Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SIMULATIVE INVESTIGATIONS OF CONDUCTIVE EMI PERFORMANCE ON DIFFERENT CONVERTER TOPOLOGIES

[1]C.KRISHNA KUMAR [2] DR.A.NIRMALKUMAR [3]M.SATHIS KUMAR

[1]Asst. Prof (SG), EEE dept., Periyar Maniammai University, Thanjavur, India
[2] Prof & Head, EEE dept, Info institute of technology,Coimbatore, India
[3]Asst. Prof, EEE dept., Periyar Maniammai University, Thanjavur, India
E-mail: [1]ckk1973@gmail.com, [2]ankhod@gmail.com, [3]msk_eie@rediffmail.com

ABSTRACT

This paper discusses a passive method of suppressing conducted electromagnetic interference (EMI) on various pulse width modulation (PWM) DC/DC converters. Snubbers are circuits which are placed across semi conductor devices for protection and to improve performance. In this paper, passive snubber such as RLD and RCD snubber is experimented and a new combined snubber is proposed. The combined snubber is designed to support the buck, boost, buck boost and cuk converters. The common mode noise (CM) and differential mode noise (DM) is simulated using PSPICE version 9.0 software. The conducted noise is measured for with and without connecting the RLD, RCD and the proposed snubber. The simulated results were compared to recommend low emission converter among the various DC/DC converter topologies.

Keywords: *Electromagnetic Interference, Snubber Circuits, Switching Frequency, Duty Cycle, Common Mode Noise, Differential Mode Noise.*

1. INTRODUCTION

DC-to-DC converter is an electronic circuit, which converts a source of direct current (DC) from one voltage level to another. DC-to-DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. The output voltage in DC-DC converters is generally controlled using a switching concept. This conversion can be done by two methods. They are: (i) LINEAR conversion and (ii) SWITCH MODE conversion.

The main effects of power device switching are:

- common mode currents flowing through the stray capacitance of the system;
- conducted electromagnetic interference that
eventually can propagate also by radiation;
- lifetime reduction of the motors and transformers insulation;
- Interference with communication systems or other electronic equipment placed in the proximity of the drive [1].

Conducted EMI occurs by the physical contact of the conductors due to induction. This is of two types. They are: (i) Common mode (CM) noise and (ii) Differential mode (DM) noise.

Conducted EM1 problems have assumed a great importance in the field of both industrial and domestic ones, owing to the possible presence of very susceptible electric appliances operating in the same environment of the drives and to the more and more stringent standard limits.
The investigation of Electromagnetic Compatibility (EMC) problerns in power electronic systems is of relevant importance in order to define their electromagnetic behavior. A snubber is a circuit connected around a power semiconductor device for the purpose of altering its switching trajectory. The main objective of snubber is to reduce power losses in the semiconductor device. It prevents fast change of voltage or current during switching, so that commutation process can become more nearly linear.

Suitable model of the converter topology have to be defined to make predictions of high frequency noises. In this paper the comparative study of EMI analysis is made on various DC-DC converters.

In this paper, a combination of RLD and RCD snubber is proposed and its effects on the mitigation of conducted electromagnetic

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

interference were analyzed. Simulation results are compared for various converters in the EMI point of view.

2. LISN CIRCUIT

A Line Impedance Stabilization Network (LISN) is used to standardize the input impedance seen from the input of the device under the test [2]. LISN consists of inductors, capacitors and resistors. The inductor and capacitor are for filtering the noise and the inductor also separates the unwanted high frequency noises.

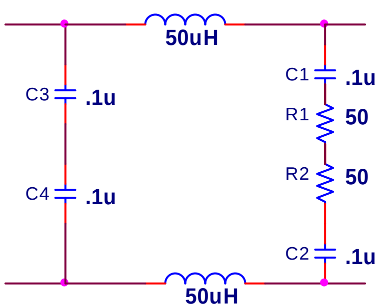

Fig1. LISN Circuit

It fulfills three main functions:

- It filters the voltage of the mains and blocks the frequencies, which are higher than the mains frequency.
- It does provide characteristic impedance to the device under test (DUT).
- The device under test (DUT) produces EMI, which transferred to a meter generally the spectrum analyzer or an EMI receiver, so that measurement is made easy [3].

