

## **Digital Simulation of SISO-ZVS-Push pull Quasi Resonant Converter for Different Loads**

**K.Deepa<sup>1</sup>, SharikaM<sup>2</sup>, Mamatha<sup>3</sup>, Dr.M Vijaya kumar<sup>4</sup>,**

<sup>1&3</sup>Assistant Professor, <sup>2</sup>P.G.Scholar, <sup>4</sup>Professor

<sup>1,2,3</sup>Amrita Vishwa Vidyapeetham, Amrita School of Engineering, Bangalore. <sup>4</sup>JNTUA, Anantapur

### **Abstract—**

**Resonant switching DC-DC converters are currently replacing hard switched converters for power supply in many applications due to their divergent advantages such as high efficiency, high frequency operation, compact structure, low EMI, etc. The paper deals with the design and simulation of SISO ZVS Pushpull converter for R, RL, RLE and DC servo drive using MATLAB/Simulink in half wave mode. The salient feature of ZVS is that the switching devices is switched on at zero voltage , so that switching losses are zero, switching stresses and volumes are reduced and power density is increased. These features increases the efficiency of the converter applied for robotic applications. The centre tapped transformer of the pushpull converter also functions as an isolation device between the source and the load.**

**Keywords— Quasi resonant converter (QRC), Zero voltage switching (ZVS), Zero current switching (ZCS), Single input single output (SISO).**

### **I. INTRODUCTION**

Nowadays major constrain in selection of power supplies for any application is its size. Lesser sized power supplies have more advantages like light weight, less space, high power density, etc. Lesser size demands smaller sized components especially inductor and transformer sizes. This could be possible only at high frequencies, which has more switching losses in switches for hard switching [11 – 13]. Various soft-switched converters using either zero-voltage switching (ZVS) or zero-current switching (ZCS) have been proposed in the literature[1- 6], and high frequency operation with reduced switching losses and EMI is achieved. The salient feature of QRC is that the switching devices can be either switched on at zero voltage or switched off at zero current, so that switching losses are ideally zero. Switching stresses, volumes are reduced and power density is increased. This feature increases the efficiency the converter. Several single-output converters are now available, based on zero-voltage-switched (ZVS) half-wave (HW) topologies. In this paper single output push pull ZVS-QRC was proposed which has two switches

that helps in reducing the control range of frequencies providing better efficiency [10]. The push-pull topology is preferred since resetting of magnetic flux in the transformer core is in built in the converter operation itself. This allows a higher duty-cycle of the switches and a greater power density of the equipment [7 – 9].

In this paper the design and simulation of the SISO ZVS pushpull converter in half-wave mode for robotic applications is carried out. The servos are used for precision positioning. They are used in robotic arms and legs. Servo refers to an error sensing feedback control which is used to correct the performance of a system. Servo or DC servo motors are DC motors equipped with a servo mechanism for precise control of angular position. Hence simulation is carried out to validate the performance of the converter for a DC Servo load and results obtained are discussed in detail.

### **II. ANALYSIS AND DESIGN OF PUSH PULL ZVS QRC**

The working of the converter and the design is explained in this section.

#### **A. Circuit Diagram**

The push-pull converter is a topology derived from a forward converter. It is basically 2 anti-parallel forward converters were each forward converter operates for one half of the cycle. This operation of the converter makes it possible to operate in I and III quadrant of B-H curve. Hence the power delivered to the load is twice that of the forward converter. To reduce the size of the transformer and inductor used for the converter, high switching frequency is selected as the operating frequency. The major drawback of selecting high frequency of operation is high switching losses in the switches. To reduce this ZVS is introduced in the switches by connecting a resonant capacitor in parallel with the switch and resonant inductor in series with the switch. This combination forms a series resonant circuit which ensures zero voltage when switching ON, increasing the efficiency of the converter by reducing the switching losses. The idealised resonant waveforms of the converter shown in Fig.1 for one switching cycle are shown in Fig.2.

