INPUT PARALLEL OUTPUT SERIES QRC FED DC SERVO DRIVE

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ABSTRACT

This paper deals with simulation of input parallel, output series QRC fed DC servo drive. 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 zero ideally. Switching stresses are low, volumes are low and the power density is high. This property imparts high efficiency and high power density to the converters. The output of QRC is regulated by varying the switching frequency of the converter. Hence it is called Frequency modulated Zero current/zero voltage switching quasi resonant converter. Simulation results show that the ZCS-QRC's have low total harmonic distortion. Input parallel output series QRC fed DC servo drive is simulated and the results are presented. This converter is proposed for DC servo motors with higher voltage rating.

I INTRODUCTION

Thyristorised power controllers are now widely used in the industry. Conventional controllers involving magnetic amplifiers, rotating amplifiers, mercury arc amplifiers, resistance controllers etc., have been replaced by thyristorised power controllers.

Controllers of DC drives and AC drives widely use thyristorised power controllers in rolling mills, textile mills, paper mills, cranes, traction vehicles and mine winders etc., Some other areas where thyristorised power controllers employed are uninterruptible and standby power supplies for critical loads, static power compensation, special power supplies for air craft and space applications, transformer tap changers and static connector for industrial power systems, power conversion at the terminals of HVDC transmission system, HV supplies for electronic precipitators and X-ray generators.

II QUASI RESONANT CONVERTER

The fundamental departure from the conventional " forced turn Off " approach is the "zero current switching" (ZCS) technique, proposed by F C Y Lee et al (1987). Replacing the switches as power switches (MOSFET, GTO) in the PWM converters by resonant switches gives rise to a new family of converters, namely "Quasi Resonant Converters " (QRC). This new family of converters can be viewed as a hybrid between PWM converters and resonant converters. They utilize the principle of inductive or capacitive energy storage and power transfer in a similar fashion as PWM converters. The circuit topologies also resemble those of PWM converters. However an LC tank circuit is always present near the power switch and is used not only to shape the current waveforms through the power switch and the voltage waveform across the device. It can also store and transfer energy from input to output in a manner similar to the conventional resonant converters.

Performance of the DC motor fed from series QRC is given in [1]. Large signal non linear model for simulation of ZCS – QRC is given in [3]. Cyclic quasi resonant converter for high performance DC to DC conversion is given in [4]. A new group of quasi resonant converters is given by [5]. The above literature does not deal with servo motor fed from input parallel, output series QRC. This work proposes parallel connection at input and series connection at output to control speed of high power drives.

A conventional Frequency modulated-zero current switching-Quasi resonant converter circuit and its operating waveforms are shown in Figs. 1 and 2 respectively. The sinusoidal current waveform in the case of zero current resonant switch/ the sinusoidal voltage waveform in the case of Zero voltage resonant switch, generated by the waveform shaping LC resonant elements creates a zero current / voltage condition for the switch to turn-off / turn-on without switching stresses and losses.

