International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

Design of Novel Closed Loop Controlled Fully Soft-Switched Isolated DC–DC Converter

T.Vasanth Naik
M-tech Student Scholar Department of Electrical & Electronics Engineering, Anurag College of Engineering, Aushapur(v);Ghatkesar(M); Ranga Reddy (Dt); Telangana, India.
Email:vasanthn17@gmail.com
R. Rekha
Assistant Professor Department of Electrical & Electronics Engineering, Anurag College of Engineering ,Aushapur(v);Ghatkesar(M); Ranga Reddy (Dt); Telangana, India.
Email: rrekha122@gmail.com

Abstract: *In this project a soft-switched single switch isolated converter is proposed for step-up applications like fuel cell systems and vehicle inverters. The proposed converter is able to offer low cost and high power density in step-up application due to the following features zero-current switching (ZCS) turn-on and zero-voltage switching (ZVS) turn-off of switch and ZCS turn-off of diodes regardless of voltage and load variation low rated lossless snubbed, reduced transformer volume compared to fly back-based converters due to low magnetizing current Improved features such as fully soft-switched characteristics of switch and diode, low rated lossless snubber and reduced transformer volume make the proposed converter achieve lower cost and higher power density compared to the conventional fly back based converter. The proposed concept is implemented by closed loop The simulation results are presented by using Matlab/simulink software*

Key words-DC-DC converter, soft switching, zero current switching (ZCS), and zero voltage switching (ZVS)

I INTRODUCTION

DC-DC converters have been of great importance in power electronics because of its simple circuits and efficient control schemes. Using this, the output voltage can be varied sleeplessly by controlling the duty ratio of the semiconductor device used in chopper. The conventional boost converter is difficult to realize high step-up conversion ratio and voltage stabilization. It leads to serious reverse recovery problem of output diode and increases the voltage or current rating of all components [1]. It can be simply achieved by using couple-inductor structure, cascade topology. [2]But the leakage inductor of the couple-inductor creates the voltage spike on the switching devices and reverse recovery problem on the output diode.

When compared with other dc-dc converter resonant converter have high efficiency and small size. For small size, the switching frequency has to be high. Therefore components size will reduces. But high switching frequency causehigh stress on the switch. If soft switching techniques have been used these switching stress can be avoided [3]-[7].Resonant converter can be classified into several converter types. They are converter with more number of switchesand converter with bulky transformer. The Leakage inductors of the transformer and resonant capacitors help to achieveZCS for rectifier diodes to overcome the reverse recovery problem [8]. However, these transformers and switchesincreases losses in the circuit and reduce the efficiency of the converter. There are some topologies which reduces theseloss es by reducing the number of switches [9]-[11] else by removing the transformer.

A single-stage quasi-resonant converter is proposed in [12] with the advantages of single switch and two diodeswithout any output inductor and utilizing the transformer in forward mode. But, soft switching is not achieved at switchturn OFF instant. In [13] the topology, it uses a smaller transformer like forward converter and not require the bulkyoutput inductor of forward topologies. But this converter requires trigger circuit to trigger the switch.

If the transformer is avoided, the overall size of the power supply size can be reduced. Converter withHardSwitching Auxiliary Circuit is introduced. In that, the converter has low conduction loss, but the auxiliary switchhas hard turn-off.A simple andeffective duty ratio control method is proposedto extend the ZVS operating range when input voltages vary widely. Soft-switching conditions over the full operating range are achievable by adjusting the duty ratio of the voltage applied to the transformer winding in response to the dc voltage variations at the port [2, 9]. Keeping the volt-second product (half-cycle voltage-time integral) equal for all the windings leads to ZVS conditions over the entire operating range. The switching mode type dc-dc converters power supply is widely used because it uses a switch in t

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

he form of transistor type and less loss components such as transformers, inductors and capacitors for controlling the output voltage. The switched mode power supply contains two different parts: control part and power part. The majority of the work is carried out by the control part for getting better control of output voltage. Generally the MOSFET is used as a control switch in Switched mode power supply for stabilizing the required output voltage. The MOSFET switches are not to be conducted continuously and they operate only under specific frequency interval, hence these switches are useful for a long future and also provide less power loss the converter circuit. The basic structure of Switched mode power supply is used for stepping up or stepping down of input DC voltage. The SMPS circuit is basically consisting of a filter at the output side for removing the ripples due to switching [14].