3. SNUBBER CIRCUITS

Hard switching exposes the switch to high stress because the maximum voltage and maximum current must be supported simultaneously [4]. This also leads to high switching loss. In practical circuits the switch stress will be even higher due to the unavoidable presence of parasitic inductance (Lp) and capacitance (Cs). Cp includes the junction capacitance of the switch and stray capacitance due to circuit layout and mounting. Lp is due to the finite size of the circuit layout and lead inductance. Lp can be minimized with good layout practice but there may be some residual inductance which may cause a ringing voltage spike at turn-.The most common reasons for using a snubber are to limit the peak voltage across the switch and to reduce the switching loss during turn-off. Snubber is an essential part of power electronics. Snubbers are small networks of parts in power switching circuits whose function is to control the effect of circuit reactance. Snubbers are classified as active snubbers and passive snubbers. Mostly the passive snubbers are used in practice. Because an extra switch is required for active snubbers, thereby increasing the power loss [5]. The snubber circuits are implemented for reducing the average power dissipation. Passive snubber network elements are limited to resistors, capacitors, inductors and diodes. Active snubbers include transistors or other active switches.

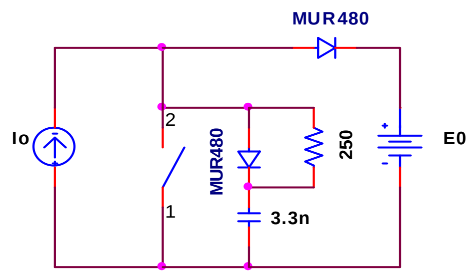

Fig 2. A Simple RLD Snubber

For high value of Cs greater the loss in R_s when the switch turns on and C_s is discharged through Rs and the switch. Depending on the size of C_s the switch voltage may reach E_o. The case where $E = E_o$ at the instant that I = 0 is defined as a “normal” snubber and Cs = Cn.

$$C = \frac{Io\,ts}{2Eo}$$

In above equation t_s is the fall time of the switch current. When small value of snubber is used (Cs < Cn) the switching loss drops quickly. As C_s is made larger however, the improvement in switch loss decreases. There are different types of passive snubbers. We have selected resistor-inductor-diode (RLD) turn-on snubber, resistor-capacitor-diode (RCD) turn-off snubber and combined (RLD+RCD) snubber. The combination snubber, using both RLD and RCD, produced very good results with low losses

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4. ANALYSIS

4.1. Buck Converter

There are many different types of converter topologies. Of those converters, buck converter is the basic converter topology

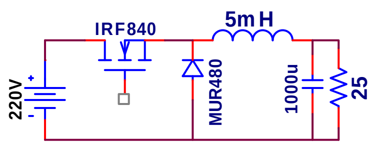

Fig 3. A Simple Buck Converter

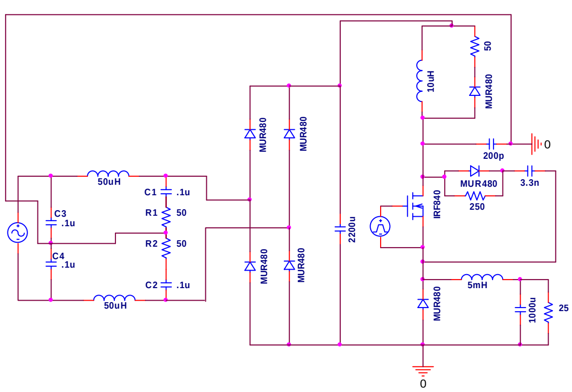

Fig.4 Buck converter with RLD+RCD snubber.

Figure 3 and 4 shows the simulation circuit of buck converter with and without combined snubber. A LISN circuit is introduced between the source and the converter [10]. A virtual simulation software version 9.0 of PSPICE is used for the simulation and the factors used are as follows:

Power MOSFET : IRF840
Diode : MUR480
Starting time : 10ms
Step size : 0.01us
Circuit Details : Cmain= 1000uF, Lmain=5mH, Ls (RLD)= 10uH, Rs(RLD) =50 ohm, R (RCD)= 250ohm, C (RCD)= 3.3nF, C (heat sink)=200pF.

The common mode and differential mode voltage is measured. The measurements were taken by connecting RLD, RCD and combined snubber respectively. The drain to source voltage and drain current is also observed to calculate the power loss of the switch.

Table 1. Noise measurements on Buck Converter

Description	V_{CM} (mv)	In dBµV	V_{DM} (mv)	In dBµV
Without snubber	0.2845	49 dBµV	3.2297	70 dBµV
With RLD	0.2012	46 dBµV	3.0001	69 dBµV
With RCD	0.2416	47 dBµV	3.1381	70 dBµV
Combined	0.1932	45 dBµV	2.121	66 dBµV

Table 1 shows the peak noise level on buck converter for with and without passive snubbers. Different types of passive snubbers are connected and the noise levels were measured. From the Table 1 it is ascertained that CM noise is lesser than the DM noise for all types of snubber and it is also observed that combined snubber results in low common mode and differential mode conducted noise. The common mode noise was reduced by 4 dBµV when compared with a buck converter without snubber. The differential mode noise is mitigated by 3 dBµV when compared with buck converter without snubbing.