### B. Modes of Operation

Whenever there is a switching action, the circuit configuration changes. This configuration has 6 such operating modes as explained below

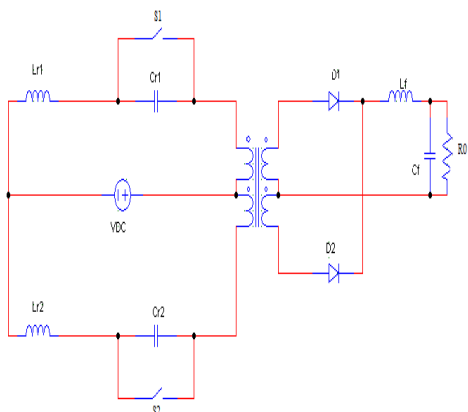


Fig. 1. Circuit diagram of push- pull ZVS-QRC

**Mode 1** In interval  $T_{d1}$ ,  $S_1$  and  $S_2$  are off. Initial conditions are  $L_{r1} = I_o$ ,  $V_{cr2} = 2V_{dc}$ . In the secondary circuit diode  $D_1$  is forward biased and  $D_2$  is reverse biased. This interval is known as power transfer interval. During this interval power is transferred from primary to secondary.

**Mode 2** Interval  $T_{d2}$  begins when  $S_2$  is turned ON,  $S_1$  is OFF. In the secondary circuit diode  $D_1$  is forward biased and  $D_2$  is reverse biased. This interval is known as resonant transition interval.

**Mode 3** In interval  $T_{d3}$ ,  $S_1$  is OFF and  $S_2$  is ON. In the secondary circuit diode  $D_2$  is forward biased and  $D_1$  is reverse biased. This interval is known as resonant transition 2 interval. Resonant inductor current,  $i_{Lr1}$  is negatively charging and resonant inductor current,  $i_{Lr2}$  is positively charging.

**Mode 4** In interval  $T_{d4}$ ,  $S_1$  is OFF and  $S_2$  is OFF. In the secondary circuit diode  $D_2$  is forward biased and  $D_1$  is reverse biased. This interval is known as power transfer interval Resonant inductor current,  $i_{Lr1}$  is negatively charging and resonant inductor current,  $i_{Lr2}$  is maintaining its charge.

**Mode 5** In interval  $T_{d5}$ ,  $S_1$  is ON and  $S_2$  is OFF. In the secondary circuit diode  $D_1$  is forward biased and  $D_2$  is reverse biased. This interval is known as resonant transition 1 interval. Resonant inductor current,  $i_{Lr1}$  is positively charging and resonant inductor current,  $i_{Lr2}$  is positively discharging.

**Mode 6** In interval  $T_{d6}$ ,  $S_1$  is ON and  $S_2$  is OFF. In the secondary circuit diode  $D_1$  is forward biased and  $D_2$  is reverse biased. This interval is known as resonant transition2 interval. Resonant

inductor current,  $i_{Lr1}$  is positively discharging and resonant inductor current,  $i_{Lr2}$  is positively discharging.