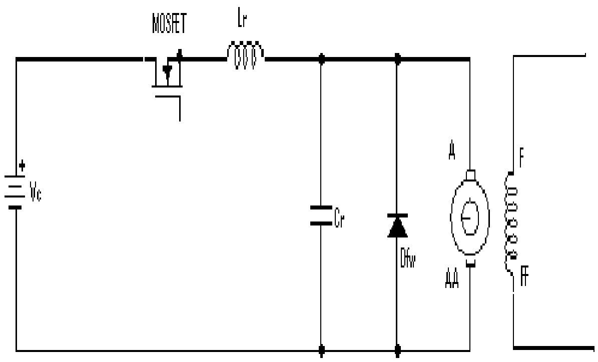

Fig 1 Power circuit of Half wave FM-ZCS-QRC fed

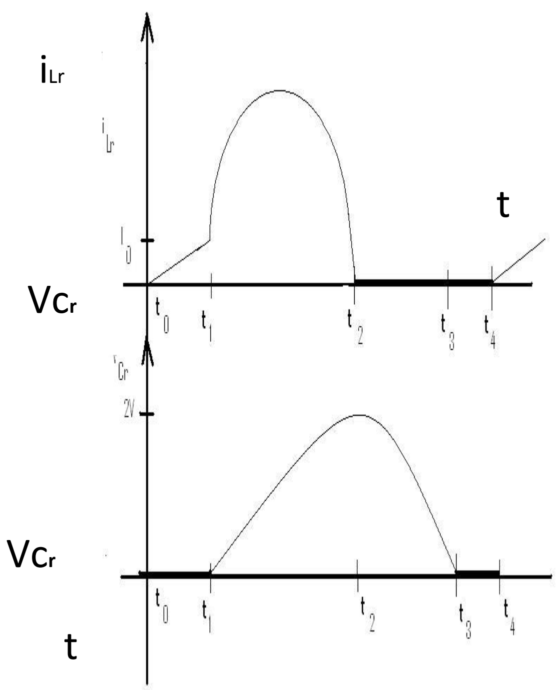

Fig 2 Waveforms of Half wave FM-ZCS-QRC

A switching cycle can be divided into four stages. The associated equivalent circuits for these four stages are shown in modes of operation for half wave and full wave circuits respectively. Assume initially free wheel diode (D_{fw}) carries the output current (I_o) and resonant capacitor voltage (V_{Cr}) is clamped at zero and switch S is off. At the beginning of the switching cycle $t = t_o$, S is switched on.

1 . MODE1 : When S is turned on at $t = t_o$, the input current (i_{Lr}) rises linearly and is governed by the state equation $V = L_r (di_{Lr}/dt)$. The duration of the mode, $t_{d1} = (t_1 - t_0)$ can be solved with boundary conditions which can be expressed by equations 1(a) and 1(b)

$i_{Lr}(o) = o$ and $i_{Lr}(t_{d1}) = I_o$ ------------------------- 1 (a)

Thus $t_{d1} = (L_r I_o/V)$ --------------------- ---- 1(b)

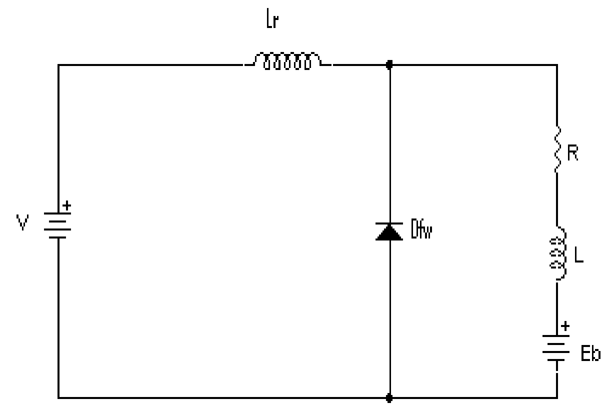

Fig 3.1 equivalent circuit for mode 1

2 . Mode 2 : At time $t = t_1$, when the input current rises to the level of I_o , D_{fw} is turned off and the amount of current ($i_{Lr}(t) - I_o$) is now charging C_r , which can be given by the state equations 2(a) to 2(f)

$C_r (dV_{Cr}/ dt) = i_{Lr}(t) - I_o$ ----------------------------- 2(a)

$L_r (di_{Lr} / dt) = V - V_{Cr} (t)$ ----------------------------- 2(b)

With the initial condition $V_{Cr}(0) = 0$

And $i_{Lr}(0) = I_o$. Therefore

$i_{Lr}(t) = I_o + (V / Z_o) \text{Sin } \omega t$ ----------------- 2©

If a half wave resonant switch is used, switch S will be naturally commutated at time when the resonating input current $i_{Lr}(t)$ reduces to zero. On the other hand, if a full wave resonant switch is used, current $I_{Lr}(t)$ will continue to oscillate and energy is fed back to source, V through D_{fw}. Current through D_{fw} again oscillate to zero . The duration of this stage $t_{d2} = (t_2 - t_1)$ can be solved by setting $i_{Lr}(t_{d2}) = 0$.

