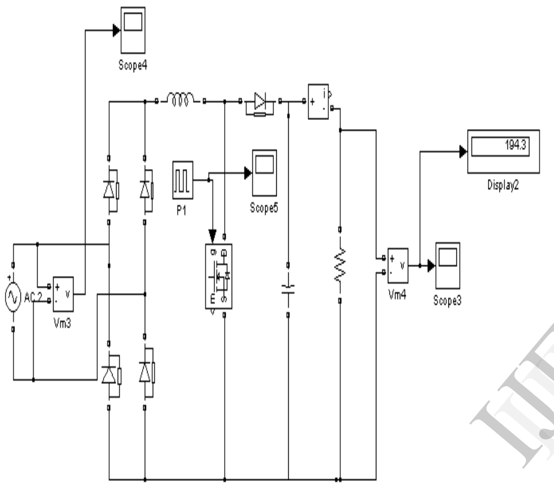

Fig.04.a. Simulation of Conventional Boost Circuit

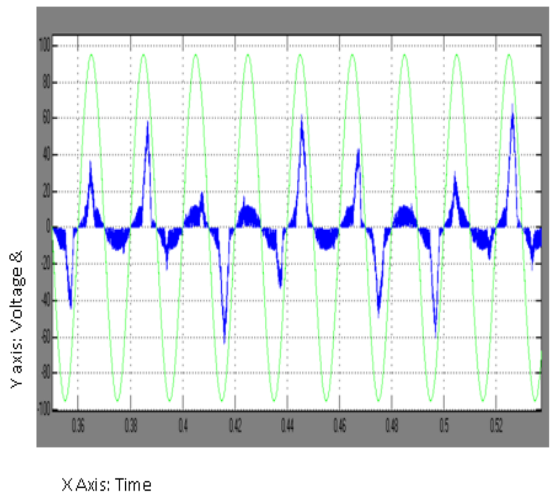

Fig.04.b. Input voltage and current waveform

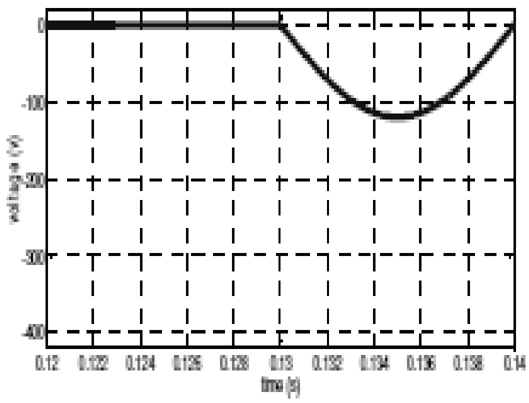

Fig.04.c. CM voltage waveforms of Conventional method

The phase angle between the voltage and current is higher. In the conventional boost PFC, the output ground is always connected to the ac source through full-bridge rectifier. So the CM EMI is less in conventional method and the voltage waveforms between power ground and the neutral of ac source during one ac period is shown in Fig.04.c whereas, in the Modified circuit while going for high power application, the output ground is connected to the ac source only during positive half-line cycle through the body diode of switches. So large pulse current from high frequency switches will flow through parasitic capacitors and brings EMI problems. To over come this problem, Dual boost converter is used and shown in Fig.05.a.

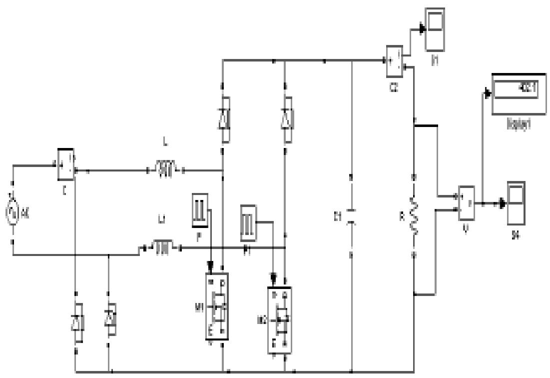

Fig.05.a. Simulation of Dual Boost Circuit

It is assumed that a controlled switch is implemented as the power MOSFET with its inherently slow body diode. AC input voltage and current are shown in Fig.05.b.It can be seen that the current and voltage are almost in phase. DC output voltage and output current are shown in Figs.05.c and 05.d respectively.

