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Survey on Reduction of Conducted EMI in Dc-Dc Converter Accomplished by Implementation of Random Modulation Schemes

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Abstract: This paper deals an overview of EMI reduction on the dc-dc converter topologies by using various random modulation schemes. Random modulation schemes include various types of randomization parameters. This paper emphasizes the effect of random modulation schemes on dc-dc converter accomplished by various random implementation methods. Modulation schemes includes the following consideration listed as randomized pulse width, randomized carrier frequency, randomized pulse position and variable duty cycle. This survey proved that randomized modulation is very effective in power spectrum density analysis. FPGA is the one of the preferable technique to implement the random modulation schemes. Randomization parameters improves the conducted noise spectrum and reduces the noise peaks of the converters output. It can effectively explain the new random modulation techniques which applied in various power electronics devices and also the results explained the EMI suppression techniques. This paper survey that the study of random modulation schemes and implementation. Effect of EMI suppression on the converter output discussed in low and high frequency ranges. Finally it proved that the random modulation scheme is the best one when compared to conventional PWM techniques.

Keywords:Random modulation schemes, power spectrum density (PSD), Field programmable gate array (FPGA), electromagnetic interference (EMI).

I.INTRODUCTION

In present, the world survives along with electronic products. Power electronics converters have the considerable quantity of electromagnetic interference. Electromagnetic interference generated by means of frequent switching operation.[1] EMI spectrums are particularly concentrated on multiples of essential switching frequency. Due to the electromagnetic interference power converter produces the considerable amount of switching losses. Switching losses in converter topologies affects the performance of EMI sensitive products.[3] In early days EMI noise reductions are accomplished by conventional methods. The conventional method causes extra cost effect on power converters. In recent electromagnetic interferences are reduced by introducing the new random modulation techniques. From the history, random modulation techniques are initiated from communication theory.

EMI reduction in electronics devices are determined by the EMC (Electro Magnetic Compatibility) regulations. From survey, electromagnetic interference on the power electronics converter effectively reduced by random modulation techniques. Random modulation techniques are effectively achieved by randomization of switching cycle parameters. Changes in switching frequency, duty ratio, pulse position results the effective impact on power spectrum density [10]. Based on the randomization parameters random modulation techniques

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are classified. Various types of random modulation schemes are discussed below.

1. Standard PWM
   T_k, d_k & α_k are fixed; ε_k is zero;
2. RPPM
   T_k, d_k & α_k are fixed; ε_k is randomized;
3. RPWM
   T_k is fixed; d_k & α_k are randomized; ε_k is zero;
4. RCFMFD
   T_k & α_k are randomized; d_k is fixed; ε_k is zero;
5. RCFMVD
   T_k & d_k are randomized; α_k is fixed; ε_k is zero;
6. RDRPPMFCF
   T_k is fixed; d_k , ε_k & α_k randomized.
7. RCFRPPMFD
   T_k , α_k, ε_k Randomized; d_k is constant;
8. RRRM
   T_k, ε_k, d_k & α_k are randomized;

(where T_k, ε_k, d_k & α_k are total time period, delay time, duty ratio & on time of the switching cycle) [6].

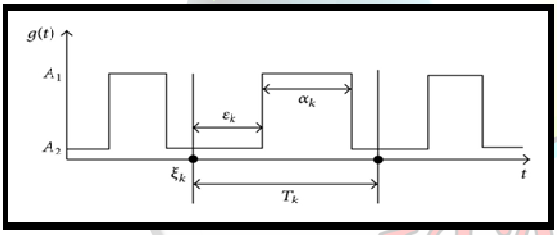

Fig.1.1 variations of switching signal quantities

The implementation of random modulation schemes are done by using Field Programmable Gate Array (FPGA). FPGA is one of the most preferred hardware to implementing the random modulation schemes. According to the studies frequency profiles are investigated through FPGA controller [4]. 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. 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 [7]. Further, 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. All above investigations are done by both minimum and maximum frequency band.