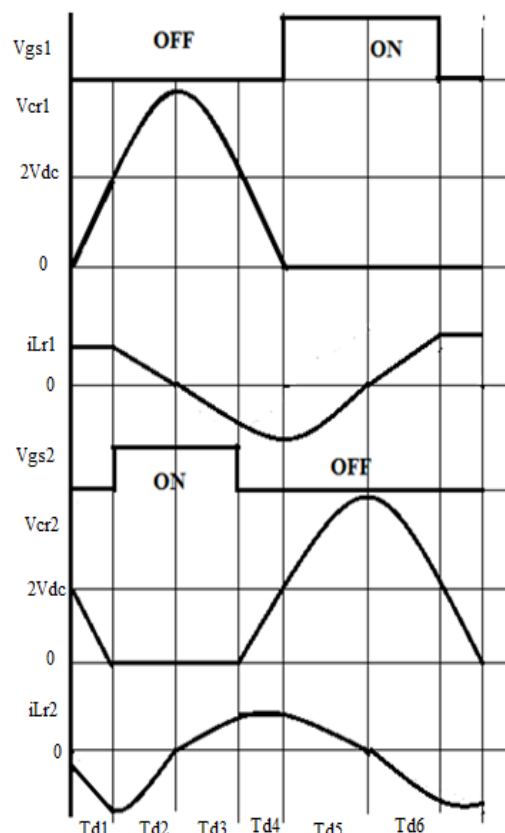


Fig.2 Theoretical resonant waveforms of push-pull ZVS-QRC.

### C. Design

The design procedure is explained for push-pull ZVS-QRC with the following specifications:

Input voltage	$V_{dc} = 15V$
Output Voltage	$V_o = 5V$
Switching frequency	$f_s = 50kHz$
Power rating	$P_o = 5W$

The characteristic impedance  $Z_o = \sqrt{L_r/C_r}$

The resonant capacitors are assumed to be equal  $C_r = C_{r1} = C_{r2} = 0.047\mu F$ .

The resonant inductors are assumed to be equal  $L_r = L_{r1} = L_{r2} = 0.16mH$ .

Power =  $T * \omega$   
Torque = 0.5 N-m  
 $\omega = 10 \text{ rad/s}$  or  $N = 95.49 \text{ rpm}$

### III. OPEN LOOP SIMULATION RESULTS

Digital simulation of the converter is carried out in MATLAB 2010A and the simulation results are presented below. The simulation is

carried out for different loads like R, RL, RLE, DC servo motor. The simulated waveforms of the circuit shown in Fig. 3 are presented from Fig. 4 to 9 for all loads as shown in table I. The gating pulses applied to switch  $S_1$  and  $S_2$  and the corresponding resonant capacitor voltage and resonant inductor current is shown in Fig.4. This waveform resembles the theoretical resonant waveforms as shown in Fig.2. From Fig.4 it is clear that each switch is switched ON when the voltage across the capacitor connected in parallel to the switch is zero. For example  $S_2$  is ON when  $V_{cr1} = 0$  (i.e) at the end of  $T_{d4}$  interval. Similarly  $S_2$  is ON when  $V_{cr2} = 0$  (i.e) at the end of  $T_{d1}$  interval. This ensures ZVS and hence less switching losses. It was observed that the resonant, output voltage and current waveforms obtained for all the loads were the same as shown in fig.4 and fig.5. From the resonant waveform presented in Fig.4 it is apparent that the peak capacitor voltage is 50V and 40V respectively in upper and lower half of primary of transformer and inductor peak current being 2A & 1A in upper and lower limbs of the transformer. From Fig.6 it is experiential that the peak voltage and current through both the diodes are 15V and 1.5A in diode 1 and 15V and 2A in diode 2 respectively. The voltages across the primary and secondary of transformer are as shown in Fig 7.

Fig.8. shows Zero voltage switching during turn ON. ZVS is achieved, if the switch is turned on when the voltage across the switch is zero (i.e) the body diode of the switch is conducting and hence the voltage across the switch will be zero. From the fig.9 it is seen that just before the time of turn-on the switch current is negative. This indicates that the body diode is conducting. So the switches  $S_1$  and  $S_2$  are operating in ZVS during turn-on. Characteristics of the DC servo drive are as shown in Fig 10. The simulation confirms that the converter produces rated armature voltage of 5V and armature current of 1A. It is further obvious that the rated speed of 10rad/sec and rated torque of 0.5Nm is achieved as per the requirement.