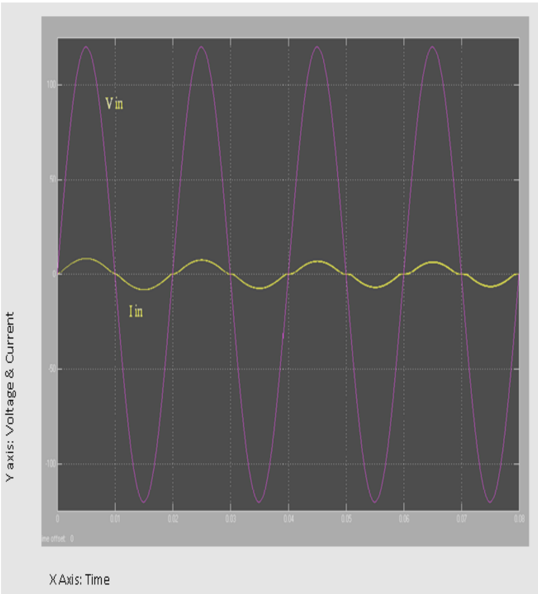

Fig.05.b. Input voltage and current waveform of Dual Boost circuit

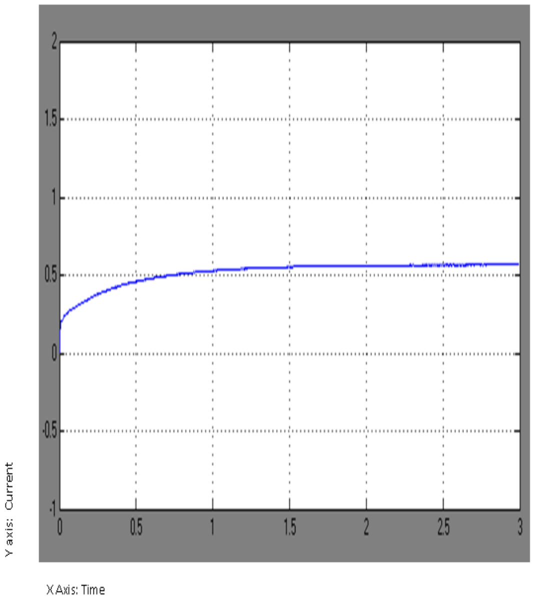

Fig.05.d. DC Current of Dual Boost circuit

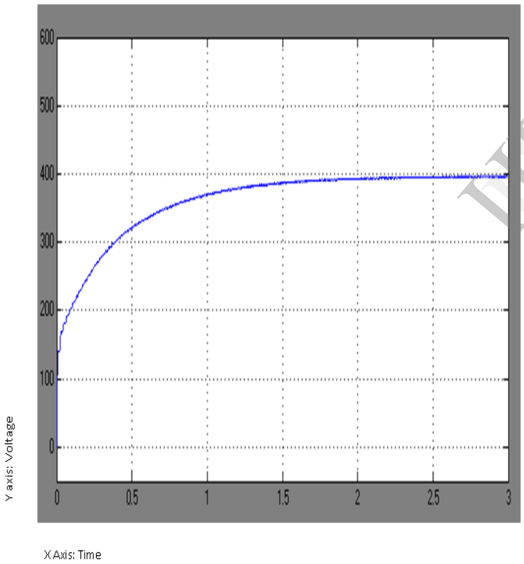

Fig.05.c. DC Voltage of Dual Boost circuit

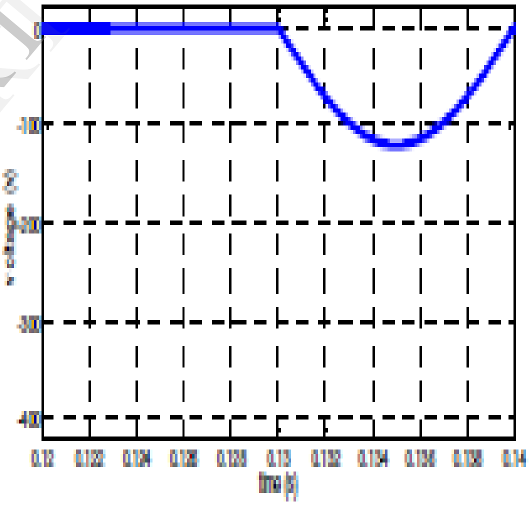

Fig.05.e. CM voltage waveforms between power ground and the neutral of ac source (Dual Boost Circuit)

One can expect higher efficiency than Boost PFC and its EMI will be lower than Boost PFC, because not only the low frequency diodes D3 and D4 connect the output ground to the ac source but the symmetric Boost inductors operate as a CM filter which can be expected to achieve higher CM EMI reduction. Fig.05.e shows the voltage waveforms between power ground and the neutral of ac source during one ac period.

