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Suppression of Conducted EMI using Random Modulation Scheme on Cuk Converter

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***Abstract*---In this paper, power spectrum analysis of cuk converter carried out by using random modulation technique. Here particularly, the randomized carrier frequency and randomized duty ratio, with randomized pulse position modulation (RRRM) was used in cuk converter. Field Programmable Gate Array was used for implementing the random modulation schemes. Due to the tractability and controllability, FPGA was implemented. In this random modulation technique spread spectrum scheme was derived for cuk converter topology. Spread spectrum technique is one of the best way to spread the generated electromagnetic signal with wide range of frequency. Power Spectrum Density (PSD) analysis for cuk converter with RRRM and conventional PWM technique were studied. From the simulation results RRRM technique provide best PSD level when compared to conventional PWM techniques. The effect of proposed RRRM scheme was simulated by using MATLAB/SIMULINK.**

***Index Terms* — Cuk converter, Electromagnetic Interference (EMI), Random Modulation schemes.**

I.INTRODUCTION

In recent years, most of the people using electronic devices such as mobile phones, laptops, E-vehicles, etc. power electronic devices are portable to use and easy to handle and these are easily available and cheap in cost. Switching is the main function of all electronic devices. Sadly, Wide of power electronics device usage causes the more EMI trouble [6]. Frequent switching operation can affect the performance of the power switching devices. EMI occurred due to frequent switching operation. Particularly, DC-DC converters experience more losses due to switching phenomenon. It gradually decreases the overall efficiency of the converter topology [12]. In tradition, filters and shielding techniques were used for EMI suppression. In recent years random modulation schemes are used in EMI suppression. According to the literature survey random modulation schemes are the best tool for analysing EMI in DC-DC converters [13]. Randomized modulation makes the best way to reduce the EMI. Random modulation schemes are greatly increasing interest in power electronics converter [1].

In random PWM technique switching signal parameters are changed. Various types of random modulation schemes are available. These RPWM techniques are obtained by randomization parameters of each switching cycle [14]. Literature survey explains the effectiveness of RPWM. Commonly the following parameters are changed in RPWM schemes. They are,

- ON time period of the switching cycle
- Switching frequency
- Total time period
- Delay time
- Width of the pulse

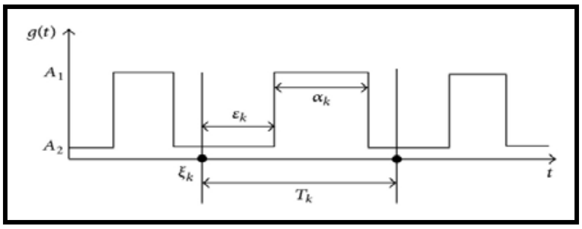

Fig.1.1 variations of switching signal quantities

According to the parameter variations in switching cycles they are classified as different types. In this paper, the randomized carrier frequency and randomized duty ratio, with randomized pulse position modulation (RRRM) was discussed. In this method, all switching cycle parameters are randomized. Results shows the RRRM scheme provides best PSD level when compared to the other random modulation schemes. RRRM technique was implemented by using FPGA controller because of its best performance. FPGA is the one of the tool, especially made for power supply applications. PSD defines the frequency response of the random modulation techniques. It describes the average power density as a function of frequency. PSD is the deterministic scheme. Basically PSD expressed in terms of Fourier analysis [11]. Analysis of PSD in terms of frequency is called as spectrum. The total power spectrum solved by parseval's identity. Power spectrum is the fundamental quantity to know about randomized switching setup [2]. In Randomized carrier frequency and a randomized duty ratio, with RPPM (RRRM): f_k, d_k, and ε_k modified [4],[5]. Power spectrum density measures provide the advantages of RRRM scheme compared with conventional PWM [3]. Spread spectrum techniques are used to spread the electromagnetic signal over the wider range of frequency. Because of the security purpose spread spectrum scheme was mostly used in electronics communication and satellite communications. Furthermore, PSD level of cuk converter with conventional PWM and RRRM was discussed and compared.

