[1.]A.P. VIJAYAKUMAR, [2.]N.R. DEVI

CLOSED LOOP CONTROLLED FORWARD CONVERTER ANALYSIS USING PI, FUZZY LOGIC AND ANN CONTROLLER

[1.] Department of Electrical and Electronics Engineering, JNTU, Hyderabad, Telangana, INDIA
[2.] Department of Computer Science and Engineering, Panimalar Engineering College, Chennai, INDIA

Abstract: Closed loop controlled model is developed for the determination of time domain specifications, transient response and steady state analysis. Simulation of DC to DC modified forward converter using active clamp-Neutral Point Connected Auxiliary Resonant Snubber (NPC-ARS) circuit, which is implemented by using PI controller, fuzzy logic controller and artificial neural network (ANN) controller, is presented in this paper for the switching mode power supply applications. Its circuit operation in closed loop controlled model and the performance of the modified forward converter is described and the simulation results are presented

Keywords: Steady state analysis, time-domain specifications, transient response and controllers and ANN controller

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 using the PI, Fuzzy and ANN controllers. The above cited papers do not deal with the comparison of

FFT analysis, voltage stress and ripple factor and do not identify a converter suitable for SMPS system.

The above literature does not deal with the comparison of modified controlled forward converter using the PI controller, fuzzy controller and artificial neural network (ANN) controller. The above cited papers do not deal also with the modeling of closed loop SMPS system and do not identify a converter suitable for SMPS system. This work aims to develop simulink models for the above closed loop forward converter system using the three controllers. A comparison is also done to find the circuit suitable for the SMPS system.

CONFIGURATION OF CLOSED LOOP SYSTEM

Figure 1 shows a closed loop circuit model of the SMPS, which is used to implement with fuzzy controller and artificial neural network (ANN) controller. In this closed loop configuration, a 230 V AC supply is connected to the bridge rectifier circuit. The output of this circuit is DC. The output voltage of the rectifier is converted into a variable DC voltage by the boost converter with frequency circuit. When the chopper is OFF, the inductor voltage add to the source voltage and current in the inductor (i_L) is forced to flow through the diode and the load (R_L). The output of the boost chopper circuit with lesser ripple is filtered by the capacitor. Conversion of DC voltage into AC is done by the high frequency switching. In high frequency switching scaled up AC voltage is induced in the transformer primary and the scaled down voltage appears across the transformer secondary. The AC voltage obtained from the secondary of the transformer is converted into DC by the half – bridge rectifier circuit, and the noise is filtered by the LC-filter, and transferred to the load. The output DC voltage is taken as feedback, to compare. The difference of error signal is amplified and it is applied to the microcontroller. The microcontroller generates switching pulses, and it is amplified by the amplifier circuit. The amplified pulses are used to turn on the circuit.

