SIMULATION & SENSITIVITY ANALYSIS OF FREQUENCY MODULATED ZERO-CURRENT-SWITCHING QUASI-RESONANT-CONVERTER FOR SERVO DRIVE APPLICATIONS

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Abstract: Interests in resonant converters arose from the quest for utilizing very high switching frequencies without unacceptable power dissipation in the semiconductor switches. Switching losses can be minimized using resonant system and also very high operating frequency can be employed allowing smaller and lighter power-conditioning equipments to be built. In addition, power density and efficiency of the power conditioning can be increased while reducing the EMI problems.

Two closed loops are designed here, first one is speed control loop which regulates the speed of the dc motor so that motor rotates in accordance with the reference speed signal and other is the current control loop which controls the input current to the motor. Switching pulses to the switch is generated by microcontroller. Switching frequency is to be varied so as to vary the output of the resonant converter, therefore it is known as frequency modulated converter.

Index Terms **- Zero-Current-Switching (ZCS), Quasi-Resonant Converter (QRC), speed control of motor, MOSFET, MATLAB Simulink**

I. INTRODUCTION

The essential function of power converters is to achieve desired power conditioning in electrical systems. In any power conversion process, it is desired to have a system that has the smaller internal power loss during energy conversion and hence higher efficiency. These objectives cannot be achieved using linear electronics. On the other hand, power electronics based conversion always uses switching techniques in its operation. However, this imposes a lot of restrictions on those conventional hard-switching power supplies. The situation becomes worse when high power and high operating frequency are required simultaneously.

This is because conventional hard-switching power conversion does not only radiate electromagnetic energy; it also creates a lot of unwanted harmonics at high frequency giving rise to a supply problem. Size and weight become other issues particularly as a complex cooling system will be needed. If soft-switching can be employed, then many of the electrical problems can be avoided or eliminated, and cooling requirements are reduced. Soft-switching is generally defined as switching the solid state components between on and off states at zero-current and/or zero-voltage conditions in order to minimize the power dissipation. The increasing popularity of soft-switching is demonstrated by the research that is being done not only to improve the design and control techniques, but also to optimize the solid-state devices for resonant switching. One of the attractions in soft-switching applications is demanded in pulse-switching for industries like welding, laser, marine, battery, and so on, where some good progress has been made.

In designing switching dc-dc converters, the effort to increase operating frequency to reduce weight, size and cost of magnetic and filter elements is constantly hampered by higher switching stresses and switching losses. By incorporating additional inductor and capacitor elements to shape the semiconductor switch’s current waveform, a “zero current switching” property can be realized.

II. STATE OF THE ART

B.K. Bose [1] and N. Mohan & W. Robbins [2] demonstrated the main features of soft switching techniques and discussed that it is not only to improve the design and control techniques but also to optimize the solid-state devices for resonant switching. Various resonant switching techniques i.e. ZCS and ZVS are described by Zhu J.Y and Ding D [3] to minimize the switching losses during the operation of power electronics switches, which in turn increases the overall efficiency and reduces EMI [4-7]. A simple Analysis of MOSFET Operating in Half-Wave Zero-current Switching Quasi-resonant Converter is proposed by N.N. Goryashin and A.S. Solomatova in 2012 [8].

III. SIMULATION SETUP

Various configurations of zero current switching quasi resonant converters in a closed loop system are designed and simulated using MATLAB Simulink software. The circuit setup and associated waveforms are shown as follows.

a. Constant reference closed loop operation:

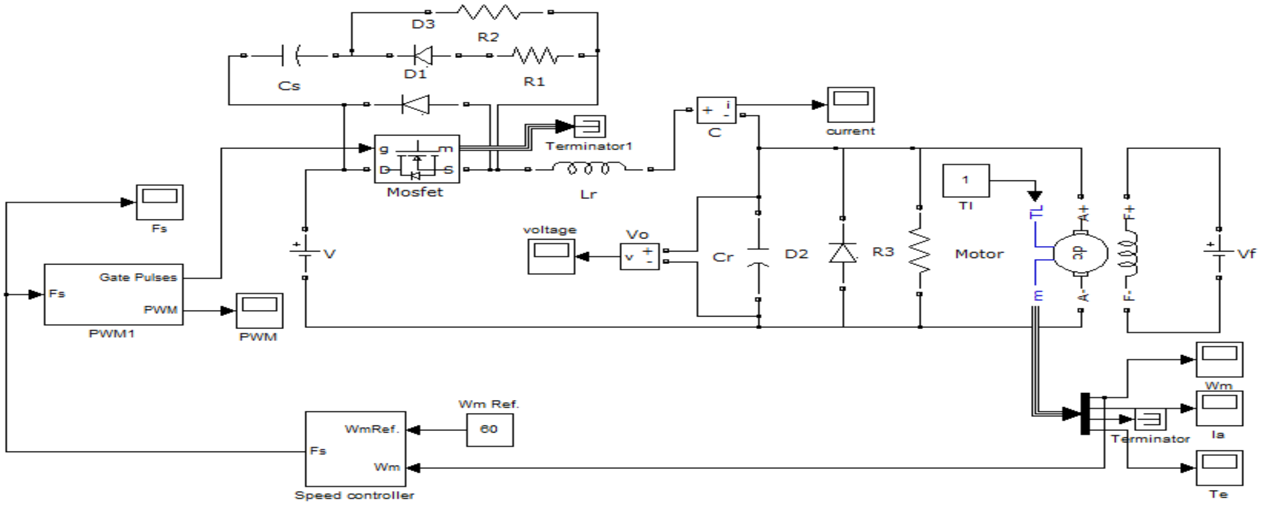

Fig.3.1. Circuit for constant reference speed signal.

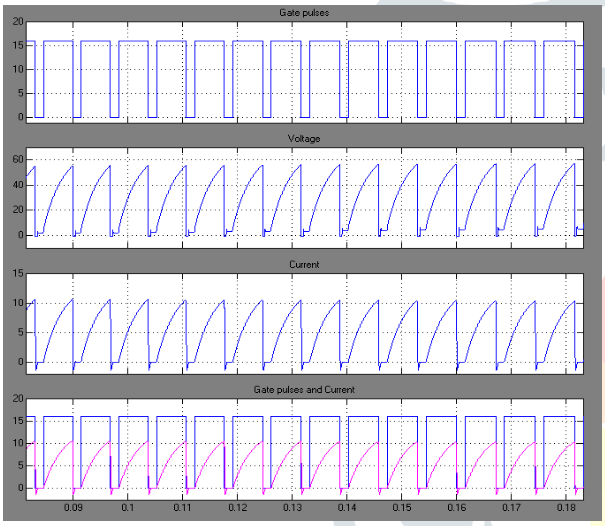

Fig.3.2.Gate pulses, voltage and current waveforms for constant reference speed signal.

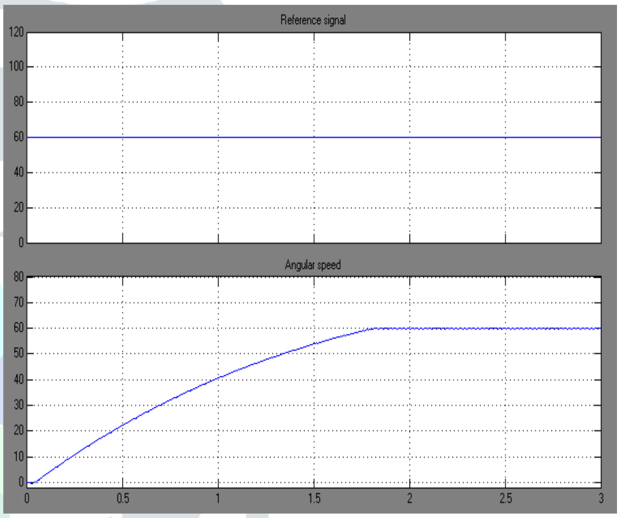

Fig.3.3. Angular speed (rad/sec) for constant reference speed signal

The closed loop model designed for constant reference signal is shown in fig.3.1. Various waveforms like gate pulses provided to the MOSFET, voltage across the capacitor, current through the inductor is shown in fig.3.2. Last waveform in the fig. 3.2 shows that the zero current switching is taking place. Fig.3.3 shows the reference speed signal and variation of angular speed of motor with time.

b. Variable reference closed loop operation:

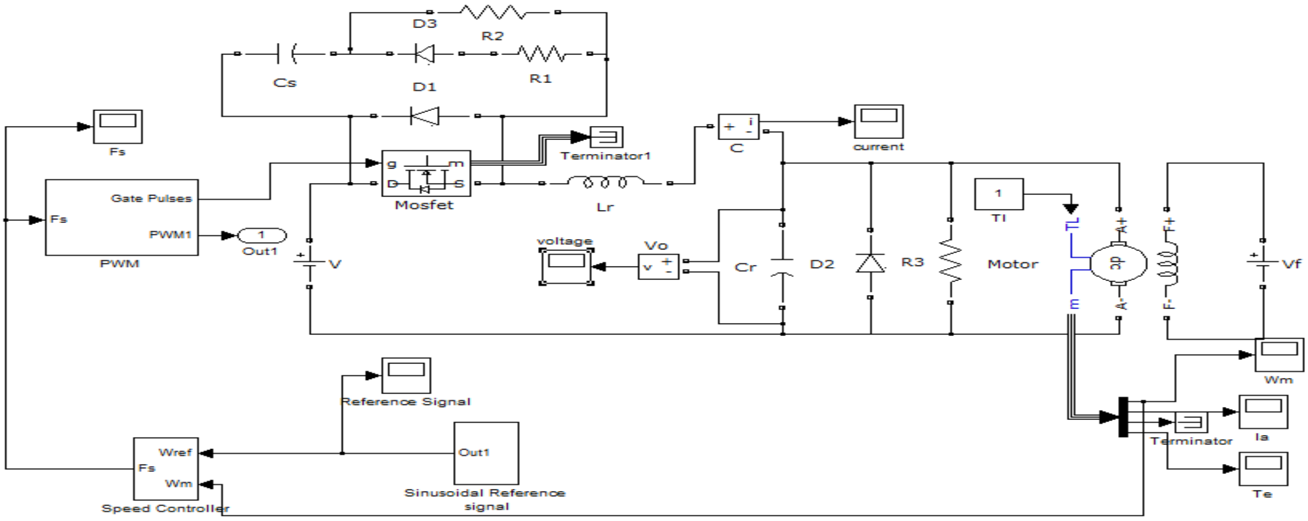

Fig.3.4. Circuit diagram for variable reference speed signal.

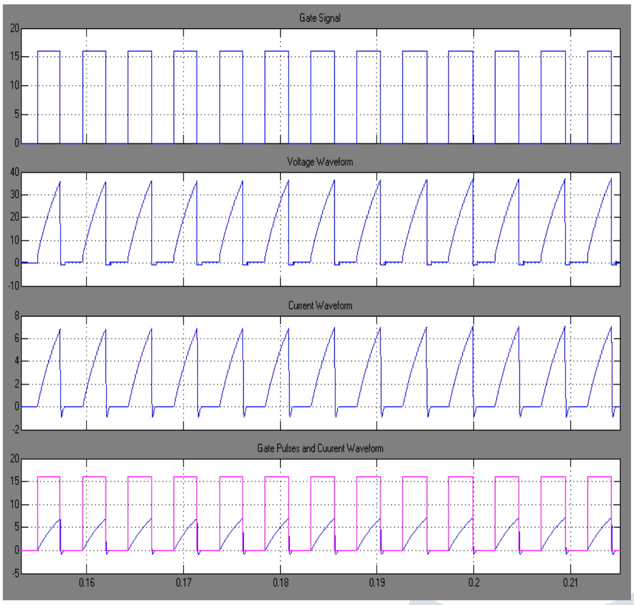

Fig.3.5. Gate pulses, voltage and Current waveforms for variable reference speed signal

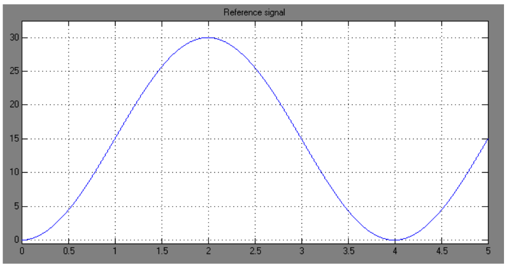

Fig.3.6. Reference speed (rad/sec) signal for variable reference speed signal

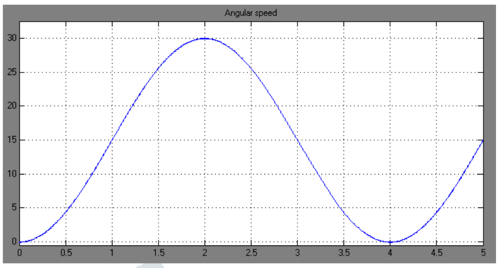

Fig.3.7. Angular speed (rad/sec) of motor for variable reference speed signal

Figure 3.4 shows the circuit diagram of closed loop model designed for variable reference signal. Various waveforms like gate pulses provided to the MOSFET, voltage across the capacitor, current through the inductor is shown in fig.3.5. Last waveform in the fig.3.5 shows that the zero current switching is taking place. The variation of reference speed signal with time is shown in fig.3.6 and variation of angular speed of motor with time is shown in fig.3.7.