4.2. Boost Converter.

Figure 5 shows a model figure of a Boost Converter. Its main application is in regulating DC

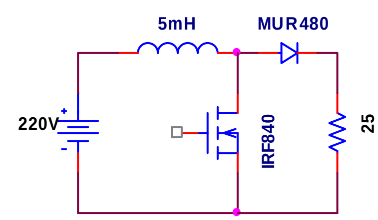

Fig 5. Simulation circuit of Boost converter

power supplies and regenerative braking of DC motors. When the switch is on, the diode is reversed-biased, thus isolating the output stage [12]. The input voltage source supplies energy to the inductor. When the switch is off, the output stage receives energy from the inductor as well as the input source. Output voltage can be obtained as

$$V0 = \frac{Vin}{(1 - D)}$$

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

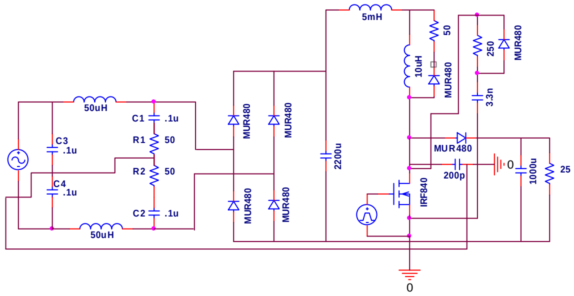

Fig 6. Boost converter circuit with RLD+RCD snubber

Figure 5 and 6 shows the simulation circuit [16] of boost converter with and without connecting combined snubber. From Table 2 it is evident that for the buck converter Without snubber, the measured common mode noise

Table 2. Noise measurements on Boost Converter

Description	V_{CM} (mv)	In dBµV	V_{DM} (mv)	In dBµV
Without snubber	1.1437	61 dBµV	4.155	72 dBµV
With RLD	1.0361	60 dBµV	4.2291	72 dBµV
With RCD	0.8992	59dBµV	3.0381	70 dBµV
Combined	0.6884	56 dBµV	3.0221	69 dBµV

and differential mode noise is in higher level when compared with converter connected with passive snubber. For the boost converter with RLD snubber, it is found that the differential mode noise is in same level as converter without snubber and there is a common mode noise attenuation of 1 dBµV. The combined snubber has achieved a very good level of attenuation for both common mode and differential mode noise by 5 dBµV.

4.3 Buck Boost Converter

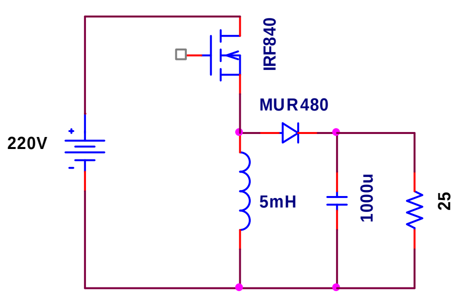

Fig 7. Buck boost converter

Buck boost converter is the cascaded connection of two basic converters of buck and the boost. In steady state the output to input voltage conversion ratio is the product of the conversion ratios of the two converters in cascade. This allows the output voltage to be higher or lower than the input voltage based on the duty ratio [21]. The output voltage can be obtained as

$$Vo = -Vin * (D/(1-D))$$

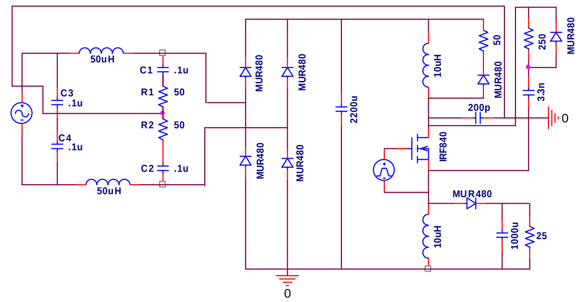

Fig 8. Buck boost converter with RLD+RCD snubber

Table 3. Noise measurements on Buck Boost Converter

Description	V_{CM} (mv)	In dBµV	V_{DM} (mv)	In dBµV
Without snubber	2.6439	68 dBµV	5.8945	75 dBµV
With RLD	1.9096	65 dBµV	4.8931	74 dBµV
With RCD	2.4343	67 dBµV	4.924	74 dBµV
Combined	0.3513	51 dBµV	2.801	68 dBµV

From Table 3 it is observed that the buck boost converter attained a differential mode noise level of 75 dBµV. It is noticed that the RCD snubber is better in common mode noise mitigation when compared with RLD snubber. There is a reduction of 5 dBµV in both and CM and DM noise when compared with the buck converter without snubber.