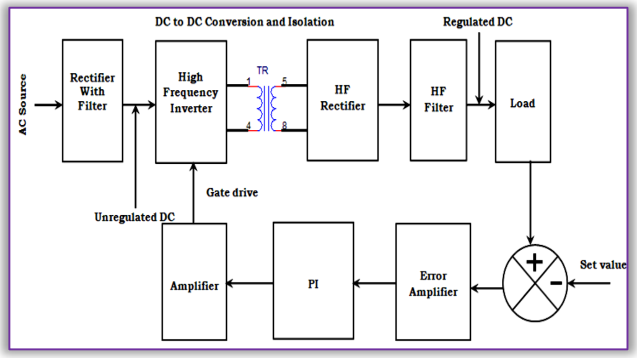

Figure 1. Circuit diagram of a closed loop model SMPS system

DESIGN OF THE MODIFIED CONVERTER

Figure 2 shows the NPC-ARS auxiliary switch in the forward converter, which is utilized in closed loop model to reduce the noise and to improve the efficiency. The necessary specifications assumed for the NPC-ARS auxiliary switch in the forward converter are frequency f = 100 kHz, ΔI = 2.5 A, and R = 100 Ω. By using the relation, $1-\delta = V_i / V_o$, $\delta = 0.5$; By using the formula, $L = V_i \ \delta / f \ \Delta I$, L=200 MH; By the relationship, $C = \delta / 2 f_r$, ;C = 250 μF; The transformer voltage ratio $V_o / V_i = K$, and by using this relationship the value of K=0.21 is obtained. The transformer primary voltage $E_1 = 4.44 * N_1 * \Phi * f$. By substituting in the equation, the value of E_1, Φ, and f in the above equation, the value of $N_1 = 4.5$. By using the equation $N_2 = (E2 / E_1) N_1$ the value of $N_2 = 9$ is obtained. Figure 3 shows the NPC-ARS auxiliary switch in the forward converter, which is to modified in the forward converter. The NPC-ARS auxiliary switch in the forward converter will reduce. The NPC-ARS auxiliary switch in the forward converter will reduce the noise and the energy is recycled to improve the efficiency of the system. By the modified SMPS system the freewheeling current is controlled and thus it reduces the switching losses in power devices.

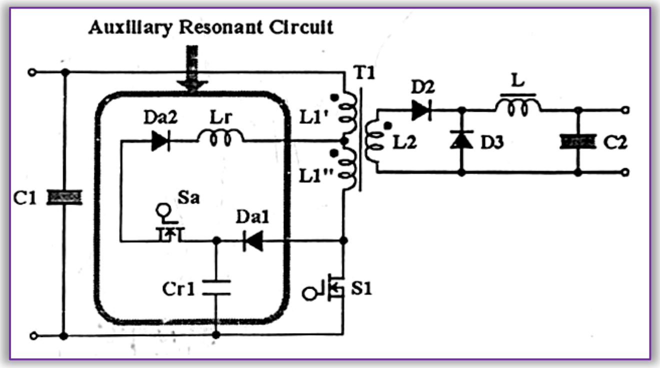

Figure 2. NPC-ARS auxiliary switch

SIMULATION PARAMETERS

The simulation parameters for the modified forward converter using the NPC-ARS circuit are 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 modified forward converter using the NPC-ARS circuit.

S.No:	Parameters Unit	Values & Items
1	Input Voltage [V]	100
2	Output Voltage [V]	42
3	Switching Frequency [KHZ]	20
4	Smoothing Capacitor [μf]/V	2200/63,100/63
5	Smoothing Inductor [mH]	27
6	'L' of NPC-ARS [μH]	10
7.	'C' of NPC-ARS [nf]	100

PI, FUZZY AND ANN CONTROLLERS

In this work develop the Simulink models for the closed loop forward converter system using PI, fuzzy and Ann controller models. A comparison is also done from the simulation results to stumble on the circuit appropriate for the SMPS system. In the closed loop PI controller, the tuning is done by using a Ziegler-Nicholas method which is defined as the ratio between the rise-time and delay-time and the integral constant is define as 1.6 with delay-time. After tuning is done as by the given method, the fixed saw-tooth pulses using PWM and the sources are compared to get the steady state. In the closed loop fuzzy logic controller, tuning is done by using the number of variables which are five and it is stated as small, medium, large, very large and very small. Between the widths of the variables, which are lies from zero and one to be stated as manual, we used a fuzzy logic controller. Fuzzy logic means a fuzzification is the process of by which the crisp quantities are converted to fuzzy logic ones. By identifying several suspicions are present in the crunchy values, the fuzzy logic values such as zero and one's are formed. The conversion of fuzzy set values is represented by (MA)-membership functions. This MA function which is a graphical illustration of the scale of contribution of each input value in a given set. The set value could be of any type, which is illustrated as Gaussian (GW), Triangular (TW), Trapezoidal (TRW), and Singleton (SW) etc... The fuzzification progression may absorb assigning (MA) membership function values for various levels of sets to the given quantities.

Fuzzy system which implements by using the rule-based reasoning such as if-then reasoning rules to determine an output response. The inference (IF) engine evaluates all the rules to perform the, if then rule-based reasoning process. Continuity, Consistency, Completeness and Interaction are the four types of properties, which has been considered by the rules based. The operators used mainly in the fuzzy set logic to erect compound based rules. AND, OR and NOT are the Rules considered have to satisfy the following. De-fuzzification is the progression of convert fuzzy to brittle values for further processing. There are some of the famous methods which are used for defuzzification such as Centroid, Weighted Average and Maximum membership method.