The main objective of the project is to regulate three multiple output voltages with dc-dc zero-voltage switching (ZVS) converter. The converter is consisting of three multiple outputs voltages. With the help of two asymmetric half bridge converters, the first and second outputs are controlled. Based on the phase shift between two and asymmetric half bridge converter, the third output is controlled. ZVS is realized for all the main switches. At high switching frequency, these multipleoutput dc-dc converters can give higher efficiency. The various stages of operation, soft switching condition and controlling schemes are also proposed. A closed loop and open loop control techniques of the three multiple output converter is explained.Soft switching techniques can reduce the switching losses and Electromagnetic interference by putting some stress on the devices. When either current or voltage is zero during the turn ON or turn OFF period, then the product of the voltage and current becomes zero, which leads to zero power loss. Hence the switching loss can be eliminated and the device can operate at high switching frequency. Size and weight of the device is reduced as the heat sink is not required.

A) Types of soft switching techniques are:

1)Zero voltage switching (ZVS)

2)Zero current switching (ZCS)

In this technique, the switching takes place at zero voltage condition

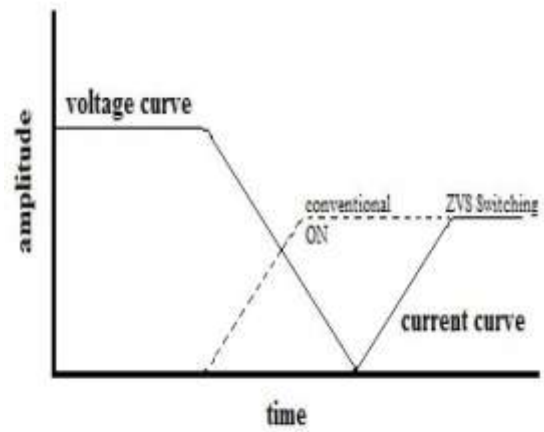


Fig. 1 Zero Voltage Switching (ZVS)

ZVS is used during turn ON of the device. Initially the main switch is OFF and the auxiliary switch is ON. So the current through the main switch is zero but the voltage is not zero. During the turn ON, voltage is made zero and current is given some time delay so that the current will begin to rise after the voltage is zero.

2) Zero current switching (ZCS)

In this technique, the switching takes place at zero current condition.

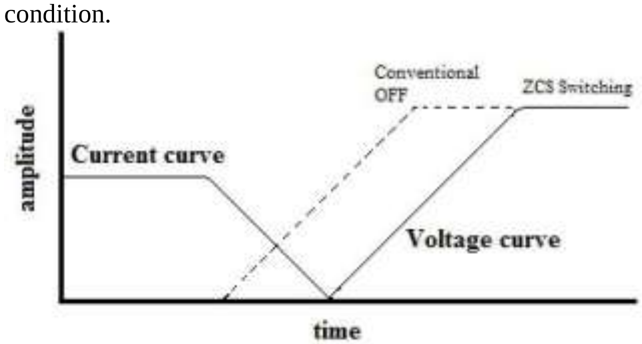


Fig.2. Zero Current Switching (ZCS)

It is used at turning OFF of the device. Initially the device is conducting. So the current through the device is not zero but the voltage across it is zero. In ZCS condition, the current is made to zero and the voltage is allowed to rise after the current becomes zero.

B) Soft switching converter topology

1). Synchronous Buck Converter:

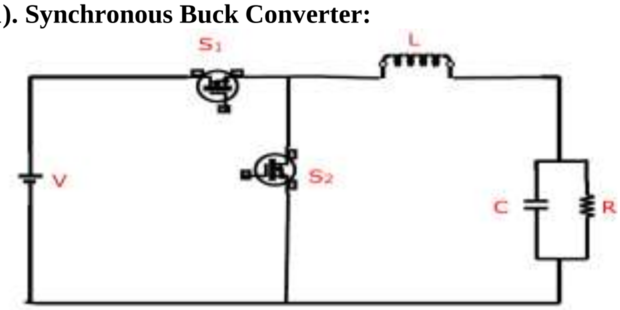


Fig.3. Synchronous Buck Converters.

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

In this converter two synchronized switches are used. To reduce the conduction losses a second switch is used in place of diode. As there is no Auxiliary circuit hence switching losses are not reduced. Hence this can be used only in low switching frequency applications.

2). Proposed soft switching boost converter with Auxiliary resonant circuit:

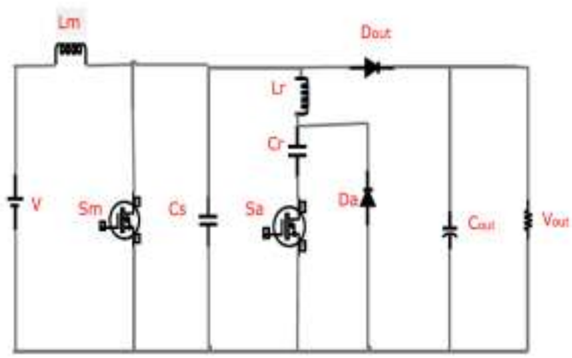


Fig.4. Boost Converter with Auxiliary Resonant Circuit.