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II. RANDOM PULSE WIDTH MODULATION SCHEMES

Random switching modulation schemes are classified in the basis of duty cycle, ON time, delay period of the pulse, switching frequency and time period [9]. Types of random modulation methods are,

- Random Pulse Position Modulation(RPPM)
- Random Pulse Width Modulation(RPWM)
- Random Carrier Frequency Modulation with Fixed Duty cycle(RCFMFD)
- Random Carrier Frequency Modulation with Variable Duty cycle(RCFMVD)
- Randomized Duty ratio, Randomized Pulse Position Modulation with Fixed Carrier Frequency(RDRPPMFCF)
- Randomized Carrier Frequency, Randomized Pulse Position Modulation with Fixed Duty ratio(RCFRPPMFD)
- Randomized Carrier Frequency, Randomized Duty ratio, with Randomized Pulse Position Modulation (RRRM)

Characteristics of various random switching schemes are explained based on the standard waveform parameters such as T_k, α_K, ε_k,d_K shown in fig1.1. Randomness level of the RRRM can be mentioned below [7],

$$\text{Randomness level } (\Re) = T_2\text{-}T_1/T_s \quad (1)$$

$$\text{Switching frequency } (f_{sw}) = f_L + K*RFS \quad (2)$$

$$WN = TN*(d_L+RDS)/1E4 \quad (3)$$

$$TN = f_{clk}/f_{sw} \quad (4)$$

$$EN = TN*(e_L+RES)/1E4 \quad (5)$$

Where,

f_{sw}= frequency of the switching device
f_L= Lower frequency limit
K = Constant parameter
RFS,RES,RDS= Integer numbers obtained from Pseudorandom output streams
f_{clk} = Clock frequency
TN = Number of steps required for fulfil the switching frequency
WN = Number of steps required for fulfil the duty ratio
d_L= Limit of Duty ratio
EN = Number of steps required for fulfil the pulse position
e_L = Lower pulse position level
E4 = For normalizing (d_L + RDS) and (e_L+ RES) to be a fraction of one
DT = Number of clocks steps to fulfil the dead time.
f_{csw}= Centre switching frequency

Table 2.1

Characteristics of Different Random Switching Schemes

SWITCHING SCHEMES	T_k	α_K	ε_k	$d_{K}= \alpha_K / T_k$
Standard PWM	constant	constant	Zero	constant
RPPM	constant	constant	Rand.	constant
RPWM	constant	Rand.	Zero	Rand.
RCFMFD	Rand.	Rand.	Zero	Fixed
RCFMVD	Rand.	constant	Zero	Rand.
RDRPPMFCF	constant	Rand.	Rand.	Rand.
RCFRPPMFD	Rand.	Rand.	Rand.	constant
RRRM	Rand.	Rand.	Rand.	Rand.

In which, α_k–ON period of gate pulse in k^{th} cycle; T_k- length of k^{th} cycle; ε_k- delay period of the gate pulse; d_K- duty ratio of switch in k^{th} cycle[15] mentioned in fig1.1. It results the total power spectrum reduction on cuk converter over the frequency band [8].

III. GENERATION OF RANDOM PULSE (RRRM)

Pseudo random sequence generator is one that generates a number of bits known as pseudo random output streams. It consists of polynomial register, shift register, seed register shown in fig3.1. It has maximum number of Linear Feedback Shift Registers. The polynomial and beginning seed values may be special to define its output number series.

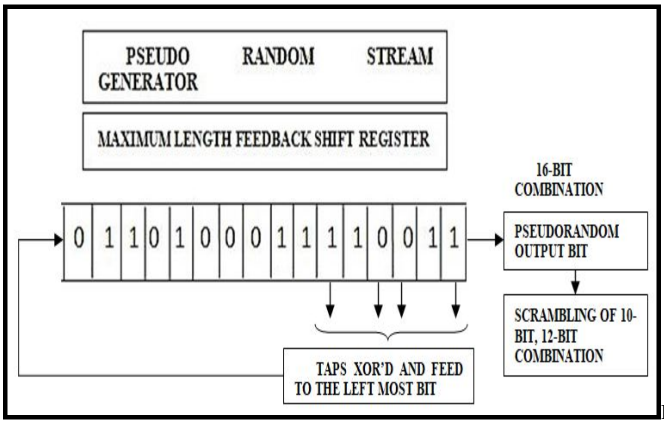

Fig.3.1.Block diagram of Pseudo random stream generator

The shift register computes the LFSR feature. The seed initialize the series of place to begin and offers examined value for synchronization. Polynomial register holds the polynomial that defines the period of the LFSR output bit series. The seed and polynomial registers need to be initialized earlier than setting the start bit in pseudo random flow series

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control files. Starting seed values must be set between 1 and 2^{n-1}.While the seed and polynomial are initialized, the LFSR is started and a growing edge of the input clock generates the subsequent stage inside the distinctive pseudorandom collection. The output of pseudo random stream generator was 16-bit combination. 12-bit and 10-bit combinations are obtained by scrambling of 16-bit output. Finally outcomes of the pseudorandom stream generator converted into integer numbers. After this conversion RES, RFS, RDS was obtained. EN, TN, WN values are calculated by using the above mentioned equations (3), (4), (5). Gate pulses are generated by using digital pulse width modulator. Here, above mentioned operations are simulated by using MATLAB program.