In the closed loop artificial neural network controller, tuning is done by using the state variables are: a (w) +b, where, 'a' is the constant, w are the change of weights and b is the bias. As by the change of weighted variables which is given in the state model an auto-tuning is done after compared with the fixed saw-tooth pulses using PWM and the sources are compared to get the steady state. In the closed loop simulink model forward converter system using PI, fuzzy and Ann controller, it operates at high frequency. The switching loss which is directly proportional to the frequency, when the switching frequency increases, the losses in the switching is decreased. In the closed loop simulink model double forward converter system DC supply of 100 V and the circuit breaker T_2 [0 2] with the switching time sequence of [0 0.5] sec are used. The step change is introduced in the input DC supply of 12 V and the circuit breaker T_3 [2 0] with the switching time sequence of [0 0.5] sec are used. The error in the output is reduced to get the steady state value. From the comparison of responses, it is seen that the closed loop system has reduced steady state error, which is maintain the voltage as constant.

SIMULATION RESULTS

The circuit diagram with the modes of modified SMPS system with an NPC-ARS switch is shown in Figure 2. The modified system consists of active power switch 'M_2', auxiliary switch 'M_1', resonant capacitor 'C_2', and the two power diodes 'D_1' and 'D_2'. The complete soft switching transition can be achieved in active power devices of the forward converter with the combine of switches 'M_1', 'C_2', and diodes 'D_1' and 'D_2' to recycle. To reduce the switching losses in each power semiconductor device, the active power switch M_2 is turned on with zero current condition and turned off at zero voltage condition. The auxiliary switch M_2 is turned on and turned off with zero current condition. In the forward type proposed soft transition in switching DC to DC conversion is described in four modes, which are: 1.Steady State Mode on, 2.Commutation Mode-1, 3.Steady State Mode off and 4.Commutation Mode 2 and they are shown in Figure 2. The modes of operation, which is already presented in the reference of 7. The open loop controlled modified forward converter is shown in Figure 3.1. DC input voltage with disturbance and DC output voltage with disturbance are shown in Figure 3.2 and Figure 3.3.

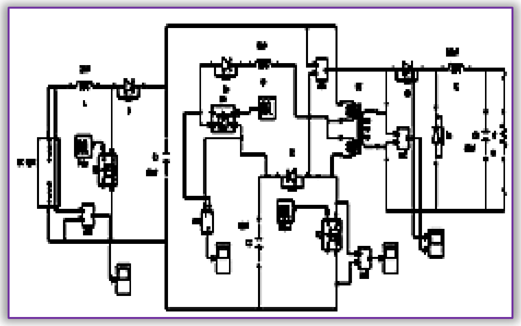

Figure 3.1 Open loop modified forward converter

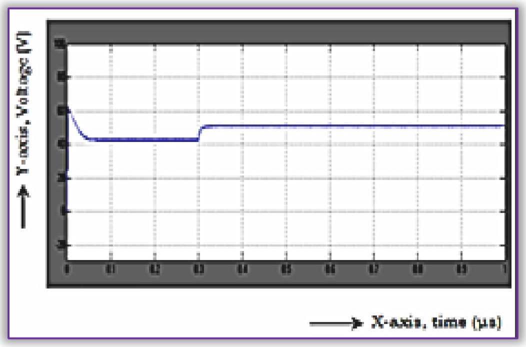

Figure 3.3. DC output voltage with disturbance

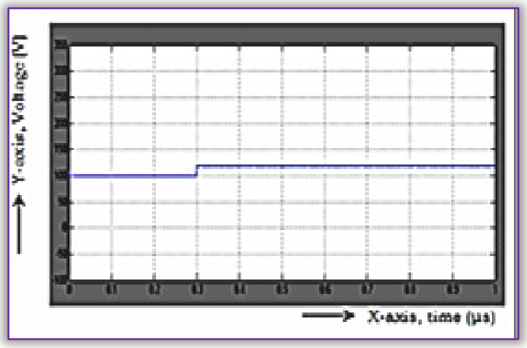

Figure 3.2. DC input voltage with disturbance

Closed loop controlled modified forward converter is shown in Figure 3.4. DC input voltage with disturbance and DC output voltage with disturbance are shown in Figure 3.5 and Figure 3.6. Modified forward converter using fuzzy logic is shown in Figure 3.7. DC input voltage with disturbance and DC output voltage with reduced error are shown in Figure 3.8

and Figure 3.9. Modified forward converter using artificial neural network controller is shown in Figure 3.10. DC input voltage with disturbance and DC output voltage with reduced error are shown in Figure 3.11 and Figure 3.12. Summary of steady state error in open loop and closed loop modified forward converter is shown in Table 2. Summary of time-domain specifications and steady state error is sown in Table 3. Summary of transient response is shown in Table.4.