In the proposed Soft Switching DC-DC boost Converter using an Auxiliary Resonant Circuit. The circuit consists of a general Boost Converter with an additional Auxiliary circuit which has a switch, inductor, capacitor and diode. By using an Auxiliary resonant circuit switching losses of a Boost Converter is reduced. In the proposed topology the generations of switching losses are avoided by forcing voltage (ZVS) or current (ZCS) to zero during switching.

II PROPOSED CONVERTER

Fig. 5 shows the circuit diagram of the proposed converter.The proposed converter consists of input filter inductor Li,switch S1, a lossless snubber which includes capacitor Cs, inductor Ls, and diodes Ds1 and Ds2, and clamp capacitor Cc atthe primary side and Lr –Cr series resonant circuit and diodesD1 and D2 at the secondary side. The lossless snubber makes itpossible to achieve ZVS turn-off of switch as well as clamp thevoltage spikes of the switch by leakage inductance. Also, theLr–Cr series resonant circuit makes it possible to achieveZCS turn-off of diodes. Fig. 2 shows three resonance operations according to the variations of resonant frequency fr1which is expressed as in (.1): the above-resonance operation (DTs < 0.5Tr1), the resonance operation (DTs = 0.5Tr1), and

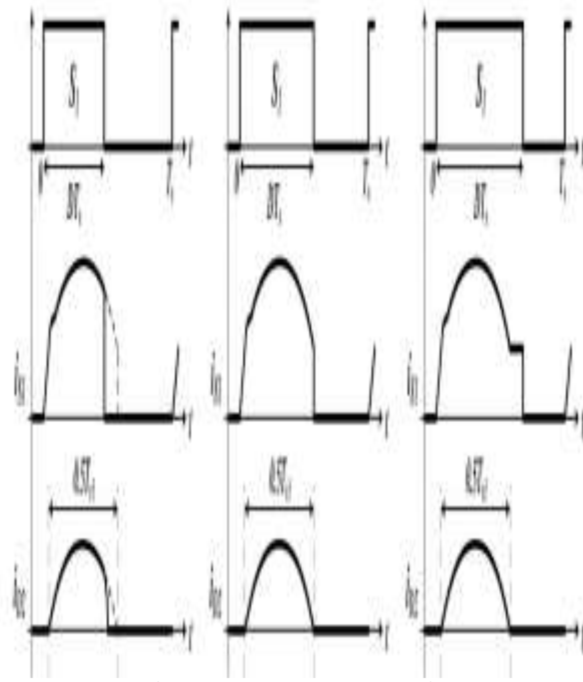


Fig.5. Comparison of switch and diode current waveform according to variation of fr1: (a) above-resonance operation (DTs <0.5Tr1), (b) resonance operation (DTs = 0.5Tr1), and (c) below-resonance operation (DTs >0.5Tr1).

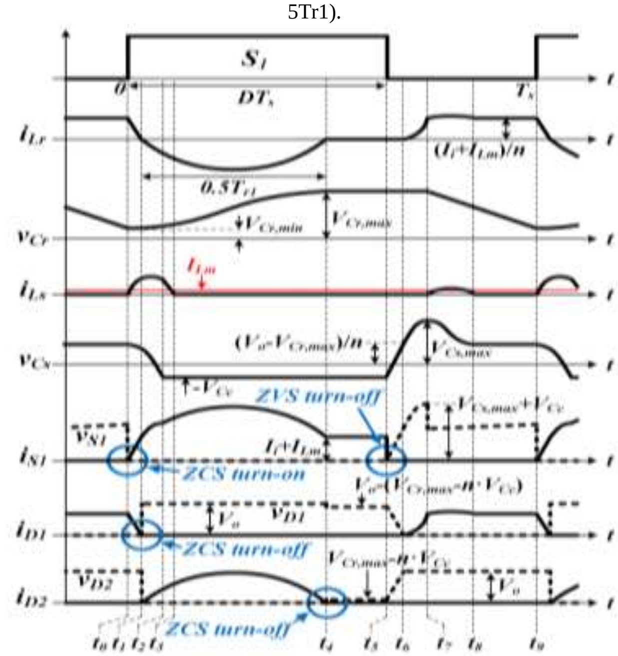


Fig.6. Key waveforms of the proposed converter in the below-resonance operation.

The below-resonance operation (DTs > 0.5Tr1)

$$f_{r1} = \frac{1}{T_{r1}} = \frac{1}{2\pi\sqrt{L_r C_r}} \quad (1)$$

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

It can be seen from Fig. 6 that the total switching losses ar esmaller for the below-resonance operation since both swit chturn-off current and diode di/dt of the below-resonance operation are smaller than them of the above-resonance op eration.Therefore, the below-resonance operation is chose n for the proposed converter.