4.4 Cuk Converter

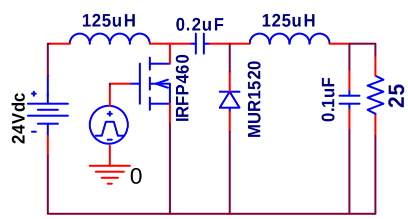

Fig 9. Cuk Converter

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 9 shows a simulation circuit of typical Cuk converter. The converter is obtained by using the duality principle on the circuit of the buck boost converter [15, 19]. The cuk converter provides a negative polarity regulated output voltage with respect to the common terminal of the input voltage. The output voltage can be obtained as

$$V_o = -V_{in} * (D/(1-D))$$

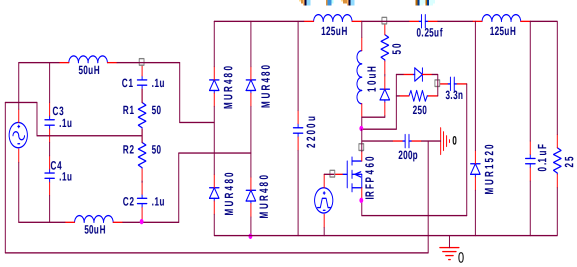

Fig 10. Cuk converter with RLD+RCD snubber.

Figure 9 and Figure 10 is the PSPICE circuit diagram of cuk converter and cuk converter with RLD+RCD snubber. [6, 7, 8, 9]

Table 4. Noise measurements on Cuk Converter

Description	V_{CM} (mv)	In dBµV	V_{DM} (mv)	In dBµV
Without snubber	1.105	61 dBµV	6.244	76 dBµV
With RLD	0.9072	59 dBµV	5.57	75 dBµV
With RCD	1.062	60 dBµV	6.325	76 dBµV
Combined	0.8131	58 dBµV	2.712	68 dBµV

From Table 4 it is observed that the cuk converter has high level of differential mode noise. For the converter without snubber, the peak value of the differential mode noise reaches up to 76 dBµV. It is evident that the differential mode noise level is higher when compared with common mode noise [12].

5. COMPARISON BETWEEN VARIOUS CONVERTERS

5.1 WITHOUT SNUBBER

Figure 11 and 15 illustrates the simulation results of the common mode noise and differential mode noise with different converter topologies. For the duty cycle of 0.6 the simulation is completed without connecting the snubber circuit. It is evident from the figures that the noise magnitude for all the converters is high in the range of 0-8 MHz. The magnitude of the differential mode noise is high compared with common mode noise in the high and low frequency ranges for all the converters. It is observed that for the buck converter the CM and DM noise levels are less compared to other converter noises and particularly in the range 0-8MHz [11]. The reduction in noise lies in the range 2dBµv-20dBµv. From Table 5 it is observed that the average conducted noise level for buck converter is less when compared with other converters [23]. The switching loss is around 8.1675 w for the buck converter which is high when compared to other type of converters.

5.2 WITH RCD SNUBBER

The simulation results of CM and DM noises are shown in figure 13 and 17. The simulation is conducted for duty ratio D = 0.6. It is observed that for the buck converter the attenuation level is good at nearly 2dBµv-20dBµv in the low frequency and high frequency ranges. In case of boost converter attenuation in the noise is nearly 1dBµV to 4 dBµV in the frequency range 0 to 1.5MHz. In buck boost converter the noise is reduced about 1 dBµV -14 dBµV. In case of cuk converter the noise is attenuated approximately by 1-6 dBµV and it is observed in the range of 0-4.5MHz. For the cuk converter the noise reduction is about 5-15 dBµV and is observed in the range of 4-27MHz.The differential mode noise is attenuated in the frequency range of 6-8MHz and the reduction is about 3-20 dBµV. From Table 7 it is observed that the average conducted noise level for buck converter is less when compared with other converters. The switching loss is around 6 W for the buck converter which is low when compared to other type of converters [13]. It is evident that the switching loss is reduced by 2 watts by connecting the RCD snubber.

