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ANALYSIS, SIMULATION AND EXPERIMENTAL RESULTS OF SMPS SYSTEM USING FORWARD CONVERTER WITH RCD SNUBBER

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Abstract: A Closed loop controlled DC to DC forward converter is a requisite for the server SMPS system. High efficiency, Isolation, Steady state voltage, Transient response, High switching frequency, reduced noises and range of steady state are all necessary requirements for the forward converter. In this paper, a 40 V forward converter system with RCD snubber is used for charging the battery of server SMPS is proposed. The proposed converter consists of a snubber circuit on the primary side and an isolation transformer and a rectifier structure on the secondary side. This paper proposed the simulation results of the forward converter with RCD snubber and it is implemented with PIC microcontroller. From comparison of performance against the simulation model with the experimental model, a suitable converter is proposed for the sever SMPS system. A 40 V proposed circuit is designed as experimental model to verify and compare it with the simulation and experimental results. This paper proposed the simulation and experimental results of the forward converter system.
Keywords: Embedded microcontroller, Zero voltage switching, Zero current switching, Reset voltage, Clamping diode and Voltage stress

INTRODUCTION

In recent years, the switching mode power supply (SMPS) system has been achieved with high power density and high performances by using power semiconductor devices such as IGBT, MOS-FET and SiC. However, using the switching power semiconductor in the SMPS system, the problem of the switching loss and EMI/RFI noises has been closed up. This course produced the EMC limitation like the International Special Committee on Radio Interference (CISPR) and the limitation of harmonics for the International standard is Electro technical Commission (IEC). For keeping up with the limitation, the SMPS system must add its system to the noise filter and the metal and magnetic component shield for the EMI/RFI noises and to the PFC converter circuit and the large input filter for the input harmonic current. On the other hand, the power semiconductor device technology development can achieve the high frequency switching operation in the SMPS system. The increases of the switching losses have occurred by this high frequency switching operation. The inductor and transformer size has been reduced by the high frequency switching, while the size of cooling fan could be huge because of the increase of the switching losses.

Our research target is to reduce the ripple and the switching losses in the SMPS system. One method is the soft switching technique and the other method is by proper choosing of filter circuit. This technique can minimize the switching power losses of the power semiconductor devices, and reduce their electrical dynamic and peak stresses, voltage and current surge-related EMI/RFI noises under high frequency switching strategy. Thus, a new conceptual circuit configuration of the double forward type DC - DC converter circuit is presented in this paper with its operating principle. In addition, it's fundamental operation and its performance characteristics of the proposed forward type DC-DC double forward converter treated here are evaluated on the basis of experimental results. A New Controller scheme for Photo voltaics power generation system is presented in [1]. The design and implementation of an adaptive tuning system based on desired phase margin for digitally controlled DC to DC Converters is given in [2]. Integration of frequency response measurement capabilities in digital controllers for DC to DC Converters is given in [3]. A New single stage, single phase, full bridge converter is presented in [4]. The Electronic ballast control IC with digital phase control and lamp current regulation is given in [5]. A New soft-switched PFC Boost rectifier/inverter is presented in [6]. Design of Single-Inductor Multiple-Output DC-DC Buck Converters is presented in [7]. Boost Converter with Improved Performance through RHP Zero Elimination is given by [8]. High-efficiency dc-dc converter with high voltage gain and reduced switch stress is given in [9]. Snubber design for noise reduction is given in [10].Comparison of active clamp ZVT techniques applied to tapped inductor DC-DC converter is given in [11].The multiple output AC/DC Converter with an internal DC UPS is given in [12].The Bi-directional isolated DC-DC Converter for next generation power distribution – comparison of converters using Si and Sic devices is given in [13]. The simulation and the experimental method of analysis are done for the low noise SMPS system which is demonstrated in [14]. Investigations on forward converter using different types of filters and experimental method of analysis for the forward converters are done, which is to compare it with the conventional circuit are clearly mentioned in [15]. Different types of filters which are utilized in the forward converters and its performance are given in [16]. Forward converter with RCD snubber using the PI controller, fuzzy controller and artificial neural network (ANN) controller are analyzed and compared to get the better performance in [17]. Analysis and reduction of voltage ripple in forward converter using a three different filters and based on the comparison, the Bi-quad high frequency filter gives better performance is illustrated in [18].

The above literature does not deal with the comparison of forward converter with RCD snubber and its experimental work implemented with PIC microcontroller. The above cited papers do not deal also with the modeling of SMPS system and do not identify a converter suitable for SMPS system.