V. EXPERIMENT RESULTS

The performance comparison of the Boost PFC and Dual boost-circuit PFC is done. The schematics of both PFCs are shown in Fig.06.a and 06.b. The Dual boost converter has higher conversion efficiency than the conventional Boost PFC rectifier over the entire measured power range.

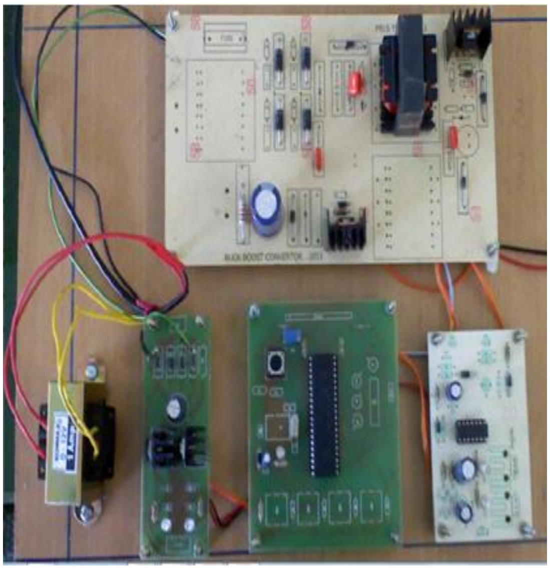

Fig.06.a. Hardware of Conventional Boost Circuit

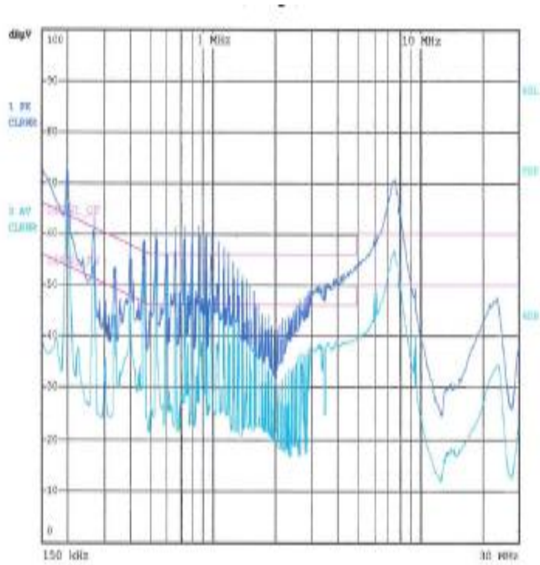

Fig.06.c. EMI measurement of conventional Ckt

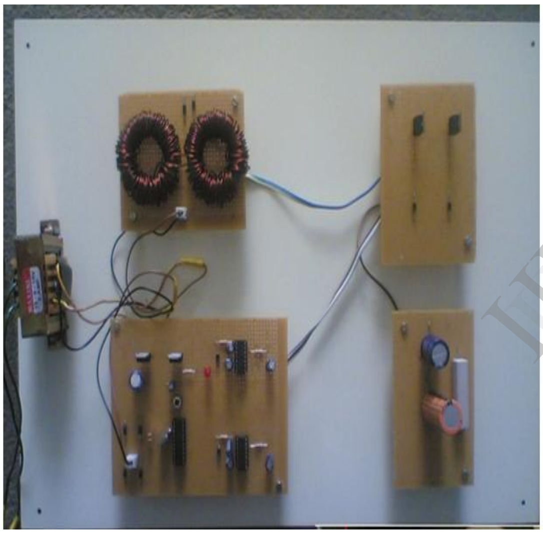

Fig.06.b. Hardware of Dual Boost Circuit

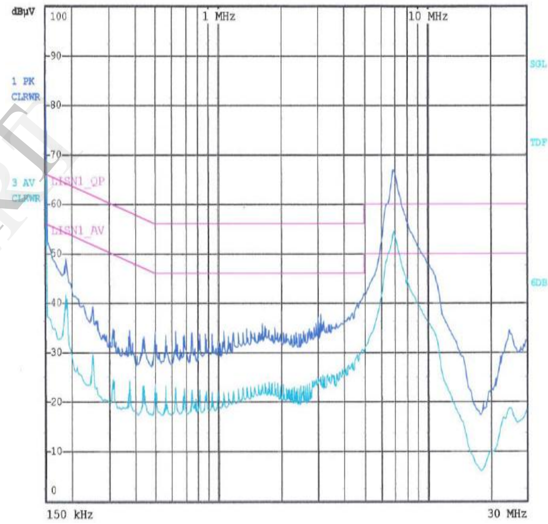

Fig.06.d. EMI measurement of Dual boost Ckt

Fig.06.c and 06.d show the measured peak and average EMI of the conventional Boost PFC and the Dual-boost-circuit PFC with the same EMI input filter respectively. As it can be seen from Fig.06.c the measured EMI value of the Boost PFC cannot satisfy the requirements over the frequency range from 436 kHz to 1.2MHz in low frequency domain. But can be seen from Fig.06.d, the Dual-boost-circuit PFC exhibits EMI reduction over the entire measured frequency range. Specifically, the measured peak EMI shows more than 10dB≤ V margin from the requirements over the entire frequency range below 3MHz. This is because the two boost inductors in Dual boost-circuit PFC operate as a CM filter and reduce the CM noise.

V. CONCLUSION

In this paper, a review of Dual Boost power factor correction converter is presented. Performance comparison of common mode electromagnetic interference (EMI) argumentation is analyzed between traditional Boost PFC converter and Dual boost (Member of Bridgeless PFC family). The simulation and experiment results show the advantages and disadvantages of Dual boost PFC topology. It also shows the valid Dual boost PFC topology for industrial application.

REFERENCES

[1]. Jee-Woo Lim and Bong Hwart-Kwon, "A power-factor controller for Single-Stage PWM rectifiers," *IEEE* Trans. *Ind. Electron***,** vol. 46, pp. 1035-1037, Oct. 1999.

[2]. Alexandre Ferrari de Souza and IYO Barbi,"'A new ZVS semi resonant high power factor rectifier with reduced conduction losses," *IEEE Tram. Ind. Electron.*, vol. 46. pp. 82-91), Feb. 1999.