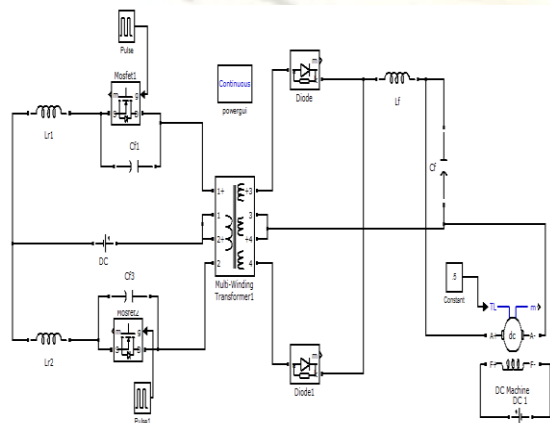


Fig. 3. Simulation circuit of SISO-ZVS pushpull converter fed DC servo motor drive.

TABLE I  
LOAD SPECIFICATIONS

R LOAD		5 $\Omega$
RL LOAD		R = 4 $\Omega$ L = 0.81mH
RLE LOAD		R = 2.5 $\Omega$ L = 0.81mH E = 2.499V
DC motor	Servo	Armature resistance, R <sub>a</sub> = 2.5 $\Omega$  Armature inductance, L <sub>a</sub> = 0.81mH