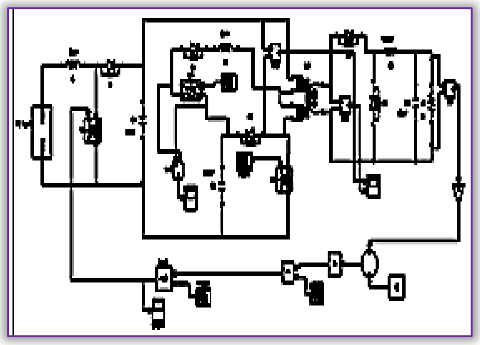

Figure 3.4. Closed loop modified converter

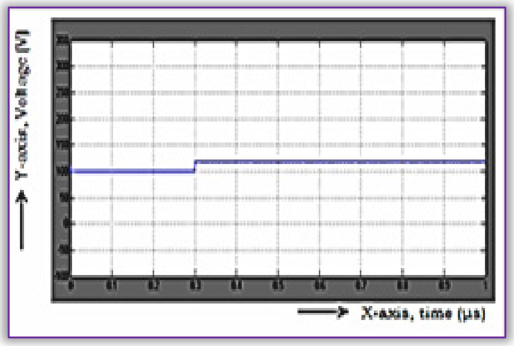

Figure 3.5. DC input voltage with disturbance

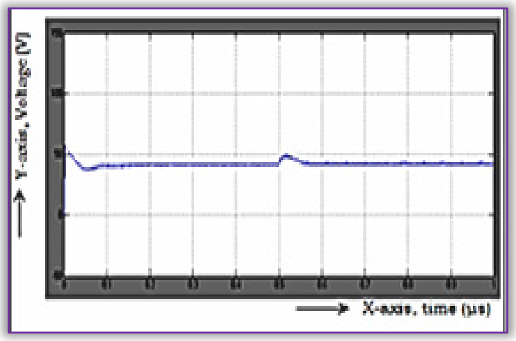

Figure 3.6. DC output voltage

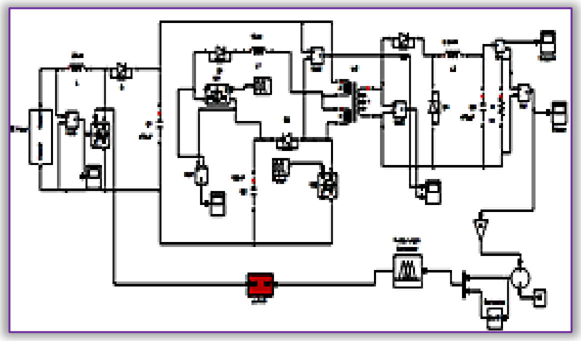

Figure 3.7. Modified converter using fuzzy logic

Table 2: Summary of steady state error

Parameter	Open loop system	Closed loop system
Steady state error	8 V	2 V

The summary of steady state error given in Table 2, which represents from the Figure 6.1 to Figure 6.5.