This work aims to develop simulink models for the forward converter system with RCD snubber and it is implemented with PIC microcontroller. The simulation and experimental results are compared to determine the deterministic value. A comparison is also done to find the circuit suitable for the server SMPS system.

SMPS SYSTEM

This section introduces the circuit diagram of a SMPS system which is illustrated in Figure 1. SMPS produces DC voltage required by the chips of a digital computer. The size of the converter in SMPS can be reduced by using high frequency converters. In this configuration an investigations on forward converter based DC to DC converter. The obtained DC voltage from the boost chopper circuit is converted into AC by the high frequency switching. The high frequency AC voltage is induced in the transformer primary and the scaled down voltage appears across the transformer secondary. The obtained low frequency AC voltage from the secondary of the transformer is converted into DC by the half – bridge rectifier circuit, and the power is filtered by the LC-filter, π-filter, high frequency cascaded filter and transferred to the load. The target of the research is to do investigations on the forward converter to develop an efficient SMPS system and it is implemented with PIC microcontroller. The simulation and experimental results are compared to determine the deterministic value. A comparison is also done to find the circuit suitable for the server SMPS system.

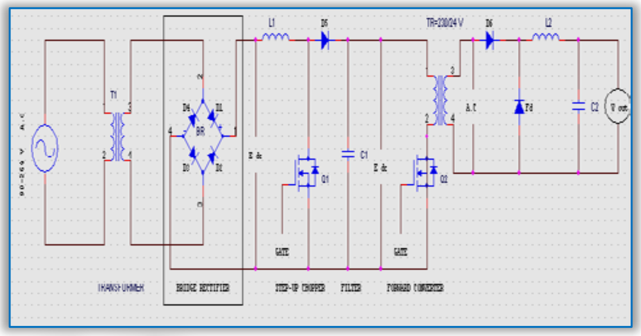

Figure 1. Circuit diagram of a SMPS system

SIMULATION PARAMETERS

The simulation parameters for the forward converter with RCD snubber is shown in Table 1. From the given parameters, the system is modeled using MATLAB-Simulink and simulated which is to check the performance of the system.

Table 1. Simulation Parameters
for the forward converter with RCD snubber

S.No:	Parameters [Unit]	Values & Items
1	Input voltage [V]	100
2	Output voltage [V]	38.8
3	Switching frequency [kHz]	20
4	Transformer ratio [V_{rms}]	2:1
5	Snubber capacitance [μf]	5000e-6
6	Snubber resistance [Ω]	10

DESIGN OF THE CONVERTER CIRCUIT

The necessary specifications assumed for the forward converter with RCD snubber are Input voltage V_{in} =100 V, Inductance (L_f) =10e-6, Capacitance (C_{f2}) =10e-6, Snubber capacitance (C) =5000e-6, snubber resistance (R) =10 Ω and R_L=10 Ω. By using the relation, f=1/T, Given time=50 μs, then f=20 kHz, By using the formula, E_1 = 4.44 f $\Phi_m N_1$ Volt, then N_1=100 turns and by using the relation N_2= (E_2/E_1) N_1, then N_2= 88 turns. The transformer voltage ratio k=E_2/E_1 = 0.9 and by using the relation, $I_0=V_O/R$=3.88 Amps. The voltage across the main switch during turn off, M_{VDS}= $V_{RST}+V_g$=Vg/1-D, by using the primary voltage=90.49 with the ratio of (1-frequency=20*10^3), then the M_{VDS}= -4.523*10^{-03}.

SIMULATION RESULTS

The SMPS system is modeled and simulated using the blocks of MATLAB SIMULINK. The simulation parameters for the forward converter with RCD snubber is given in Table 1. The forward converter with RCD snubber is shown in Figure 2.a. DC input voltage is shown in Figure 2.b. Driving pulses for the main switch M is shown in Figure 2.c. Primary and secondary voltages of the transformer are shown in Figure 2.d and Figure 2.e. DC output voltage is shown in Figure 2.f. The output current is shown in Figure 2.g. Variation of efficiency with the input voltage is shown in Figure 2.h. Forward converter with RCD snubber at variable load and variable frequency are given in Table 2.