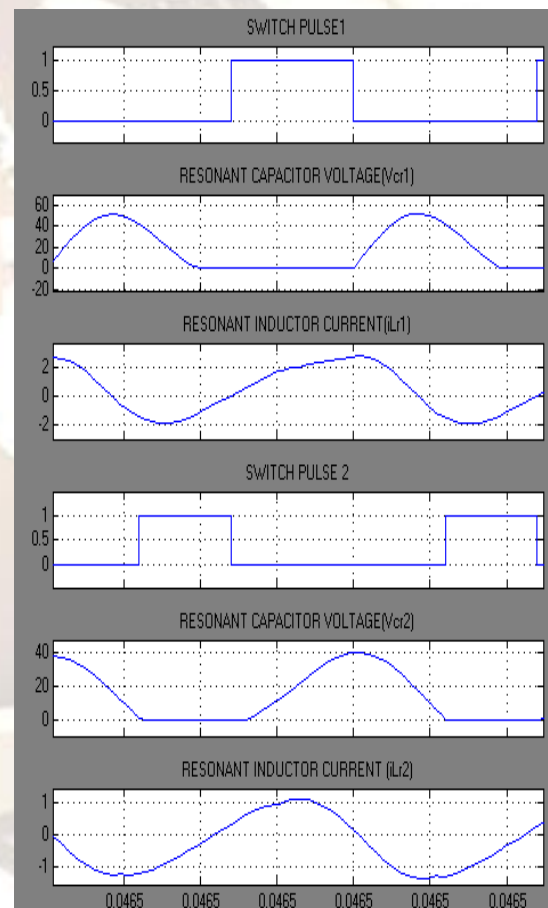


Fig 4. Resonant waveforms

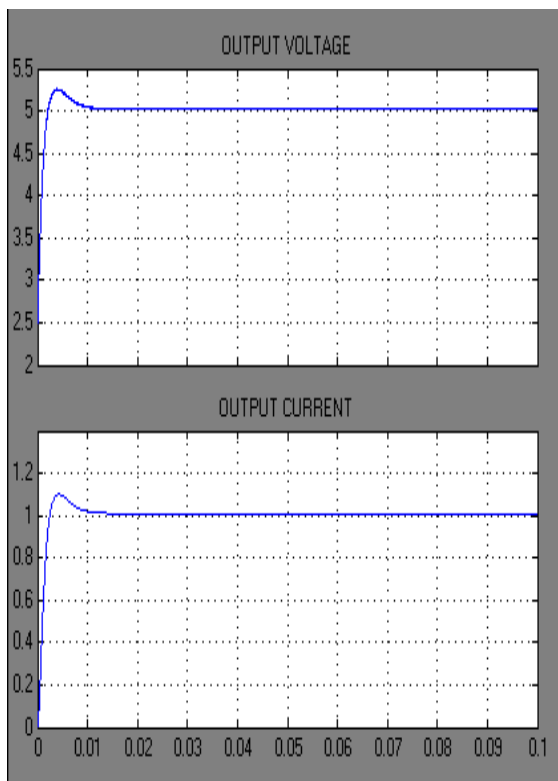


Fig. 5. Output voltage and current

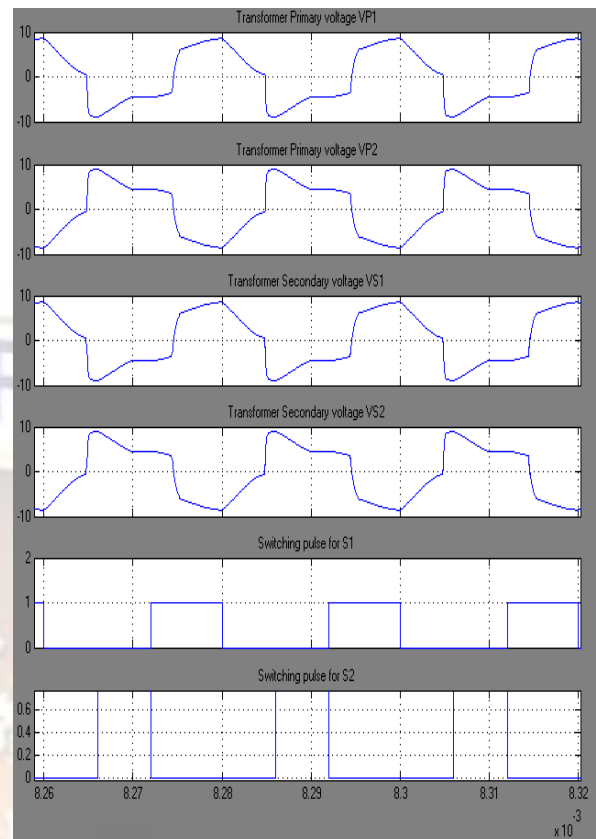


Fig.7. Transformer primary and secondary voltages with switching pulses.

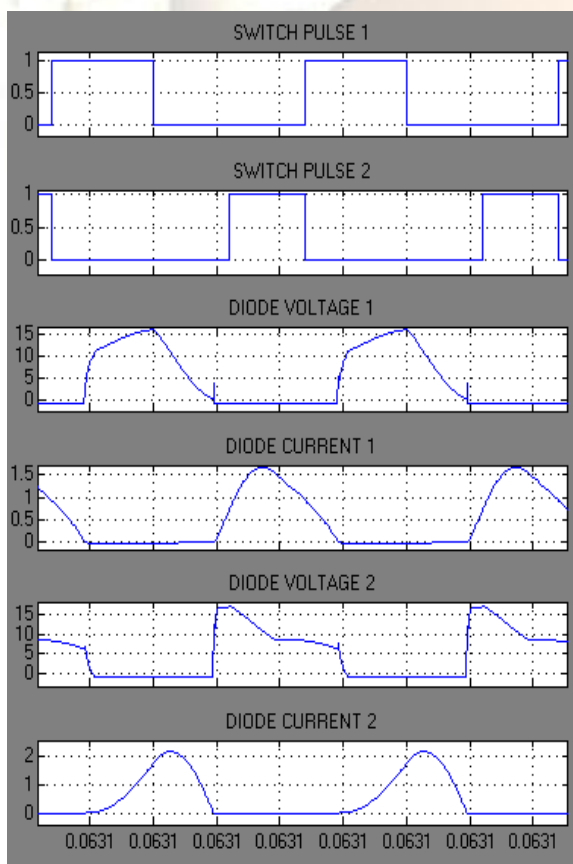


Fig.6. Diode voltages and currents with gate pulse.