[3] .Ugo Monconi, I' A bridgeless PFC configuration based on L4981 PFC controller," *STMicroelecrronics Applicarion Noles,* AN1606, Nov. 2002.

[4] P. Kong, S.Wang, and F. C. Lee, "Common mode EMI noise suppression in bridgeless boost PFC converter," in *Proc. CPES Power Electronics Conf.*, Apr. 2006, pp. 65–70.

[5] H. Ye, Z. Yang, J. Dai, C. Yan, X. Xin, and J. Ying, "Common mode noise modeling and analysis of dual boost PFC circuit," in *Proc. Int. Telecommunication Energy Conf.*, Sep. 2004, pp. 575–582.

[6] P. N. Enjeti and R. Martinez, "A high performance single phase AC to DC rectifier with input power factor correction," in *Proc. IEEE Applied Power Electronics Conf.*, Mar. 1993, pp. 190–195.

[7] J. C. Salmon, "Circuit topologies for PWM boost rectifiers operated from 1-phase and 3-phase ac supplies and using either single or split dc rail voltage outputs," in *Proc. IEEE Applied Power Electronics Conf.*, Mar. 1995, pp. 473–479.

[8] A. F. Souza and I. Barbi, "High power factor rectifier with reduced conduction and commutation losses," in *Proc. Int. Telecommunication Energy Conf.*, Jun. 1999, pp. 8.1.1–8.1.5.

[9] T. Ernö and M. Frisch, "Second generation of PFC solutions," in *Proc. Power Electronics Europe*, 2004, no. 7, pp. 33–35.

[10] J. Liu, W. Chen, J. Zhang, D. Xu, and F. C. Lee, "Evaluation of power losses in different CCM mode single-phase boost PFC converters via simulation tool," in *Rec. IEEE Industry Applications Conf.*, Sep. 2001,pp. 2455–2459.

[11] Tim. Williams, "EMC for product designers," in press. Newnes, 2001.

[12] H. Ye, Z. Yang, J. Dai, C. Yan, X. Xin, and J. Ying, "Common mode noise modeling and analysis of dual boost PFC circuit," in Proc. Int. Telecommunication Energy Conf., Sep. 2004, pp. 575-582.

Authors

M.Gopinath has obtained his B.E degree from Bharathiar University, Coimbatore in the year 2002. He obtained his M-Tech degree from Vellore Institute of Technology; Vellore in the year 2004.He completed his Ph.D at Bharath University, Chennai. He is working as a Professor/EEE, at Dr.N.G.P Institute of Technology, Coimbatore. His Area of interest is Power Electronics. He has published over 20 Technical papers in National and International Conference proceeding/Journals.