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5.3 WITH RLD SNUBBER

Similarly, figure 12 and 16 shows the CM and DM noise comparison of different DC/DC converters. It is observed in the frequency ranges of 0-10MHz and 18-20MHz, the reduction is about 20 dBµV. Buck-boost converter is better in the particular frequency range 4-14MHz than the cuk converter and the noise is attenuated by 3-8dbuv. For Cuk converter the noise attenuation is observed in the frequency range 0-4MHz and also 14-20MHZ and is about 1 dBµV -10 dBµV. The mitigation of differential mode noise for the buck converter is good [18] when compared to other converter and also reduction is found in the frequency range of 1 MHz to 15 MHz. From Table 6 it is observed that the average conducted noise level for buck converter is less when compared with other converters. The switching loss is around 6 W for the buck converter which is low when compared to other type of converters [17]. It is evident that the switching loss is reduced by 1.5 watts by connecting the RLD snubber.

5.4 WITH COMBINED SNUBBER

For a duty cycle of 0.6 [20], the simulation results of the CM and DM noises are shown in figure 14 and 18.By connecting RCD+RLD snubber [14], buck converter has least noise than other converters. This reduction is about 5-20 dBµV particularly in the frequency range 1-4MHz, 8-14MHz, and 16-18MHZ. From Table 8 it is observed that the average conducted noise level for buck converter is less when compared with other converters [22]. The switching loss is around 6 W for the buck converter which is low when compared to other type of converters. It is evident that the switching loss is reduced by 3 watts by connecting the RLD + RCD snubber.

Table 5. Converters without Snubber

Converter	V_{ds} (V)	I_D (A)	V_D(V)	V_{CM} (mV)	dbuv (CM)	V_{DM} (mV)	dbuv (CM)
Buck	1.4850	5.5	100.495	0.2845	49	3.2297	70
Boost	0.9832	5.4	250.680	1.1437	61	4.1850	72
Buck-boost	0.7375	5.3	227.830	2.6439	68	5.8945	75
Cuk	0.3510	5.4	237.670	1.1050	61	6.2440	76

Table 6. Converters with RLD Snubber

Converter	V_{ds} (V)	I_D (A)	V_D(V)	V_{CM} (mV)	dbuv (CM)	V_{DM} (mV)	dbuv (CM)
Buck	1.2730	5.2	100.127	0.2012	46	3.000	69
Boost	1.8819	5.3	249.620	1.0361	60	4.229	72
Buck-boost	1.6127	5.4	223.790	1.9096	65	4.893	74
Cuk	1.1762	5.2	227.370	0.9072	59	5.570	75

Table 7. Converters with RCD Snubber

Converter	V_{ds} (V)	I_D (A)	V_D(V)	V_{CM} (mV)	dbuv (CM)	V_{DM} (mV)	dbuv (CM)
Buck	1.1930	5.0	101.32	0.241	47	3.1381	70
Boost	1.8112	5.2	247.78	0.899	59	3.0381	70
Buck-boost	1.6071	5.1	232.85	2.434	67	4.9240	74
Cuk	1.1973	5.3	225.34	1.062	60	6.3250	76

Table 8. Converters with RLD+RCD Snubber

Converter	V_{ds} (V)	I_D (A)	V_D(V)	V_{CM} (mV)	dbuv (CM)	V_{DM} (mV)	dbuv (CM)
Buck	0.975	5.20	103.570	0.193	45	2.121	66
Boost	0.873	5.23	243.582	0.688	56	3.022	69
Buck-boost	0.628	5.05	235.620	0.351	51	2.801	68
Cuk	0.2003	5.25	224.120	0.813	58	2.712	68