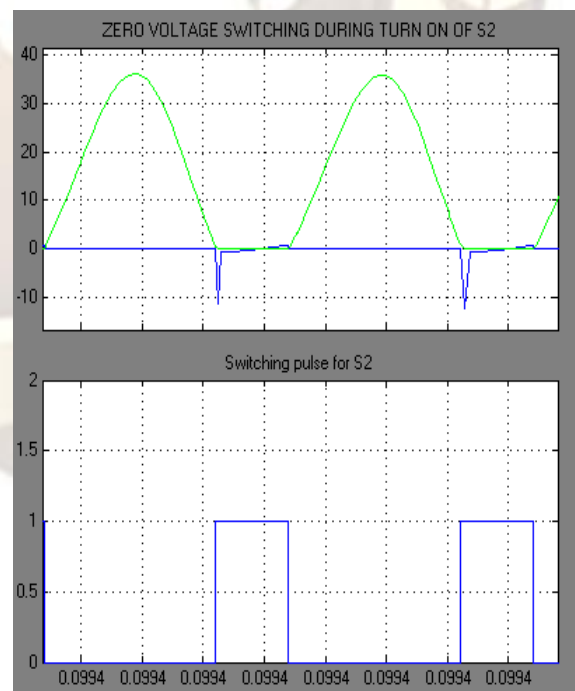


Fig.8. Switch1 waveforms with its switching pulse.



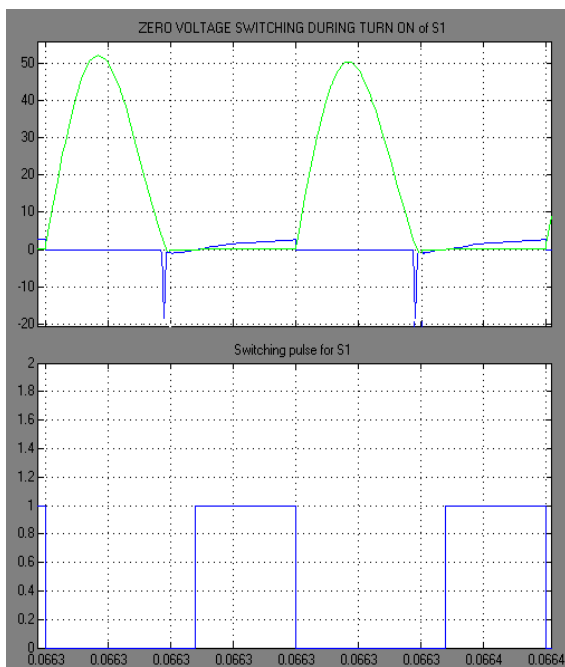


Fig.9 Switch2 waveforms with its switching pulse.

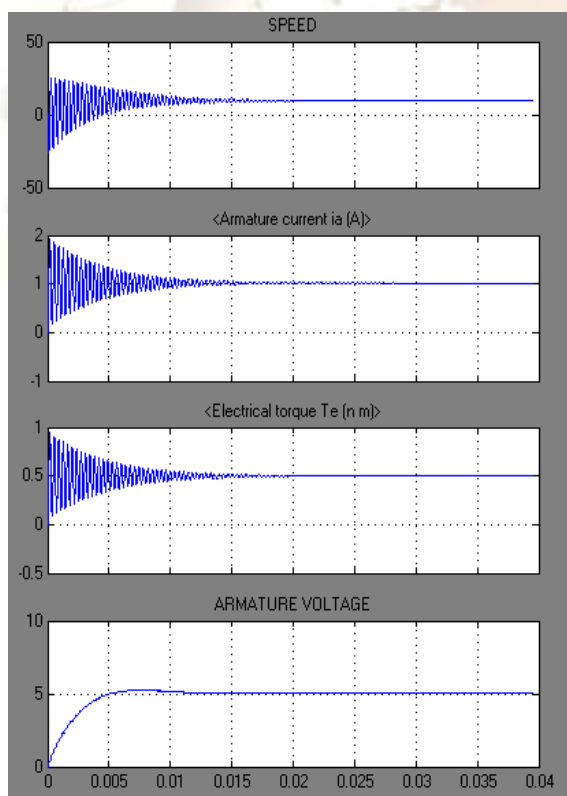


Fig.10 Characteristics of DC servo drive.