Thus , $t_{d2} = \alpha / \omega$ ------------------------ 2(d)

Where $\alpha = \arcsin (Z_o I_o / V)$ ------------- 2(e)

$\Pi \leq \alpha \leq 3\pi / 2$ for half wave mode

$3\pi / 2 \leq \alpha \leq 2\pi$ for full wave mode

At time t_2, V_{Cr} can be solved using

$V_{Cr}(t_{d2}) = V (1 - \text{Cos } \alpha)$ -------------- 2(f)

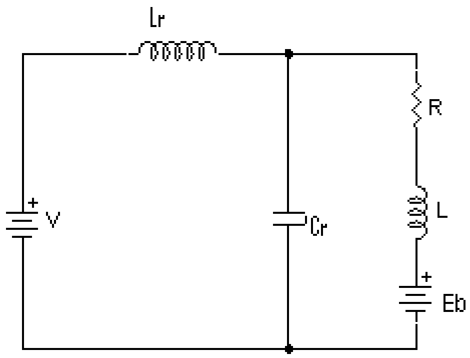

Fig 3.2 equivalent circuit for Mode 2 operation

3.MODE 3: This stage begins at t_2, when the current through inductor L_r is zero. At $t = t_2$, S is turned off. The Capacitor C_r discharges through the load to supply constant load current. Hence V_{Cr} decreases linearly and reduces to zero at t_3. The state equation for this mode is given by the equations 3(a) to 3(c)

$C_r(dV_{Cr}/dt) = I_0$ ------------------------ 3(a)

The duration of this stage

$t_{d3} = (t_2 - t_1)$ ------------------------------ -3(b)

can be solved with the initial condition.

$V_{Cr}(o) = V(1 - \cos\alpha)$ ---------------------------- ---3©

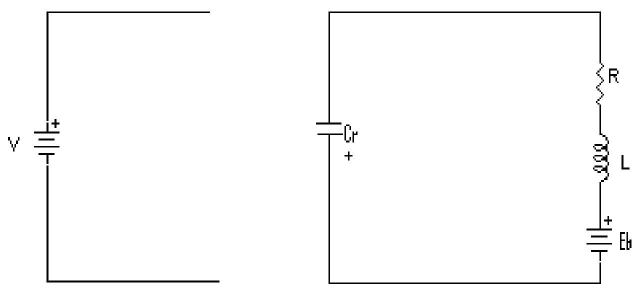

Fig 3.3 equivalent circuit for Mode 3 operation

4.Mode 4 : This stage starts with the conduction of freewheeling diode and the armature current freewheels through D_{fw} for a period t_{d4} until S is turned on again. The duration of this stage is

$t_{d4} = T_S - t_{d2} - t_{d3}$ ------------------------------------ 4(a).

Where T_S is the period of a switching cycle.

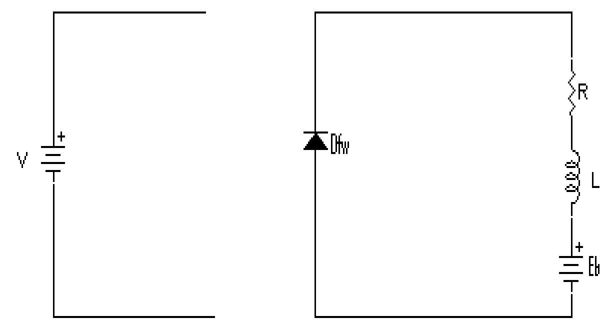

Fig 3.4 equivalent circuit for Mode 4 operation

III SIMULATION RESULTS

The understanding of the operation of a power electronic circuit requires a clear knowledge of the transient behaviour of current and voltage waveform for each and every circuit element at every instant of time. For the easy understanding of the transient response computer aided simulation software's were used. The FM-ZCS-QRC has been simulated using MATLAB simulink software. For simulation purpose the values chosen are $L_r = 168\ \mu H$, $C_r = 2.2\mu F$, $V = 75V$, $R_a = 5\ \Omega$, $L_a = 30$ mH, and $E_b = 35$ V.