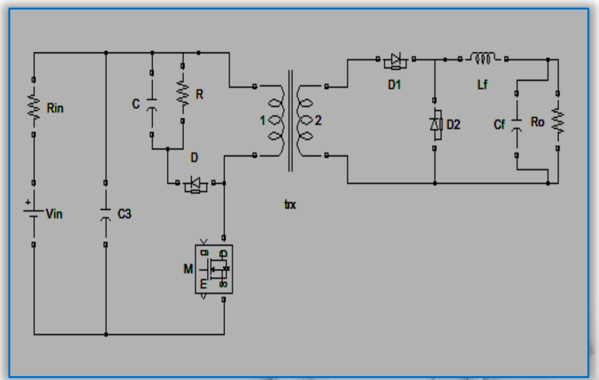

Figure 2.a. Converter with RCD snubber

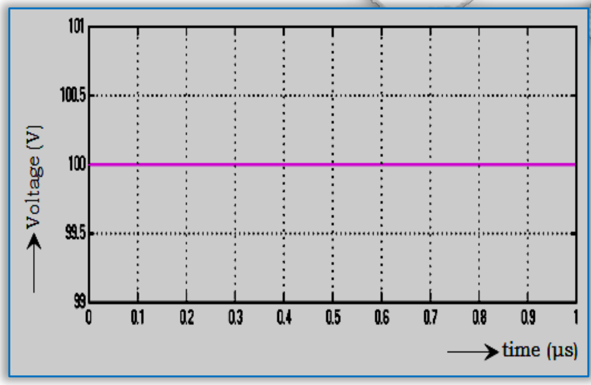

Figure 2.b. DC input voltage

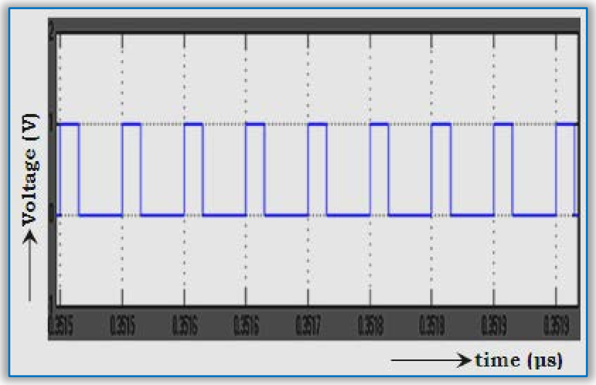

Figure 2.c. Driving pulses for switch M

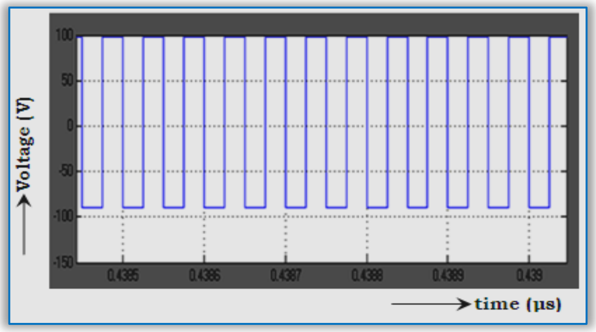

Figure 2.d. Transformer primary voltage

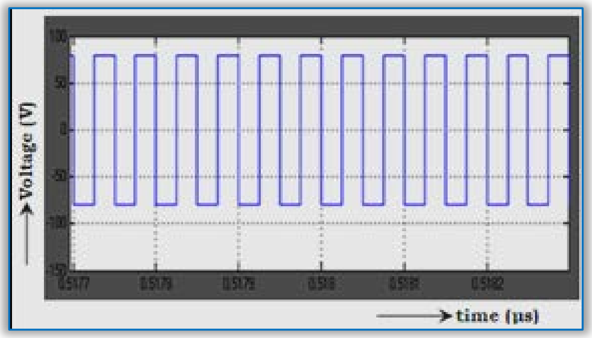

Figure 2.e Transformer secondary voltage

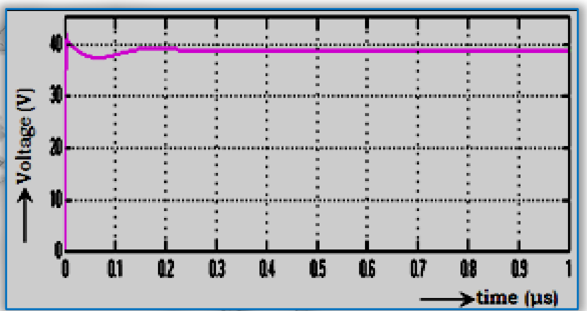

Figure 2.f DC output voltage

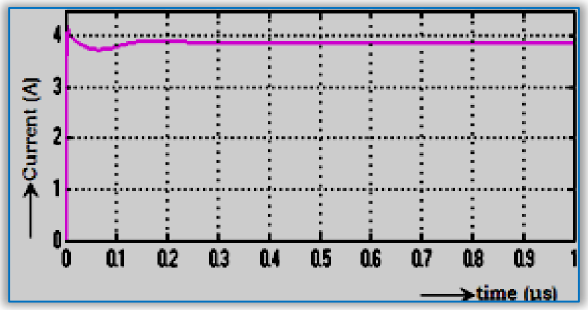

Figure 2.g. Output current

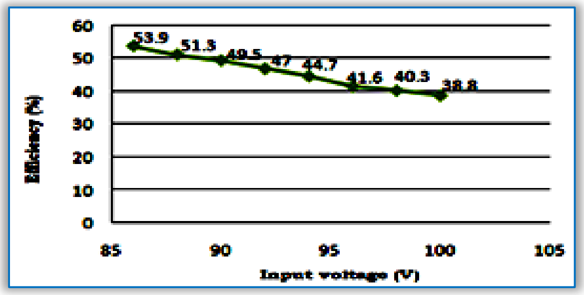

Figure 2.h Variation of efficiency with input voltage

Table.2: Forward converter with RCD snubber at variable load with frequency

S.No:	Load Resistance R_L (Ω)	Output Voltage V_O (Volts)	Frequency (kHz)	Load Current I_L (Amps)
1	10	38.8	5	3.13
2	20	39.11	10	2.84
3	30	39.22	15	2.80
4	40	39.27	20	2.63
5	50	39.31	25	2.52

HARDWARE PARAMETERS

The hardware parameters for the forward converter with RCD snubber is shown in Table 3. From the given parameters, the system is designed and modeled using PIC-Microcontroller which is to check the performance of the system.

Table 3: Hardware Parameters for the forward converter with RCD snubber

No:	Parameters [Unit]	Values and Items
1.	Input Voltage [V]	100
2.	Load Resistance [Ω]	10
3.	Output Voltage Vo [V]	40
4.	Switching frequency [KHZ]	20
5.	Smoothing Capacitor C1,Cf [μf]	$90e^{-6}$, $90e^{-6}$
6.	Smoothing Inductor L [mH]	$10e^{-6}$