A) Operating Principles

Figs.7 and 8 show key waveforms and operation s tates ofthe proposed converter in the below-resonance oper ation, respectively. In order to simplify the analysis of the steady-stateoperation, it is assumed that the input filter and magnetizing inductances are large enough so that they can be treated as constantcurrent sources during a switching p eriod. It is also assumed thatclamp and output capacitances are large enough so that they canbe treated as constant vol tage sources during a switching period.The voltage VC c a cross the clamp capacitor is the same as theinput voltage V i. In the below-resonance operation, nine modesexist withi n Ts.

Mode 1 (t0–t1): This mode begins when switch S1 is turn edON. Equivalent circuit of this mode is shown in Fig. 8(a). Ls andCsstart resonating and resonant current iLs flows through Ls, Ds1, Cs, and S1. The voltage and current of re sonant components are determined, respectively, as follow s:

$$i_{L_s}(t) = v_{C_s}(t_0)\sqrt{\frac{C_s}{L_s}}\sin(\omega_{r2}(t-t_0)), \quad t_0<t<t_2 \tag{2}$$

$$v_{C_s}(t) = v_{C_s}(t_0)\cos(\omega_{r2}(t-t_0)), \quad t_0<t<t_2 \tag{3}$$

Where ωr2 = 1/√LsCs. Since induced voltage VC r, min–n VC c–Vo across Lr makes time interval from t0 to t1 very short,current iLr appears to decrease almost linearly. Curre nt throughS1 increases with the slope of iLr, resulting in Z CS turn-on ofS1. The turn-on loss of switch associated wit h energy storedin MOSFET’s output capacitance is negligi ble in this low inputvoltage application. This mode ends w hen current iLrreaches 0 A. It is noted that diode D1 is tur ned OFF under ZCScondition.

Mode 2 (t1–t2): This mode begins when current iLr chang esits direction. Equivalent circuit of this mode is shown in Fig. 8(b). Lr and Cr start resonating and resonant current i Lrflows through Lr, Cr, and D2. The voltage and current o f resonant components are determined, respectively, as foll ows:

$$i_{L_r}(t) = (V_{Cr,\min} - nV_{Cc})\sqrt{\frac{C_r}{L_r}}\sin(\omega_{r1}(t-t_1)), \quad t_1<t<t_4 \tag{4}$$

$$v_{C_r}(t) = nV_{Cc} - (nV_{Cc} - V_{Cr,\min})\cos(\omega_{r1}(t-t_1)), \quad t_1<t<t_4 \tag{5}$$

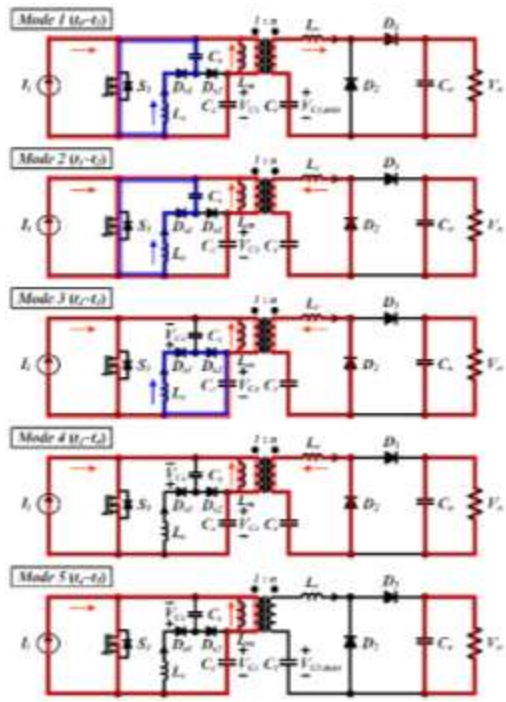
Whereωr1 = 1/√LrCr. When voltage across snubber capaci torCsequals –VC c, Ls–Cs resonance ends.

Mode 3 (t2–t3): This mode begins when diode Ds2 is turn edON. Current iLs is determined by following equation, a nd thismode ends when current iLs reaches 0a

$$i_{L_s}(t) = -\frac{V_{Cc}}{L_s}(t-t_2) + i_{L_s}(t_2), \quad t_2<t<t_3. \tag{6}$$

It is noted that diodes Ds1 and Ds2 are turned OFF under ZCScondition.

Mode 4 (t3–t4): The Lr –Cr resonance keeps on during thi smode and ends when current iLr reaches 0 A. Note that di odeD2 is turned OFF under ZCS condition.