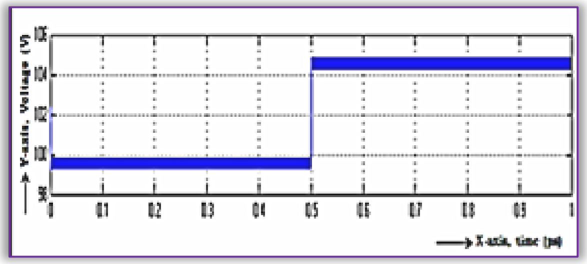

Figure 3.8. DC input voltage with disturbance

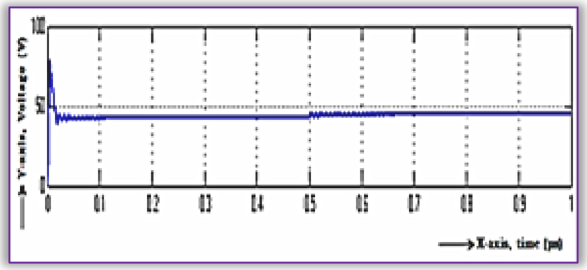

Figure 3.9. DC output voltage

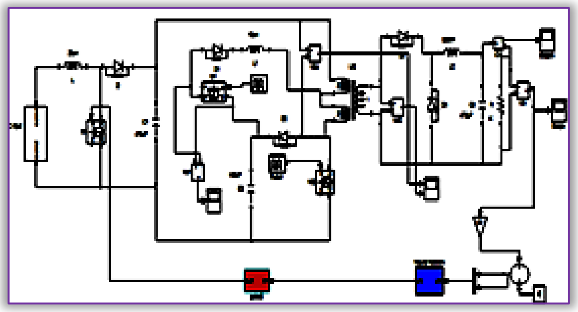

Figure 3.10. Modified converter with ANN logic

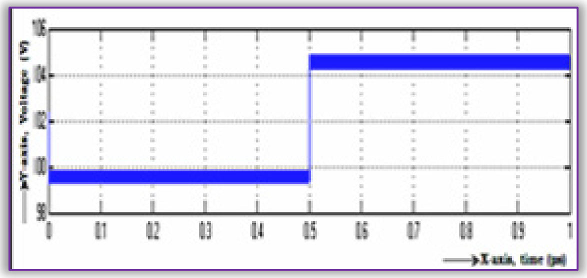

Figure 3.11. DC input voltage with disturbance

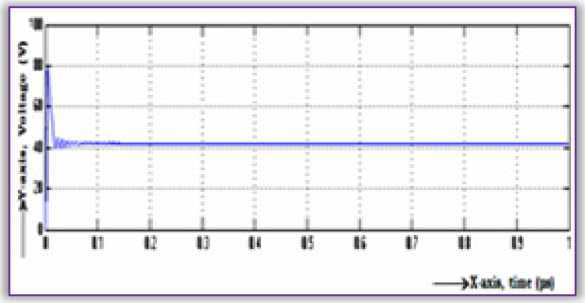

Figure 3.12. DC output voltage

Table 3: Summary of time-domain specifications and steady state error

Modified converter	Tr	Ts	Tp	Vp	Ess
PI controller	0.036	0.56	0.53	2.7	0.5
FUZZY controller	0.024	0.32	0.29	0.02	0.2
ANN controller	0.022	0.13	0.11	0.01	0.1

Table 4: Summary of transient response

Transient Response			
t_d(ms)	t_r(ms)	t_p(ms)	t_s(ms)
0.01	0.02	0.03	0.2
Transient and range of Steady state			
Transient State (ms)		Steady State (ms)	
0 – 0.2		0.2 onwards	
Peak over shoot Mp (A) = 13.9 volts			

From the Table 3, the comparison has been done from the PI controller, fuzzy logic controller and also with the artificial neural network (ANN) controller. The steady state response, range of transient and steady state and peak over shoot are described in Table 4. The comparison has done to determine the steady state performance of the modified forward converter which is utilized in the SMPS system.

CONCLUSIONS

Closed loop controlled modified forward converter is simulated using the blocks of mat lab-Simulink. To determine the steady state, the closed loop controlled model is implemented as with PI controller, fuzzy logic controller and artificial neural network controller (ANN) controller and it is simulated using the Simulink model. The comparison has been done from the three controllers, to determine the steady state analysis. From the comparison of the three controllers, the steady state error (Ess) is reduced in the artificial neural network controller. By using the ANN controller, the error is reduced as high and it is suitable for the forward converter system.

References

[1] Tamer T.N. Khabib, Azah Mohamed, Nowshad Admin, "A New Controller Scheme for Photo voltaics power generation system, "European journal of scientific research ISSN 1450-216X vol.33 No.3 (2009), pp.515-524.

[2] J. Morroni, R. Zane, D. Maksimovic, "Design and Implementation of an adaptive tuning system based on desired phase margin for digitally controlled DC-DC Converters", IEEETrans. Power Electron., vol.24, no.2, pp.559-564, 2009.