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

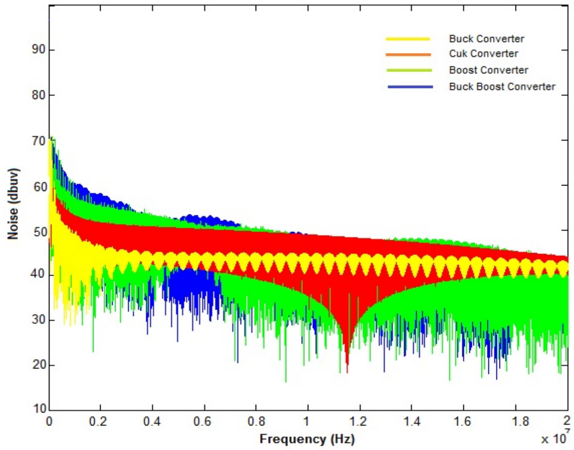

Fig11.Comparison of converters for common mode noise without snubber

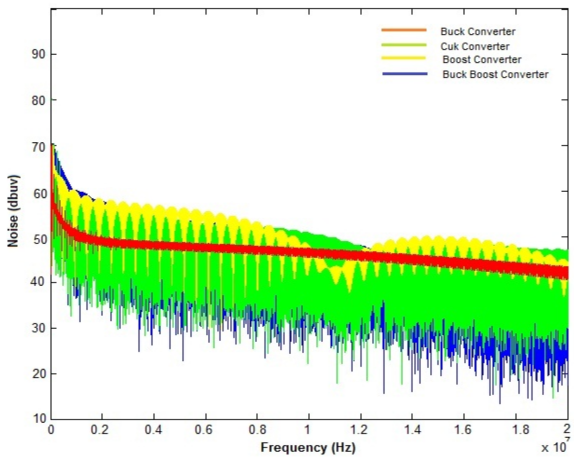

Fig 12.Comparison of converters for common mode noise with RLD snubber

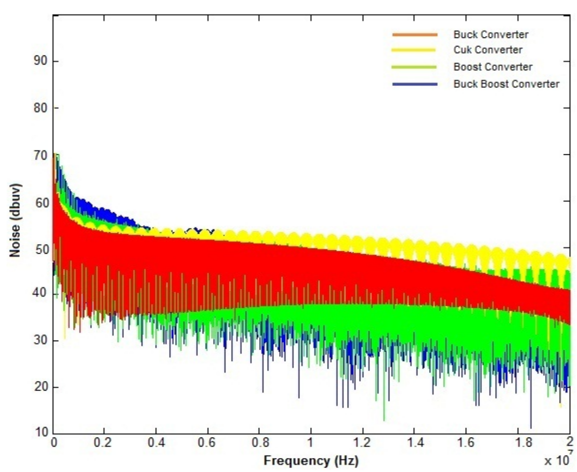

Fig 13.Comparison of converters for common mode noise with RCD snubber

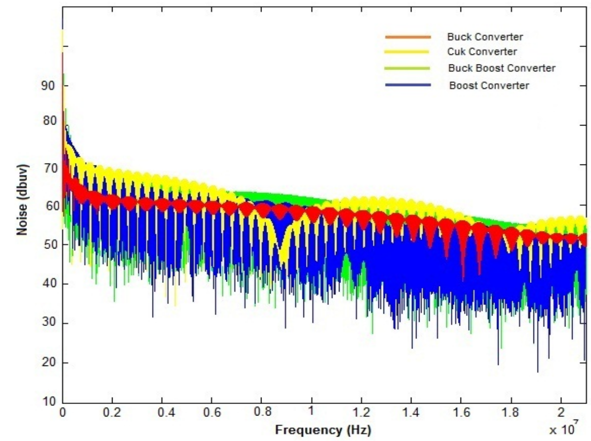

Fig 14.Comparison of converters for common mode noise with RLD+RCD snubber

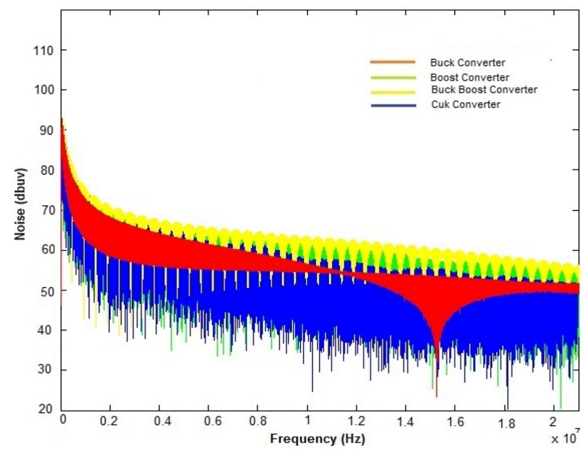

Fig15. Comparison of converters for differential mode noise without snubber

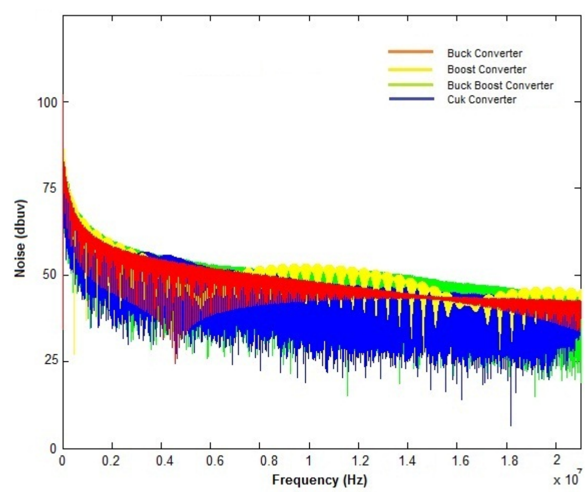

Fig 16.Comparison of converters for differential mode noise with RLD snubber

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

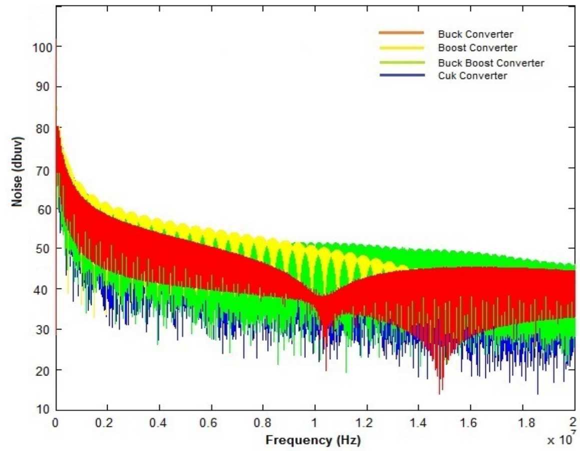

Fig 17.Comparison of converters for differential mode noise with RCD snubber

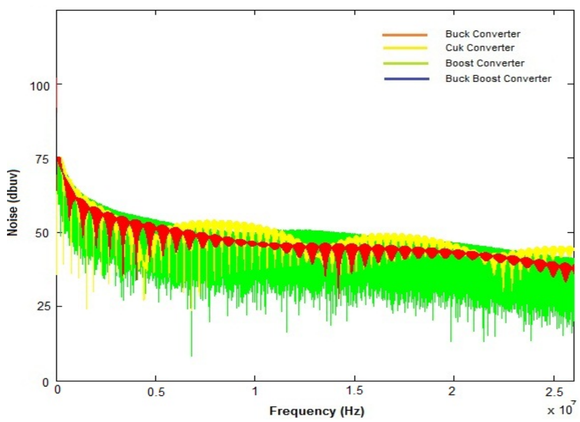

Fig18. Comparison of converters for differential mode noise with RLD+RCD snubber

6. CONCLUSION

This research paper aimed at simulation and comparison of different converter with and without RLD, RCD and combined (RLD+RCD) snubber circuits. The EMI was analyzed in the range of 9 KHz to 30 MHz. The main cause for this EMI in this circuit is due to the high switching frequency of power MOSFET. Using passive snubber circuits such as RLD, RCD and RLD+RCD snubbers reduced this. The following are found through this analysis:

The conducted noise produced in buck converter is lesser for fixed duty cycle than other converters. The noise produced in cuk converter is greater than buck converter but less than that of other converters. Noise produced by buck boost converter is higher than all the other converters. It is therefore concluded that the combined snubber results in good mitigation of conducted EMI and reduced switching losses.