International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

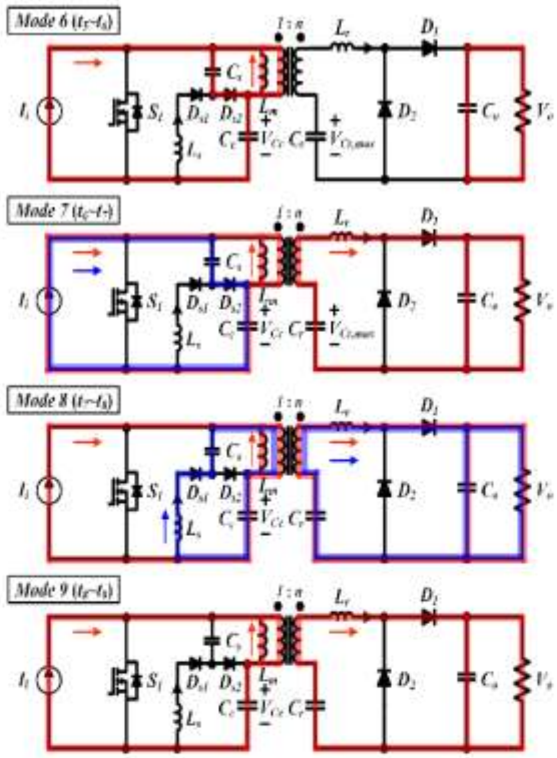


Fig.7. Operation states of the proposed converter in the below-resonanceo peration.

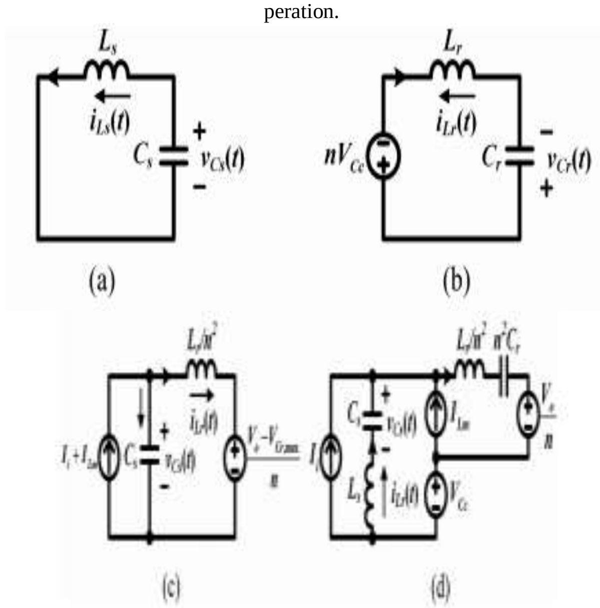


Fig.8.Equivalent resonant circuits. (a) Mode 1–2 (t0 –t2). (b) Mode 2–4 (t1 –t4). (c) Mode 7 (t6 –t7). (d) Mode 8 (t7 –t8)

Mode 5 (t4–t5): During this mode, a constant current flow sthrough S1 whose value is the sum of the input current Ii andthe magnetizing current ILm.

Mode 6 (t5–t6): The mode begins when S1 is turned OFF. Then, Ii + ILm flows through Cs, Ds2, and Cc. Voltage acr osssnubber capacitor Cs which is determined by the follow ingequation increases linearly with the slope of (Ii + ILm)/ Cs,resulting in ZVS turn-off of S1

$$v_{Cs}(t) = \frac{I_i + I_{Lm}}{C_s}(t - t_5) - V_{Cc}, \quad t_5 < t < t_6 \tag{7}$$

This mode ends when VCs becomes equal to (Vo –VCr, m ax)/n.

Mode 7 (t6–t7): This mode begins when diode D1 is turne dON. Equivalent circuit of this mode is shown in Fig.8(c). Lr andCsstart resonating and resonant current iLr flows thr ough Cs,Ds2, Lr, D1, and Cr. Assuming that Cs <<n2Cr, v Cr canbe considered constant, and resonance frequency ωr 3 can bedetermined by Cs and Lr. Therefore, the voltage a nd current ofresonant components are determined, respecti vely, as follows:

$$i_{Lr}(t) = (I_i + I_{Lm})[1 - \cos(\omega_{r3}(t - t_6))], \quad t_6 < t < t_7 \tag{8}$$

$$v_{Cs}(t) = \frac{I_i + I_{Lm}}{n}\sqrt{\frac{L_r}{C_s}}\sin(\omega_{r3}(t - t_6)) + \frac{V_o - V_{Cr,\max}}{n}, \quad t_6 < t < t_7 \tag{9}$$

Where ωr3 = n/√LrCs. This mode ends when current iLr b ecomes equal to (Ii + ILm)/n.