IV. INPUT PARALLEL OUTPUT SERIES CONVERTER

Input parallel output series QRC with RLE load is shown in Fig 4(a).Driving pulses for the switch are shown in Fig 4(b), Voltage across the load is shown in Fig 4(c). Servo motor system operating at full load is shown in Fig 5(a). Load is represented as a 5A current sink . Output voltage is shown in Fig 5(b). The current through the inductor is shown in Fig 5(c). Servomotor operating at no load is shown in Fig 6(a). Output voltage is shown in Fig 6(b). Current through the inductor is shown in Fig 6(c). Open loop controlled drive system is shown in Fig 7(a). A step rise in input voltage is given as shown in Fig 7(b). The Dc output voltage also increases as shown in Fig 7(c). Closed loop system is shown in Fig 8(a). A controlled rectifier is recommended at the input to vary the DC output voltage. The voltage across the machine is approximately equal to the back emf. It is sensed using a potential divider. Actual voltage is compared with the reference voltage. The output is processed through a PI controller. The output of PI controller is used to generate proper pulse width to adjust the DC voltage. The response of closed loop system is shown in Fig 8(b). it can be seen that the closed loop system reduces the steady state error. Therefore the speed remains constant.

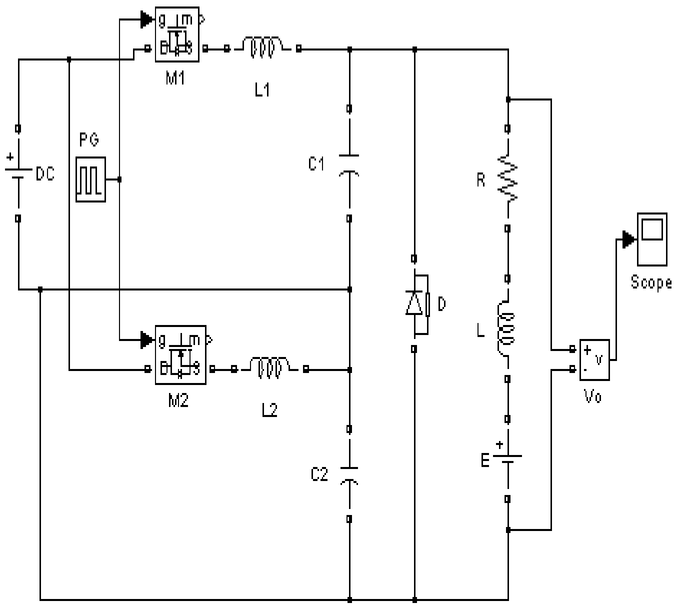

Fig 4a Input parallel Output series QRC fed DC servo motor

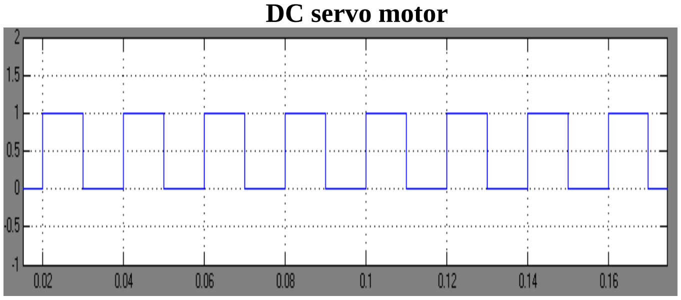

Fig 4b Driving pulses for Switches

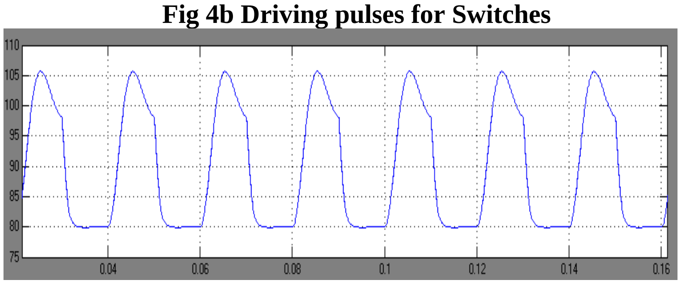

Fig 4c Output Voltage

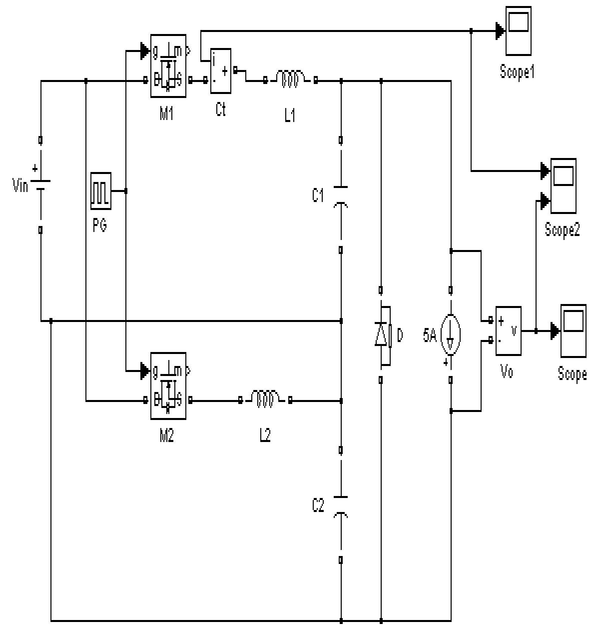

Fig 5a Input Parallel Output Series QRC system with full load

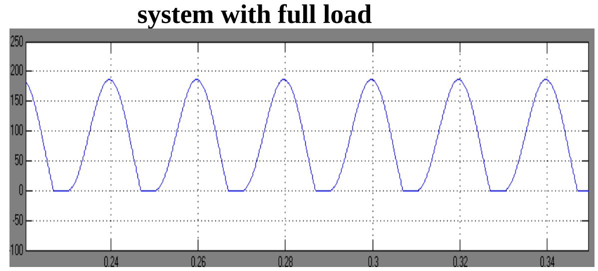

Fig 5b Output Voltage

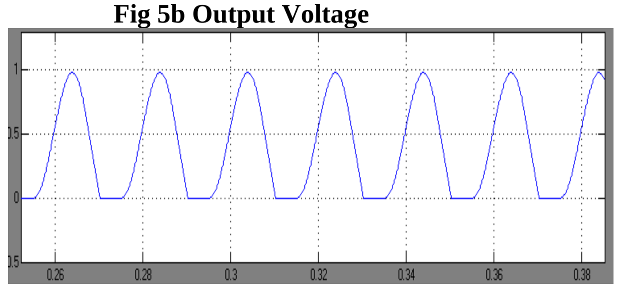