#### IV. CONCLUSIONS

Modelling of SISO ZVS Pushpull converter is done and Simulation was successfully carried out in

MATLAB 2010 for all loads as shown in Table I. This paper proposes a SISO ZVS Pushpull with resonance in primary side of transformer for DC servo drive. Fig. 10 proves the efficiency of the converter for feeding a DC servo drive for robotic applications. Fig.4 confirms that each switch is switched ON when the voltage across the capacitor connected in parallel to the switch is zero.. This ensures ZVS and hence less switching losses and higher efficiency. Implementation of this topology is simple even for high frequency operation. Switching stresses get reduced since voltage and current waveforms have lesser slope as shown in Fig.8 and Fig.9. Power density is increased since the volume is reduced. From all the above said features the converter fed Servo drive is a viable alternative for robotic applications.

#### REFERENCES

- [1] Liu K.H. and Lee F.C.Y, "Zero-Voltage Switching Technique in DC/DC Converters", IEEE transactions on power electronics, vol. 5, no. 3. July 1990, pp.293-304
- [2] B.Andreyca, "Zero voltage switching resonant power conversion", Application note, Unitrode corp, slus138, pg.3\_329 - 3\_359.
- [3] G.Uma, M. Shanthy and C. Chellamuthu, "Design and Implementation of Constant Frequency Soft Switched Regulated Power Supply for Aerospace Applications", IEEE-ISIE 2000, Cholula, Puebla, Mexico, pg 107 – 119.
- [4] Kattamuri Narasimha Rao, Vyza Chinna Veera Reddy, "Digital Simulation of FM-ZCS-Quasi Resonant Converter Fed DC Servo Drive Using Matlab Simulink, serbian journal of electrical engineering vol. 6, no. 2, november 2009, pp 227-237.
- [5] K.Narasimha Rao Dr.V.C. Veera Reddy "Implementation of FM-ZCS-Quasi Resonant Converter fed DC servo drive", IEEE, Emerging trends in Engineering and Technology, ICETET-2009, pp.709-715.
- [6] Bal Mukund Sharma, A. N.Tiwari, K. P. Singh, "Design and Simulation of Soft Switched Converter Fed DC Servo Drive" International Journal of Soft Computing and Engineering (IJSCE), Volume-1, Issue-5, November 2011, pg.95-100.
- [7] Wilson C. P. de Aragao Filho, I. Barbi, "A Comparison Between Two Current- Fed Push-Pull DC-DC Converters- Analysis, Design and Experimentation", IEEE Telecommunication energy conference, Boston,1996, pp. 313 – 320.
- [8] B. Swaminathan and V. Ramanarayanan, " A Novel Resonant Transition Push-Pull DC-DC Converter", J. Indian Institute of Science, Nov.- Dec. 2004, pp.1782-1789.

- [9] S. Arun, S. Rama Reddy, "ZVS LCL push-pull dc-dc converter with closed Loop controlled pi controller", IET-UK International Conference on Information and Communication Technology in Electrical Sciences (ICTES 2007), Dec. 20-22, 2007, pp.175-179.
- [10] S. Arulsevi, C.Subashini and G. Uma, "A New Push-Pull Zero Voltage Switching Quasi-Resonant Converter: Topology, Analysis and Experimentation", IEEE Indicon 2005 Conference, Dec. 2005, pp 482-486.
- [11] L.Umanand, "Power electronics essentials and applications", Wiley Publications, First Edition, 2009.
- [12] Ned Mohan, "Power electronics, Converters Applications and Design" Wiley Publications, second Edition, 1995.
- [13] Muhammad.S. Rashid, "Power Electronics Circuits Devices and Applications", 3<sup>rd</sup> edition, 2004.