REFERENCES:

[1] Henry W.Ott, "EMC Engineering" third edition, A.John Wiley @ Sons, INC., publications.

[2] Model 3810/2 "Line Impedance Stabilization Network Manual " EMC test systems, Feb 1996 Rev C –PN399197.

[3] W.Khan-ngern, "Electromagnetic compatibility Experimental laboratory on Power electronics" *ICEMC* 2002/Bangkok.

[4] Charl.G. Steyn, Jacobus D. Vanwyk, "Optimum Non linear Turn-off Snubbers: Design and Application" *IEEE transactions on Industry applications*, Vol.25. No.2 March/April 1989.

[5] Yuh-yin Lu, Zhi-Huachen, Chung-Hsiung Yen and Hsiang-chen Huang "Measurements and Improvements of Conducted electromagnetic interference emission caused by the switching circuits" *IEEE Proceedings of the first International conference on Innovative Computing, Information and control* 2006.

[6]. U-Yaisom, C., W. Khanngern, and S. Nitta, "The Study and analysis of the conducted emi suppression on power mosfet using passive snubber circuits". *International Symposium on Electromagnetic Compatibility*, China, May 21-24, 2002.

.

[7] Jia Kelin; Wang Jingmei; Wu Chang; Bi Chuang "New method for conducted EMI noise diagnosis" *Electronic Measurement and Instruments, ICEMI '07*. 8th International Conference on Aug. 16 2007-July 18 2007 pp.4-59 - 4-63.

[8] Qian Liu, F. Wang, D. Boroyevich,, "Conducted EMI noise prediction and characterization for multi-phase-leg converters based on modular-terminal-behavioral equivalent EMI noise source mode" *Power Electronics Specialists Conference, 2006. PESC '06*, pp.1 – 7.