7.	Capacitance of Snubber circuit	$5000e^{-6}$
8.	Resistance of Snubber circuit	10 ohm
9.	Power MOSFET	IRF 840
10.	Power Diode	IN4007

EXPERIMENTAL RESULTS

Experimental set-up of a forward converter with RCD snubber circuit is developed using PIC microcontroller. The PIC microcontroller PIC16F84A is used to generate the driving pulses for the main switch, to turn on and off to process and the experimental results are obtained. The low noise SMPS System with forward type switching with RCD snubber circuit is designed and the hardware module is shown in Figure 5.a.

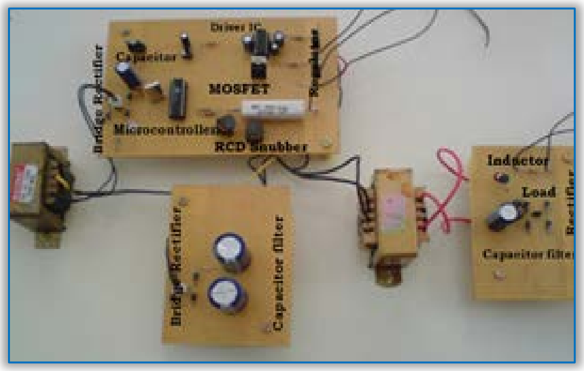

Figure 5.a. Hardware model of forward converter using microcontroller

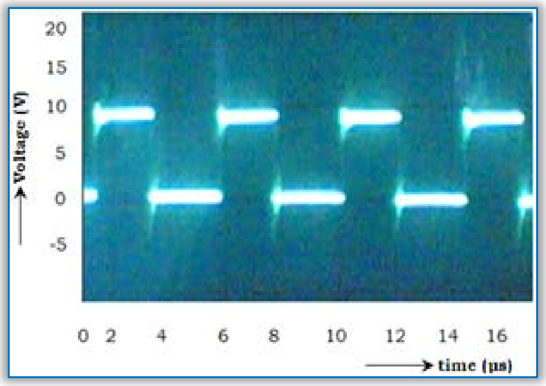

Figure 5.b. Driving pulses for the main switch M

The PIC Microcontroller 16F84A is used to generate the driving pulses for the main switch 'M' is shown in the oscillogram of Figure 5.b. Primary and the secondary voltages of the transformer are shown in the oscillogram of Figure 5.c and Figure 5.d.

The DC output voltage is shown in the oscillogram of Figure 5.e., and the output voltage across 50 ohm resistance is shown in Figure 5.f. Hardware parameter for the forward converter system is given in Table 3.

The experimental results are obtained for forward converter with RCD snubber at variable load and variable frequency are given in Table 4.

The comparison between simulation and experimental results are given in Table 5.