IV.SIMULATION RESULTS AND DISCUSSION

Cuk converters are used as a voltage regulator in hybrid wind-solar applications. Particularly, cuk converter consists of low switching losses and the better efficiency [10]. It has better output current characteristics due to output side inductor. It also called as a capacitive fly back converter [8].

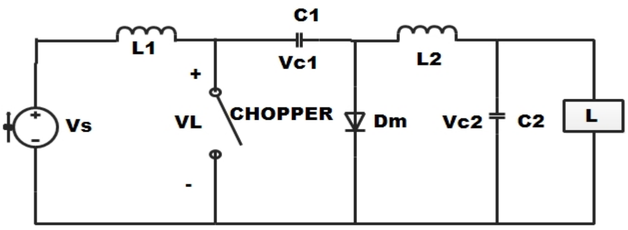

Fig4.1 Basic model of cuk converter

Initially cuk converter was simulated by the application of conventional PWM technique. Here after gate pulse, output voltage and PSD analysis was shown in fig 4.2 to fig 4.4.

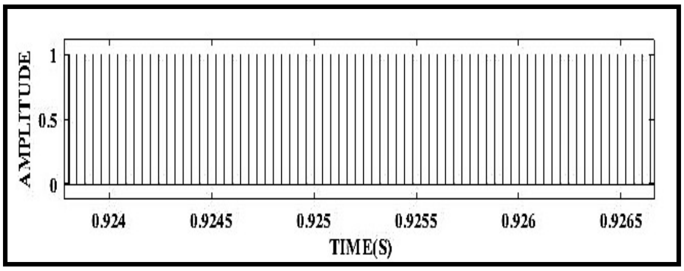

Fig.4.2 Gatepulse waveform of conventional PWM

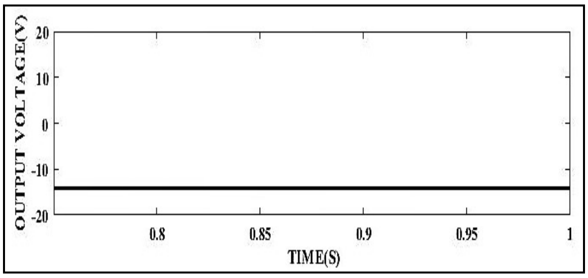

Fig. 4.3 output voltage waveform of cuk converter

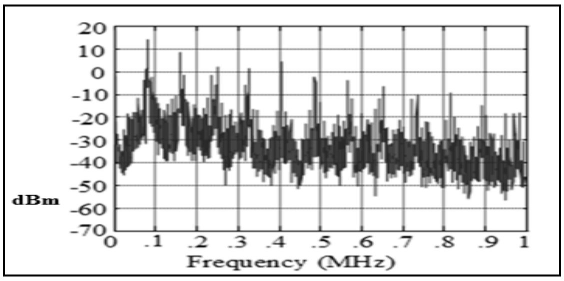

Fig.4.4 Spectrum analysis of cuk converter with conventional PWM

The following random waveforms are generated by using MATLAB program.