Mode 8 (t7–t8): This mode begins when diode Ds1 is turn edON. Equivalent circuit of this mode is shown in Fig. 8(d). Ls,Cs, Lr, and Cr start resonating and resonant current i Lr flowsthroughLs, Ds1, Cs, Cc, Lr, D1, andCr. Assuming thatCs <<n2Cr and Ls >> Lr/n^2, the voltage and current of resonantcomponents are determined using the superpositi on principle,respectively, as follows:

$$i_{Ls}(t) = \left[V_{Cc} + \frac{V_o}{n} - \left(V_{Cs,\max} + \frac{V_{Cr,\max}}{n}\right)\right] \times \sqrt{\frac{C_s}{L_s}}\sin(\omega_{r2}(t - t_7)), \quad t_7 < t < t_8 \tag{10}$$

$$v_{Cs}(t) = \left[V_{Cc} + \frac{V_o}{n} - \left(V_{Cs,\max} + \frac{V_{Cr,\max}}{n}\right)\right] \times [1 - \cos(\omega_{r2}(t - t_7))] + V_{Cs,\max}, \quad t_7 < t < t_8 \tag{11}$$

Assuming thatiLr ≈ (Ii + ILm)/n during this mode, voltage vCr is determined by the following equation:

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

$$v_{Cr}(t) = -\frac{I_i + I_{Lm}}{nC_r}(t - t_7) - V_{Cr,\max}, \quad t_7 < t < t_9 \qquad (12)$$

This mode ends when current iLs reaches 0 A.

Mode 9 (t8–t9): Switch S1 is in the turn-off state, and the sumof the input current and magnetizing current is being transferredto the secondary. Current iD1 is equal to (Ii + ILm)/n. Thismode ends when switch S1 is turned ON.

The average current of magnetizing inductor Lm is equal toaverage current of snubber inductor Ls since ILs,avg = IDs2, avgand IDs2, avg = ILm,avg. Therefore, it should be noted thattransformer core volume of the proposed converter is muchsmaller compared to that of the flyback-based converter sinceILs,avg (= ILm,avg) can be designed to be small.

The closed loop operation carried out by the voltage controller (PI controller) processes the error signal and produces appropriate current signal (*I*S). The current signal (*I*S) is multiplied with unit sinusoidal template which is produced by using phase locked loop (PLL), to produce *I*S sinωt. The load current *iL* subtracted from the *I*S sin ωt to produce the reference current signal *i*S*. As the boost inductor current can't be alternating, the absolute circuit gives the absolute value of the reference current signal *i*S* that is *iC**. The actual signal (*i*C) and the required reference signal (*iC**) are given to the current controller to produce the proper gating signal. The current controller adopted is a hysteresis current controller. Upper and lower hysteresis band is created by adding and subtracting a band '*h*' with the reference signal *i*C* respectively shown in the Fig. 8. The inductor current is forced to fall within the hysteresis band. When the current goes above the upper hysteresis band, i.e. *i*C *+*h*, the pulse is removed resulting the current forced to fall as the current will flow through the load. When the current goes below the lower hysteresis band i.e. *i*C *-*h*, the pulse is given to the switch, so the current increases linearly.