[9] Hongyu Li, D. Pommerenke, Weifeng Pan, Shuai Xu, Huasheng Ren, Fantao Meng, Xinghai Zhang, "Conducted EMI simulation

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

of switched mode power supply", *IEEE International Symposium on Electromagnetic Compatibility, 2009. EMC 2009*, pp. 155 - 160

[10] Bob Mammano, Bruce Carsten, "Understanding and optimizing electromagnetic compatibility in SMPS" *Power Seminar*, 2003.

[11] K. Mainali, R. Oruganti, "Simple analytical models to predict conducted EMI noise in a power electronics converter" *33rd Annual Conference of the IEEE Industrial Electronics Society*, 2007. IECON 2007.pp. 1930 – 1936.

[12] Power electronics systems theory and design, Jai P.Agarwal. Prentice Hall, 15-Feb-2001

[13] IRF 840 datasheet

[14] C. U-Yaisom, V.Tarateeraseth,W.Khan-ngern, S. Nitta" The Analysis of Mixed Series and Parallel Snubbers to reduce Conducted EMI Emission on a Switching Converter"*IEEE conference on Electromagnetic Compatability*, 2002.

[15] N. Mohan, T.M. Undeland and W.P. Pobbons, "Power Electronics Converters Applications and Design", Second edition, John Wiley and Sons: Singapore, Inc. 1995.

[16] Kenichiro Fujiwara and Hiroshi Nomura, " A Novel Lossless Passive Snubber for Soft-Switching Boost-Type Converter" *IEEE Trans. Power Electronics*, Vol. 14, no.6, 1999, pp.1065-1069.

[17] J.D Van Wyk, Fred C.Lee Power electronics technology- status and future, *Proceedings of IEEE PESC* 1999, pp 3-12.

[18] J.Shao, R.L. Lin, F.C. Lee, and D.Y. Chan, "Characterization of EMI Performance for Hard and Soft Switched Inverters". *Applied Power Electronics Conference and Exposition*.2000 APEC2000. Fifteenth Annual IEEE Vol.2, 2000 pp. 1009-1014.

[19] W.Teulings, et al., A new technique for spectral analysis of conducted noise of a SMPS including interconnects, *Proceedings of IEEE PESC* 1997, pp. 1516-1521.

[20] S.Kaitwanidvilai, K. unchaleevarapan, B. Hutawarakornand Y. Prempraneerach, "The Effect of Switching Frequency and duty cycle on SMPC Conducted Emission: Simulation and Experimental", *IPEC '99 Conference Proceedings* 1999, vol. 1,pp. 667- 672.

[21] Kenichiro Fujiwara and Hiroshi Nomura, "A Novel Lossless Passive Snubber for Soft-Switching Boost-Type Converter", *IEEE Trans. Power Electronics* , vol. 14, no.6, 1999,pp.1065- 1069.

[22] H.P. Yee, "An EMI Suppression MOSFET Driver", *Applied Power Electronics Conference and Exposition*, APEC '97 Conference Proceedings 1997, 12th Annual, 1997, vol.1,pp. 242-248.

[23] John C. Fluke, Sr, "Controlling Conducted Emissions by Design," Van Nostrand Reinhold,1991,pp.49-63.

Journal of Theoretical and Applied Information Technology
15th March 2012. Vol. 37 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

AUTHOR PROFILES:

Mr. Krishna Kumar, born on the year 1973, in Kumbakonam, India. He received the degree of B.E., and M.Tech from Bharathidasan University and SASTRA University in 1994 and 2002, respectively. He is doing his research program in ANNA University, Coimbatore. He researches in the area of EMI on Power Converters. Presently he is working for Periyar Maniammai University, Vallam, Thanjavur as Assistant Professor (SG) in the Department of Electrical and Electronics Engineering.

Dr.A.Nirmal Kumar, Head of Electrical and Electronics Engineering Department in Bannari Amman Institute of Technology, Sathyamangalam completed his graduation and post graduation in Electrical Engg. from Calicut and Kerala University respectively. Completed his Doctorate from Bharatiar University in Power Electronics. He has more than 30 years of teaching experience. He is guiding at present 20 research scholars. He is the recipient of Institution of Engineers Gold Medal for the year 1989. He has many publications in national and international journals to his credit.

Mr.M.Sathis kumar born on the year 1982, in Tiruchirappalli, India. He received the degree of B.E., and M.Tech from Bharathidasan University and SASTRA University, in 2003 and 2009, respectively. He is interested in the area of Embedded Controller on Power Converters. Presently he is working for Periyar Maniammai University, Vallam, Thanjavur as Assistant Professor in the Department of Electrical and Electronics Engineering.