Fig 5c Current through Inductor

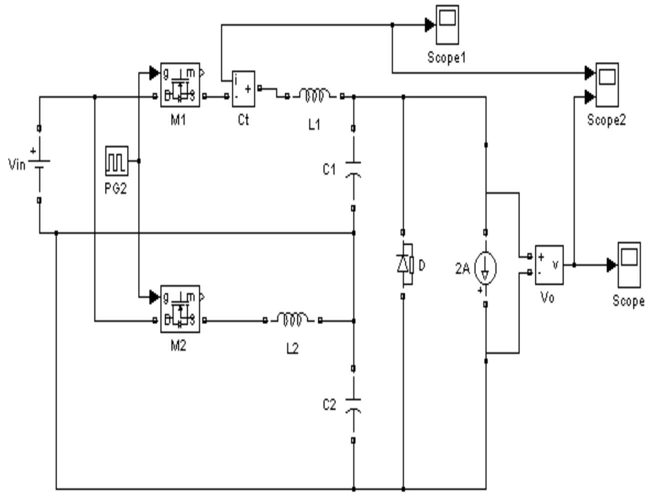

Fig 6a Input Parallel Output Series QRC system with no load

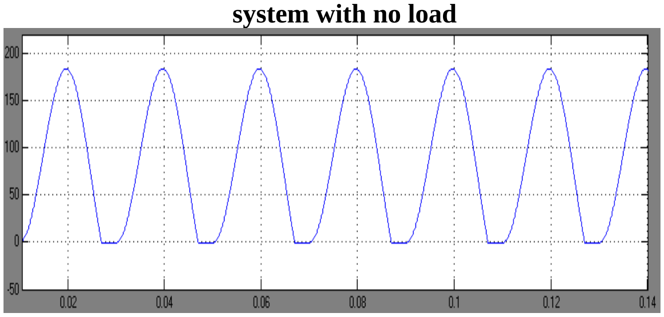

Fig 6b Output voltage

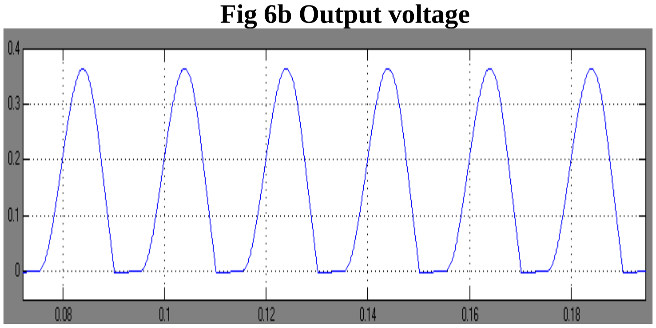

Fig 6c Current through inductor

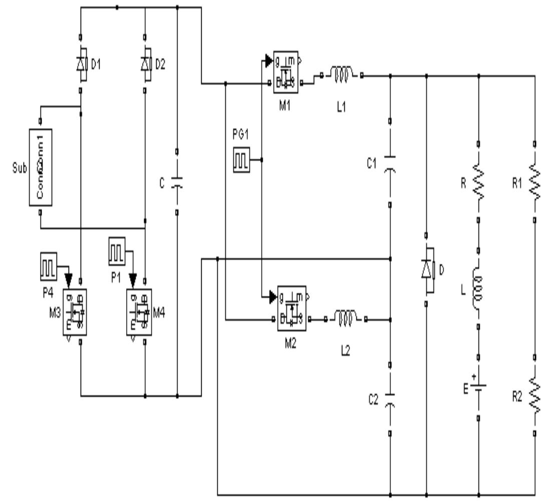

Fig 7a circuit diagram of open loop system

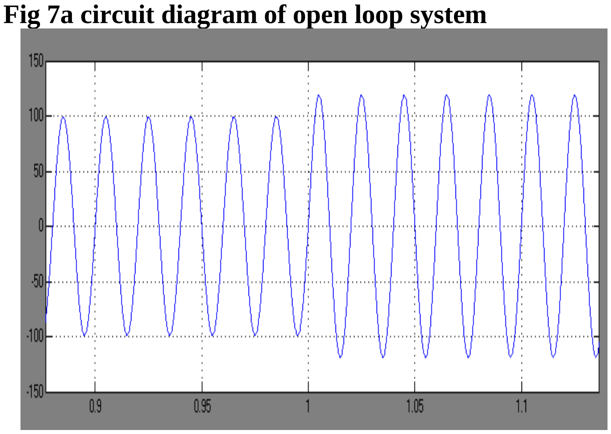

Fig 7b input voltage with disturbance

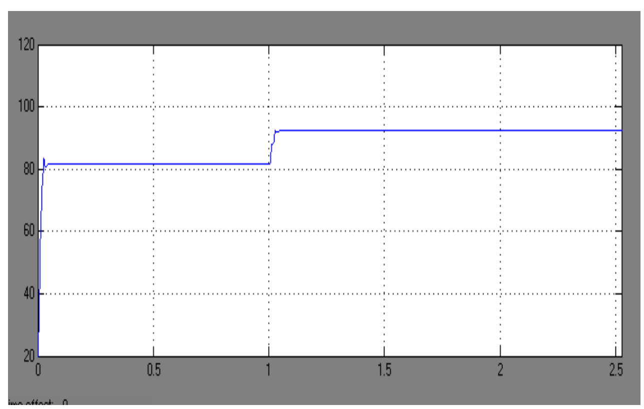

Fig 7c output voltage with disturbance

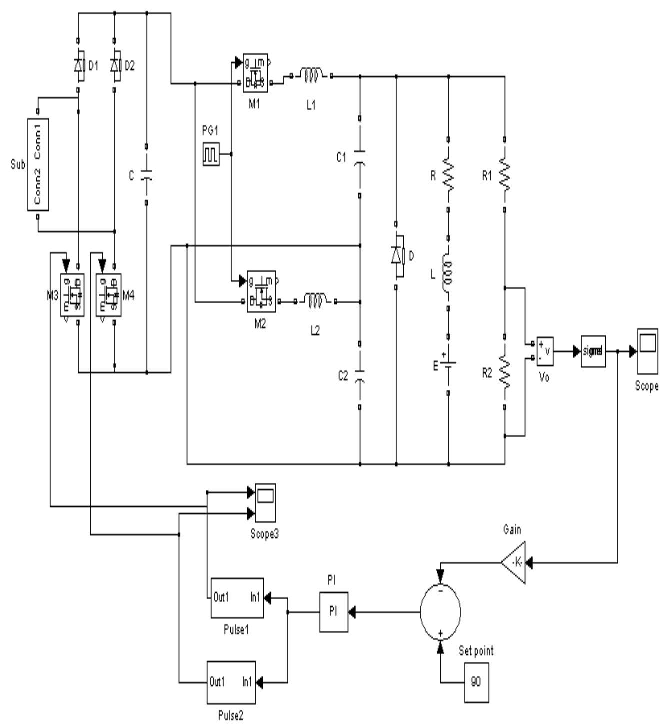

Fig 8a circuit diagram of closed loop system

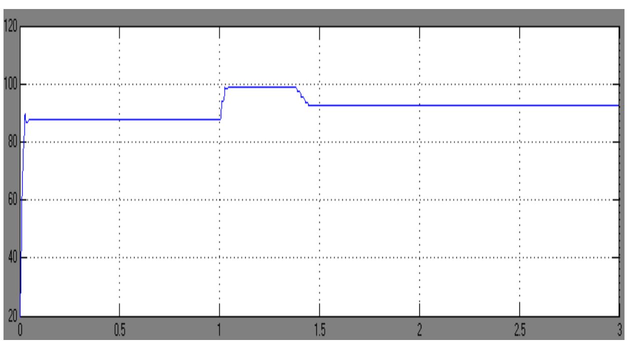

Fig 8b output voltage with disturbance

V CONCLUSION

The input parallel output series QRC fed DC servo drive was simulated using matlab simulink in open loop and closed loop. By virtue of this modeling approach , design of quasi resonant converters can be realized efficiently and effectively by using soft switching technique. Switching stresses get reduced since voltage and current waveforms have lesser slope. Power density is increased since the volume is reduced. The approach of maintaining zero current switching condition is also identified from the simulated waveforms ie., whenever current is zero, switch S turns on and off. QRC fed Servo drive is a viable alternative to the conventional DC drive since it has less losses and high power density. The speed of the servo motor can be varied by varying the off time of the QRC. Input parallel output series QRC is suitable for high power drives since the output voltage is doubled. Closed loop controlled DC drive is successfully modelled and simulated using simulink. The response indicates the speed is a constant.

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