[3] M. Shirazi, J. Morroni, A. Dolgov, R. Zane, D. Maksimovic, "Integration of frequency response measurement capabilities in digital controllers for DC-DC Converters, "IEEE Trans. Power Electron.,vol.23, no.5,pp.2524-2535, 2008.

[4] Hugo Ribeiro, Beatriz V. Borges, "New single stage, single phase, full Bridge Converter, "submitted for appreciation to the Technical committee of IEEE ECCE-Energy conversion congress and exhibition, 2009.

[5] Y. Yin, M. Shirazi, R. Zane, "Electronic Ballast control IC with digital phase control and lamp current regulation, "IEEE Trans. Power Electron., vol. 23, no.1, pp.11-18, 2008.

[6] Yungtaek Jang,David L.Dillman and Milan M.Javanovie, "A New soft-switched PFC Boost Rectifier with Integrated Flyback Converter for stand –by Power, "IEEE Trans.on Power Electronics, pp.66-72, No.1, 2006.

[7] M. Belloni, E. Bonizzoni, and F. Maloberti, "On the Design of Single-Inductor Multiple-Output DC-DC Buck Converters", Proc. of 2008 International Symposium on Circuit and Systems (ISCAS), pp. 3049-3052, 2008.

[8] S.Kapat, A. Patra, and S. Banerjee, "A Current Controlled Tri-State Boost Converter with Improved Performance through RHP Zero Elimination", IEEE Transactions on Power Electronics, Vol. 24, No.3, pp. 776-786, 2009.

[9] R.J. Wai, C. Lin and Y. Chang, "High-efficiency dc-dc converter with high voltage gain and reduced switch stress, " IEEE Transactions on Power Electronics, vol. 54, no.1, 2007.

[10] S.Havanur, "Snubber design for noise reduction in switching circuits, "Alpha & Omega Semiconductor, Tech. Rep., 2007.

[11] S.Abe, T. Ninomiya, Comparison of Active-Clamp and ZVT Techniques Applied to Tapped-Inductor DC-DC Converter with Low Voltage and High Current, Journal of Power Electronics, Vol.2, No.3, pp.199-205, 2002.

[12] Arturo Fernandez, Javier Sebastin, Maria Hernando, "Multiple output AC/DC Converter with an Internal DCUPS,"IEEE Trans on Industrial Electronics, vol.53, no.1., 2006.

[13] Aggeler,D, Inove,S, Akagi,H, Kolar,J.W, "Bi directional isolated DC to DC Converter for next generation power distribution-comparison of converters using Si and Sic devices" Power conversion conference-agoya, 2007, PCC apos; 07, volume, Issue, 2-5 April 2007 Page(s):510-517.

[14] Vijayakumar.P and Rama Reddy.S "Simulation and Experimental Results of Low Noise SMPS system using forward converter" in the Asian Power Electronics Journals (APEJ), Vol.9, No.1, 2015, Page: 1-7.

[15] Palamalai Vijayakumar.A and Ramakrishnan Devi, "Simulation and experimental analysis of forward converters" LAP-Lambert Academic Publishing, Germany. Pages:121, 2016

[16] Palamalai VijayaKumar.A and Ramakrishnan Devi, "Investigations on forward converters using LC, PI and Bi-quad High Frequency filters" in the LAP-Lambert Academic Publishing, Germany. Pages:149, 2016

[17] Vijayakumar.P and Devi.R., "Closed loop controlled forward converter with RCD Snubber using PI, fuzzy logic and artificial neural network controller" in the Annals of "DUNAREA DE JOS" University of Galati, Fascicle III, 2016, Vol.39, No.2, ISSN: 2344-4738. ISSN-L1221-454X, Electrotechnics, Electronics, Automatic Control and Informatics.

[18] P.Vijayakumar and Ramakrishnan Devi, "Analysis and reduction of voltage ripple in forward converter using a bi-quad HF filter" in the ANNALS of Faculty Engineering Hunedoara– International Journal of Engineering, Tome XV [2017] – Fascicule 1 [February], ISSN: 1584-2665, Pages: 97-102.

ACTA TECHNICA CORVINIENSIS BULLETIN OF ENGINEERING
ISSN: 2067-3809