II.LITERATURE SURVEY

This section detailed about the random modulation schemes and its effect, suppression of conducted EMI, spread spectrum techniques on DC-DC converters. From the paper **[1], Aleksandar M.Stankovic, George C, Verghese, and David J. Perreault. "Analysis and synthesis of randomized modulation schemes for power converter"** says the objective study of random modulation scheme for power converters. Power spectrum of signals, autocorrelation and formulas are derived for various type of random modulation techniques from the stationary one. Various types of random modulation schemes and their analytical results are discussed. Narrowband and wideband spectrum presents in random modulation schemes were numerically solved in this paper. So far random modulation schemes are preferred only for inverter to reduce the acoustic noise. In this paper they are discussed the random modulation scheme benefits for all DC-DC power converters. Finally this paper was concluded by comparing both narrowband and wideband spectrum. However, the random modulation schemes exhibit more effectiveness in narrowband spectrum only. The use of random modulation scheme is better utilization of harmonic content with wider frequency range.

[2] Bech M.M, Pedersen J.K., F. Blaabjerg, and Trzynadlowski A.M., "A methodology for true comparison of analytical and measured frequency domain spectra in random PWM converter".
In this paper, characteristics of frequency domain analytically derived by the use of random PWM techniques. Experimental results are proved the algebraic equations. Initially these techniques are originated from digital signal processing technique. Proper measure should be considered to avoid the difficulties of this technique. Also this analysis presents the new methodology to overcome the difficulties. Switching frequency modulation and lag-lead pulse positions are expressed and verified by using experimental results on DC-DC converters. Comparison of analogous between FFT analysis and filter causes the error, but this analysis minimized the error by selecting the proper measurements. Power Spectrum Density of the random PWM techniques were studied on DC-DC converter.

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Further evaluation of this technique applied in the industrial applications.

[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' said the random PWM technique deals the control of full bridge dc-dc voltage converter.

In this paper RPWM technique based on the randomization parameters such as time period and peak position βT (half period). This paper presents the voltage analysis using Power Spectrum Density (PSD) and effects of random modulation techniques. Results taken out from the basis of electromagnetic compatibility (EMC) and they compared with conventional PWM techniques. This analysis results that the maximum spread of PSD of an optimal value of the variation of

parameter β. Two interesting non-linear methods are such as the trust region method and the simplex algorithms are used for problem optimization. Experimental results expose the mathematical model of Power Spectrum Density of output voltage. Problem created by this techniques solved by the two non linear algorithm.

[4] 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.

In this paper, various type of random PWM techniques are discussed. Standard PWM, randomized pulse position modulation, randomized carrier frequency modulation with variable and fixed duty ratio and randomized duty ratio, randomized carrier frequency and randomized pulse position (RRRM) methods were discussed. Randomization parameters are used to define the random PWM technique. Mainly three randomized parameters are decided the switching signal. Randomization parameters are carrier frequency, pulse position and duty ratio. Implementation of random pulse width modulation techniques are perfectly done by using Field Programmable Gate array (FPGA). Further, the FPGA controller implemented in common mode, differential mode and conducted noise characteristics of the DC-DC converter. Spread spectrum characteristics of the various random PWM techniques are experimentally investigated. Experimental results of conducted noise characteristics are compared. From the results RRRM methods attains the best EMI performance. It provides the improved conducted noise performance at both low frequency and high frequency ranges.

[5]Franc Mihali˘, Dejal Kos, (November 2006) 'Reduced Conductive EMI in Switched-Mode DC–DC Power Converters Without EMI Filters: PWM Versus Randomized PWM' says the reduction of electromagnetic interference without using any filter on the Switch Mode Power Converters (SMPS). Comparative study has been done between conventional PWM and random PWM technique on the dc-dc converter. The comparative investigation of RPWM was driven by the DSP-2 board with the TMS320C32 against conventional PWM technique. In low frequency ranges the spread spectrum of the dominating frequency at low frequency ranges was done by using the power spectrum density (PSD). Frequency analysis and EMI effects on dc-dc converter was analysed by Discrete Fourier Transform (DFT). DFT used to estimate the level of conducted EMI and it was experimentally verified with standard CISPR 25 regulation. This paper clearly shown that the PWM with limited speed drive and suitable snubber circuits reduce the conducted EMI. In this paper comparative investigation of the different random PWM technique and conventional PWM on dc-dc synchronous rectifier was discussed.