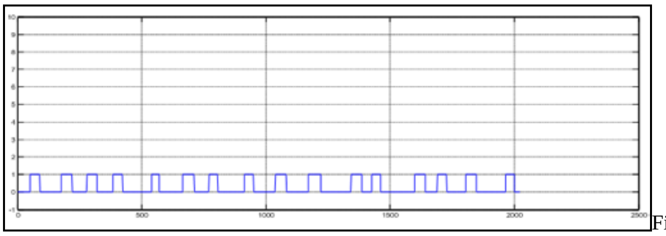

Fig.4.5.only one vector 16 values of EN, WN&TN values

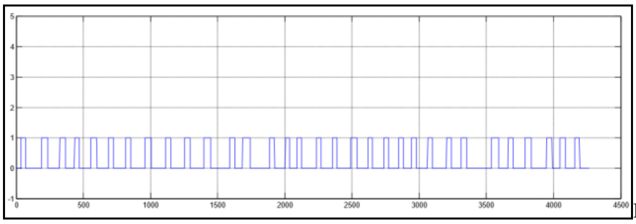

Fig. 4.6 32 values of EN,WN& TN values

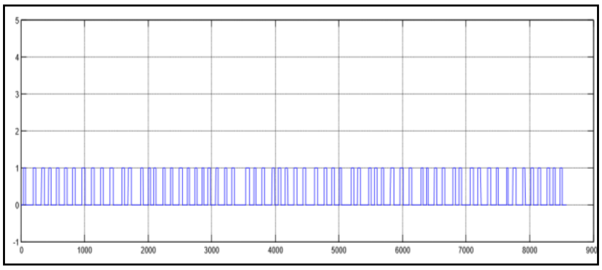

Fig.4.7 64 values of EN,WN& TN values

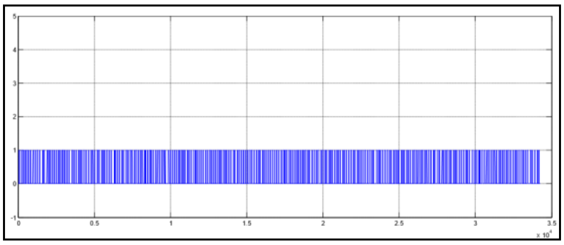

Fig.4.8 256 values of EN,WN & TN values

Further, the generated random pulses are applied to the cuk converter. After that, output voltage, PSD level was shown in fig 4.9& fig 4.10.

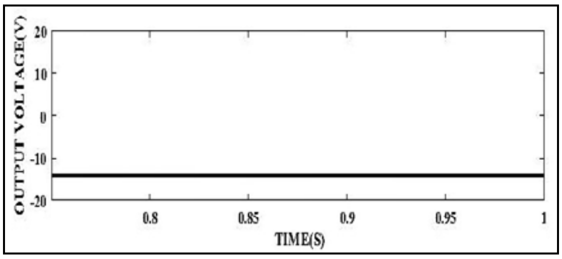

Fig.4.9 output voltage waveform with RRRM

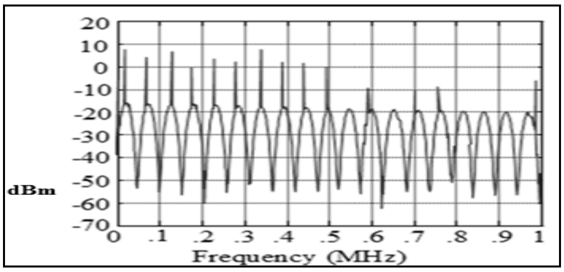

Fig.4.10 spectrum analysis of cuk converter with RRRM scheme

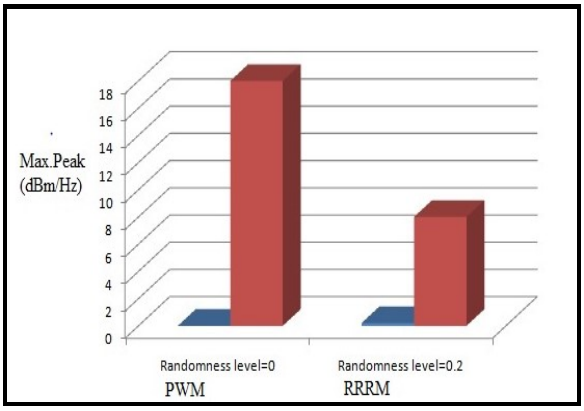

Fig.4.11 comparative results of conventional PWM and RRRM

Table 3.1
Comparative results of PWM technique and RRRM technique

MODULATION SCHEMES	RANDOMNESS LEVEL	CUK MAXPEAK(dBm/Hz)
PWM	0	18
RRRM	0 to 0.2	8

Power Spectrum Density of both PWM and RRRM techniques are simulated and compared. From this, maximum peak of the cuk converter became greatly reduced in RRRM scheme. PSD level of the cuk converter attains best when using RRRM scheme.