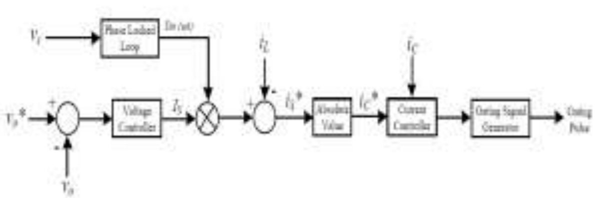


Fig 9 Adopted control scheme for the Closed Loop operation

III.MATLAB/SIMULATION RESULTS

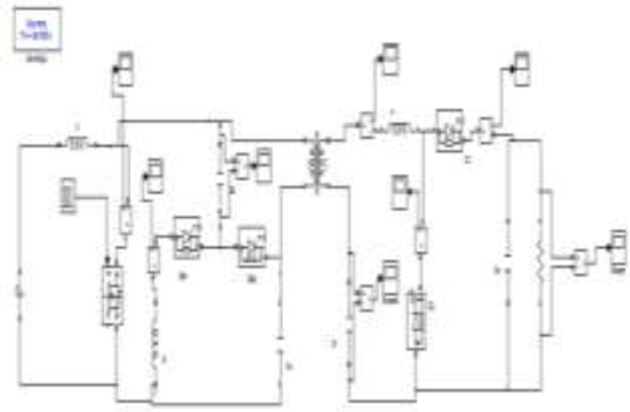


Fig 10 Matlab/simulation circuit of Synchronous Buck Converters

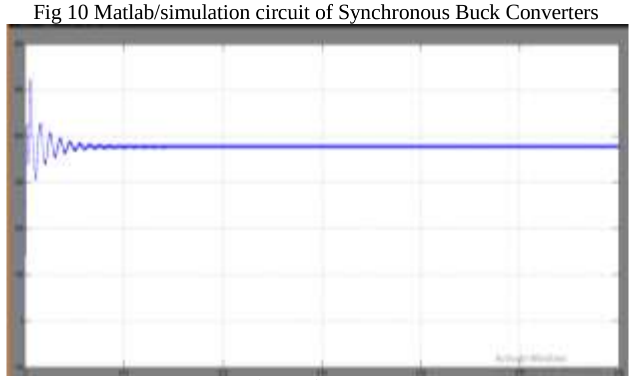


Fig 11 simulation wave form of buck converter output voltage

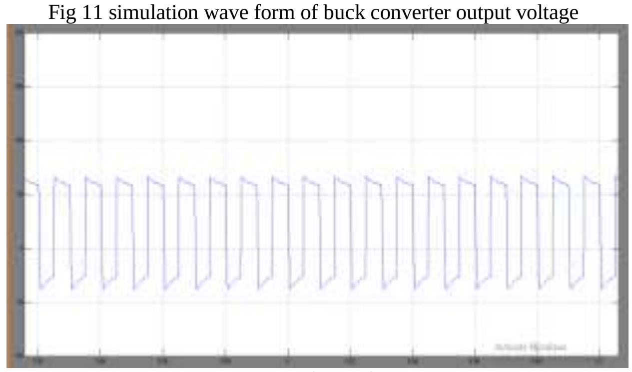


Fig 12 simulation wave form of capacitor voltage

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 02
February 2017

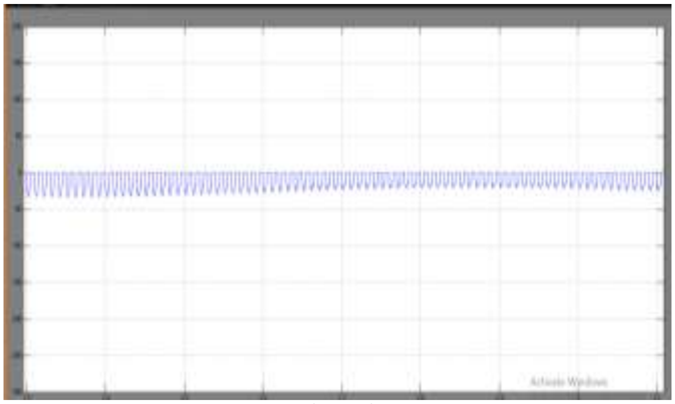


Fig 13 simulation wave form of switching current

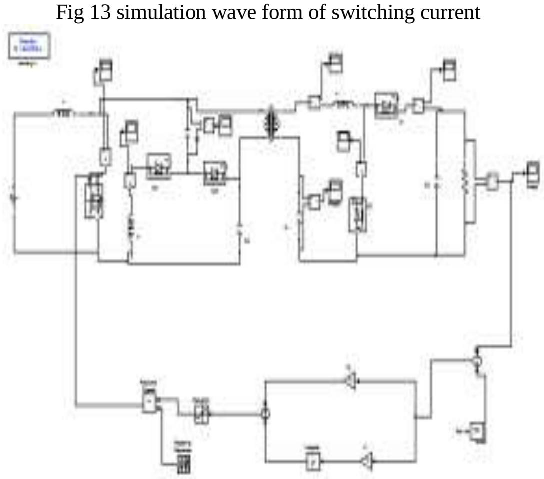


Fig 14 Matlab/simulation circuit of Synchronous Buck Converters with cl osed loop