[6] 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'

This paper delivers the EMI on the dc-dc converter topologies and conducted noise characteristics of digital controllers. Clock frequency, randomization ratio percentage, frequency modulation profile and spread spectrum scheme are factors are discussed. Due to the price and performance, the implementation of random modulation schemes are done by using Field Programmable Gate Array (FPGA). Sawtooth modulation, markov chain based random modulation and pseudo random stream modulation schemes are experimented. Finally the pseudorandom method attains best EMI performance. Conducted noise characteristics are improved not only in low frequency ranges and also in high frequency ranges.

[7]Krishnakumar.C, P Muhilan, M Sathiskumar, M Sakthivel (2015), "A New random PWM Technique for Conducted-EMI Mitigation on CUK Converter" says that the random modulation technique is suitable for suppressing the EMI on dc-dc converter topology. In this paper they are introducing the new random modulation scheme for cuk converter topology. Constant Trailing Edge, Randomized Pulse Width Modulation (CTERPWM) technique is proposed and Power Spectrum Density was analytically expressed. CTERPWM was applied for cuk

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converter and simulation results are validated at continuous conduction mode. Comparative investigations are carried out for the RPWM and CTERPWM. From this, comparative results proved that the CTERPWM reduced the electromagnetic interference on the cuk converter and it spread the conducted noise spectrum over the wide range of frequency.

[8]Lev-Ari H., Stankovic A.M.,(2003)'Analysis and Optimization in Design of Randomized PWM Switching Patterns in DC/DC Converters' says the synthesis aspects of randomization modulation. This paper discussed the problem in PSD and choosing the optimum randomization method. Due to the non-linear spectral formula synthesis problem is difficult. In this paper randomized modulation techniques for dc/dc converters are discussed. And this paper introduced optimization and an analytical tool that represents the clear tradeoffs. It outlines the total spectrum reduction and limitations.

[9]Tetsuro Tanaka, Tamotsu Ninomiya and Koosuke Harada, "Random-Switching Control In DC-to-DC Converters" In this paper smoothening of noise spectrum and the concept of random modulation scheme was studied. They discussed the properties of switching noise in dc-dc converter. Also it describes the switching characteristics of dc-dc converter. Theoretical comparison of switching-noise spectrums drawn and it also explains the switching noise characteristics. Two different types of control circuits are introduced and experimentally validated. The comparative investigation shows that the random PWM provides the smooth noise characteristics. Two control circuits are used to realize the effectiveness of random PWM technique. Effectiveness of random modulation schemes are investigated experimentally by using control circuits. From the comparative investigation control circuit-I provides the best smoothening of switching noise spectrum.

[10]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,"

This paper derived the various type of random modulation scheme for dc-dc converter. Also it derived the PSD and randomness expression for the each random modulation techniques. Transfer characteristics of various dc-dc converters were presented. From these various random modulation schemes we found the suitable method for dc-dc converter. This paper addressed the randomness level on the power spectrum density and conducted noise characteristics of dc-dc buck converter on low frequency. PSD for each and every random modulation schemes were discussed. Characteristics of diode voltage versus randomness level of the each random modulation scheme for dc-dc buck converter were drawn. Comparative analysis was carried out to find the best choice of random modulation scheme for dc-dc buck converter. From the PSD analysis randomized carrier frequency modulation with fixed duty cycle (RCFMFD) attained the best conducted noise characteristics. Comparative study results the RCFMFD Reduction of EMI on dc-dc buck converter at differential mode and continuous conduction mode (CCM).

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