From the fig.3.6 and fig.3.7 it can be seen that the motor is able to follow the variation in the reference signal.

IV. CONCLUSION

The closed loop configurations of ZCS-QRC are designed in accordance with the calculated values and are simulated using MATLAB simulink software. The basic idea behind this approach is to vary the switching frequency of the QRC such that the motor is bound to rotate in accordance with the reference speed signal. By virtue of this modeling approach, design of quasi resonant converters can be realized efficiently and effectively by using soft switching techniques. The approach of maintaining zero current switching condition is also identified from the simulated waveforms i.e. switching of switch S takes place only when the current is zero. The soft switching technique (zero current switching) to minimize the switching losses thereby increasing overall efficiency of the converter is implemented in the design.

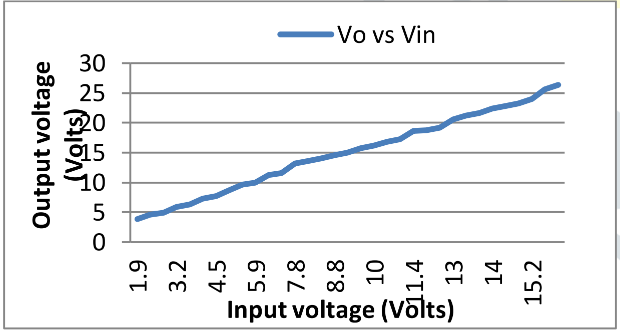

Fig.4.1 Variation of output voltage with input voltage at constant switching frequency for resistive load

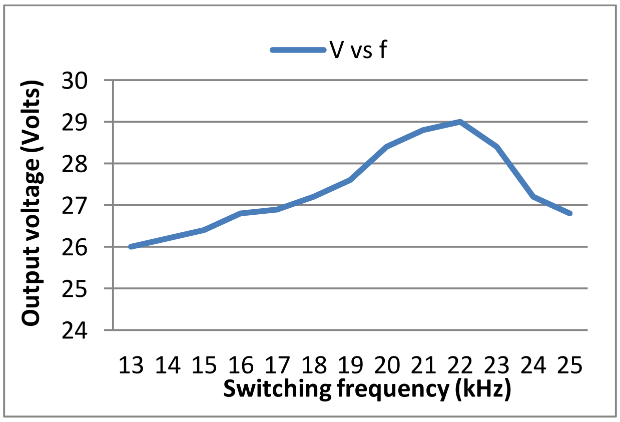

Fig.4.2 Variation of output voltage with switching frequency at constant input voltage for resistive load

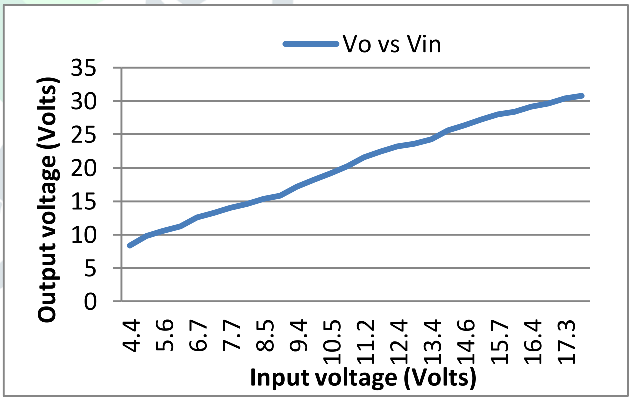

Fig.4.3.Variation of output voltage with input voltage at constant switching frequency for motor load

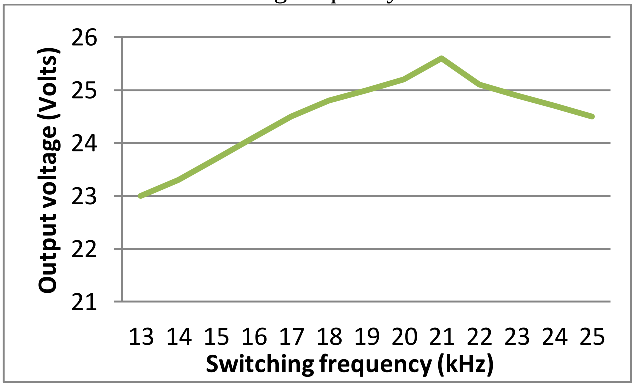

Fig.4.4. Variation of output voltage with switching frequency at constant input voltage for motor load