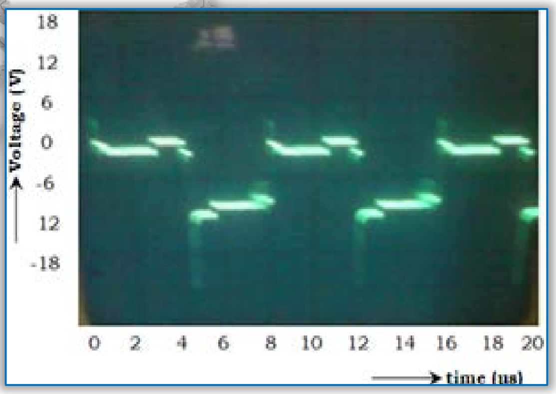

Figure 5.c. Primary voltage of the transformer

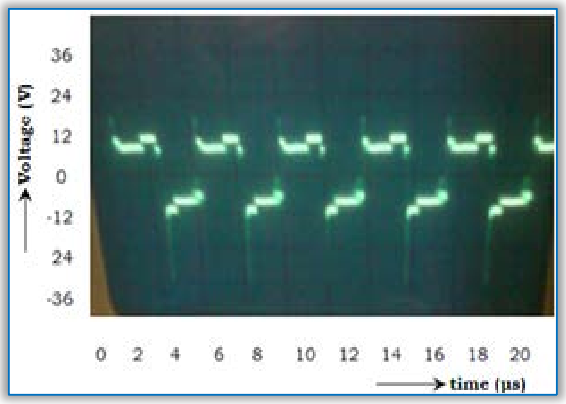

Figure 5.d. Secondary voltage of the transformer

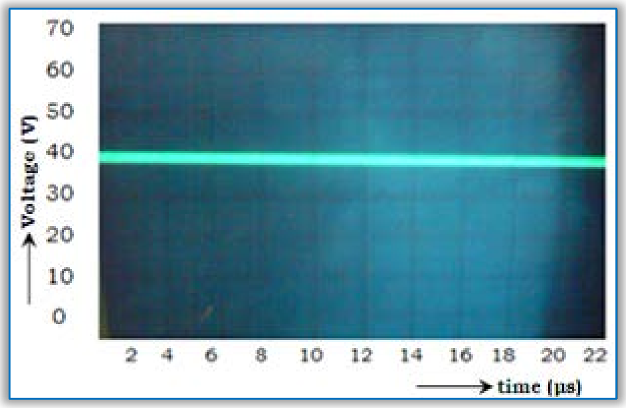

Figure 5.e. DC output voltage

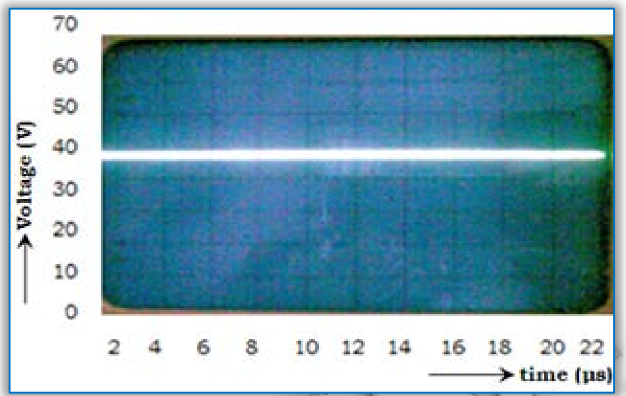

Figure 5.f. DC output voltage across the variable load resistance

Table 4: Experimental results for converter with RCD snubber at variable load with frequency

No:	Load Resistance R_L (Ω)	Output Voltage V_0 (Volts)	Frequency (kHz)	Load Current I_L (Amps)
1	10	37.3	5	3.10
2	20	37.6	10	2.76
3	30	38.0	15	2.70
4	40	38.3	20	2.53
5	50	38.9	25	2.49

Table 5: Comparison between the simulation results of the converter and the experimental results of the converters at variable load

No.	Load Resistance R_L (Ω)	Output Voltage V_0 (Volts)	
		Simulation Results	Experiment Results
1	10	38.8	37.3
2	20	39.11	37.6
3	30	39.22	38.0
4	40	39.27	38.3
5	50	39.31	38.9

CONCLUSION

Forward converter with RCD snubber system is simulated using the blocks of MATLABSIMULINK. This system is designed and implemented as hardware model and tested in the laboratory and the results are obtained. The simulation results and the experimental results of the forward converter system with RCD snubber are compared. The forward converter system has reduced the noise in the output.

From the results, it is observed that the forward converter is suitable for the SMPS System. From the results, it is observed that the experimental results closely agree with the simulation results.

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