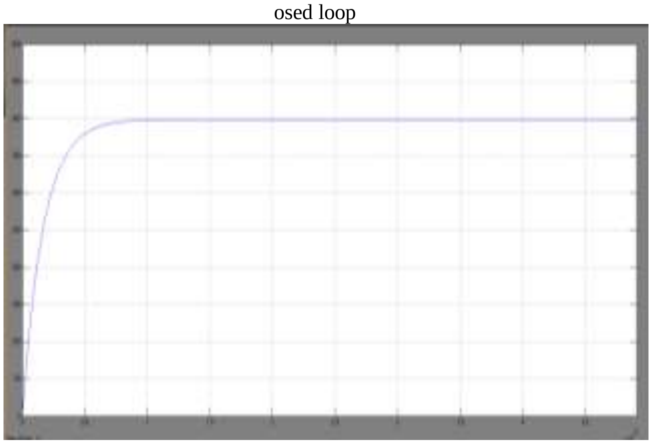


Fig 15 simulation wave form of buck converter output voltage with close d loop

IV CONCLUSION

These papers explain a Closed Loop Control of Fully Soft-Switched Isolated DC–DC Converter.A DC-DC converter for high step up and high power applicatio ns is proposed. From the simulation results it is obser ved that ZVS turn on and ZCS turn off of all the swit ches is obtained. The voltage stress across the switch es is much lesser. Compared with other topologies, it requires less number of switches and no need of bulk y transformers. This topology is simpler and cheaper. The single switch resonant converter offer advantag es of soft switching techniques thus reduce switching losses and voltage stabilization. The zero voltage sw itching for switch and zero current switching for ener gy blocking diode is attained. And voltage regulation for the load changes also attained for the proposed to pology.

REFERENCES

[1] J. M. Kwon, W. Y. Choi, and B. H. Kwon, "Singl e-switch quasi-resonant converter," IEEE Trans. Ind. Electron., vol. 56, no. 4, pp. 1158–1163, Apr. 2009.

[2] A. Emrani, E. Adib, and H. Farzanehfard, "Single -switch soft-switched isolated DC–DC converter," IE EE Trans. Power Electron., vol. 27, no.4, pp. 1952–1 957, Apr. 2012.

[3] J. M. Kwon, W. Y. Choi, and B. H. Kwon, "Singl e-switch quasi-resonant converter," IEEE Trans. Ind. Electron., vol. 56, no. 4, pp. 1158–1163, Apr. 2009.

[4] A. Emrani, E. Adib, and H. Farzanehfard, "Single -switch soft-switched isolated DC–DC converter," IE EE Trans. Power Electron., vol. 27, no.4, pp. 1952–1 957, Apr. 2012.

[5] D. A. Ruiz-Caballero and I. Barbi, "A new flybac k-current-fed push-pull DC-DC converter," IEEE Tra ns. Power Electron., vol. 14, no. 6, pp. 1056–1064, N ov. 1999.

[6] M. Nymand and M. A. E. Andersen, "High-effici ency isolated boost DCDC converter for high-power low-voltage fuel-cell applications," IEEETrans. Ind. Electron., vol. 57, no. 2, pp. 505–514, Feb. 2010.

[7] K. B. Park, G. W. Moon, and M. J. Youn, "Two-t ransformer current-fed converter with a simple auxili ary circuit for a wide duty range," IEEE Trans. Powe r Electron., vol. 26, no. 7, pp. 1901–1912, Jul. 2011.

[8] F. J. Nome and I. Barbi, "A ZVS clamping mode-current-fed push–pull DC–DC converter," in Proc. IE

EE Int. Symp. Ind. Electron, vol. 2, 1998, pp. 617–621.

[9] V. Yakushev, V. Meleshin, and S. Fraidlin, "Full-bridge isolated current fed converter with active clamp," in Proc. IEEE Appl. Power Electron.Conf. Expo., vol. 1, 1999, pp. 560–566.

[10] R. Watson and F. C. Lee, "A soft-switched, full-bridge boost converter is employing an active clamp circuit," in Proc. IEEE Conf. Power Electron.Spec. Conf. Rec., vol. 2, 1996, pp. 1948–1954.

[11] S. Han, H. Yoon, G. Moon, M. Youn, Y. Kim, and K. Lee, "A new activeclamping zero-voltage switching PWM current-fed half-bridge converter,"IEEE Trans. Power Electron., vol. 20, no. 6, pp. 1271–1279, Nov. 2005.

[12] J. Kwon and B. Kwon, "High step-up active-clamp converter with input current doubler and output-voltage doubler for fuel cell power systems,"IEEE Trans. Power Electron., vol. 1, no. 1, pp. 108–115, Jan. 2009.

[13] H. Kim, C. Yoon, and S. Choi, "An improved current-fed ZVS isolatedboost converter for fuel cell application," IEEE Trans. Power Electron.,vol. 25, no. 9, pp. 2357–2364, Sep. 2010.

[14] C. D. Davidson, "Zero voltage switching isolated boost converter topology," in Proc. IEEE 33rd Int. Telecommun. Energy Conf., Oct. 2011, pp.1–8.

Author's profile:

T Vasanth naik, Received B. Tech. in Electrical and Electronics Engineering From Ananthi Institute of Technlologyin 2014,Currently Pursuing M.Tech. (Power Electronics and electricalDdrives) From Anurag college of engineering, Aushapur(v),Ghatkesar(m), R.R DIST,Telangana.

R Rekha, at present she is an Assistant Professor in the department of EEE in Anurag college of engineering, Ranga Reddy Telengana, India. Received B. Tech. degree in EEE from CVSR College of Engineering in 2008. Received M. Tech. degree in CVSR College of Engineering,2011.