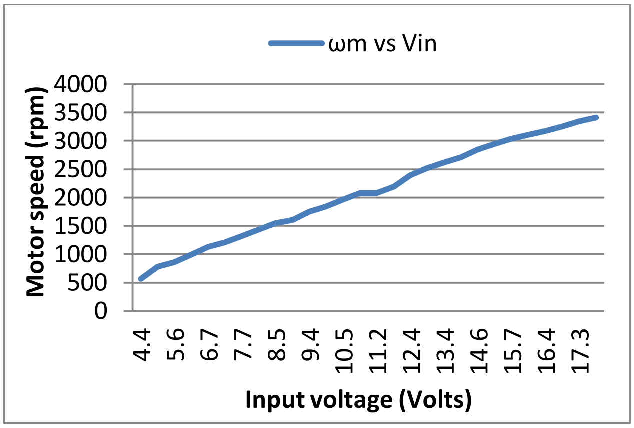

Fig.4.5.Variation of motor angular speed with input voltage at constant switching frequency for motor load

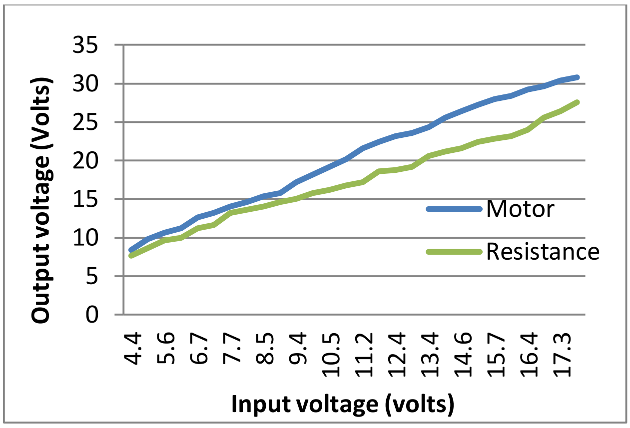

Fig.4.7. Comparison of variation of output voltage with input voltage at constant switching frequency for motor and resistive load

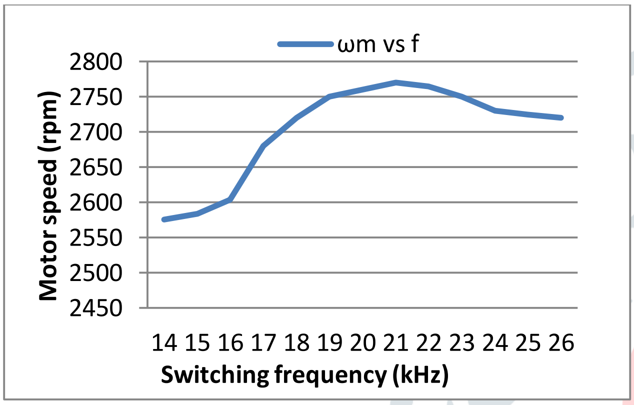

Fig.4.6.Variation of motor angular speed with switching frequency at constant input voltage for motor load

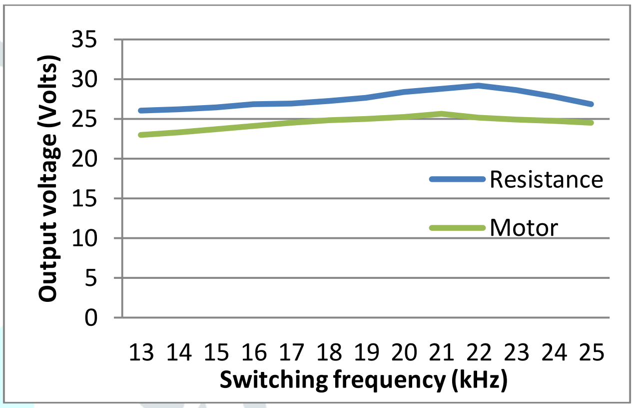

Fig.4.8.Comparison of variation of output voltage with switching frequency at constant input voltage for motor and resistive load

From Fig.4.7 it can be concluded that for the same switching frequency both the graphs varies linearly with input voltage but slope for motor load is more than that in case of resistive load. In Fig.4.8 variation of output voltage for both resistive and motor load are shown. The curve for motor is much flatter as compared to that resistive load. This is because resistive load adds resistance to the circuit and motor load adds an inductance to the circuit that is why in case of resistive load Q factor is greater than the Q factor for motor load.

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