V.CONCLUSION

This test has characterized and explained the power Spectrum Density of the cuk converter through the utilization of conventional PWM and RRRM. Because of undesired performance of PWM scheme isn't a best desire for EMI-sensitive products. In PWM technique noise spectrum conduction become quite excessive. The RRRM scheme hits the best PSD level. Gate pulses are generated by using various frequency, pulse position and duty ratio. FPGA controller turned to generate the gate pulses. Here, program was simulated for obtaining random gate pulse by utilization of MATLAB. The randomization parameters had been pick out the output that adopts better Power Spectrum Density performance. Simulation outcomes are exhibits the PSD analysis of the cuk converter. In future, EMI analysis has been carried out on cuk converter with proposed prototype been utilized.

REFERENCES

[1]Alessandar M.Stankovic, George C, Verghese, and David J. Perreault,(1995), 'Anlaysis and synthesis of randomized modulation schemes for power converter',IEEE Transaction on power electronics, vol 10,No,6.

[2]Bech M. M., Pedersen J. K., F. Blaabjerg, and Trzynadlowski A. M.,(May 1999). 'A Methodology for True Comparison of Analytical and Measured Frequency Domain Spectra in Random PWM Converters,' IEEE Trans. Power. Electron., Vol. 14, No. 3, pp. 578-586,.

[3]Boudouda1 A., N. Boudjerda1, B. Nekhoul1, K. El Khamlichi Drissi, and K. Kerroum,(2011),'Optimized Dual Randomized PWM Technique for Full Bridge DC-DC Converter' Piers Proceedings, Marrakesh, Morocco.

[4]Dousoky G. M., Shoyama M., and Ninomiya T., (2009), 'FPGA-based design and implementation of spread-spectrum schemes for conducted noise reduction in DC–DC converters' in Proc. IEEE-ICIT, pp. 527–532.

[5]Dousoky G. M., Shoyama M., and Ninomiya T.,(2011) 'FPGA-Based Spread-Spectrum Schemes for Conducted-Noise Mitigation in DC–DC Power Converters: Design, Implementation, and Experimental Investigation', IEEE Transactions On Industrial Electronics, Vol. 58, No. 2.

[6]Franc Mihaliˇ, Dejal Kos, (November 2006) 'Reduced Conductive EMI in Switched-Mode DC–DC Power Converters Without EMI Filters: PWM Versus Randomized PWM'. IEEE Transactions On Power Electronics, Vol. 21, No. 6.

[7]Gamal M. Dousoky, Shoyama M., and Ninomiya T.,(2010), 'On Factors Affecting EMI-Performance of Conducted-Noise-Mitigating Digital Controllers in DC-DC Converters—An Experimental Investigation'.978-1-4244-5287 IEEE.

[8]C Krishnakumar, P Muhilan, M Sathiskumar, M Sakthivel (2015), "A New random PWM Technique for Conducted-EMI Mitigation on CUK Converter', Journal of Electrical Engineering Technology, Vol.10, no.3, pp. 916-924,

[9]Lev-Ari H., Stankovic A.M.,(2003)'Analysis and Optimization in Design of Randomized PWM Switching Patterns in DC/DC Converters', 15830-7803-7754-IEEE.

[10]M.H Rashid,(2011),power electronics handbook,3rd edition, Elsevier ,pp.249354

[11]Ninomiya T., Tanaka T., and Harada K., (1990) 'Noise reduction of switching mode power converters by random-switching control', in Proc. IPECTokyo, pp. 1165–1172.

[12]Stankovic A.M., Verghese G. C., and D. J. Perreault, (Nov. 1995) 'Analysis and synthesis of randomized modulation schemes for power converters', IEEE Trans. Power Electron., vol. 10, no. 6, pp. 680–693,.

ISSN 2229-5518
[13]Tanaka T., K. Harada, and T. Ninomiya, “Noise analysis of dc-to-dc converter with random switching control,” in Proc. INTELEC’91, Nov. 1991, pp. 283–290

[14]Tetsuro Tanaka, Tamotsu Ninomiya and Koosuke Harada, “Random-SwitciIing Control In DC-to-DC Converters”:CH2721-9/89/0000-0500, IEEE 1989.

[15]Tse K. K., H. S.-H. Chung, S. Y. R. Hui, and H. C. So, “A comparative investigation on the use of random modulation schemes for DC/DC converters,” IEEE Trans. Ind. Electron., vol. 47, no. 2, pp. 253–263, Apr. 2000.